The role of governments, space agencies, and industry in civilian space development

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Governments played a decisive role at the beginning of spaceflight, and they still do, even if more recent developments have seen the increasing presence of non-governmental entities. In this section, we explore the role of governments and their agencies versus other actors in the development of human presence in space.

1 The military beginning of space flight

If we look back to the very beginning of spaceflight, we will find that besides the first purely ideal and theoretical steps, the role of governments has been essential.

It is helpful to compare the development of the first functional airplane with that of the first rocket able to reach space. This insight allows us to fully understand why space rocketry began the way it did.

The Wright brothers were accomplished mechanics and smart researchers, well-connected with fellow human flight enthusiasts in the world. They made good use of the experiences of Otto Lilienthal[1] in the 1890s with gliders and were actively supported by Octave Chanute the aviation pioneer. But what materials did they need to make a functional airplane? The Wright Flyer[2] was constructed of wood, covered with fabric, with some metal cables. The Wrights made their small engine, not an advanced model but essentially similar to the car engines of the time, perhaps even simpler. The propellers were made of wood and driven by bicycle chains (the Wrights were bicycle makers). The first airplane was built with little expense and some good craftsmanship. So, they were able to build a fully functional and usable airplane with very limited technologies and financial means.

The first experimenters, aiming to achieve spaceflight, include Fritz von Opel[3] founder of the Spaceflight Society in Germany who commissioned the first purpose-built rocket-powered aircraft in 1929. Eugene Sanger conceived the sub-orbital vehicle Silverbird[4] in 1936 and the American Robert Goddard created the first liquid-fueled rocket[5] with 34 launches between 1926 and 1941. Such pioneers could only make small rockets, very far from the ability to reach space. They were well aware of the need for the resources of a national state to reach outer space which lay beyond the earth's orbit. To enlist government support some of the experimenters of the time, including exponent of advanced potential Hermann Oberth[6] and Goddard himself, proposed military uses of high-altitude rocketry. Goddard did not succeed in raising support because the American Army of that time was focused on airplane development, deeming rocket development a secondary issue. Goddard was hired to develop a rocket-assisted take-off system for airplanes.

So, it came about that Wernher von Braun[7], a pupil of Oberth's, made the first successful rocket that reached orbit, in 1942 during WWII, within a military project that aimed to produce advanced weapon systems for the war[8]. The rocket, the A4[9], was built with specialized alloys, and a fuel feed system employing advanced industrial turbo-pumps reaching very high rotational speed and resisting high temperatures. The engine also reached very high temperatures and pressures, requiring specialized materials.

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1 Lienhard, John - "Wright and Lilienthal" https://engines.egr.uh.edu/episode/162
2 "The Wright Flyer (also known as the Kitty Hawk" - https://en.wikipedia.org/wiki/Wright_Flyer
3 Winter, Frank H., "A Century Before Elon Musk, There Was Fritz von Opel" - https://www.smithsonianmag.com/air-space-magazine/century-elon-musk-there-was-fritz-von-opel-180977634/
4 Robinson, Tim, "From Sänger to Avangard – hypersonic weapons come of age" - https://www.aerosociety.com/news/from-saenger-to-avangard-hypersonic-weapons-come-of-age/
5 Uri, John, "95 Years Ago: Goddard's First Liquid-Fueled Rocket" - https://www.nasa.gov/history/95-years-ago-goddards-first-liquid-fueled-rocket/
6 https://en.wikipedia.org/wiki/Hermann_Oberth
7 https://en.wikipedia.org/wiki/Wernher_von_Braun
8 Collins, Patrick & Autino, Adriano V., "What the Growth of a Space Tourism Industry Could Contribute to Employment, Economic Growth, Environmental Protection, Education, Culture and World Peace" - https://spacerenaissance.space/wp-content/uploads/2020/04/The_Growth_of_a_Space_Tourism_Industry.pdf
9 https://en.wikipedia.org/wiki/V-2_rocket

The fuel used was not comparable to previous small rocket gasoline, the A4 engine required new propellants (both fuel and oxidizer) industrial products hard to produce to handle. Constructing the rocket required an advanced factory and its subsequent launch posed a series of operations that involved a team of skilled engineers and complex infrastructures.

The first artificial satellites were built in a militarized environment, using hardware derived from weaponry development. Unfortunately, perhaps, it was far easier to finance these projects in such a way. Sputnik 1[10], the first satellite to reach orbit in 1957, was launched by a modified R7 intercontinental ballistic missile (ICBM). America had undertaken two different projects for reaching orbit, one managed by the Navy and one managed by the Army. Initially, the Navy project received the most attention, and only after the spectacular failure of the Vanguard rocket, was the Army, project technically led by von Braun, allowed to move forward and eventually succeeded through the Jupiter C launcher (an advanced version of the Jupiter-A intermediate-range ballistic missile, IRBM) to put the Explorer I satellite in orbit.

2 The birth of civilian space projects

Immediately after the success of the Army project in 1956, the US government began to somehow separate military from civilian space projects. The existing governmental research agency for aerodynamics NACA (National Advisory Committee for Aeronautics) had already described significant results, ranging from the well-known NACA cowling for air-cooled aircraft engines to low drag wing profiles (airfoils). These airfoils permitted warplanes such as the P-51 Mustang to run about 50 km/h faster than the British Spitfire although using the same Rolls Royce Merlin engine –. In October 1958 the NACA was transformed by President Eisenhower and became NASA (National Aeronautics and Space Administration) although keeping the NACA personnel and absorbing the research laboratories of both the Army and the Navy. It was designated as a non-military civilian agency with a primarily scientific purpose, but in reality, it remained strictly linked to military prospects in several ways.

NASA performed not only aerospace research but many authentic spaceflight projects, culminating with the Apollo program to put a man on the Moon, a venture which succeeded in 1969 and continued on with five more lunar missions, five of these six missions were landed directly on the Moon.

It is significant that all the astronauts included in the Apollo program were military officers, who originated either from the Air Force or from the air service of the Navy, although as NASA astronauts under civilian administration, they were discharged from corresponding military forces. Neil Armstrong, the first man on the Moon, was a naval aviator who had piloted a carrier-based Grumman F9F Panther fighter bomber in the Korean War, before joining NASA and piloting, among other vehicles, the X-15 rocket plane (a joint project of the Air Force and NASA).

The first nonmilitary US astronaut was the geologist and US Senator Harrison Schmitt, who was one of the two last men to walk on the Moon till the present day (Apollo 17, December 1972).

The only other country that has independently sent humans to space in the XX century was the Soviet Union, which was succeeded by the Russian Federation after the dissolution of the Union in 1991. The Soviet Union reaped extraordinary successes during the early space age: they put the first satellite in orbit, the first man in space (Yuri Gagarin 1961), the first multiple crew in space, the first woman in space (Valentina Tereshkova 1963), the first extravehicular activity, the first space rendezvous with and without docking. Due to the political system of the USSR, the distinction between military and non-military activities was even less defined than in the US as in all cases space activities belonged to the state, and because independent private enterprise did not have any particular role.

The attention of the SRI community is often focused on crewed space exploration, since our purpose is not only humanistic but proposes the rapid expansion of humankind in space, including the long-term settlement of human populations outside our original planet. Within this immediate perspective, we might to some extent set aside an important aspect of the collective space enterprise continuum, the radical placement of many singular unmanned probes that have provided enormous contributions to scientific knowledge of the Solar System since the early phase of spaceflight and the ensuing decades that we have shortly described.

10 https://en.wikipedia.org/wiki/Sputnik_1

3 The post-Apollo age

After the American successes in the Moon race, interest in human spaceflight quickly dwindled. Both the governments who had sponsored the early “space race” were preoccupied elsewhere. Von Braun’s Mars project was rejected by the US Congress, while the Soviet Union gave up the early Moon program deciding that putting a man on the lunar surface was a secondary issue – a decision that might have been due to both the failures of the N-1 moon rocket and the premature death of Sergey Korolev, the inspiring head of the Soviet space program.

All National space agencies, regardless of the type of political orientation of their country, will be subject to political decisions that follow their intrinsic logic. Politicians require specific motivations and criteria to undertake investments in national projects.

It is easy to see how two completely different political systems, Russia and America, had reached the same strategic point: cut the expenses for human spaceflight, while maintaining a limited activity to keep the wholesale technical and industrial base alive. Certainly, though and without prejudice “authoritarian” or “socialist” regimes will also seek consensus. Looking at the US perspective, the public was not necessarily interested in space, while the political elite was focused firstly on ending the Vietnam War and secondly on terminating the other Cold War and addressing economic problems at home. Of course, the US established space industry, as connected to, and coinciding with military industry interests, provided a source of consensus, so the concept of liquidating NASA altogether never came to the fore. In parallel motion, the USSR also had continuing economic troubles, while managing the oppositional side of the Cold War and starting its own Vietnam in Afghanistan.

Both space-faring countries then decided to orient towards low Earth orbit (LEO) objectives. The Apollo and Soyuz vehicles, both designed to go to the Moon even if only one country succeeded, were restructured as limited programs to fly low. The USSR began developing space stations intended as space laboratories: the Salyut stations and then the much more advanced Mir. The US developed Skylab in 1966 for 2 billion dollars, one-tenth the amount spent on Apollo, abandoning the Skylab program seven years later and initiating a new program to make space access cheaper, a good idea that veered off far too soon.

Space access was extremely costly, not only because it was a real and specialized investment, but even more so because it was negotiated following the logic of the military under the control of the government. Private industry in partnership did not take any risk: they were paid on a cost-plus-fee basis, which means that timelines and cost increases were borne by the government. Government agencies needed to report to the political layer, which meant that they needed to be highly efficient and have large bureaucracies: everything posed or included must be formally justified, following complex procedures. This technique was applied both to the USA and the USSR.

4 The history of the Space Shuttle

The story of the Space Shuttle is a good example. It was conceived as being a cheaper model to reach each earth orbit, making use of the expedient concept of reuse. But then political logic was applied: to start with cheaper operations may not mean cheaper development. The project was subject every year to justification and political approval, with the constant threat of being canceled if Congress did not agree to sustain its cost. As often happens with military projects, to justify cost a program is designed to concentrate all adjacent capabilities. This objective meant that all types of space launch potentials were then focused into one single solution and a single platform, thereby canceling all other NASA launcher projects. As engineers know only too well, requiring too many performances and too much capacity from a single device means that it becomes far more complex and costlier and it will never perform at optimal levels in many tasks. The space shuttle, which cost about the same as the Apollo program, was in many ways an experimental project that successfully demonstrated essential and progressive skills, such as the (partial) reusability of vehicles and the manipulation of objects in space.

If we look at the history of the TFX program of the Sixties, which resulted in the F-111 fighter bomber, together with the more recent story of the F35 many similarities may be indicated, as well as. Both of these programs had started with the aim of cost reduction and then evolved into being one of the most expensive military planes ever built, eventually reaching the level of over 400 billion. Of course, these were military projects, but the comparison demonstrates how the Space Shuttle program, despite being a civilian program and not a military –asset – followed the same course.

The demand for cross-range capabilities, again coming from the military, together with cost considerations, brought the government to the deletion of the reusable booster program. Since the Cold War continued to cool down even more, equitable agreements with the USSR were reached. for the reduction of nuclear weapons (SALT I 1972, and SALT II 1979 will apply to this time frame) so production of new ICBMs was slowed down, then stopped. To keep the industrial basis of the missile industry going, the Space Shuttle included two solid rocket boosters instead of its first stage, basically using the technology of ICBMs but designed as reusable artifacts. The official explanation was that they were cheaper than other alternative solutions.

The space shuttle orbiter was very large, with the ability to carry many kinds of payloads, including upper stages which were designed to launch interplanetary probes as well as large military satellites. It seems that military requirements for high weightage and large size of payloads, together with the idea that this had to be the only launcher for everything, brought to the overstretched dimensions of the orbiter. Moreover, being winged and having to bring the main engines to orbit and back down – since no reusable first stage was conceived – the total mass of the orbiter became even larger. Furthermore, since only the orbiter carried the necessary engines, they had to be strapped aside the main tank and not on top of it as logic would require for an orbiter.

The first launch of the Space Shuttle as we know it took place in 1981.

The orbiter was reusable, but it required a complex overhaul after each flight. The same conditions were required for the side boosters. The space shuttle had no plausible safety measures in case of in-flight failures. It soon became clear that the shuttle program had not reduced the cost to orbit, in fact, its cost per kg to orbit was higher than that of Saturn V. It never replaced the necessity for cost-effective reusable launchers.

Two of the orbiters were lost in tragic accidents, killing 14 crew members in total.

On January 28, 1986, the Space Shuttle Challenger broke apart 73 seconds into its flight, killing all seven crew members aboard. The cause was a leakage of hot gases from the booster rocket segments: the seals were incorrectly designed and never worked well, while the low ambient temperature at the launch site caused them to fail. The hot gases caused the explosion of the main tank.

On February 1, 2003, the Space Shuttle Columbia disintegrated during reentry. The cause was damage to the thermal protection of a wing leading edge, caused at launch by a piece of foam falling from the main tank. The heat of reentry seared off the wing, starting the complete disintegration of the vehicle.

The skewed and hasty design of the Shuttle played a major part in both accidents. Other reasons concurred to the poor balance of the Shuttle program. The original design, by Krafft Ehricke, was a fully reusable two stages to orbit, including a winged carrier, following the experience of the X15. The pressure of the expendable-rockets lobbies, on one side, and the government's interest to keep the space frontier under governmental control, brought to review the design, in favor of a non-fully reusable vehicle concept. Another meaningful condition, that made the shuttles weaker than the direct competitor, the Russian Soyuz, was that the shuttles were produced as 5 unique pieces, and not produced by an industrial production chain. The Soyuz, instead, though its design is the same of the 1960's, is being produced on an industrial base, so the machine and its parts are always recent, and in good shape, not overused.

5 Single Stage to Orbit attempts

Within the Strategic Defense Initiative, which was started by President Ronald Reagan in the early 1990s, McDonnell Douglas created a demonstrator for a future Single-Stage To-Orbit (SSTO) launcher with vertical take-off and vertical powered landing, the McDonnell Douglas DC-X. It flew several times, after 1993, followed by a second prototype called DC-XA, proving that it could take off, hover, move horizontally, flip around, and land vertically. The military project was eventually canceled, but NASA took this up for a while, within a reusable launch vehicle program (RLV), that had been established during the interim. After an accident in 1996, which caused severe damage to the second prototype, it too was canceled.

NASA preferred to pursue the Lockheed Martin VentureStar proposal, which was to be an SSTO program as well but this design would land horizontally on a runway like the Space Shuttle, rather than the vertical landing ability of DC-XA. The X-33 demonstrator was ordered, but it suffered a failure in the test of its main hydrogen tank. The demonstrator was never completed and the VentureStar project was canceled in 2001.

The story of DC-X and X-33 shows how promising investigating projects may be quickly canceled due to the oppressive decision-making process of government agencies, while the Space Shuttle shows how their political management may lead to cost overruns and significant failures.

The Space Shuttle had its final flight in 2011, which imposed a gap in the US ability to send crews to orbit since no other American vehicle was available until 2020.

6 The history of space stations

The story of the space stations is also very significant for our purposes.

The USSR, as mentioned before, had put in orbit a series of space stations called Salyut, from 1971 to 1986, and later on was able to assemble a large and efficient space station in Low Earth Orbit, the Mir (peace in Russian), which operated from 1986 to 2001, seeing the USSR being replaced by the Russian Federation as its owner The Mir provided extensive contribution to science operating in LEO, which has not been described in this paper, although we will focus on the international cooperation it triggered.

Russia was running into financial difficulties in the early 1990s, but at the same time, the USA had obtained the Space Shuttle without a port on the space side – essentially because of budget restrictions as well. This factor brought into focus the agreement of 1992 between the USA and Russia: the Mir and the Shuttle would be operated together, with the Shuttle bringing a docking node to the Mir while US astronauts and Russian cosmonauts would work together in space. There was some precedent to this arrangement: in 1975 a joint USA-USSR mission took place, comprising docking of Apollo with a Soyuz capsule through a purpose-built adapter module. The process was more symbolic than significant, but it was a starting point for further interchange. The Shuttle-Mir program offered a wealth of contents in its short duration even more significantly starting up an equitable era of cooperation and bringing international proficiency to the much more ambitious International Space Station.

Post-Soviet Russia created a space agency on the model of NASA, called Roskosmos. The two agencies learned how to work together within the Shuttle-Mir program, conducting many leading space activities and even facing and solving emergencies together. The Mir also hosted several other international astronauts from countries around the world

Mir was de-orbited in a controlled way in 2001, after a failed attempt to continue its operation within a private initiative. Russia decided to support only the new ISS.

In fact, as far back as 1993 USA and Russia had actually started cooperation to build a completely new space station together, one which would replace both the Mir-2 (the successor of the Mir as planned by Russia) and the Freedom station which was conceived but never actually built by the US, it is perhaps reasonable to think of ISS as the fusion of the two potentials.

The European Space Agency (ESA) as well as the Japanese JAXA and the Canadian CSA also joined the project, which then became by far the most complex space project ever constructed and a brilliant example of international cooperation. The ISS is now 25 years old, as its first module was launched in 1998, and the number of cumulative days in space put together by its many crews is impressive. It might be considered the highest point reached by national agencies, working together in a large and unusual coalition, showing that in space the logic of international cooperation may take a formative perspective.

The space race, though starting from the use of modified weapons, shows us how humanity reached a high (also literally) level of common purpose and harmonic development.

In more recent years here, on Earth, international cooperation has certainly reached a very low point with a frightening level of threats and open hostility, and the war in Ukraine bringing us to the brink of direct open war between NATO and Russia. It is almost unbelievable that the same nations are still cooperating in space with the ISS. Just 400 km above the surface of the Earth nations that are almost at war here below are still working together.

7 New private dealers enter the scene

The ISS is a wonderful accomplishment, but it may also be something of a finite end. We can analyze other and related developments that will any case involve the process of international development and collaboration to a greater or lesser extent.

Prospects changed significantly when innovative private entities initiated an agenda to build space launchers on their behalf. They could undertake this work partially because of their own escalating financial capability, but also owing to the support of several space agencies as well as conventional private-sector space clients.

The most significant of all these companies is SpaceX, which was devised and brought to significant success by a visionary entrepreneur, Elon Musk. Musk based his wealth on the creation of Paypal, which was sold for 1,5 billion US$ after generating such a value. Musk is an example of the approach to space that is the opposite of what had come before a single entrepreneur doing what only governments could do in the past.

It must be recognized that Musk started by fulfilling a contract with DARPA, the Defense Advanced Research Projects Agency. A military program, one which was also responsible for designing and obtaining the original phase of our global web internet through the ARPANET program more than 50 years ago. DARPA financed Falcon 1, the first fully private and commercial orbital launcher. The company expanded with a contract for COTS, the NASA platform that replaced the Space Shuttle in resupplying the ISS. This project was extremely innovative because it clearly marked the switch from governmental projects to be managed by the agency and assigned to manufacturers under cost-plus fee agreements, to a commercial contract for a complete project with a biddable lump sum price, including the development of the vehicle, its construction and operation. The agency acted only as a client and supervisor. This formula is the way that private entities operate. Without both NASA and the military investment, there would be no SpaceX.

SpaceX adopted an innovative industrial approach when compared with most commercial companies: full vertical integration, with all the significant components of the vehicle manufactured in-house and even the ground infrastructure built under the full control of the company.

The basic concept was to make a reusable launcher that could, ideally, simply be refueled and launched again without the need for significant refurbishments between flights, just like a commercial airplane. This idea had not been properly achieved till now: although only the first stage of current SpaceX rockets, the Falcon series, is reusable, the purview for making the second stage of the Falcon reusable has been set aside, in favor of the development of the new “Starship”.

Nowadays the Falcon 9 represents a space workhorse cumulating a total weight to orbit per year larger than all other launchers combined. Its cost is unbeatable even though it does not fully monopolize the launcher market. National agency launcher programs continue to provide the other side of the paradigm.

SpaceX developed, within a commercial program for cargo, the Dragon capsule, the only vehicle in the program capable of not only carrying cargo to the ISS but also returning materials to Earth.

NASA has also initiated the commercial crew program, to replace not only the cargo-carrying capability of the Space Shuttle but its crew-carrying capacity as well. NASA's commercial program in early phases financed the development of new space capsules by several competitors culminating with the assignment of contracts in 2014 to two companies: SpaceX and Boeing. The contracts were based on the fully commercial open market concept. SpaceX then developed the Dragon 2 capsule, the successor of Dragon 1 which they had developed for cargo service. On 30th May 2020 the first crewed flight by Dragon 2, which is still considered a test flight, took place, bringing American astronauts to the ISS on an American vehicle for the first time since the retirement of the Space Shuttle. Until that point, American astronauts were obliged to fly on Russian Soyuz capsules owing to the retirement of the Space shuttle. Since then seven more crew rotation flights have been achieved with the last launch of Dragon in August 2023 carrying an international crew from Japan, the US, Russia, and Europe.

In summary, commercial launchers have now reached a full maturity, while the role of many governmental agencies remains essential and clear: they are the main clients of commercial companies and developers of experimental projects that could not be sustained by private entities through open and competitive marketplace dynamics. The private sector must now start to run on its legs. SpaceX is again leading the charge: Elon Musk sees an opportunity for the development of satellite constellations that can bring Internet connections where ground connections are not feasible The Starlink constellation is now extensively operating and still rapidly growing, thanks to the low-cost launch capability of SpaceX.

The opening phases made possible the next generation of SpaceX launchers: named Starship, which once again leverages a prescient NASA contract, this time awarded to SpaceX for the production of the lunar lander, operating within the Artemis Return to the Moon program. The contract also has other partners including private clients such as Japanese billionaire Yusaku Maezawa. Yet again we see a cooperation between a national agency and a commercial company – even if the Artemis project is partially based on an earlier approach, using Orion and the Space Launch System.

In the meanwhile, other companies such as Axiom Space are starting out with their own projects, leveraging the affordable cost for launch offered by SpaceX – and in cooperation with NASA, developing plans to attach their modules to the ISS.

The space company created by another of the richest men in the world, Jeff Bezos, Blue Origin, is progressing at its own pace, with another partially reusable launcher, the New Glenn. Smaller companies like RocketLab and Relativity Space are proposing lightweight reusable launchers.

It seems as if the US is simmering with commercial activities going in the right direction (up!). It is obvious that NASA's contribution, therefore government involvement, is still decisive for human spaceflight, even if a large commercial launch sector is now thriving and the paradigm has changed. The SLS launcher seems like a remnant of another era – a very costly one.

In the meanwhile, Russia is still anchored to the earlier system, even if its political system is not so closely aligned with communist ideology. Due to the current international situation, it is now joining forces with China and its independent projects in space. Russia is second to none and its skillful engineers could well develop solutions as advanced as those of SpaceX and even more so if they were given the opportunity.

China commenced its own national space program later than all others, moving on the base of Russian technology at the onset. Despite being a communist society, in the 1990s it opened its economy to the global free market, triggering a phase of explosive development which brought the nation to Gross National Product of second place in the world by GNP, after only the USA. Even so, in many ways, China does not necessarily or willingly cooperate with others, apart from technological transfer from Russia. China is fostering a private sector, but until now its space activity remains well under the control of the National Space Agency. The Tiangong space station is fully functional and a Moon program has been announced, in cooperation with Russia.

Europe is another essential actor on the space scene, essentially moving on the earlier path. As typically happens, each European political entity does not always overlap with the others: the European Union is neither a state nor a federation and the European Space Agency is not directly linked to it, as it includes important states that are not in the EU, like UK (which exited from the EU consortium) and Norway (which never entered). So, the European Space Agency (ESA) may not be cohesive, lacking the support of certain states, and therefore it must count on the consensus of various governments, each one with its own agenda.

The activities of ESA are numerous and significant, but it is still missing the independent capability to carry crew to space. It must be said that the situation of European launchers is not so good, since Europe never embraced the concept of reusability. The new Ariane 6 is not designed to be reusable and it has not flown yet – it may even be outdated before its first launch. It is hard to see what applications Ariane 6 will find, apart from the captive launches of ESA missions. The current independent launch capacity of Europe is almost nil since Ariane 5 was retired, Ariane 6 is waiting for its first launch and Vega is a small launcher with problems of reliability. No European crew vehicle currently exists.

Government agencies still have an essential role, and an agency without a government – or with too many governments – has troubles.

India and Japan have seen significant space programs, following the traditional space development paradigm. It must be said that India has achieved extraordinary results with very limited investments, all based on its own hardware and technology. It has not launched a crew yet, but it plans to do so, developing its own spacecraft. Japan is following a different path, through international cooperation and ventures, which allowed it to include its astronauts on the ISS. But, again, Japan has no independent capability to launch a human crew.

Our conclusion is that government agencies are decisive for all space activity. The US private sector sports a launch company, SpaceX, that can send a yearly weight to orbit larger than all the other entities of the world together, but even now the company depends to a large extent on NASA and military contracts, as well as the telecommunication and Earth observation satellites. The latest assignment is a contract for the launch of the X-37, the secretive military mini-shuttle.

8 Civilian space development has not kicked off yet

Civilian space development has not really meshed in yet, at least not as a global phenomenon. Government agencies will support advanced science but not necessarily industrialization in space, and they are not expected to. The alternative sector where governments are willing to spend, besides scientific development per se, is the military, a conundrum that would lend itself to further analysis.

Private investment requires the prospectus of a business venture that can bring profits, and this expectation currently involves only telecommunications, specifically constellations, for the Internet.

The lack of suitable legal frames for the space industry and mining activity is a limiting factor, but plausible and technologically viable industrial developments cannot be privately financed for other reasons as well. The business cases for asteroid mining or power production in space do not close: huge investments are needed for their development, with a return time frame still unfeasible for a privately funded entity.

The majority of the portfolio is based on government contracts: essentially Earth observation and positioning systems. Motivations that can move governments to invest in space are badly needed. They may come, realistically, from the notion of seizing certain space resources and assets that are expected to be useful in the future, such as favorable locations near the poles of the Moon. These resources may not provide enough motivation for private investment, but maybe enough for national interest.

We see that the Starship project of SpaceX takes a large part of its financial support from NASA in collaboration with the Artemis program. That bodes well for future achievement unless some political decision pushes the flow in another direction.

9 Recommendations for governments, industry, and space advocacy

The political level is of course influenced by public opinion, and this is something still painfully lacking: most people subscribe to the concept that space is useless, apart from hosting telecommunications and positioning systems, the Earthbound services, and that life outside Earth is impossible.

The most important job for space advocacy organizations is the creation of larger support for space among the general public, aiming to influence governments to provide funds for research that will allow a further reduction of the cost of access to space.

A virtuous schematic, encompassing international collaboration among public entities and private enterprises might be the following one:

- Government agencies make contracts for space projects such as space habitats or Moon stations for research purposes
- Companies develop low-cost vehicles and systems to meet agency requirements in a competitive environment
- Private investors exploit the lower cost of space access to develop:
- Orbital debris mitigation and recovering
- In space manufacturing (some products may be better or exclusively produced in microgravity), including the reuse of orbital debris
- Moon and asteroid mining
- In space power and propellant production, from extraterrestrial resources

Currently, the USA is more or less following this scheme, while China is moving into some first steps, and most other nations still cling to older schemes of agency-driven activity.

Space agencies should pay more attention to factors that allow doing business in space: for instance, there is no reason to expect space workers to live in a microgravity environment. Production facilities for in-space technologies will be in microgravity, but crews must be allowed to spend some of their time out of it, with the use of simulated gravity.

The criteria apply to all factors of human health protection, that are mentioned in other sections of this document. These are enabling factors that are better developed by agencies since they concern a level of research and experimentation that is not intended for a specific business but to enable business activities in general. This method should be a goal for agencies rather than the responsibility of private investors.

Space advocacy associations should seek out support and raise public awareness of these critical issues, this is, therefore, our role.

The role of governments, and national space agencies, is relevant at all levels:

- national level, in supporting their space industry with proper action, i.e. providing contracts and developing the essential research strains, functional to civilian space development
- in the international arena (geopolitics), favoring collaboration and fair competition, working at the U.N. as state parties, and helping the evolution of the regulatory frame of space programs
- in the space environment (astropolitics):
  - to ensure guaranteed room for collaboration and fair competition, and favoring international framework agreements – such as Artemis and ILRS – as a methodology oriented to cultivate the best practices
  - to ensure that civilian initiative not be stifled by an overwhelming military presence on the Moon and in other space environments
  - that the possibility of joint scientific research between scientists from rival powers will be guaranteed, taking an example from some best practices, e.g., the ISS
  - that some important clauses of the Outer Space Treaty, namely, not to bring weapons of mass destruction into space, are respected.