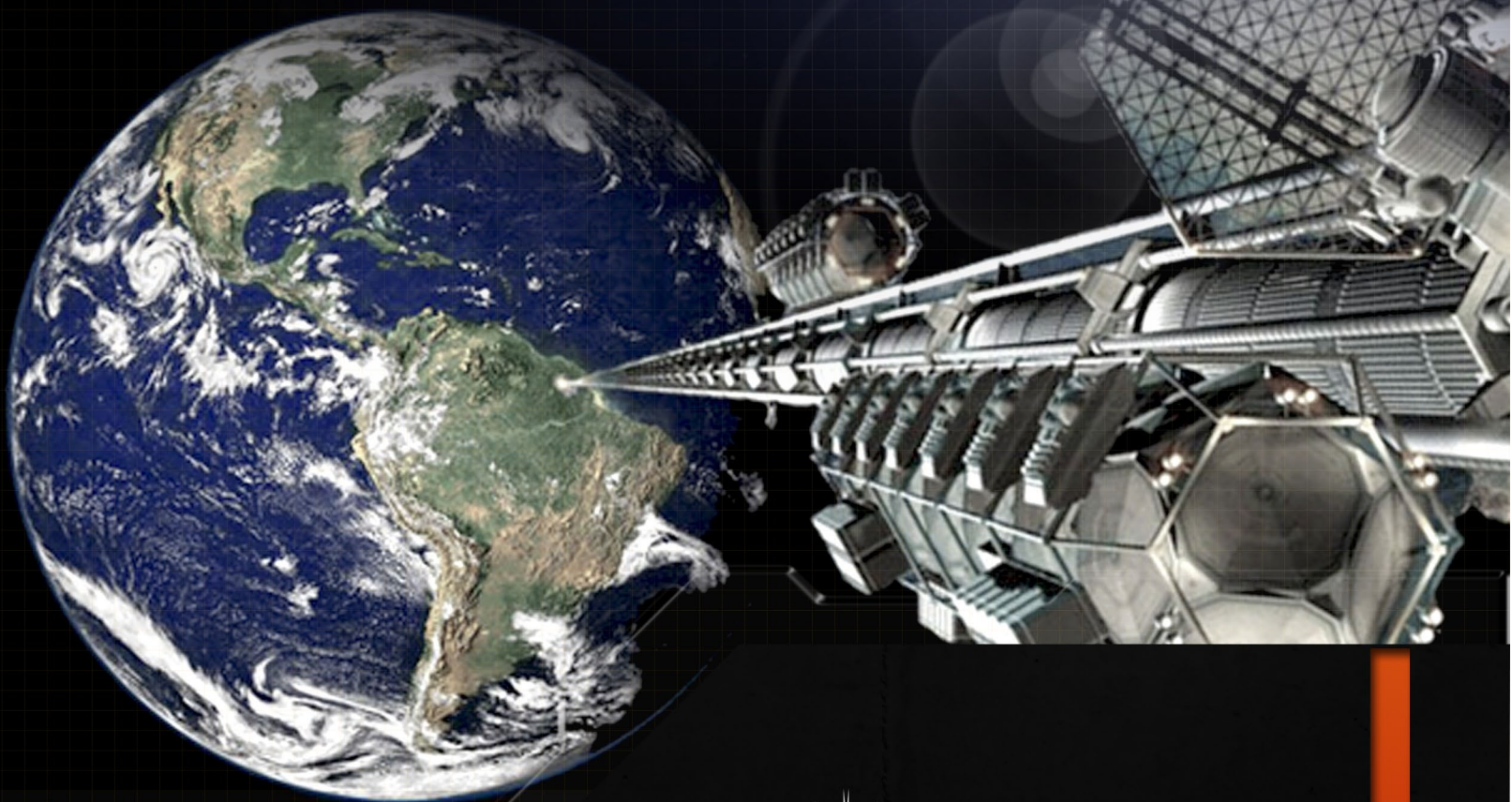


# SPACELIFT



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In February 2014, [Wikistrat](#) ran an internal simulation led by Bruce Wald, former director of the U.S. Navy's space research program, in which 75 analysts (including veterans of the sector) were asked to forecast the shape of the private space industry in the second half of the 21<sup>st</sup> century. Over 30 scenarios were generated, ranging from very conservative to optimistic projections – such as this one, which examines possible future efforts to construct a space elevator. It was written by this simulation's supervisor [Yoni Dayan](#), with insights from experts such as Dr. Brad Edwards and Jerome Pearson, as well as Dr. Peter Swan and Ted Semon from the ISEC.

## SUMMARY

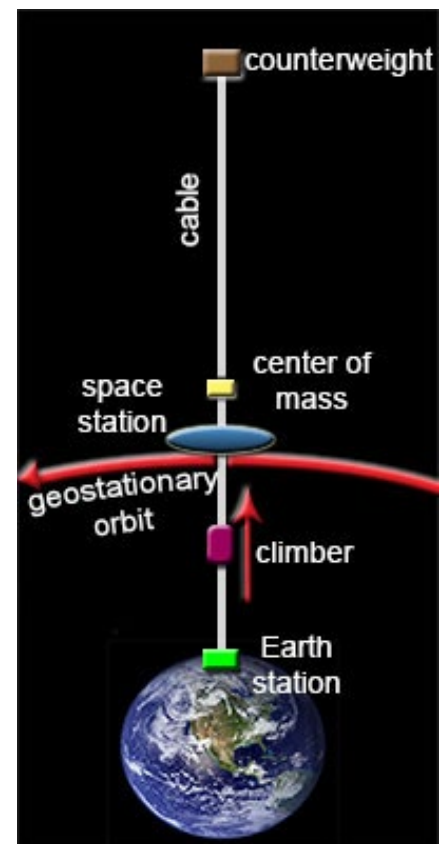
In 2065, SpaceLift, a primarily French company and former business branch of Airbus's Astrium Space Transportation, rises to prominence when it sets up a space elevator, establishing a physical connection stretching from the Earth's surface into space. The elevator consists of vehicles moving up and down a tether kept taut by Earth's centripetal force. Turned from a conceptual design into a reality thanks to the development of a new nanomaterial strong enough to support its own phenomenal weight, the megastructure renders the conventional launchers used for a century mostly irrelevant and slashes the costs of sending a payload to orbit. By making space travel more universally accessible and affordable, SpaceLift revolutionizes this domain and enables the rapid expansion of the space industry, as well as space exploration.



## ORIGINS

The space elevator is created under the direction of current SpaceLift CEO Claude Deveaud. Born into a family passionate about space and related to famous French astronaut Patrick Baudry, Deveaud attends "l'Ecole de l'Air" and becomes a test pilot for the "Centre Nationale d'Etudes Spatiale" (CNES) before heading special projects for Astrium Space Transportation, a branch of Airbus Defence & Space. Here he oversees the development of the rocket Ariane 8 in 2048. Facing intense competition from the proliferation of new reusable vehicles, ESA and Arianespace (which managed the Ariane program) sees their leading market share drop significantly. This prompts the French space industry and its European counterparts to search for solutions. In view of his forward-thinking approach, Deveaud is nominated to be the head of Astrium Space Transportation to address this situation.

Deveaud had long been fascinated by the space elevator concept, which would permanently link Earth to space through a cable maintained in balance between a ground anchor and a counterweight as a result of the planet's spin. The structure is designed to have its [center of mass above geostationary orbit](#) in order to hold and to remain synchronous with Earth's rotation. Deeply influenced by Russian scientist Konstantin Tsiolkovsky's idea of a tall tower touching space, by Yuri Artsutanov's space elevator in 1960, by Jerome Pearson's studies, and above all, by Arthur C. Clark's *Fountains of Paradise* that features such a technological marvel, Deveaud knows that this edifice would revolutionize the exploration and commercial exploitation of space. It would free humanity of the tremendously expensive, encumbering, inefficient and dangerous rocket launchers – of which 90% of their mass are propellant and containment – which had prevented the democratization of space and the expansion of this industry since the mid-20th century.





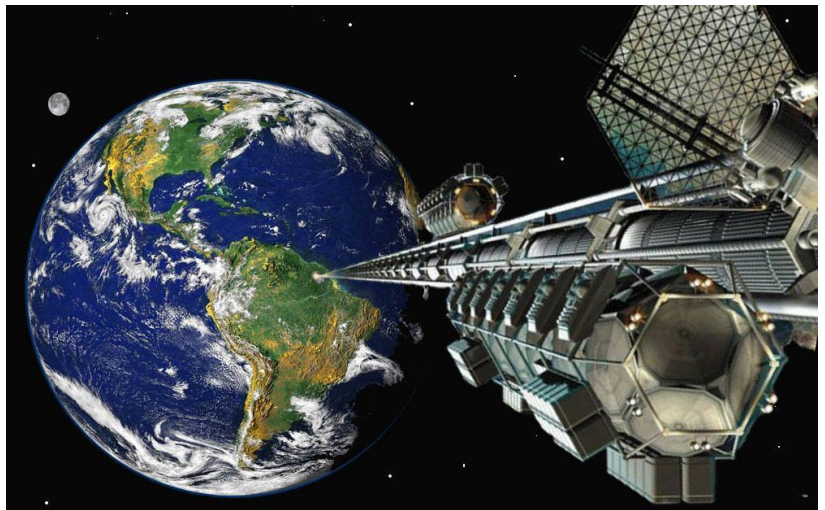
Deveaud closely follows the experiments from the [NASA Institute for Advanced Concepts](#), the [ISEC](#) and [Spaceward](#)'s advocacy for this structure, a multitude of contests (e.g., NASA-Spaceward's [Space Elevator Challenges](#), most recently [one](#) organized by the Technion) as well as companies' projects (e.g., [Liftport Group](#)). He is acutely aware of the technical obstacles involved in such a project. These include, most prominently, the absence of a sufficiently strong material capable of withstanding the colossal strains which would be applied on the tether. In 2047, such issues bring forward the failure of the first prototype made by a Japanese-Indian-American joint venture and based partially on an old [Obayashi Corp project](#), as the carbyne used to build the cable does not fulfill its laboratory potential under real conditions.

After mobilizing Europe's finest scientists in nanomaterial and some of the top engineers of the first attempt (frustrated by the lack of will of their local space industries to pursue this concept after the 2047 fiasco), the engineering of a material called "Astralyne" in 2050 finally allows the planning of a megaproject scheduled for the 2060s. Named "SpaceLift", by 2060 it is managed by a European consortium, mostly privately-run and funded but including public participation. Much like Ariane, Airbus and ESA, the larger part of the space companies in the consortium, as well as its headquarters in Toulouse, are French. SpaceLift is representative of the French space industry and illustrates the importance of this domain for the country that persistently has [the second-largest expenditure on space per capita after the United States](#) throughout the 21st century.

## BUSINESS PLAN

SpaceLift's **main activity** is to transfer people and material between Earth and space via an elevator. It totally recasts this sector by providing an extremely affordable, convenient, secure and almost pollution-free method to move weight into orbit and beyond, making conventional rocket launchers mostly obsolete for that use (excepting some specific applications). SpaceLift democratizes transportation into space, similar to how the advent of railroads, or bigger, faster and mass-produced planes (along with the deregulations and the ensuing reduction of industry fees) democratized transcontinental and air travels.

Even if around 2060, new reusable rockets – such as Ariane 9 and especially spacecrafts like Yuzhou Feichuan's "Star Ride CZ-2" – contribute to a lowering of the cost of launching payloads into orbit ([from \\$5,000/kg-\\$20,000/kg in the beginning of the 2000s](#), or higher for manned launch, to an average of \$1,500/kg), the opening of the first SpaceLift tether divides these costs by fifteen to around \$100/kg – dropping to \$25/kg when four tethers are available two years after the space elevator's inauguration. By 2070, this ratio decreases further to only \$12/kg thanks to various optimizations, de facto disrupting the industry with inexpensive tickets for the middle class to make trips into space. The orbital station has six docks for clients to pick up their goods and travelers. Each cable linking the "Montagne Bellevue" ground station (located in French Guiana) to the space station has its own hypersonic Super MagLev (magnetic levitation) climbers. The scalable nature of the space elevator as well as the option to synchronize climbers makes it possible to lift more than 10,000 tons at one time.



The space elevator rising from French Guiana and its climbers (*composition of NASA satellite image and [Ken Brown's](#) concept art*)

**The second revolutionary service** is the renting of two facilities to build spacecrafts, satellites and other equipment in a zero-gravity environment – a manufacturing process which was only feasible in very limited scope before.

**The third service** is space tourism. Beginning in May 2068, the station is able to welcome 500 simultaneous visitors, giving them the opportunity to see Earth from space and experience weightlessness in special chambers for a few hours before rotating in with the next group. Tickets cost less than \$1,000.

There are two categories of customers:

1. **Private companies** that wish to launch satellites, to transfer personnel and to send material to build equipment directly in space, or to bring back to Earth resources mined in asteroids and the Moon.
2. **National space agencies** for the same applications as above, as well as for their own ambitious space exploration and colonization programs, including the first international settlements of Jupiter's Europa and Io moons in 2080. The exceptional daily transportation capacity of the space elevator and its zero-g factories are instrumental in the colonization efforts which had been constrained until now by the cargo-hold size of conventional space launchers.

Aware of the Channel Tunnel's lackluster economic performance in the 1990s due to delays, large cost overruns and a difficulty in reaching a break-even point, and being well-versed in new responsible project management methods of the 2050s, the heads of the SpaceLift consortium make sure that the construction of the elevator **has a controlled budget and is profitable very quickly**. With the extensive use of 3D and 4D printing, virtual architecture, Astralyne derivatives, public involvement through the largest crowdfunding effort ever seen, backing from the EU and investments from venture capitalists, the megastructure technical costs only exceed the initially-expected \$20 billion sum by \$1 billion (2010s value).

The expenditure breakdown is as follows: \$5 billion for research on Astralyne, \$4.5 billion for cable production, \$4 billion for ground infrastructures in French Guiana, including the power generating and beaming station, with the rest spent for the space station, the climbers manufacturing and a few contingencies. The operating costs, counting the maintenance, are limited as the structure is conceived with minimal requirements such as energy. Likewise, the personnel budget (administration, crew, technical staff) is restrained through automated processes like repair drones and the deployment of a holographic crew. Moreover, those costs are quickly compensated via the services provided, particularly the renting of the docks and the zero-g facilities that are booked for years, at premium prices as there isn't a comparable offer in the market. This drives SpaceLift to build four new space factories in the 2070s.

With clever patenting of the tethers' nanomaterial and an aggressive business approach with the inclusion of potential competitors through close technology licensing, SpaceLift secures the control of 85% of commercial space transportation in less than five years (much like a forecast detailed in a book published 60 years before, [\*Leaving the Planet by Space Elevator\*](#)). This warrants a fast return on investment and annually generates a multi-billion stream of income to the joy of the thousands of crowdfunders who benefit from profit-sharing, as well as advantages in the utilization of the elevator depending on their level of participation and rare goodies from SpaceLift's highly popular merchandising, aptly engendering a worldwide "Space Elevator Fever." This paradigm shift in the sector pushes the majority of the private industry to use SpaceLift's services in the 2060s and 2070s, as well as competitors' elevators later in the century. This shift also progressively alters the way spaceships are designed, as most of them no longer require the lift-off and landing phases and are instead assembled in space and remain there. Governments maintain their own fleet of rockets and reusable vehicles to keep their independence and for emergency, but the positive geopolitical context leading to a peaceful international management of space exploitation and the first-class credence of SpaceLift as a company with Europe behind it nevertheless push them to primarily employ the elevator as well.

By 2099, seven elevators are operated: three by SpaceLift, which is also contracted to build two additional ones that are run by other nations, and three more are set up by the competition. This is enough for the space traffic of the time, especially as the budget requisites and new regulations aiming at framing the edification of such megastructures prevent more of them from being erected.

## SCOPE

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The first phase of the business concentrates on Earth's orbit. Much like Eurotunnel, SpaceLift is the company both building and operating the space elevator. At its inauguration in 2065 and for the following five years, the firm focuses on this activity, while space travels and material shipments further away from the elevator are assumed by private companies and national space agencies. Due to the space elevator's success, SpaceLift builds similar structures in 2069 and 2071 on the few permanent settlements on the Moon and Mars, critically boosting their expansion.

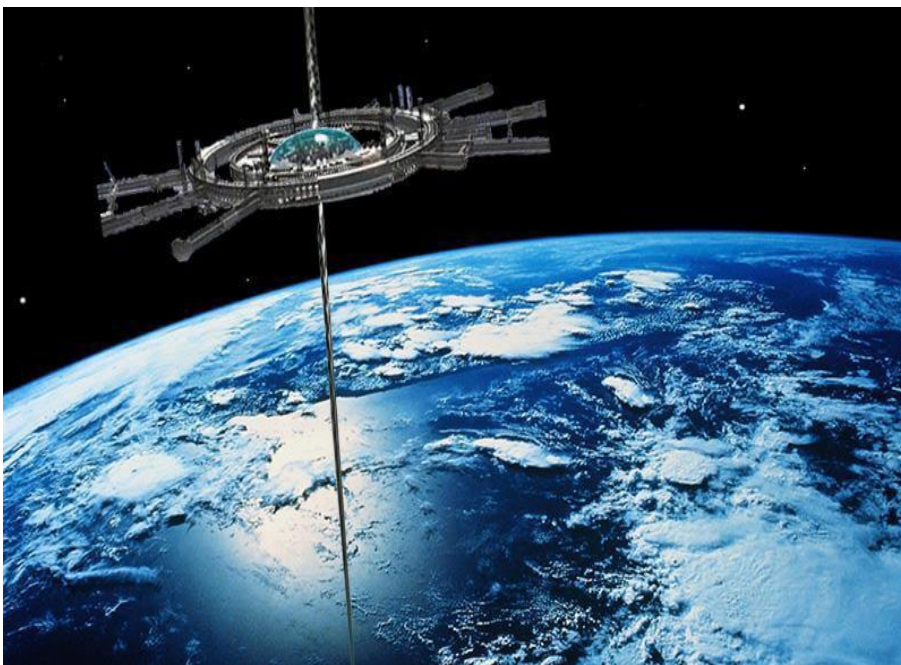
In 2070, SpaceLift sets another couple of tethers, going 20,000 km beyond the counterweight for a total length of 120,000 km, dedicated to space travel by means of the force of projection. Newly-designed "climbercrafts" gain so much speed through Earth's rotational motion and their acceleration on the cable that they exceed escape velocity (the speed needed to break free from gravity) and are catapulted into space where they can reach Jupiter – whose gravity can be used to send the climbercrafts farther out in the solar system without the propulsion from thrusters being necessary ([see Part V of this study](#)). **This new business is the second revolution brought by SpaceLift**, as the possibility to cheaply and conveniently "exchange" huge payloads of material and people between the space elevators of Earth, the Moon, Mars and later Jupiter's and Saturn's moons allows the exponential development of human settlement in space which had been narrowed until then by the constraints of conventional spacecrafts and rocket launchers, such as cargo hold, price, etc. This is later considered by historians as the true beginning of the "space age" involving deep space exploration.

## TECHNOLOGIES

### Challenges to Overcome

The primary technical challenge for SpaceLift (which had hindered previous projects) is to engineer the strongest material on Earth to compose the cable. The structure must attain specific strength characteristics in its tensile strength/density ratio to support maximum stress caused by its own weight under the effect of constant gravity. Some incredibly strong material such as [carbon nanotubes](#), graphene and [carbyne](#) had already been in use in the first half of the 21st century, but it had been impossible to produce thousands of kilometers of continuous wires that had reliable performances outside of test conditions.

Finally, around 2050, the “Astralyne,” a revolutionary nanomaterial complying with the [space elevator feasibility conditions](#), is designed thanks to breakthroughs in 4D printing and chain synthesis. The tether is around 60MYuri ([60 GPa-cc/g](#) – note that Giga-Pascal is a unit of measurement for tensile strength; steel wire is 0.5 MYuri/Gpa-cc/g) and approximately 100,000 km long. The first cable is set much like bridges of the past. First, a spacecraft uncoils a “string” of Astralyne which is tied to the ground station on Earth. Then, construction climbers add other strings to the initial string while ascending it, progressively thickening it to complete the cable. Those climbers are then accumulated and combined at the far end of the cable to constitute the “apex anchor,” which is the counterweight for the elevator. It is the largest engineering structure ever created, far outclassing the Great Wall of China. Three other cables are set in the same fashion between 2065 and 2067.



Space station (composition using parts of NASA/Jet Propulsion Laboratory concept, [source](#))

The second innovation brought by Astralyne is its adaptive intelligent nature derived from the 4D printing, as the cable is capable of dynamically adjusting and distributing a part of the tensile strength/density ratio of its sections depending on the stress applied. This grants the tether a great deal of stability and resistance to the wobbles provoked by the movement of climbers and cosmic disturbances such as solar winds, without the need of thrusters to correct its position which would have introduced several issues such as gas refilling. Likewise, it helps counter the potentially dramatic repercussions of rare defects like cracks left during the fabrication or those that could be caused by incidents on the cable, and can be considered as an advanced “[flaw tolerant design](#)” which was presented half a century before.

The climbers also overcome many challenges met by previous space elevator concepts, especially their too-low speed. The Coriolis force created by the Earth’s rotation had deflected the vehicles in the first prototypes, pulled the cable away from its initial position and generated dangerous oscillations which were offset by painfully slow ascending speeds. Thanks to the remarkable strength and adaptive characteristic of Astralyne, the supra-conductivity of the cable, the use of an exceptionally light-yet-resistant alloy to build the climbers (benefiting from the advancements in nanomaterials employed for the tether), and the careful orchestration of the ascending and descending vehicles to reinforce the cable



balance and avoid [critical velocities](#) that would build up dangerous vibrations, these “Super MagLevCrafts” can reach very high speeds with massively decreased oscillations on the tether, near-optimal thermal control and anti-corrosion to surmount any problems with atmosphere interactions. More precisely, the climbers increase their vertical speed from a few hundred km/h in the heavy-gravity portion of their course when they use a track and roller system to be physically supported. They then switch to magnetic levitation when atmospheric drag force and Earth’s gravity are reduced to reach a speed of up to 2500 km/h (especially beyond the [Karman line](#), the boundary between aeronautics and astronautics set at 100 km above ground). The modules with breathable air designed for human transportation and attached to the climbers include various technological progresses in air revitalization, water recovery and waste processing to cut the costs of life support. Lastly, they dispose of a passive radiation shielding thanks to the properties of Astralyne.

The space elevator meets other difficulties during its construction and its current operation. The fear of colliding with orbital debris when the project was planned was quickly alleviated by an international campaign aiming at cleaning space in the 2050s to improve its commercial exploitation. When SpaceLift’s assembly begins, 78% of the pieces smaller than 10 cm in Low Earth Orbit had been removed. Nevertheless, the structure contains a tracking system, as well as a small fleet of dedicated vehicles (advanced version of the [ElectroDynamic Debris Eliminator](#) built by an Euro-American joint-venture) for object interception and collection, as well as batteries of lasers used in last resort to deflect or destroy debris detected too late. Additionally, the edification of this gigantic structure makes the local populations (Europeans, Mulatto, Maroons and Amerindian groups) as well as the neighboring countries of Suriname and Brazil worried that it could fall on them. This concern is taken into account from the start by ensuring that the cables are permanently protected from accidents and terrorist attacks, and that the portion that could drop on Earth in case of emergencies is made to descend into a controlled zone of the Atlantic Ocean. Finally, the protests against the environmental impact of the ground station are toned down through the economic inclusion of the Guiana inhabitants and eco-friendly practices in the elevator’s construction.

## Operating, Requirements and Logistics

The service needs both a ground port and a space station. The ground port is built in 2060 in French Guiana’s “Montagne Bellevue.” The site is ideal, as it is near the equator, allowing to gain around one kilometer of altitude in the transportation’s course, and providing a strong anchor to the space elevator. It is an eco-structure, confining the imprint on the lush surrounding environment, but it significantly alters the mountain, which spurrs activism in France (and locally) to preserve the rich biodiversity of the region. Except for the anchor, the rest of the Earth infrastructures (such as the international airport and the harbor) are built on the coast near Saint-Laurent du Maroni and Mana, joining the ground station through a subterranean pollution-free monorail that follows the road between Saint-Laurent and Maripasoula. The Earth port is a few hundred kilometers away from the CNES launch base of Kourou, in order to avoid any incidents with the Ariane 9 rocket, now scarcely used but maintained for hypothetical problems with the elevator.

Typically, the travelers and materials are delivered in the new Mana International Harbor or at the Saint-Laurent Airport, and brought to the ground station through the tube, while particularly encumbering goods can be carried directly at the Montagne Bellevue Earth port with low emission vertical take-off airplanes. An automated system loads the shipment into adapted containers, which are then attached to an electromagnetic climber that transports them to Low Earth Orbit in one hour, and to the space station in less than fifteen hours by navigating one of the four tethers. The station consists of multiple linked modules (the first being launched in 2057) located at geostationary orbit at 35,800 km of altitude, and before the counterweight. The inner section holds the zero-g facilities, whereas the rotating outer rim simulates gravity. It is large enough for 400 people to transit, with numbers increasing when the four tethers become operational in 2067. The containers can be dropped down into an elliptical orbit leading them to LEO where they can be either recovered or circularized at this orbit with their embedded small rockets. Fewer customers choose this option than at the beginning of the century, as development in space is profoundly changed by the elevator. Its low costs and huge capacity nullify several advantages of LEO – like heretofore being the cheapest and easiest place to reach in space. Although this orbit is still favored for some applications such as remote sensing, the majority of the containers continue their course toward the GEO station and are then stored outside of it. The station includes six docks (two reserved for ESA, four for rent) for



customers to receive their goods or for travelers, and two factory units to build vessels or satellites in space.

For energy, SpaceLift cleverly multiplies the input in order to reliably satisfy the extremely high power requirements of the climbers, especially at full-load capacity and when they are in Earth's atmosphere. First, large wireless transfers are used between the ground station and the Super MagLev Crafts via a laser beaming system. This process greatly lowers the associated costs and increases the climbers' effectiveness by reducing their weight, as they are deprived of a proper energy source such as a nuclear reactor or fuel tanks. The solar panels of the ground station which produce the main source of power are made of innovative cells that stack multiple sheets of nano-material such as Astralyne derivate (in a similar fashion to an [MIT concept of the beginning of the century](#)) to achieve a record 85% efficiency. This same technology is implemented in the cells covering the climbers' hull, which gathers both the beams from the ground station as well as the sunlight. Completing this first circuit, the energy created by the descending vehicles is collected through regenerative braking and reintroduced in the tether by leveraging its supra-conductivity to transfer additional power to the ascending climbers in a nearly fully autonomous cycle. Lastly, the space elevator performs much like an electrodynamic tether, and collects low energy from Earth's electromagnetic field through the climbers acting as conductors during their course, which is sufficient for certain consumptions such as the lights.

At the dawn of the 22nd century, SpaceLift is designing a new brand of space elevators using an even stronger and "intelligent" material named Sideralyne that may be capable of propagating sinusoidal waves at the proper frequency on the tether which the climbers would "ride" at high speed to slide between the ground and the apex stations with far lower energy requirements than the 2065 elevator.

