IAC-18,D4,2,12,x47829

Building in Space: first steps in civil expansion beyond Earth

Version: 1.01 - 18/09/2018

Adriano V. Autino[a]*, Stefano Ferretti[b], Luigina Feretti[c], Alfredo Roma[d], Stefano Antonetti[e]

[a] *Space Renaissance International, President and Co-Founder, adriano.autino@spacerenaissance.org*
[b] *European Space Policy Institute, stefano.ferretti@espi.or.at*
[c] *INAF, Istituto di RadioAstronomia, lferetti@ira.inaf.it*
[d] *Former responsible at ESA of the Galileo project for Italian Ministry of Research, Space Renaissance Italia, President alfredo.roma@spacerenaissance.org*
[e] *D-ORBIT, Marketing Manager, stefano.antonetti@deorbitalservices.it*
** Corresponding Author*

Abstract

Space Renaissance International (SRI)[1], with a key role played by its Italian chapter[2], organized a stakeholders platform and discussion forum around the paradigm change from space exploration to civil expansion and settlement beyond Earth. The various members contributed with insights and views from Space Agencies, industry and academia, including also NewSpace entrepreneurs, students and civil society representatives. The objective of this initiative is to highlight the relevance of the NewSpace paradigm for the economy, with a focus on Italy, while evaluating the valuable benefits and opportunities of social and cultural developments related to space activities. The key element of this paper is to identify key recommendations and future strategies to accompany the transition from the current space exploration approach, towards an innovative concept of "space industrialization", which includes the construction and maintenance of space infrastructures directly in space, also by reusing space debris and space resources, and by developing new capabilities for civil passenger transportation and accommodation in space. Some examples are provided in terms of reusable launch systems approaches (e.g. Space X) and Additive Layer Manufacturing technology, highlighting the technological and economic benefits for the industrial development of Earth's orbit and beyond. The paper further elaborates on enabling technologies that could be further investigated as a first priority: low-cost orbital transport for civil passengers, inter-orbital maneuverability concepts, horizontal takeoff and soft acceleration during Earth to orbit travel, innovative and safer re-entry approaches. Among others, priority should also be given to scientific research to protect life and health; e.g. cosmic radiation protection, space habitats with artificial gravity by rotation, artificial ecosystems and exo-gardening and horticulture. This framework also includes reflections on key legal aspects, and a critical review of the Outer Space Treaty of 1967 and the International Maritime Law. The paper in its conclusion highlights how the leaders of such technological developments will benefit from significant returns on investments, but could also ignite a new Renaissance, five hundred years after the Italian one.

Keywords: (civilization expansion, civilian space passengers, space industrialization, economic growth, renaissance, space debris recover and reuse)

Acronyms/Abbreviations

Acronym	Description
ADR	Active Debris Removal
AG	Artificial Gravity
AM-1	Anti Meridiem 1
ASI	Agenzia Spaziale Italiana
BIRALES	BIstatic RAdar for LEo Survey
CEO	Chief Executive Officer
CNR	Consiglio Nazionale della Ricerca
DASS	Distretto AeroSpaziale Sardegna
ESA	European Space Agency
ENAC	Ente Nazionale per l'Aviazione Civile
ESPI	European Space Policy Institute
EU	European Union
IAC	International Astronautical Congress
IAF	International Astronautical Federation
INAF	Istituto Nazionale di Astro Fisica
ISRU	In Situ Resources Utilization
ISS	International Space Station
LHP	Loop Heat Pipes
NEREUS	Network of European Regions Using Space Technologies
NGO	Non Governative Organization
OST	Outer Space Treaty
PHP	Pulsating Heat Pipe
ROI	Return Of Investment
SETI	Search for ExtraTerrestrial Intelligence
SRI	Space Renaissance International
SR2S	Space Radiation Superconductive

	Shield
SSA	Space Situational Awareness
SST	Space Surveillance and Tracking
TLC	Tele Communication
UK	United Kingdom
UN	United Nations
UNCOPUOS	United Nations Committee On the Peaceful Uses of Outer Space
USA	United States of America
USSR	Union of Soviet Socialist Republics
VBN	Vision Based Navigation

1. The distance between dream and reality is decreasing

The Second National Congress of Space Renaissance Italia[3] was held at the INAF, in the CNR Research Area, in Bologna on the 18th and 19th of May 2018. The Congress has been a clear success confirmed by the numerous messages of appreciation for the choice of the theme "Orbital laboratories, first level of civil expansion into outer space" and for the quality of the high level presentations delivered by prominent speakers.

The Congress outlined the importance and timeliness to begin traveling in space as civil passengers, not only as trained astronauts. This implies changing some mission requirements to allow citizens to fly on a spacecraft almost as if it was an airliner, and conduct various activities such as working, doing business, or tourism, in outer space. Civil spacecrafts will need to have controlled acceleration bearable by passengers[4], safer and more comfortable re-entry in the atmosphere[5][6], protection from the cosmic radiation[7][8][9]. Some earthling technologies, such as welding[10], additive manufacturing, wastes reuse, will also need to be adapted, tested and qualified in order to extend their use in space. The orbital and cislunar habitats will need to be endowed with artificial gravity[11], in order to allow longer permancence of the civilian settlers. These were some of the themes discussed by the Orbital Laboratories session, chaired by Dr. Stefano Ferretti. The congress then hosted a twin session on Space Law, chaired by Prof. Alfredo Roma, that addressed the legal aspects associated with these upcoming challenges. It also addressed, on the occasion of the 50th anniversary of the Outer Space Treaty[12] which was celebrated in October 2017, the urgency of a NewSpace law system, compliant with the private commercial activities that will take place in space during the next decades.

The various contributions were intervowed by the underlying theme of the industrialization of space and the highly innovative character of the NewSpace industrial sector and its associated business ecosystem that is quickly developing worldwide. The Congress has also been a great opportunity to discuss and better understand the unfolding social processes that will further develop in the near future, thanks to the development of the NewSpace economy. In this context, the key theme of the orbital laboratories was initially proposed by Prof. Rodolfo Monti during the I National Congress of Space Renaissance Italia in May 2014, and refocused, upon some suggestions by Jeff Greason (former CEO of XCOR), during the II World Congress of the Space Renaissance International, October 2016[13].

A significant number of key stakeholders presented their views and insights from different angles, including the ones of Aerospace Clusters, Space Agencies, SMEs, Space Industry, Academia, NGOs and citizens. In total 42 speakers, 9 companies, 2 aerospace districts or clusters (Emilia-Romagna and Sardinia), 3 agencies (ESA, ASI, ENAC), 5 universities and research institutes, 2 associations, 4 artists artists attended the congress, together with a large number of specialists and space enthusiasts. In additions to that,. 5 round tables were held.

Among the various participants, the congress attracted several key note speakers. The Congress also hosted Enrico Dini, a visionary entrepreneur, who conceived 3D printing for lunar constructions[14], and some exemplary italian NewSpace companies: D-ORBIT[15], Ferrari Farm[16], Technologies For Innovation[17]. Prof. Cao, on behalf of the Aerospace District of Sardinia[19], gave a first-class testimony on the results achieved by the DASS in recent years, developing projects in the range of fifty millions euro. Gaetano Bergami, President of the Aerospace Cluster of Emilia-Romagna, described a very efficient and high-quality ecosystem, encompassing structured and growing companies.

The history of the so-called NewSpace worldwide movement can be summarized according to few milestones.

SpaceShipOne undermines the monopoly. In 2004, thanks to Paul Allen's 30M sponsorship, ScaledComposites won the X-Prize[20], a 10M prize established 10 years earlier by Greg Mariniak and Peter Diamandis. SpaceShip One flow at 100 km altitude, and repeated the flight after three days, with a simple maintenance and refueling. Burt Rutan's company opened the first crack in the monopoly that had governed the aerospace market in the previous fourty years. SpaceShipOne made it clear that it is possible to go to space -- or at least to its boundary at suborbital trajectory -- at costs enormously lower than those demanded by the establishment of the traditional aerospace industry. The prices esatblished by the defence suppliers are no longer the benchmark. The transport of astronauts trained for exploration purposes

is no longer the only way to travel in space. Transporting civilian passengers in space, for tourism or business purpose, became a realistic objective. In 2009, the Space Renaissance Philosophical Manifesto[21] was written and Space Renaissance International was founded. It was inspired by the Italian Renaissance of 1500, when the De' Medici family sponsored the Renaissance of art and culture, decreeing the exit from the Middle Ages. Space Renaissance was targeted to refound the general philosophy, still heavily pre-Copernican, terrocentric and completely unaware that we are immersed in a cosmic ecology. It announced an open world philosophy, and the urgent need for a larger world vision, initially including at least the geo-lunar space, the so-called Greater Earth, or the Earth's gravitosphere.

The Great Hope Of Space Tourism. In 2011, the first world congress of Space Renaissance International[22] acknowledged the warning of the great astrophysicist Stephen Hawking: Civilization will not survive beyond this century, if it will not expand into space. The growth, in itself a factor of great success of our species, if further forced in a closed system will lead to growing cyclical crises, endemic conflicts over the remaining scarce resources and probably to an implosion of civilization itself. The congress identified space tourism as the industrial development sector capable of growing its business, generating the large numbers needed to open up the space frontier to private initiative. The resolution of the congress[23], however, had made it clear that space tourism, alone, might not be enough to reverse the global crisis. Therefore the public support and the contribute by other industrial and commercial branches were highly required.

2015 - Space X opens the age of reusable rockets. In December 2015 Space X successfully experienced the safe return on ground of a Falcon 9 first stage[24]. To date, 2018, this technology can be considered reliable and proven.. Together with the entry into the market of Chinese and Indian launchers, reusable rockets contribute to lowering the cost of transporting payloads in orbit by an order of magnitude. The monopoly of the so-called spendable rockets, lasted more than 40 years, is broken, and even the traditional aerospace giants are forced to reposition themselves[25]. The result is a formidable impulse of growth in the NewSpace sector, especially in the United States, but the wind is now blowing impetuously in Europe too. In 2018, Space X successfully launched Falcon Heavy, bringing two of the three first stage rockets back to the ground in a controlled way. On board there was a Tesla Roadster car, a highly iconic payload, full of great industrialist symbolism[26].

The distance between dream and reality is decreasing In 2016, the 2nd World Congress of the Space Renaissance International recognized the paradigm shift that was taking place: two disruptive technologies - reusable rockets and additive manufacturing (3D printing) - are lowering the cost of earth orbit transportation[27]. NASA opened its market to NewSpace companies. The monopoly of spendable rockets is broken. The Congress takes note of the technical, political and regulatory difficulties encountered by space tourism, which have so far prevented it from taking off[28]. Lowering the cost of transporting Earth orbit of materials and trained astronauts, the great challenge makes a leap in level. In order to trigger the phase of civil expansion into space, the transport of civilian passengers will need to be developed, at low cost, in conditions of safety and comfort, and protection of human life and health. This is a package of mission requirements, and regulatory requirements quite different from the space exploration missions ones[29]. The change of paradigm kicked-off, but it requires an awareness, a priority and a focus of investment efforts that are still largely insufficient.

Industrial development areas propaedeutic to civil expansion into outer space. There's a number of industrial activities, besides space tourism, which can give a ROI in a reasonable times[30]. Therefore such activities, if properly priorized, can work as a powerful booster of an expansionist program. Recovery and reuse of space debris and wreckages is the very first one[31]. Such a program, at least in its recovery part, is also very much needed, for the sake of orbital safety[32]. Once we will have proper orbital infrastructures, targeted to capture orbital debris, the logical following step will be to re-process them, getting powders to be input for 3d printing. Space debris will then constitue a big materials platform for orbital ISRU, the very first bricks of the orbital factories. Assembly of satellites and vehicles in orbit is the second large industrial perspective[33]. Needless to say, assembling satellites and spacecrafts in orbit will meaningfully decrease the cost of design, construction and launch[34]: a first step towards a self sustaining space industrial development. Furthermore, there's a number of in-orbit operations[35]: transport and maintenance of satellites in orbit[36], refuelling stations, repair shops[37], orbital sites, orbital yards, spaceports, habitats[38]. And, of course, all the activities tied to space tourism, such as hotels and lodging facilities, passengers transportation systems (Earth-Orbit, inter-orbit, Earth-Moon). Products from zero gravity, asteroid[39] and lunar mining[40] are other very promising industrial activities, on which several startups were already born[41]. The commercial use of the ISS could maybe be the very first step on such a program[42], though it is not endowed by artificial

gravity, and likely to transform it for AG would cost more than building a new infrastructure, properly designed for civilian activities.

Priority to enabling technologies. To enable geo-lunar industrialization, it is necessary to press the accelerator on a series of technologies. We aim to properly stress the importance of humanism[43], as a necessary background for any scientific and technological design and development. Starting from the need of real persons is key, and we believe that the European culture is prime, in such an endevour. First of all, if technicians and business men need to travel in space in big number, the cost of the transport vehicles shall be reduced. More, the vehicles need to be properly designed to transport civilian passengers, and not requiring any astronautic training[44]. Accelerations should not exceed those of a normal airliner, not too much at least[45]. In this respect, collaboration between civil aeronautics and space vehicles developers is highly useful[46]. Softer and safer atmosphere return technologies are required[47]. Protection against cosmic radiation[48] is top priority, and so artificial gravity[49]. Last, but not least, man cannot live in a full metal artificial environment: any space habitat, be it constructed on a celestial body surface or in orbit or in a Lagrange point, shall be endowed with vegetable terrestrial life[50], not only for food production, but also for the sake of environmental / psychological health. That means to accelerate the experimentation of artificial ecosystems in closed environments.

2. Building in Space: innovative technologies for the in-orbit construction and operations of space infrastructures

In the NewSpace ecosystem, the future of Human Space exploration and settlement is becoming of interest not only for Space agencies and industries, but also for NewSpace entrepreneurs and civil society. This NewSpace paradigm promises economic benefits and valuable opportunities for social and cultural developments related to space activities.

The future strategies that could accompany the transition from the traditional space exploration approach, towards innovative concepts, include the construction and maintenance of orbital infrastructures directly in space, also by reusing space debris and by exploiting space resources.

The exploration of new planets, the construction of a Moon base, the successful completion of a long duration mission to Mars, the continued operations of the International Space Station, all require innovative manufacturing and repair technologies, that could well operate in space and suit a variety of systems, such as crew pressurised modules, radiators, fluid systems, pipe lines and truss structures, engines and aero-shells.

This idea of "space industrialization" would require a number of innovative concepts and technologies[51], some of which are already close to becoming potential game changers: reusable launch systems and sub-orbital transport for civil passengers; Additive Layer Manufacturing (3D printing) and innovative welding processes; on-orbit assembly and servicing; new solutions to better live and work in Space.

Not to forget, innovative business and economic models will be required together with the advances of technology to foster and support the technological developments needed. All revolutions, as well as consistent evolutions, have come along with economical and societal changes, that also in this case will have to be studied and addressed.

Advanced propulsion systems and Space mobility

In line with the NewSpace economic trend, it is becoming important to also ensure new and cheaper ways to access space, including new models of space transportation, both in orbit and to orbit.

In this context also the mission requirements are changing, in line with new visions of both space agencies and private actors. For example building spaceports in the lunar surroundings and Moon or Mars villages is becoming more and more a topic of discussion. Space mining and deep space missions are also becoming part of the NewSpace paradigm and require particular attention.

Both the technological and the economical feasibility are key drivers in the space propulsion arena and some innovative concepts are being developed and were presented at the conference by the company Technologies For Innovation[52].

Virtual technologies for aerospace applications

In the area of suborbital flights it is important to underline to essential contribution of virtual and augmented reality for the management of flight operations. The time horizon for the development and deployment of such operational services in air traffic control, is until 2050. New systems are being developed to integrate digital information, automation and big data[53]. An excellent example is the EU funded program "Resilient Synthetic Vision for advanced control tower air navigation service provision", led by the University of Bologna, which is laying the ground for new integrated systems that will respond to the needs of Air and Space Traffic Management in the coming decades.

The RemoveDebris mission, presented by Prof. Aglietti (Surrey Space Centre, UK) is the first European Active Debris Removal (ADR) mission[54] to

give an in orbit demonstration of the viability of a series of cost effective technologies that can be used to observe, capture and destroy space debris. The satellite is deployed via the NanoRacks Kaber system into an orbit of around 400 km. The concept consists of a main mini satellite platform of approximately 100kg mass that once in orbit will release two 2U cubesats which will act as space debris. Key technologies will be tested: Vision Based Navigation (VBN), to observe and quantify the relative dynamics between an uncooperative debris and the platform preparing for its retrieval, two technologies for debris capture, namely a net and a harpoon, and finally a de-orbit sail, to increase the satellite platform drag, thus reducing its speed and orbit altitude until it burns into the Earths atmosphere. The last experiment to be performed will be the drag sail. During a real mission this would be the last phase, when the platform and the debris that it has captured are deorbited together, destroying them burning into the atmosphere. The design of the mission from initial concepts through to manufacture was presented: a significant contribution to achieving the ultimate goal of a cleaner Earth orbital environment, and a stepping stone toward commercial exploitation.

Hydroponics technique for the cultivation of healthy products in hermetic, sterile and computerized new generation greenhouses. Agriculture plays an important role in the history of the civilizations. It is known that agricultural production depends on the natural condition of the environment, in particular from seasons and geographical situation, as well as from unforeseen events such as drought, floods, diseases, frost, excessive heat, etc... These variables raises difficulties in traditional cultivation. In recent years, pollution of soils and groundwaters with fertilizers and pesticides added many criticalities to the process. The resources are running low and the shortage of farmland is an increasing issue, also due to the massive migratory flows from the countryside to the urban centres, the consequent expansion of urban centres and the worrying climatic and geological changes. In order to address such multiple and contemporary challenges, Ferrari Farm has designed and built a hydroponics system, made of sterile, hermetic and fully computerized greenhouses, unique in Europe[55]. The plant is made of 2 glass greenhouses and 1 phytotron isolated from the external environment, built to create a confined environment designed for advanced indoor cultivation. This new generation and high technology solution allows the cultivation in conditions of absolute sterility, regardless of the external environment. The greenhouses are completely hermetic without any exchange with the external environment, decontaminated in such a way that the internal environment is completely controllable and independent from the external environment. Proper "electronic cultivation recipes" codify, command and control in continuous real time all of the climatic and nutritional parameters: in every moment, every day and for the whole life of the plant. In this way, higher productions and higher qualitative standards are obtained, as well as the advantage of cultivating in every place: space, or environmentally extreme locations on a planet, above ground or under ground, in old abandoned buildings, in containers, in confined environments such as phytothrones. And in long-term space missions and possible space colonies..

3. New Space and Cooperative Efforts

Space 4.0 – spurring sustainable space business. Space 4.0[56] identifies the evolution of the space sector into a new era, characterised by a more and more interconnected and dynamic playing field, where the interaction among multiple and diverse space actors around the world, e.g. private companies, academia, industry and citizens generates new needs and opportunities. A new spirit of interaction between governments, private sector, society and politics, in the frame of Industry 4.0, the unfolding fourth industrial revolution of manufacturing and services. The European Space Agency is working to foster the global competitiveness of the European space sector, fully integrating its benefits into the European society and economy, through sustainable space business activities.

Working toward the implementation of the Moon Village approach: The MOON VILLAGE ASSOCIATION. The Moon village is an innovative approach based on the synergy of several actors, public (space agencies) and private (companies, research centers, universities) [57]. Originated by Jan Woerner, ESA Director General, the idea is not pursued by a single agency as much as by a larger community of people interested in space exploration. The Moon Village has a wider scope than the exploration of our satellite: it is intended as a first step along the way of establishing humankind as a spacefaring civilization. The use of the Moon as a stepping stone for the exploration and then the settling of our solar system (starting with Mars) and beyond is an integral part of the concept.

Platforms for microgravity and parabolic flights. Space and related research programmes always required the microgravity as an intermediate resource, sometimes alternative to spaceflight. Due to the entailed costs and risks, access to space requires testing experiments, systems and training crews in advance of the mission. In this context, microgravity represents a precious resource to the point that over time different ways of achieving it have been developed. Various platforms are available today. In particular, the research on parabolic flight,

conducted by ESA[58], deepened the flight mechanics, the validation process of a typical payload and the psychophysical challenges that the experimenters faced during the flight.

A regulatory framework for suborbital commercial operations. The growing interest and development of novel technologies in commercial sub-orbital operations and some envisaged industry interests at national level brought ENAC, the Italian Civil Aviation Authority, to study, evaluate and analyze this emerging field with the aim to develop an effective and, as much as possible, flexible regulatory framework that accommodates sub-orbital commercial operations within the existing aviation and airspace system[59]. Possible applications of suborbital operations include transportation of humans and/or payload for business, microgravity experimentations, space flight training. The goal is to enable the development of horizontal take-off and landing sub-orbital operations from existing airports within the Italian territory, primarily assuring an adequate level of safety for third parties on ground, namely uninvolved people and properties, and other airspace users. As far as commercial operations are concerned, the mandatory control of the hazards for people onboard, associated with this unique type of operations, will be defined as well, in line with the state of the art and the development of the sector. Selection of a suitable site for the spaceport activities, building a value chain based on a well defined regulation for spaceport certification, a specific operationcentric and holistic regulation for spaceplane operations, including Air/Space Traffic Management, will be developed based on the actual foreseeable operational scenarios.

A Galactic Guide to Space Entrepreneurship. In the summer of 2017 a group of space enthusiasts from over 20 countries met to discuss space entrepreneurship at the International Space University. From this international and interdisciplinary gathering, the astropreneurs.space project was born, consisting of a handbook and a web tool[60]. In our handbook, The Galactic Guide to Space Entrepreneurship, and its corresponding website, astropreneurs.space, we walk entrepreneurs through the characteristics and special challenges of creating a space company, aiming to provide a comprehensive set of tools, guidelines, and best practices for “astropreneurs": not only useful resources such as funding tips, legal advice, competitions, events and courses, but also inspiring stories about exciting companies which are starting to operate in New Space all over the world. The paths they have followed and their stories, as well as their tips on becoming successful astropreneurs. The business model is a community-driven resource, where prospective space entrepreneurs can connect to co-founders, employees with technical expertise, consultants, and incubation or acceleration programs, highlighting the need for funding and technical expertise. Many more services such as legal advice, internationalisation, communication, and branding are in the program.

Involvement of Italian regions in the European Network NEREUS (Network of European Regions Using Space Technologies)[61]. The mission of the network is to spread the use and understanding of space technologies, namely EO/Copernicus, Global Satellite Navigation (Galileo/EGNSOS), Telecommunications and Exploration Technologies. The initiative brings together as Full Members 26 European Regions and 36 Associate Members (companies, universities, research organisations, regional networks etc.) from 9 Member States. The Italian regions (Veneto, Lombardia, Piemonte, ToscanA, Abruzzo, Basilicata, Lazio, Puglia) are the largest group on the platform with many Associate Members from Italy. The network’s activities are focused on three major strands: 1) Political Dialogue and advocacy for matters of regional space use towards the European institutions and ESA as well as relevant Member State organisations 2) lnterregional Co-operations & Partnerships (partly EU and/or ESA-funded) 3) Technological Trends and Developments relevant for future Space Solutions and User Needs. Particualr focus on outreach and promotion activities, political dialogue, data access. The network focus on linking space with non-space sectors as well as to raise awareness for the potentials of space for sectors outside the space sector. The network also serves as a forum for discussion and exchange how space and in particular the downstream sector could be better developed making better use of regional specifities and capabilities.

4. Cosmic Ecology

Studies of Cosmic ecology are aimed at presenting the relation between a human being and the space environment, and analyze the condition of human life in space. In this framework, it is crucial to search for intelligent extraterrestrial life, investigate how to build a comfortable environment for humans outside of the Earth, study the space debris orbiting the Earth and examine possible solutions to protect astronauts from cosmic radiation. These topics were discussed during the Congress, and are briefly described below.

Search for intelligent life. The search for intelligent life is based on scientific observations and has important philosophical implications. The international effort, coordinated by SETI[62], is active since about 40 years. The Italian antennas are used in piggyback mode to search for radio signals which cannot be produced by natural phenomena, and thus must be artificially

produced by intelligent civilizations, who have evolved to a high technological level. Several suspicious signals have been detected so far, but none has been confirmed according to the post detection protocol document. The search continues, of course, and will be refined in the future. The use of very modern and sophisticated methods from earth and in orbit have allowed the discovery of several extrasolar planets (exoplanets) up to distances of about 3000 light years: more than 3500 have currently been cataloged, and some of them show conditions favorable to life, thus they are potentially habitable. These will be primary targets for the search of intelligent signals with future radio telescopes.

The possible discovery of extraterrestrial life would have strong philosophical implications. In the history, there several thoughts indicating that the search for extraterrestrial intelligent life has always been considered in the ideas of great philosophers since the ancient Greeks up to now[63]. The knowledge of the cosmos has always been coupled with the awareness of the human condition in the Universe. It is obvious that the discovery of extraterrestrial life would also strongly impact on the main current religions.

Space environment and occupation. Much progress has been made in recent years on the space occupation, with big developments in space economy. The border between science and science fiction is changing, thanks to modern state-of-the-art technologies. A revolution is currently represented by the small satellites, which are very light thus allow a significant cost reduction. They can change our vision of space exploration and prepare the way for space colonization.

The conditions of the terrestrial environment that has dominated our planet since its formation and during its evolution, and the deep knowledge of how life has been produced and has developed on Earth represent unique information, crucial to understand the conditions for the developments of life on other planets[64]. We can say that man has evolved on Earth by adapting the environment to his needs and can coexist with other species[65]. From the knowledge of the terrestrial ecosystem, we can figure out solutions to develop a comfortable habitat out of the Earth[66]. We will have to use science and technology to reproduce our ecological niche outside the Earth, and modify the environment to produce the resources necessary for life (food, energy, etc.)[67].

Space debris. The number of space debris orbiting Earth has dramatically grown in recent year, and it is currently estimated that there are more than 750, 000 debris objects are larger than 1 cm orbiting Earth. The exact number is however difficult to estimate due to the lack of reliable technologies able to detect debris smaller than 5-10 cm. Any of them represents a serious threat for the safety of space missions and a possible danger on the population if they fall to the ground. It is therefore very important to obtain information with high precision on the shape, size, position and trajectory of debris. As part of the Space Situational Awareness (SSA) Program, ESA is conducting research, together with European industry and developing technologies to detect and track space debris and issue an alert when evasive action may be necessary [68]. Italy is involved in this program and is member of the Space Surveillance and Tracking (SST) Consortium, which aims at detecting space debris, and determining their orbits to predict hazards to operational spacecrafts, such as a potential collision with a debris object, or to infrastructure on ground, such as from a reentering object[69]. The radar system BIRALES (BIstatic RAdar for LEo Survey)[70], which is used for this project, has successfully monitored the re-entry of the Chinese station Tiangong1 and its plunge in the Pacific Ocean at the beginning of April 2018.

In order to be effective in mitigating and reducing the risks caused by the space debris, detection technologies shall have to be supported by enhanced satellite capabilities, such as automation in performing collision avoidance maneuvers, and debris mitigation subsystems that increase the reliability and the autonomy of satellite platforms at the end-of-life.

Regulations, and the compliance with those, are still a critical issue in order to convey towards effective space debris mitigation and remediation solution. A great effort is being put in place by governamental bodies and Space Agencies, however the time needed for effective measures might be long, in the order of tenths of years.

Cosmic radiation protection. The future long term missions in deep space will expose astronauts to harmful radiations which increase the probability of developing serious diseases, even with fatal outcome. Scientists have analyzed the expected radiation exposure levels and how well humans can tolerate these levels, and concluded that protection from cosmic radiation is essential in space. The realization of efficient protecting shields is a compelling challenge for scientists and engineers. Recent studies have been carried out in the framework of the EU Project SR2S (Space Radiation Superconductive Shield)[71]. This project worked to devise a solution for an active radiation shield involving superconducting magnets. Based on detailed simulations with new materials and new configurations, the study has provided a complete conceptual design of a superconductive active shield for space manned missions. The proposed shield is based on toroidal coils arranged in a non-axial geometry (pumpkin configuration), located around the

habitat module. A light reliable conductor based on MgB2 embedded in a titanium matrix was developed and prototype tapes were produced. Other fundamental key technologies are related with the thermal control system: a new extra-long Pulsating Heat Pipe (PHP) suitable for space cryogenics was also demonstrated and the use of Loop Heat Pipes (LHP) was consolidated and validated [72]. These studies could have important technological fallout in other fields as well.

5. The Space Law amidst the ford

Although States still have a leading role in outer space activities, in the last ten years, private enterprises have been more and more involved in outer space activities. International space law has not been updated accordingly, leaving to national authorities the task to adopt in their domestic law system its relevant provisions. These activities comprise, *inter alia,* the use of satellites for telecommunications, the transportation of supplies to the ISS and recently the planned tourist suborbital flights. In a not too far future, even space mining will be an activity performed by private enterprises. Since the first Sputnik flight in 1957 for many years the outer space activities have been driven by USSR and USA for political or military purposes. In the last twenty years many countries have developed their outer space activities that seem to become increasingly driven by economic purposes.

Today, it is probably necessary to examine the *corpus juris spatialis* in relation to the different activities that have arisen in recent years, in order to reach an agreement on the adequacy or inadequacy of the existing legal system, which is basically formed by:

- UN Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies
- UN Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space
- UN Convention on International Liability for Damage Caused by Space Objects
- UN Convention on Registration of Objects Launched into Outer Space
- UN Agreement Governing the Activities of States on the Moon and Other Celestial Bodies

In addition, we have to consider the different national laws of the space faring countries, developed thanks to the promoting action of UNCOPUOS. Till now a limited number of countries have developed their national space law, which however lacks some matters such as the environment, relating especially to space debris. Attention should be put on European Space laws, agreements and conventions, which includes the different roles of ESA and the European Commission, especially in relation to the EU Space projects Galileo, Egnos and Copernicus. In this context, the Framework Agreement signed in October 2003 between ESA and the European Commission was an important achievement for a concrete collaboration between the two European institutions[73]. Further additions recently agreed and the EU Space Strategy of 2016 posed new elements to our attention for discussion and further elaboration.

In order to develop future space activities it should also be resolved the never-ending discussion on the separation between airspace and outer space. In 1957 the Hungarian physicist Theodor Von Karman proposed an equation to establish a specific altitude at which aerodynamic pressure is overcome by ascension pressure, i.e. the point where ascension depends on speed and trajectory of the object (the so-called *Karman line*). Since then such a separation has been identified in 80 or 100 km from the Earth's surface but a precise level has never been legally established, except in the Australian and Danish domestic law systems, which have fixed that separation at 100 km. The matter is very important as such separation would decide when liability for damage caused by spacecraft (moving in airspace and outer space) would be regulated by air law or space law[74].

Property and Ownership should be examined especially in relation to space mining or to the construction of space stations. Since space treaties establish that outer space is *res nullius* we should probably replace the concept of property with licence and concession.

By definition space infrastructures are "dual use", civil and military, despite Article IV of the Outer Space Treaty stipulates that "*Outer space shall be used for peaceful purposes exclusively".* Actually, Article III of the same treaty provides that space exploration has to be carried out in accordance with international law and the Charter of the UN (1945), which by article 51 recognizes the right to resort to force in two instances for self-defensive actions. In effect, since the beginning the space exploration has been guided by the political and military powers. Today, there is a concrete danger for the weaponisation of space and the United Nations should take concrete actions in order to prevent such a scenario[75].

Remote sensing was developed originally by the use of planes. Now, besides planes we can deploy satellites and drones. These flying objects can collect a huge number of information: images, videos, TLC, telephone conversations, positioning of persons and vehicles, etc. Such data may be processed and stored in places out of any control, infringing in many cases the right to privacy. This is now possible thanks to a vast kind of sensors containing sophisticated technology. The use of this technology is mainly in the hands of governmental

entities for security purposes, but now even private entities or individuals can have access to these technologies, including satellites. Unfortunately, there are many gaps in the present system of regulation of both remote sensing and dissemination of data collected by such a technology. In addition, disputes on remote sensing collection of data before national courts suffer from non-homogeneous procedure rules in the different countries.

Virgin Galactic and other companies have developed prototypes of spacecraft able to navigate in the airspace and outer space for pleasure or recreation. Tourist activities may also include long-term stay in orbital facilities or hypersonic suborbital intercontinental flights for transportation. Hence, again it would be useful to establish the level of separation between airspace and outer space for the application of air law and space law to the two phases of the flight, for liability reason (e.g. damage suffered by tourists) or navigation purposes. Air law already contains these cases, the outer space law doesn't. Another tricky aspect concerns the status of the tourist: should he be considered an astronaut and subject to the provisions of the Space Treaties?

Another current matter concerns the space mining. A thick book has already been published on all legal aspect of space mining. Even for this activity the existing norms appear updated and insufficient to regulate the exploitation of natural resources in outer space[76].

Outer space, like Earth, presents environmental problems, mainly caused by space debris. Since the beginning of the human space adventure in 1957, thousands of satellites have been launched. Many of them have come to their life end and are no more under a ground control. In addition, there are old rockets and abandoned spacecraft. Abandoned material and satellite collisions have produced approximately 170 million debris. Such debris, even of small size, move at a very high speed and represent a concrete danger for the operating satellites. Some of these debris contain radioactivity material and toxic fuel. Only in 2011, six thousand tons of space debris re-entered the Earth atmosphere burning in the atmosphere. Again, it has to be stressed that the current UN space treaties are outdated or insufficient to deal with the serious problem of space debris, and unfortunately the on-going discussions in the UNCOPUOS have not yet produced a complete and consolidated set of guidelines. Soft law may help, but a binding legal instrument must be negotiated between States like the Convention on the law of the Sea for the protection of space and Earth environment[77].

Cyber operations carried out by State entities have certainly the power to create great disruption to a modern society that have a wide reliance on space technologies for navigation, communication and economic transactions. Through space infrastructures a State may produce a space blockade to another country. A number of cyber operations against space infrastructures have already been witnessed like, for example, the Terra AM-1 satellite and Landsat 7 compromised by Chinese hackers. The existing set of international rules prohibits such a harmful activity. Unfortunately, the existing space law does not yet contemplate the ability of malicious users to affect the space object of a launching State.

Finally, a deep attention should be put on the insurance of space activities. We expect that the increase of private space activities (estimated in 323 billion dollars per year) will lead to many disputes that, till now, have been resolved by arbitration. Also, these two matters would require a more clear and solid legal framework.

6. Outcomes and Reccomendations

The Congress, at the end of the two days discussion, approved a final motion[78], including some key recommendations:

Final Resolution

The 2nd National Congress of Space Renaissance Italia "Orbital workshops, first level of civil expansion in space",

considering

- the fundamental contribution that the Space Economy can provide to the industrial and economic development of our country;
- the excellent skills that exist in Italy and the tradition that our country owns in the aerospace sector;
- the promising appearance of a New Space sector in Italy;
- the great contribution that Italy can give, with its strong humanist culture of attention to the person, to the expansion of civilization in space;
- the fundamental and urgent contribution that industrial development in space can give to overcoming the global crisis and the strong relaunch of the planetary economy;

invites

the Italian Government and the proper institutions to adopt and support the following approach in relation to the national aerospace sector:

1) To give an high priority to the following research lines, all of them essential to allow the transport and accommodation of civilian passengers and the prolonged permanence of people in space:

- low-cost space transportation systems for civil passengers and goods,
- low acceleration spacecrafts (both on launch and re-entry),
- safe and comfortable re-entry into atmosphere,
- protection from cosmic radiations,
- orbital habitats equipped with artificial gravity through rotation, artificial ecosystems in closed environments.

2) To promote the development of an annual exhibition event in the New Space / Space Economy sector in Italy.
3) To support the establishment of a national coordination of the New Space sector, which will put in system the industries of the sector, the universities, the research institutes, the space agencies, also in consideration of the recently approved law (Law n.7 11 January 2018).
4) To define and adopt a national law for the removal and reuse of existing space debris, wreckages and scraps, and the prevention of the creation of new debris.
5) To promote and support the strong Italian leadership in the sector of the mitigation, monitoring and remedy of space debris, as well as the recovery and reuse of them.
6) Sharing, by the leading industries of the New Space sector, the best practices for the creation of virtuous chains, also through the development of a database of Italian New Space companies.
7) Mentoring by institutions for the allocation of regional, national and European funds to carry out the mentioned projects.
8) To develop a favourable policy towards New Space companies, through incentives to make the industries of the sector competitive, leading to the hiring of young graduates and expert personnel, and contributing to the return of excellent profiles of emigrants abroad.
9) To encourage the creation of thematic Investment Funds, intended to support the development of the New Space industry.

The Congress commits the Board of Directors of Space Renaissance Italia to develop and promote the above in the next four years, putting in place initiatives for coordination, promotion and outreach on the national territory at all levels.

7. Moving forward: an open letter to UNISPACE+50

This letter -- largely inspired by the outcome of the conference in Bologna, was handed to about 200 participants to the UNISPACE +50 conference, at UN Centre in Wien, from 18 to 20 June 2018[79].

The UNISPACE+50 conference is of great significance, addressing a crucial juncture in the crisis of growth that civilization is experiencing. Only an outlook for long lasting cultural and socio-economic growth will properly mitigate social imbalances and fears, and act as the leading factor for peace.

The development of the NewSpace sector, which is triggered by the advent of reusable rockets, new materials and processes, including additive layer manufacturing technologies, is quickly generating a unique industrial and cultural revolution. This remarkable paradigm has the inherent capacity of ensuring the right to development for all Earthlings, as was stated by the UN "Declaration on the Right to Development" in 1986. In progressively shifting the context and burden of industrial development outwards from the Earth's surface, it will also support the goals of the UN Agenda 2030 for Sustainable Development. This important potential describes the social perspective that we have called the "Space Renaissance".

We greet with enthusiasm the announcement that UNISPACE+50 welcomes the participation of NGOs, including Space Renaissance International, an organization that promotes expansion into space, as a means to reverse the global crisis and ensure the continuation and progress of civilization.

We take this opportunity to renew our most urgent recommendations: that the United Nations act within all their means to support the immediate prospect of the industrialization of Earth orbit and of geolunar space; based on a long-term strategy that includes the human expansion, and extension of civil rights, into outer space. In such a strategy the following leading objectives should be pursued:

- Low-cost, safe and comfortable transportation of civilian passengers in space, and protection of their life and health during travel and while working and living in space;
- The development of technologies for the recovery and recycling of space debris, as a high priority;
- The developing of construction technologies in-orbit, along with dedicated programs for their in-orbit validations to be initiated at the earliest phase;
- The exploitation of asteroids and planetary resources — which could eventually enable the construction of large rotating infrastructures in geolunar space — building on upcoming initiatives and programs (e.g. cislunar Deep Space Gateway, Moon Village), in order to allow permanent living

and working conditions in bespoke space settlements.

We recommend that the United Nations:

- Encourage the definition and adoption of national laws for the avoidance of any further proliferation of space debris and the removal of existing space debris and wreckages;
- Promote the sharing, within the leading industries of the NewSpace sector, of the best practices for the creation of virtuous supply chains;
- Support national policies favorable towards NewSpace companies, through various incentives, making the sector's industries competitive, and leading to the hiring of both young graduates and expert personnel;
- Encourage the creation of thematic investment funds suitably designed to support the development of the NewSpace industry.

We believe that these plans could significantly advance notable objectives in working towards the scope of a full maturity. The engagement of the United Nations for a creative paradigm, would uphold international cooperation in space and enhance the universal benefits of space activities for humankind. It is of paramount importance that the United Nations supports the NewSpace community in creating a virtuous circle, with the involvement of new actors that will enable both public and private investments for civil activities in space.

In conclusion Space Renaissance International recommends the United Nations fully inform the veracity and coherence of the existing and guiding principles of space law vis-à-vis the new kind of space activities and the multitude of actors involved (being both public, private, governmental and non-governmental platforms). Within this context, the Outer Space Treaty, which had recently celebrated the 50th anniversary, is universally recognized as primary basis and equitable foundation of space activities. Considering that various interpretations are now being developed at national level, it is becoming very apparent that appropriate and inclusive global governance structures could ensure the adequate exploitation of extraterrestrial resources by ensuing commercial and private activities. In this way supporting the effective enterprises of the NewSpace economy, in developing plans to conduct commercial activities in outer space, on the Moon, asteroids and other celestial bodies.

Acknowledgements

Hereafter the list of the speakers (except the authors of this paper):

- Andrea Comastri (INAF OAS Bologna), Tiziana Venturi (Direttore INAF-IRA), Messaggio di Benvenuto
- Marco Lombardo, assessore Attività Produttive Comune di Bologna, Messaggio Inaugurale
- Giovanni Caprara (editorialista Corriere della Sera), Introduzione
- Lanfranco Zucconi, AIPAS, Futuri scenari dell'industria spaziale italiana
- Giacomo Cao, DASS, Il contributo del DASS al nuovo rinascimento italiano
- Gaetano Bergami, Presidente Cluster Aerospaziale Emilia Romagna, Il futuro delle missioni spaziali: possibilità per l'industria italiana di entrare nella Space Economy. Considerazioni e proposte.
- Maria Antonietta Perino, Thales Alenia Space, Exomars and Beyond
- Luca Rossettini, D ORBIT CEO, Recupero e riutilizzo di detriti e rottami spaziali e loro riconversione per produzione 3d orbitale
- Francesca De Crescenzio, Università di Bologna, Tecnologie virtuali per l'aerospazio
- Guglielmo Aglietti, Surrey Space Centre, RemoveDebris mission, from concept to orbit
- Elena Toson, T4i S.r.l., Sistemi avanzati di propulsione e mobilità spaziale
- Giorgia Pontetti, Ferrari Farm, L'utilizzo della tecnica idroponica per la coltivazione sulla Terra di prodotti sani e "puliti" in serre ermetiche, sterili e computerizzate di nuova generazione
- Enrico Dini, D SHAPE CEO, Elementi di arredo lunare
- Daniele Leoni, Space Renaissance Italia, Development Manager, Privatizzazione dello spazio, spazializzazione della società, idee di business new space
- Elena Cecconi (flauto) e Noemi Manzoni (voce recitante), "Myths and Magic, Dreaming of Space" Recital
- Andrea Vena, ESA, Space 4.0 – spurring sustainable space business
- Giancarlo Genta, Politecnico di Torino, Working toward the implementation of the Moon Village approach: The Moon Village Association
- Pietro Bedogna, Bedogna technologies S.r.l., Piattaforme per microgravita' e voli parabolici
- Alessandro Cardi, ENAC, A regulatory framework for suborbital commercial operations
- ASTROPRENEURS/ISU, A Galactic Guide to Space Entrepreneurship
- Roya Ayazi, NEREUS Secretary General, Partecipazione delle regioni italiane al Progetto NEREUS
- Tommaso Tosi, Filosofia e Scienza, Ordinamento cosmico. La civilizzazione spaziale e il nuovo nomos dell'Europa
- Anna Masutti, Università di Bologna, Progetto Galileo, aspetti di liability

- Marco Ferrazzani, ESA, Space debris: regulatory and technical tools at ESA
- Giulia Pavesi, GSA, Tutela ambientale nello spazio
- Jacopo Bertelli, Università di Torino, La rivoluzione spaziale e la fondamentale impresa del diritto
- Carlo Golda, Università di Genova, Navigazione spaziale ed aspetti militari dello spazio
- Giovanni Favero, Accapierre Srl, Assicurazione spaziale, un mercato in crescita
- Stelio Montebugnoli, INAF, Ricerca della vita intelligente: pianeti extraterrestri e SETI
- Alessandro Mazzi, Università di Urbino, La vita extraterrestre tra filosofia e spiritualita'
- Germano Bianchi, INAF, Osservatorio di Medicina, Detriti spaziali: problematiche, tecniche osservative e risultati del radar italiano BIRALES
- Claudio Portelli, ASI, Difficoltà nella mitigazione dei rischi spaziali e futuri rimedi per preservare l'ambiente spazio
- Roberto Battiston, ASI, President, Cosmic radiation protection and SR2S project
- Leopoldo Benacchio, INAF Osservatorio di Padova, Programmi spaziali: quando l'utopia diventa realtà
- Barbara Cavalazzi, Università di Bologna, Lo sviluppo della vita negli ambienti primitivi e nello spazio
- Enrico Feoli, Università di Trieste, Quale nicchia ecologica per noi fuori dalla Terra?
- Roby Guerra, blogger, poeta e scrittore, Life on the Sun? Poesie spaziali per David Bowie
- Alessandro Sciaraffa, artista multimediale, I Lunatici parlano alla Luna
- Chiara Chiesa, Space Renaissance Italia Communication and Outreach Officer, Il programma di outreach di SR Italia 2018-2021

References

[1] Space Renaissance International main website http://spacerenaissance.space/
[2] Space Renaissance Italia website https://spacerenaissance.it/
[3] Program and Acta of the 2nd Space Renaissance Italia national congress https://sritac.spacerenaissance.space/
[4] Patterson, Relford E. Rayman, Russell B. - Aerospace Medicine: Effects of Gravity, Acceleration, and Microgravity in the Aerospace Environment - 2011 31 March http://www.iloencyclopaedia.org/part-xvii-65263/transport-industry-and-warehousing/air/aerospace-medicine-effects-of-gravity-acceleration-and-microgravity-in-the-aerospace-environment
[5] Dream Chaser, successful cooperation with Sierra Nevada for future NASA mission - 2018 29 March https://www.cira.it/en/communication/news/collaborazione-con-snc-per-test-sul-dream-chaser/
[6] De Matteis, P.P., Russo, G., The USV_X Concept - Mastering Key-Elements for Future Reentry Systems, 1st International ARA Days - Atmospheric Reentry Systems, Missions and Vehicles, Arcachon – France, 3-5 July 2006
[7] An overall look on the cosmic rays protection issue https://en.wikipedia.org/wiki/Health_threat_from_cosmic_rays
[8] SR2S Report Summary - 2016 3 June https://cordis.europa.eu/result/rcn/183926_en.html
[9] Ambroglini F., Battiston R., Burger W. J. - Evaluation of Superconducting Magnet Shield Configurations for Long Duration Manned Space Missions, Front. Oncol., 2016 08 June https://www.frontiersin.org/articles/10.3389/fonc.2016.00097/full
[10] Longhurst, W. R., Cox, C. D., Gibson, B. T., Cook, G. E., Strauss, A. M., Wilbur, I. C., Osborne, B. E. - Development of friction stir welding technologies for in-space manufacturing, 26 August 2016 https://link.springer.com/article/10.1007%2Fs00170-016-9362-1
[11] Hollingham, R. - Giant, spinning space-stations that generate their own artificial gravity have been envisaged for decades. So, why has no one built one? - 2014 18 November http://www.bbc.com/future/story/20130121-worth-the-weight
[12] United Nations Treaties And Principles On Outer Space - United Nations New York, 2002 http://www.unoosa.org/pdf/publications/STSPACE11E.pdf
[13] Autino, A., with contributes by Greason, J., Hunting, E., Collins, P., Perez, M., Sinclair, A. Woods, A. - Theses and Acta of the SRI 2nd World Congress, Skype, 2016 30 September - 2 October https://spacerenaissance.space/congress/sri-2nd-world-congress-from-space-exploration-to-space-settlement/
[14] Building a Lunar Base with 3d Printing (ESA) http://www.esa.int/Our_Activities/Space_Engineering_Technology/Building_a_lunar_base_with_3D_printing
[15] D-ORBIT http://www.deorbitaldevices.com/
[16] Ferrari Farm http://www.ferrarifarm.com/
[17] Technologies For Innovation http://www.t4innovation.com/
[19] Aerospace District of Sardinia http://www.dassardegna.eu/
[20] SpaceShipOne re-opened the astronautic way, after 36 years! http://www.tdf.it/2004/n_12_eng.htm

[21] The Space Renaissance Manifesto https://spacerenaissance.space/wp-content/uploads/2012/07/The_Space_Renaissance_Manifesto.pdf
[22] The first world congress of Space Renaissance International https://spacerenaissance.space/congress/sric-2011/
[23] The final resolution of the first SRI World Congress https://spacerenaissance.space/media/SRIC_Final_Resolution.pdf
[24] Wall M., Wow! SpaceX Lands Orbital Rocket Successfully in Historic First https://www.space.com/31420-spacex-rocket-landing-success.html
[25] Martin, Rod D., Reusable Rockets and the Dawn of the Next Space Age https://worldview.stratfor.com/article/reusable-rockets-and-dawn-next-space-age
[26] Autino, A., A car towards the Asteroid Belt https://spacerenaissance.space/blog/2018/02/23/a-car-towards-the-asteroid-belt/
[27] From Space Exploration to Space Settlement https://spacerenaissance.space/congress/sri-2nd-world-congress-from-space-exploration-to-space-settlement/
[28] Space Renaissance International 2nd World Congress The final resolution https://spacerenaissance.space/wp-content/uploads/2016/10/Motion-final-resolution.pdf
[29] Autino, A., Sinclair, A., Collins, P., Perez, M., A Position Paper on Civilian Space Development and Space Technology approved by the SRI Board December 17th 2016 https://spacerenaissance.space/wp-content/uploads/2016/12/SRI_Position_Paper_December_2016.pdf
[30] Autino, A., Seven million and a half kg of gold in orbit https://spacerenaissance.space/blog/2017/06/20/seven-million-and-a-half-kg-of-gold-in-orbit/
[31] Aglietti, Guglielmo S. - RemoveDebris mission, from concept to orbit https://sritac.spacerenaissance.space/wp-content/uploads/2018/07/RemoveDebris_ASTRA_v3.pdf
[32] Portelli, C. - Difficulties in mitigating risks from space debris and future remedies for preserving the space environment (Italian language) https://sritac.spacerenaissance.space/wp-content/uploads/2018/07/SRITAC2-2.2_Portelli.pdf
[33] Boyd, Iain D. et Al, On-Orbit Manufacturing and Assembly of Spacecraft https://www.ida.org/idamedia/Corporate/Files/Publications/STPIPubs/2017/P-8335.pdf
[34] Patané, Simon C. et Al, Archinaut: In-Space Manufacturing and Assembly for Next-Generation Space Habitats http://spacearchitect.org/pubs/AIAA-2017-5227.pdf
[35] Swarts, P. - On-orbit operations the next frontier for space, experts say https://spacenews.com/on-orbit-operations-the-next-frontier-for-space-experts-say/
[36] Abhishek KRISHNA et Al, In-Orbit Maintenance The Global Picture http://chaire-sirius.eu/wp-content/uploads/2016/10/Krishna-et-al.-2016-In-Orbit-Maintenance-The-Global-Picture-Unknown.pdf
[37] NASA Goddard Space Flight Center, On-Orbit Satellite Servicing Study https://sspd.gsfc.nasa.gov/images/NASA_Satellite_Servicing_Project_Report_2010A.pdf
[38] Wang, B. - Gateway Foundation Spaceport envisions large scale space construction https://www.nextbigfuture.com/2018/06/gateway-foundation-spaceport-envisions-large-scale-space-construction.html
[39] Providing Resources to Fuel Industry and Sustain Life in Space https://www.planetaryresources.com/
[40] Lempriere, M. - Mining the Moon https://www.mining-technology.com/features/mining-the-moon/
[41] Jet propulsion Laboratory Caltech, How Moon mining could work https://www.jpl.nasa.gov/infographics/infographic.view.php?id=11272
[42] Werner. D. - NASA's ISS Director explains the role commercial industry could play in operating ISS. Spoiler: Station is not for sale. https://spacenews.com/nasas-iss-director-on-role-commercial-industry-operating-iss/
[43] Autino, A. - Facing the 21st Century's Civilization Challenges by the Tools of Astronautic Humanism https://spacerenaissance.space/media/papers/Facing-the-21st-Century-Civilization-Challenges-by-the-Tools-of-Astronautic-Humanism.pdf
[44] Snead, M. - An engineer's view of what low-cost, reusable, commercial passenger space transportation means http://www.thespacereview.com/article/3152/1
[45] G. Harry Stine, Space Power Chapter 3: Space Transportation http://space.nss.org/space-power-chapter-3-space-transportation/
[46] Memorandum of Cooperation among US FAA, Italy ENAC and ASI https://www.faa.gov/about/office_org/headquarters_offices/ast/programs/international_affairs/media/

Memorandum_of_Cooperation_FAA_Italy_ENAC .pdf
[47] ESA blog, Reentry: accurate navigation is everything http://blogs.esa.int/rocketscience/2015/02/05/the-facts-on-reentry-accurate-navigation-is-everything/
[48] Feretti, L. - Cosmic radiation protection and SR2S project https://sritac.spacerenaissance.space/wp-content/uploads/2018/07/SRITAC2-2.2_Feretti.pdf
[49] Space Exploration, Why is tethered artificial gravity hardly ever considered? https://space.stackexchange.com/questions/18816/why-is-tethered-artificial-gravity-hardly-ever-considered
[50] Bloom, H. - Garden the Solar System Green the Galaxy http://howardbloom.net/wp-content/uploads/2018/03/garden-the-solar-system-green-the-galaxy.pdf
[51] Ferretti, Stefano - Technologies for the construction of space infrastructures https://sritac.spacerenaissance.space/wp-content/uploads/2018/06/Ferretti-Technologies-for-the-construction-of-space-infrastructures-FERRETTI.pdf
[52] Toson, Elena - Advanced propulsion systems and space mobility - https://sritac.spacerenaissance.space/wp-content/uploads/2018/06/SRITAC2-Elena-Toson-v05.pdf
[53] De Crescenzio, Francesca - Virtual Technologies for Aerospace - https://sritac.spacerenaissance.space/wp-content/uploads/2018/07/SRITAC2-1.3_De-Crescenzio.pdf
[54] Aglietti, Guglielmo S. - RemoveDebris mission, from concept to orbit https://sritac.spacerenaissance.space/wp-content/uploads/2018/07/RemoveDebris_ASTRA_v3.pdf
[55] Pontetti, Giorgia - Hydroponic Farming: everywhere on Earth and above - https://sritac.spacerenaissance.space/wp-content/uploads/2018/07/SRITAC2-FERRARI-FARM.pdf
[56] Vena, Andrea, European Space Agency – ESA and Space 4.0 – Spurring Sustainable Space Business – https://sritac.spacerenaissance.space/wp-content/uploads/2018/07/SRITAC2-1.4_Vena.pdf.
[57] Genta, G. - Working toward the implementation of the Moon Village approach: The MOON VILLAGE ASSOCIATION - https://sritac.spacerenaissance.space/wp-content/uploads/2018/07/SRITAC2-1.4_Genta.pdf
[58] Bedogna, P. - Platforms for microgravity and parabolic flights - https://sritac.spacerenaissance.space/wp-content/uploads/2018/07/SRITAC2-1.4_Bedogna.pdf
[59] Cardi, A. - A regulatory framework for suborbital commercial operations - https://sritac.spacerenaissance.space/wp-content/uploads/2018/07/SRITAC2-1.4_Cardi.pdf
[60] Belingheri, P., Astropreneurs - The galactic guide to space entrepreneurship - https://sritac.spacerenaissance.space/wp-content/uploads/2018/07/SRITAC2-1.4_Astropreneurs.pdf
[61] Ayazy, R. - Involvement of Italian regions in the European Network NEREUS - https://sritac.spacerenaissance.space/wp-content/uploads/2018/07/SRITAC2-1.4_Ayazi.pdf
[62] Montebugnoli, S., et Al - SETI-Italia: Present Activities and Future Real Time Data Processing System, Astrobiology Conference 2010, LPI Contribution n. 1538, p. 5011
[63] Mazzi, A. - La solutudine di Adamo, Alieni tra filosofia e spiritualità https://sritac.spacerenaissance.space/wp-content/uploads/2018/07/SRITAC2-2.2_Mazzi.pdf
[64] Cavalazzi, B., Westall, F., 2018, Biosignatures for Astrobiology, Verlag, Springer International Publishing, in corso di stampa, pp. 390
[65] Cavalazzi, et Al, 2018, Astrobiology, the Emergence of Life, and Planetary Exploration, in: Planetary Geology, Berlin, Springer, 2018, pp. 347
[66] Feoli, E., Ganis, O. Ricotta, C., 2013, Measuring diversity of environmental systems, 2013, in Book: Pedodiversity, Chapt 2, p.29
[67] Benacchio, L., 4 maggio 2018, Turismo spaziale, tutte le startup che ci porteranno tra le stelle, Il Sole 24 ore
[68] Morselli, Di Lizia, P., Bianchi, G. Paoli, J., 2015, A new high sensitivity radar sensor for space debris detection and accurate orbit determination, Proceedings of the 2nd IEEE International Workshop on Metrology for AeroSpace
[69] Portelli, C., Alby, F., Crowther, R., Wirt, U., 2010, Space Debris Mitigation in France, Germany, Italy and United Kingdom, Advances in Space Research, Volume 45, Issue 8, p. 1035
[70] Bianchi, G., INAF-IRA Detriti spaziali: problematiche, tecniche osservative e risultati del radar italiano BIRALES
[71] Battiston, R. - Final Report Summary - SR2S (Space Radiation Superconductive Shield) https://cordis.europa.eu/result/rcn/183926_en.html
[72] Parker, L.J., 2017, Radiation Protection for space colonists and travelers, Room The Space Journal, issue 2(12)
[73] Failat, Y., Ferreira-Snyman. A. - Outer Space Law: Legal Policy And Practice - Globe Law and Business Ltd 2017.

[74] Von Der Dunk, F. – National Space Legislation in Europe – Martinus Nijhoff - 2011
[75] Roma, A. – Space Blockade: a thread to space activities? Aviation & Space Journal – University of Bologna – Oct/Dec 2014.
[76] Lee, R. – Law and Regulation of Commercial Mining of Minerals in Outer Space – Springer Verlag 2012.
[77] Hameed, H. – Active Debris Removal – The issue of Consent – The Aviation & Space– University of Bologna – July/Sept 2016
[78] Mozione finale del 2ndo Congresso Nazionale di Space Renaissance Italia - https://spacerenaissance.it/2018/05/25/mozione-finale-del-2ndo-congresso-nazionale-di-space-renaissance-italia/
[79] An Open Letter To UNISPACE+50 Conference - https://spacerenaissance.space/blog/2018/06/25/an-open-letter-to-unispace50-conference/