Sustainable logistics in Space

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"Space is hard", as they say, and logistics helps explain why it's hard.

Sending people, materials, or delicate instruments to space means strapping them to a towering controlled explosion – a rocket – which even today has a "failure rate" of 2-10% (please take a moment to imagine this "failure"). Once up there, precisely calculated & timed engine burns send the item gliding to its assigned orbit at 7 km per second. Returning is no less arduous: special heat shields are needed to survive. And we should return what we send up! An astronaut's wrench at those speeds would annihilate a tank, let alone an exquisite satellite worth hundreds of millions. As the International Space Station enters its twilight years, the focus of government logistics moves to the Moon, which, even for grizzled space engineers, is *much* further.

A revolution is afoot in space logistics, starting with miniaturised electronics, first made for smartphones, now allowing shoebox-sized "nanosatellites". This reduction in costs brings space within reach of aspirational students & entrepreneurs. Since SpaceX began a reusable rocketry renaissance, launching has never been cheaper. And the initially bare-bones tiny satellites have exciting new capabilities when launched in swarming, coordinated flocks, or "constellations". They can map the entire Earth in a day, or provide continuous internet access to the planet.

These developments are like Christmas every day – wonderful at first, but likely unsustainable. Sustainability is now a concern across space logistics, as access to space becomes cheaper, privatised, and continuous – more "normal". Commercial actors performed their *first* on-orbit servicing on February 25th, to refuel & repair satellites rather than discard them. Governments are keen to employ materials from the Moon itself (known as In Situ Resource Utilization (ISRU)), and eventually manufacture there. Academic researchers are focusing attention on space debris, an inevitable by-product of cheap launches and vast constellations.

The Moon: the sleeping satellite must awaken

Lunar mining marks a historic shift in space logistics, and in human civilisation: for the first time, *we seek resources from another body than Earth*. After the 2009 remote detection of water by Indian and American orbiters, several space resource exploration companies have arisen – and fallen. Some remain, e.g. the Japanese firm ispace, and United Launch Alliance (ULA), a Boeing-Lockheed Martin joint venture. Academic communities have formed, and Luxembourg is now a cluster for space resources actors, partly by offering rare legal clarity on resource ownership. Last year, the U.S. Geological Survey began evaluating Lunar regolith (soil) as resource reserves. Lunar water attracts the most attention, to support human exploration, and may be refined to oxygen and hydrogen, for breathing or rocket fuel. Billions of tonnes of ice may lie in "craters of eternal shadow", but need in situ verification to justify astronomical valuations. After government exploration, envisioned markets include fuel for satellites, and in the fullness of time, a "cis-Lunar economy" extracting metals (e.g. from ilmenite) and silicon. Titanic scientific, technological, legal, and economic uncertainties will be tackled in the 2020s by many missions, with NASA already contracting commercial delivery services to the Moon.

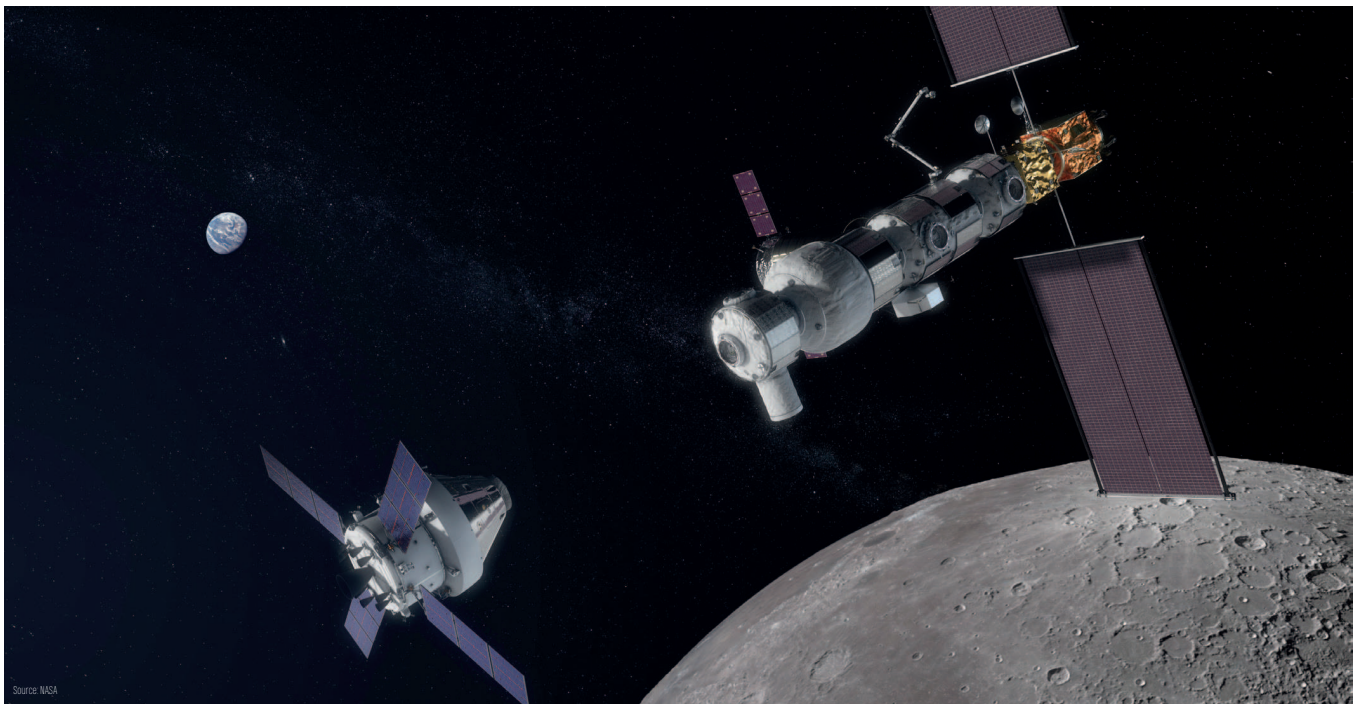
EPFL taking the lead

Few space industry actors consider all these transformations holistically, despite their shared impact on space logistics. Thus in response, the EPFL Space Center (eSpace), based in Lausanne, last year launched a research initiative called Sustainable Space Logistics. It aims to build a new community, ensuring the satellite operators talk to the R&D engineers, the NASA planners coordinate with the fast-moving entrepreneurs, and the academic researchers exchange ideas widely.

One key message of sustainability is interconnectedness: whether the telecom industry decides to shift mostly to low-flying, swarming constellations – or to high-orbit, half-billion-dollar behemoth "stations" – affects the on-orbit servicing businesses. Similarly, the business case for sourcing materials from the Moon is shaped by rapidly diminishing launch costs.

A concrete application of sustainable space logistics is the Swiss start-up ClearSpace. It was selected in November by the European Space Agency to lead an €86M programme to remove a piece of space debris, with a mission in 2025. This will be the first-ever demonstration of a solution to space debris, and of a new profession: space garbageman. Born & incubated at eSpace, ClearSpace was spun off with key personnel.

With the *Sustainable Space Logistics* research initiative, the EPFL Space Center is positioned as a hub for the current revolution, ensuring long-term, sustainable thinking drives us forward. The Space Center is seeking partners, sponsors, and ideas – and know-how from logistics practitioners. ■



Source: NASA