## #BIG TRENDS

# Space exploration

## Trend Analysis in the Space Industry

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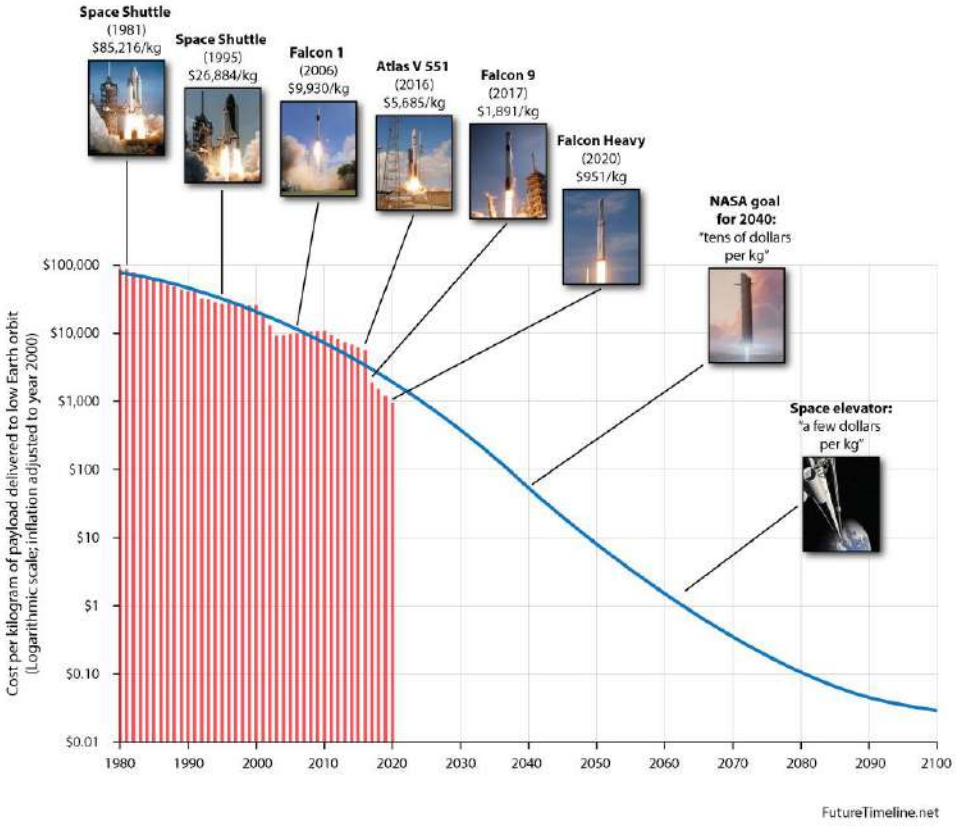
**Authors: Max Ritt & Willem Spigt**

# Introduction

The world is in the midst of a new space race after half a century of almost being silent. The focus during the last 50 years has been primarily on manned low-Earth-orbit missions and unmanned scientific exploration. But this has started to change recently. Due to high levels of private funding, technological advancements, and growing public interest are reshaping the industry and its potential. The increase of space flight is mainly driven by the cost of launching 1 kg in space is getting increasingly cheaper (see figure 1). As of now launching 1 kg into LEO (lower earth orbit) cost around 2500 USD. Elon Musk, owner of SpaceX, however, expects to be able to launch objects weighing approximately 150 ton for 1.5 million USD (for comparison the whole ISS station weights around 450 ton), so 1 kg into LEO for approximately 10 USD in the future (Elon Musk, 2020). The following three important trends in the space industry will be discussed; mining in space, space tourism and satellites.

**Figure 1**

*Launch costs over the years*



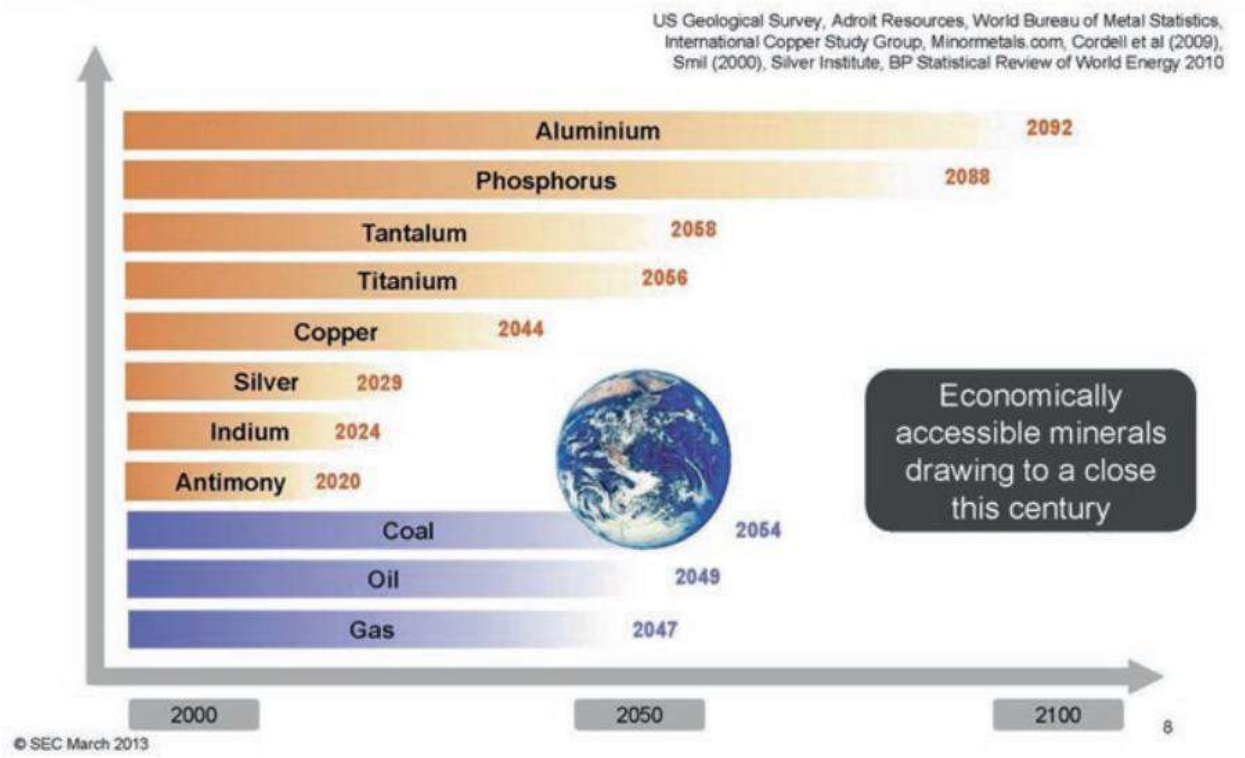
# Mining

Due to the global growing economy there will increasingly be more minerals consumed, some experts claim that the earths metals and minerals will be depleted within 50 years (Jowitt et al., 2020). Figure 2 gives an indication when a variety of minerals will be depleted. Therefore, it is often argued that we should start to consume less and recycle minerals. Others however, argue that mining minerals in space is the solution to this urgent problem. This section will explore what possibilities there are in space mining.

There are many different minerals that are mineable in space, in this article there is a focus on lunar mining and asteroid mining. With lunar mining, the following basic elements can be found on the lunar surface, often trapped in rock; oxygen (O), sodium (Na), magnesium (Mg), aluminum (Al), silicon (Si), calcium (Ca), titanium (Ti) and iron (Fe). But also, phosphate (K) and Rare Earth Elements (REE) such as gold (Au) and Cobalt (Co) are elements that are available on the lunar surface, which are important elements as gold is needed in computers and smartphones, and cobalt one of the necessary elements for among other things EV batteries. In addition, to all this, there is also much water available, which is captured in ice, at places where there is a permanent shadow such as the dark side of the moon and in some craters (Sivolella, 2019). See figure 3 for the most prominent minerals available on the lunar surface.

**Figure 2**

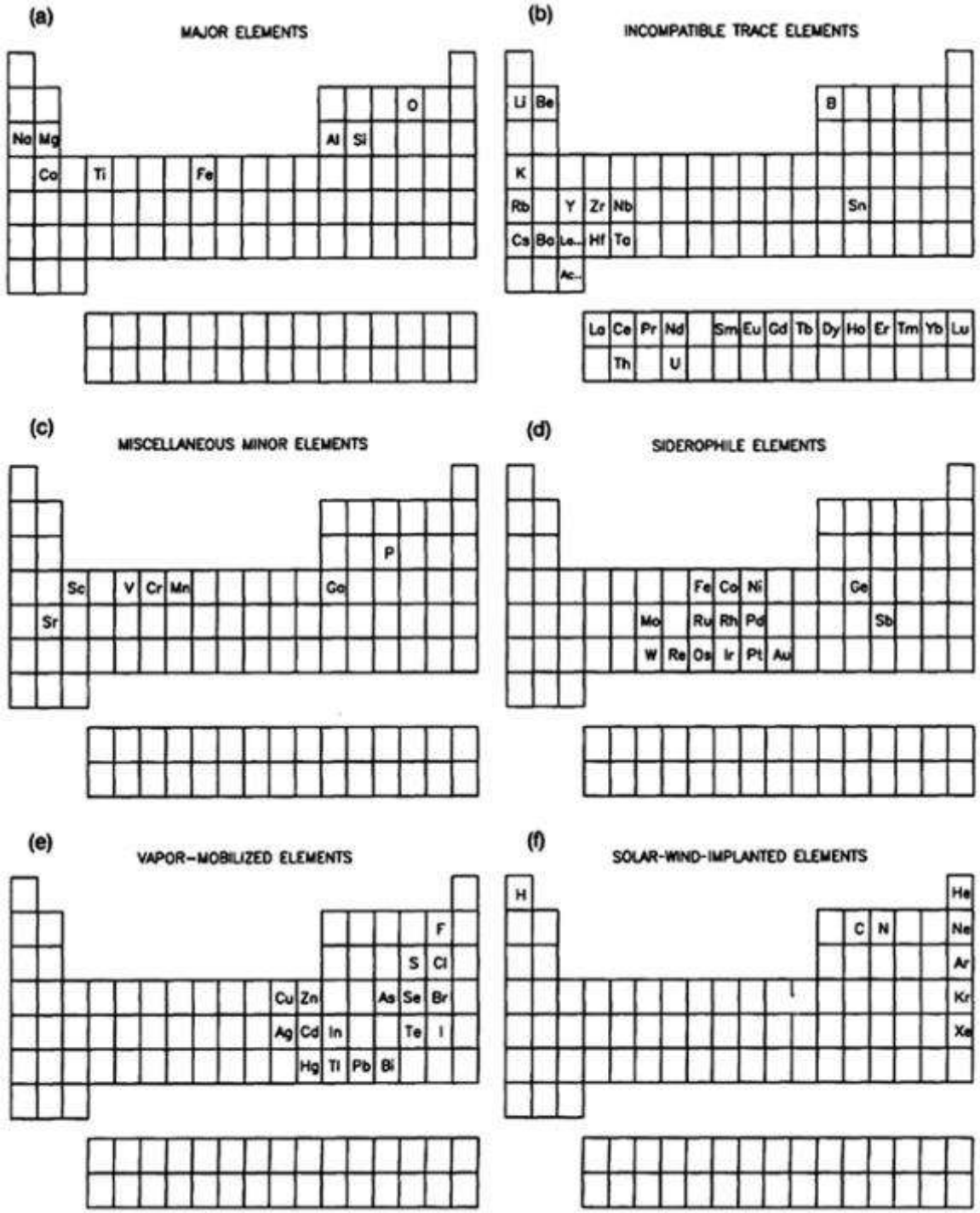
*Project shortages of economically accessible minerals.*




Adapted from *The Importance of Natural Resources from Space and Key Challenges* by Jakhu et al., 2016. Original graphic by Shackleton Energy Company. All rights reserved

**Figure 3**

*A periodic table of all elements found on the lunar surface*



Next to the moon, asteroids can be mined. In 2019, more than 784.000 asteroids were counted, many in an asteroid ring between Jupiter and Mars also called the 'Main Belt'. In general, there are 26 different types of asteroids, which are divided into three big families of different type of asteroids; C-group which are stony asteroids, containing primarily a mixture of clays, organic matter but also containing 92% iron, 7% nickel and about 1% cobalt. The S-group which is also part of the stony asteroids, but have a different composition then the C-group and the X-group of asteroids, which are mainly mettalic asteroids, as well as asteroids which have compositions entirely different from those in the other two groups (Sivolella, 2019).

To start the mining process, analysis must be done on the location of a planet or asteroid. To analyze if it has materials that can be economically viable mined. To mine there are several methods that can be used. There is underground mining which is mining below the surface using a series of tunnels and shafts. Tools used here are drilling or blasting the tunnels, very similar as on earth. but also, on surface mining, using open pits or strip mining, which is often much safer and gives more flexibility. On the moon we most likely will use the same techniques, however humankind need to keep account of the reduced gravity and the lack of a similar atmosphere as on earth. For example, machinery needs to be heavier, the use of explosives has to be done more cautious. In addition to that, gathering the material has to be done with some kind of vacuum and the absence of an atmosphere will complicate the management and retention of fluids used with drilling. For the first mining operations on the lunar surface, experts actually suggest to use a century old technique using a cable operated drag scraper (see figure 4). For underground lunar mining experts suggest to use the same techniques used on earth, however, modifying them for lunar use (Sivolella, 2019).

**Figure 4**

*The proposed cable operated drag scraper*

Adapted from *Space Mining and Manufacturing: Off-World Resources and Revolutionary Engineering Techniques* by Sivolella, 2019. All rights reserved

In terms of asteroid mining, other newly developed techniques will be used, experts suggest to use harpoons to attach satellites to the asteroid surface, directly afterwards a small thruster will be used to counteract the recoil of the harpoons and to make sure asteroids stay in

their orbit. Because of the absence of gravity, different ways of mining have to be used to make sure no fragments are released into space. One proposed way of mining is using several cables around asteroids. Grabbing the asteroid as well as using it to brake it up into smaller pieces and placing it in a bag, which after being filled can be processed in a plant in space (perhaps Low Earth Orbit). In terms of asteroid mining, here are two main players in this market; Deepspace Industries (short DSI, in 2019 bought over by Bradford Space to focus on propulsion (Foust, 2019) and Planetary Resources (bought over by ConsenSys a blockchain company, in 2019). Which used it capabilities in space to launch a set of satellites to observe the earth (ConsenSys, 2019). With these two acquisitions of the most important players in the market, planetary mining as well as asteroid mining now seem further away than ever before. Only a few small players are left such as Astroid Mining Company and Moon Express. However, there are some significant developments in Europe. Recently in 2020, Luxembourg and the ESA (European Space Agency) announced a strategic partnership called European Space Resources Innovation Centre or ESRIC in short (Businesswire, 2020). In which the public as well as private sector can focus together on space resources research and development. Additionally, ESA is considering mining on the lunar as soon as 2025. Not for one of the above-mentioned minerals, but for Helium-3. Which may prove useful for fueling future fusion reactors (Jamasmie, 2019).

Also, on the other side of the pond, in the United States, institutions are focused on asteroid and most of all planetary mining. As NASA together with several countries have signed the NASA Artemis Accords (12 countries in total, so far in June 2021). This global legal framework is an effort to get all allies together in order to go back to the moon within the next decade, among the activities that are planned are mining of the lunar surface as well as other planets (NASA, 2021).

# Tourism & Hypersonic flights

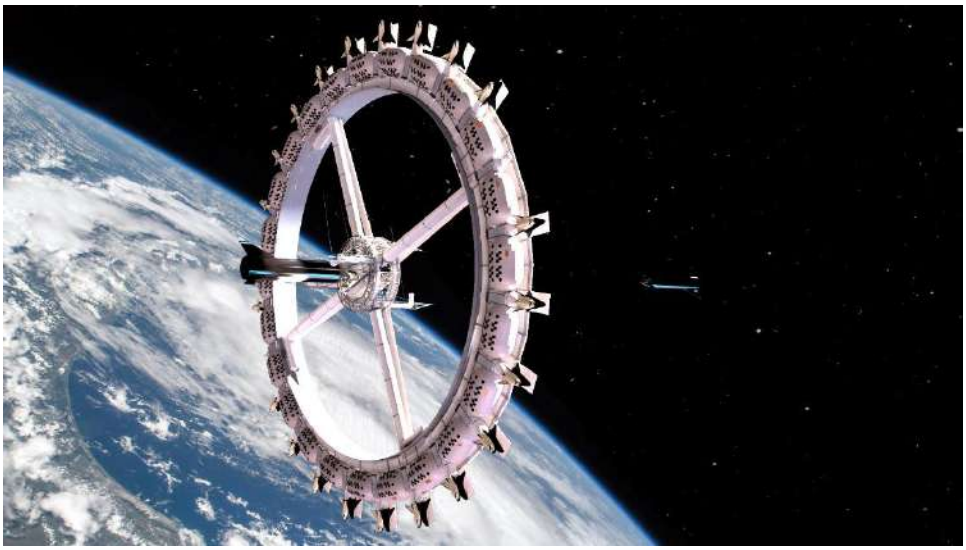
The second trend is somewhat more feasible than the first one. This is the space tourism, in which mainly tourist flights in earth's orbit are part of. Space tourism is not considered revolutionary since in 2001 Mr. Tito a wealthy American paid 20 million dollar to be able to get a seat in a Russian rocket and was the first privately funded person in space (Crouch, 2001). Space tourism could be a major step towards a bigger human presence in space. Nowadays there are several companies offering this. Virgin Galactic, with its SpaceShipTwo (SS2), Blue Origin with its Shephard rocket (Chang, 2020) and lastly XCOR Aerospace build the XCOR Lynx. Initially its launch date was set for 2016. However, this got postponed a few times, eventually XCOR Aerospace went bankrupt in 2017.

The Russian space agency also offers tourist space flights, in its Soyuz spacecraft. However, this is only done if there is one seat left. Lastly, there is SpaceX which also offers space flights, this company already signed a contract with Axiom Space, another private space company to launch 3 private citizens to space in 2022 (Kooser, 2021).

In addition to that, there are also new concepts launched, such as a Space hotel called Voyager Station (see figure 5 for a graphical representation of the station). Which will be able to house 400 persons at a time, it will include a bar, restaurant, event center and private living quarters (Ruiz, 2021). Additionally, it will include gravity, about 1/6 Earth gravity. This project recently reached its fund-raising goals of one million US Dollars and is expected to be finished and operational by 2027. This concept is designed and build in a corporation with the Gateway Foundation and Orbital Assembly. In which both still have investment opportunities which are relatively inexpensive (Orbital Assembly, n.d., Gateway Foundation, n.d.).

**Figure 5**

*A graphical representation of the Voyager Station will look like*



For now orbital space tourism is still for the very wealthy. However according to a study by Crounch (2001) at 3 million annual passengers rate the price could drop to 10.000 US Dollars per person. According to other surveys in the paper of Crounch (2001), many people are willing to spend a substantial amount of their annual salary to participate in space tourism. A stay at the Space Hotel will also be rather expensive in the beginning, as the builders claim the passengers will need a net worth of about 50 million US Dollars to make it financially feasible (Ruiz, 2021).

Another trend involving space tourism is hypersonic flight. In which the passengers fly faster than the speed of sound. Flying faster than 3000 mph (or about 4828 km/h) with a Mach usually higher then 5 (NASA, n.d.). Assembly of hypersonic planes is difficult and developing such a plane has its challenges such as, the effects on the passengers of 5 Mach could be fetal. Additionally, the planes have to be built with unconventional materials, which are heat resistant and do not wear too much.

There has been one plane already capable of almost achieving hypersonic speeds, which used to be a reconnaissance plane, build by Lockheed in the 1960 and used by the US military for 24 years. This plane was called the SR-71 Blackbird (Smithsonian National Air and Space Museum, n.d.). Additionally, a research project of NASA in 1967 achieved hypersonic speeds called the X-15 (NASA, 2014). Now a well-known aerospace company announced plans to develop a passenger plane with these capabilities, which is Aerion Space with its AS3 plane. This plane will be able to seat 50 passengers and will be able to fly from Los Angeles to Tokyo in less than 3 hours. It is expected to be launched at the end of this decade (O'Hare & Sillers, 2021). It can be concluded that hypersonic flying is still in its beginning stages.

# Satellites

There are currently over 1,700 active satellites orbiting Earth, but this figure will increase up to ten-fold in the next decade according to ARK Invest (ARK, 2020). Most people are unaware of how much we currently rely on satellite and space technologies in our daily lives. From GPS navigation to quick credit card authorization, from farmers optimizing our food to tracking every bit of the worldwide supply chain. Satellites have become an important foundational technology we heavily rely on.

Advanced space and satellite systems will play an even more significant role in our future lives. Only half of the world's population has access to the internet, and the rate of adoption is dropping (Shepherd, 2020). An airspace solution could act as a spark for connecting the rest of the planet. Space and satellite technologies will also be used in vehicles such as air taxis, drones, self-driving automobiles, and other applications.

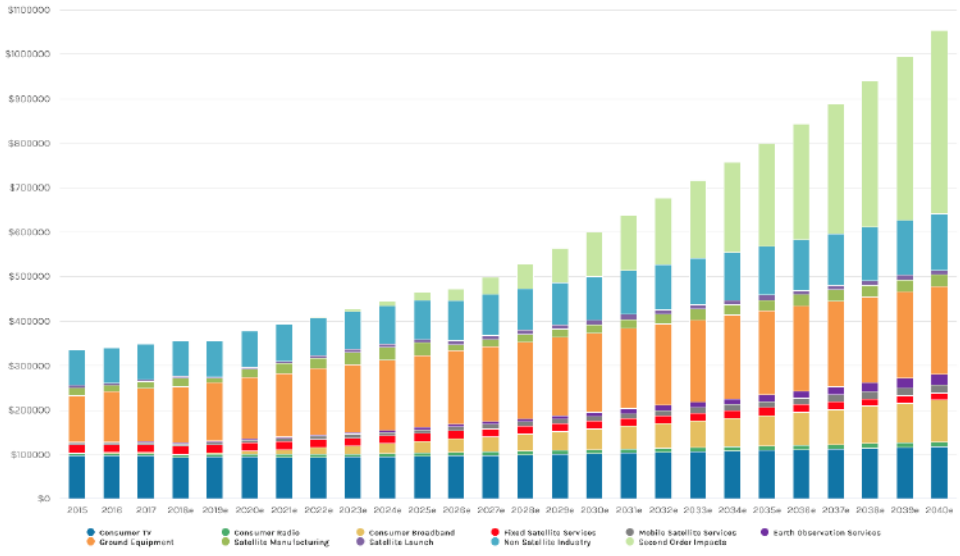
According to Morgan Stanley (2020), satellite broadband will account for 50% of the global space economy's expected growth by 2040, and as much as 70% in their most optimistic scenario. Launching satellites that provide broadband Internet access will result in lowering the cost of data at a time when demand for it is increasing.

Furthermore, they argue in their report that the demand for data is increasing at an exponential rate, while the cost of access to space is decreasing by orders of magnitude. The biggest

opportunity is to provide internet access to underserved and unserved areas of the world, but there will also be increased demand for bandwidth from autonomous cars, the Internet of things, artificial intelligence, and virtual reality (Morgan Stanley, 2020).

**Figure 6**

*Global Space economy forecasts until 2040*




Adapted from *Morgan Stanley Space investing in Space Exploration*. all rights reserved

# Concluding the opportunities

It can be concluded that space flight race is back to life after 50 years of minimal progress. The rapidly declining costs per kg result into a noticeably big opportunity for a variety of industries. To begin with the mining industry can massively benefit from this. However, the former two big players in this market have been acquired by other companies and have changed the plans of these pure play space mining companies to a different strategy. Only a handful of smaller companies are trying to make space mining a reality. The ESA and the NASA do however have plans on the long term to make asteroid and planetary mining a reality. The Space Tourism industry is already in a much further stage compared to the mining industry. The players that are already providing this service are Virgin Galactic, Blue Origin and XCAR. Furthermore, there is even a space hotel in development. In the future SpaceX will also offer commercial spaceflight. For now, orbital space tourism is only possible for the very wealthy. Currently, only half of the world's population has access to the internet, and the rate of adoption is dropping. The space industry could act as a spark for connecting the rest of the planet since bringing satellites online is becoming increasingly cheaper. On top of that, new technologies that are currently in development require a huge amount of bandwidth resulting in a satellite boom in the coming decades.

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