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A Brief Overview of

Space Policy

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Summary
Space policy is about the plans and activities of political actors in Outer Space, their motives and strategies. Political actors are nation states, but also international organizations like the United Nations (UN) and the European Space Agency (ESA). The review of UN Space Law has shown that the framework is challenged by plans to start exploitation and settlements of celestial bodies, in particular Moon and Mars.
An overview on space activities, where unmanned satellite and research probes are standard, is followed by a summary of policies and strategies of the leading actors (US, Europe, China, Russia, India and Japan) and a review of military and security issues in Outer Space: Anti-Satellite Weapons, Laser Weapons and Satellite Hacking were identified as key challenges. Environmental problems also exist in Space, in particular space debris and protection of lunar and Martian water reserves. A key problem are the long space travels. Nuclear space engines may appear in the 2020ies to solve these problems. Recent research has shown that the hurdles for microbial life in Outer Space and other planets may be lower than expected. There is a risk that human missions inadvertently create extraterrestrial microbe variants instead of discovering new life and may contaminate lunar and Martian water reserves. Low or no gravity (microgravity) was identified as largest biologic hurdle for long-term settlements and space travels.

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1. Fundamentals

1.1 Introduction

Space policy is about the plans and activities of political actors in Outer Space, their motives and strategies.

Political actors are nation states, but also international organizations like the *United Nations (UN)* and the *European Space Agency (ESA)*. In addition, there are commercial actors such as *Blue Origin* and *SpaceX* with rockets, and *RocketLab* with a private orbital launch site[1]. In addition, several national and international scientific organizations are involved in research. Thus, actors can have political, economic and scientific motives (or a motive mix) to act in Outer Space. The Outer Space can be differentiated by usage in different zones:

Table 1: Outer Space Sectors

Sector	Details	Primary Usage
Orbital Space	Low Earth orbit (LEO): below 2,000 km Medium Earth orbit (MEO): between 2,000 and 35,786 km Geosynchronous orbit (GEO): Geocentric circular orbit of 35,786 km High Earth orbit (HEO): higher than 35,786 km	Satellites, International Space Station (ISS) Environmental issue: space debris
Cislunar Space	The space up to the Moon	The region of Outer Space that could be physically controlled by human mankind at the moment (currently the factual limit of military strategies)
Moon and Mars	Neighbored celestial bodies	Unmanned robotic research missions ('Mars Rover'), targets for future settlements Environmental issue: Lunar and Martian water
Solar system	Comprising eight planets and hundreds of larger planetoids, also periodically returning comets and asteroids	Can be reached with research satellites, but travel not yet possible. Near-Earth asteroids are a major security issue.
Far Outer Space	Everything outside the solar system	Observation by astronomy/telescopes

From this table, it is clear that 'active' space policy is only reaching up to the Moon at the moment and in the near future to the Mars while anything else is still out of reach from a practical and political perspective.

1.2 Geostrategy of Outer Space

Geopolitical and geostrategic thinking is experiencing a comeback in times of dwindling resources and growing insecurity in politics, raising the question of what is understood by geopolitics and geostrategy in the 21st century and how this is reflected in practice.

[1] Pekkanen 2019, p.93

Power manifests itself today in **control over people, territories, resources and information**, related measures are also known as **geopolitics** or **geostrategy**. Power in this context is the ability to enforce something against the will of others.
There are different definitions of geopolitics, but the core of the definitions is **spatial power politics**, the geostrategy is the underlying concept.
In the past, the focus was mainly on land control, today an integrated geostrategic approach dominates with the factors space (land and sea) and time (resources and demography). A substantial difference to past geopolitics and geostrategy is that unlike in previous (neo) colonialism, actors are looking now for ideally **for resource-rich but uninhabited territories** where actors do not have to worry about anyone (off-shore, polar regions).

And this is also the key aspect of Outer Space strategies: the primary aim is to settle on Moon and Mars which are not inhabited and if technically possible, to exploit resources, from there and also from celestial bodies. This may allow territorial expansion, advantage in military conflicts and the mitigation of resource shortage on earth. A particular issue is **Rare Earth Elements (REE)**[2] such as rare metals for digital devices as currently there is no sufficient recycling of these metals from old devices. Also new lunar energy sources such as **Thorium**[3] and **Helium-3** are under discussion.

For practical purposes, two regions of outer space are most relevant, the **orbital space** with satellites, space stations around the earth, and then the Moon and the Mars. However, currently a physical control of the Mars is technically not possible, so the second strategic area is the **cislunar space**, i.e. everything up to the moon.
Outside the Mars, active research by unmanned regions can cover the **solar system** (the first *Voyager* mission has reached the borders of the solar system in 2019), while everything outside the solar system can only be (passively) observed by **astronomy**.
Thus, the geostrategy of outer space can be handled as an extension of terrestrial geostrategy as follows:

[2] McLeod, CL, Krekeler MPS 2017
[3] Cannara 2011

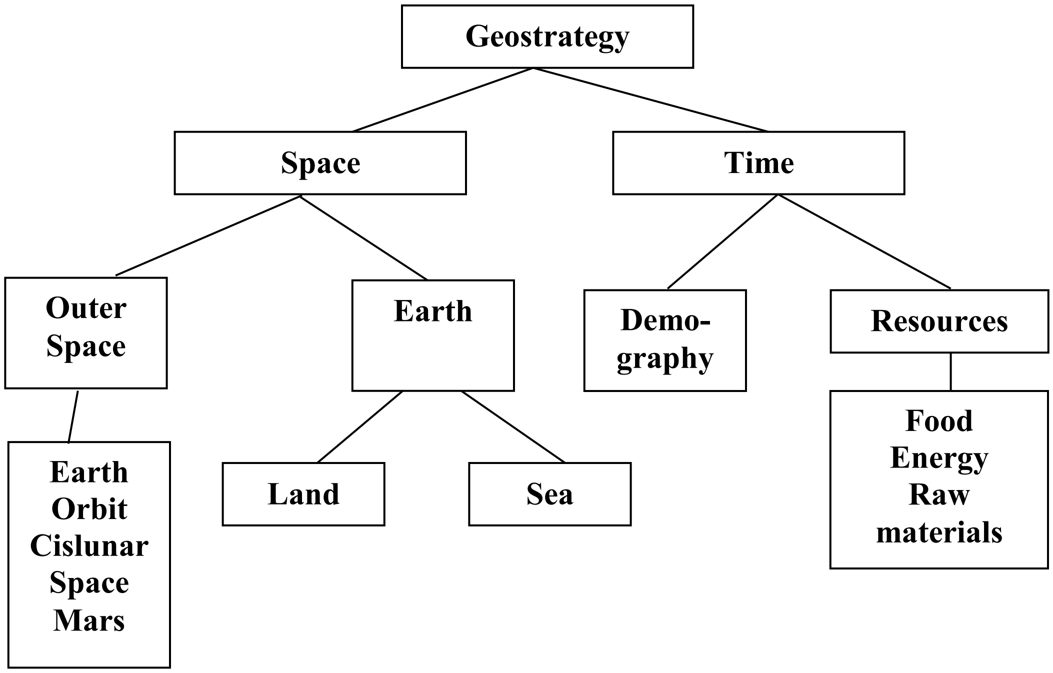

Fig.1: The Integrated Geostrategy including Outer Space
Source: own presentation

2. Legal Framework

2.1 The United Nations Space Law

Space Law can be described as the body of law applicable to and governing space-related activities[4].

The *United Nations Office for Outer Space Affairs (UNOOSA)* is the United Nations office responsible for promoting international cooperation in the peaceful uses of outer space. UNOOSA serves as the secretariat for the *United Nations Committee on the Peaceful Uses of Outer Space (COPUOS)*.

The **five United Nations treaties** on outer space are[5]:

- The **Outer Space Treaty** (Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies), entered into force 1967
- The **Rescue Agreement** (Agreement on the Rescue of Astronauts, the Return of Astronauts[6] and the Return of Objects Launched into Outer Space), entered into force 1968

[4] UNOOSA Website 2020
[5] UNOOSA Website 2020
[6] Russia uses the term *cosmonaut*, China the term *taikonaut*

- The **Liability Convention** (Convention on International Liability for Damage Caused by Space Objects), entered into force 1972
- The **Registration Convention** (Convention on Registration of Objects Launched into Outer Space), entered into force 1976
- The **Moon Agreement** (Agreement Governing the Activities of States on the Moon and Other Celestial Bodies), entered into force 1984, but low ratification

Key regulations[7] are:

- the *Outer Space Treaty* prohibits States from placing in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, installing such weapons on celestial bodies, or stationing such weapons in outer space in any other manner. The Moon and other celestial bodies shall be used exclusively for peaceful purposes and prohibits the establishment of military bases, installations and fortifications, the testing of any types of weapons and the conduct of military maneuvers on such celestial bodies.
- Outer space, including the Moon and other celestial bodies is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means. The Treaty establishes the exploration and use of outer space as the "province of all mankind".
- The Moon Agreement expands on these provisions by stating that neither the surface nor the subsurface of the Moon (or other celestial bodies in the solar system), nor any part thereof or natural resources in place, shall become property of any State, international intergovernmental or non-governmental organization, national organization or non- governmental entity or of any natural person.

Further, the United Nations have adopted **five principles**[8] governing

- the Activities of States in the Exploration and Use of Outer Space
- the Use of Artificial Earth Satellites for International Direct Television Broadcasting
- the Remote Sensing of the Earth from Outer Space
- the Use of Nuclear Power Sources in Outer Space
- the Exploration and Use of Outer Space for the Benefit and in the Interest of All States

The principles state that activities should be in line with the UN treaties, beneficial and peaceful and non-discriminating, i.e. should not exclude developing countries from opportunities in outer space.
The United Nations noted 2019 an increasing erosion of the agreements of space law, see notes 30 ff[9] as some States try to promote their national vision and norms as international standards which undermines the strict compliance with the prohibition of national appropriation of outer space. A particular problem is the planned exploitation of the natural

[7] UNOOSA Website 2020
[8] United Nations 2017, pp.43-68
[9] United Nations 2019, notes 30 ff.

resources of celestial bodies (Moon, Mars, asteroids). This is in line with a general global trend of treaty decline and exit[10].

2.2 Space Mining: ISA as role model?

There is need for more legal clarity for mining and resource use in Outer Space. Sometimes authors suggest the *Antarctica Treaty* as role model for Outer Space Activities, but this is not realistic, as this forbids exploitation. Space activities and settlements on Moon and Mars would overstretch the financial resources of any actor in the long run, i.e. there needs to be some return on investment to enable enduring activities and settlements by mining and/or other resource uses.

A successful example on Earth is the *International Seabed Authority (ISA)* that was established by the *United Nation Conventions on the Law of the Sea (UNCLOS)* to organize and control all mineral-related activities in the international seabed area beyond the limits of national jurisdiction, in particular the exploitation of polymetallic nodules.

Here, states can apply for the exploitation of seabed areas for a defined time range. Typically, two areas have to be taken by a state, and one of this is reserved for the future to avoid rapid overuse. States can also form groups which apply together for areas, so smaller states can combine their activities. Also, observation of environmental effects is done by the ISA.

For Outer Space, this model would keep the ultimate control at the United Nations, but allow capable states to start exploitation (and by using commercial companies on behalf of an applying state, these could also be active). “Environment” in outer space would mean in particular the avoidance of space debris and in case of Moon and Mars, the regulation of lunar and Martian water reserves, as these are limited, but critical resources for any future settlements.

[10] Pekkanen 2019, p.95

3. Space Activities and Actors

3.1 Activities

3.1.1 Satellites

A satellite is an object that has been intentionally placed into orbit, in 2019 several thousand satellites are assumed to be in orbit, less than half of them approximately still operational. Around 2,000 active satellites are in orbit controlled by more than 100 governments as well as commercial entities from more than 50 countries[11].
However, tens of thousands of small satellites are projected to launch in this decade for communications and Earth observation[12].
Satellites can serve a lot of functions[13], in particular

- **Earth observation**: land monitoring, marine environment monitoring, atmosphere monitoring, climate change, emergency management and security
- **Space observation** including detection of Near-Earth Objects such as asteroids
- **Global satellite navigation systems** for accurate and reliable positioning and timing information for autonomous and connected cars, railways, aviation and other sectors, in particular the *Global Positioning System (GPS)* from US, *Galileo* from Europe and *Glonass* from Russia. High-precision navigation is reserved for military purposes
- **Communication Satellites** for television, data transfer and telecommunication in particular in regions where it is difficult to build infrastructure, because otherwise earth and deep-sea cables may have much higher data flow rates
- **Espionage and Reconnaissance**: The information from satellite pictures is also known as **Imaging Intelligence (IMINT)**. The largest satellite-based intelligence organization is the United States *National Reconnaissance Office (NRO)*. Satellites stepwise replaced spy planes which were initially used after World War 2. The EU has a Satellite Center *EU SatCen* which supports the *Intelligence Center IntCen*.
- **Military satellites** for detection of missile attacks or as ‘killer satellites’

3.1.2 The International Space Station ISS

The *International Space Station (ISS)* is a habitable artificial satellite in low Earth orbit with an average altitude of 400 km. The ISS is a joint project of the *NASA (United States), Roscosmos (Russia), JAXA (Japan), ESA (Europe),* and *CSA (Canada)* and is used in particular for microgravity and space environment research in biology, human biology, physics, astronomy, meteorology and for the testing of spacecraft systems.

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[11] CRS 2019
[12] Pekkanen 2019, p.93
[13] EU 2019

3.1.3 Space Robotics/Unmanned Missions

Except the ISS and the planned Moon landing in the *Artemis* program of the NASA, the space routine is done by **unmanned (uncrewed) missions** to save costs and to reduce risks for humans. Any launch of a space object without humans is an unmanned mission, such as exploration and communication satellites.

Space Robotics is not precisely defined. In daily routine, any unmanned space probe can be called a robotic probe, but in research, this typically means remotely controlled devices used for complex operations in space.

Prominent examples for Space Robotics are:

- **Lunar landers**: e.g. for identification of lunar water (*Chandrayaan-1*)
- **Mars Rovers**[14]: e.g. for detection of life on Mars (*Curiosity*)
- **Asteroid probes**: e.g. for influencing their course to avoid collision with earth and analysis (*Hayabusa* probe)
- **Unmanned robotic aircraft**: *X-37* from Boeing conducted five long space flights in the past decade (almost 2 years during last flight in 2019), and is considered to be a reliable, reusable, uncrewed space test platform for the US Air Force
- **Space telescopes**: such as *Hubble* which significantly improved the understanding of the structure and dynamics of the universe
- **Space debris collectors**: *e.Deorbit* satellite of the ESA planned for the mid 2020ies

3.2 Actors

3.2.1 United States

The *National Space Policy* from 2010 defined the following goals[15]:

- Energize competitive domestic industries
- Expand international cooperation on mutually beneficial space activities
- Strengthen stability in space
- Increase assurance and resilience of mission-essential functions
- Pursue human and robotic initiatives to develop innovative technologies
- Improve space-based Earth and solar observation capabilities

These goals are still valid in early 2020. Already in 2010, it was suggested that the United States shall develop and use space nuclear power systems where such systems safely enable or significantly enhance space exploration or operational capabilities[16].

The Trump Administration released 4 **Space Policy Directives** (SPD-1 to-4):

Space Policy Directive-1 from 2017 directed to lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring new knowledge and opportunities.

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[14] Pekkanen 2019, p.94
[15] USA 2010, p.4
[16] USA 2010, p.8

Space Policy Directive-2 from 2018 "Streamlining Regulations on Commercial Use of Space," deals with the matter of commercial spaceflight licenses.
Space Policy Directive-3 from 2018 "National Space Traffic Management Policy" is focusing on *Space Situational Awareness (SSA), Space Traffic Management (STM)*, and development of appropriate Science and Technology research to support expansion and interoperability of SSA and STM systems.

Space Policy Directive-4 from 2019 directed to submit a legislative proposal to establish a *US Space Force*, which was then enacted by Congress. In more detail, this includes

- the creation of the *US Space Force (USSF),* a separate military service under the Department of the Air Force
- reestablishment of the *US Space Command (USSPACECOM)* -which already existed from 1985-2002- and 2 subordinate units, the *Combined Force Space Component Command* for space based services, including GPS navigation, space-based data, satellite communications, and the *Combined Space Operations Center Missile Warning Center*, for protecting military space systems, including those of the *National Reconnaissance Office (NRO)*
- maintenance of *Space Development Agency (SDA)* created in March 2019 to accelerate the process for acquiring space systems to meet emerging space threats[17].

The *Presidential Memorandum on Launch of Spacecraft containing Space Nuclear Systems* from 20 August 2019 addresses the use of *radioisotope power systems (RPSs)* and nuclear fission reactors used for power and propulsion[18]. It is stated that the use of nuclear power "is vital" to keep US dominance in space.
US authorities are required to evaluate low uranium-enrichment systems with a very low probability of accidents and exposure of human to radiation.

The *National Aeronautics and Space Administration (NASA)* is the agency of the United States for the civilian space program. In December 2019, CNN reported that the NASA discovered water on Mars only one inch beneath the surface.

The NASA Key programs that are still active are shown below.
ISS cooperation since 1993: The *International Space Station (ISS)* combined NASA's *Space Station Freedom* project with the Russian *Mir-2* station, the European *Columbus* station, and the Japanese *Kibō* laboratory module
Commercial programs since 2006: NASA awarded Commercial Resupply Services contracts to *SpaceX* (with *Falcon 9* rocket) and *Orbital Sciences Corporation*
Artemis program since 2017: The goal of this program which includes cooperation with commercial companies and the ESA is to land "the first woman and the next man" on the lunar South pole region by 2024. Artemis would be the first step towards a sustainable presence on the Moon, and an important step to a Mars mission.
Unmanned missions: Over 1,000 missions were conducted by the NASA, mostly exploration and communication satellites.

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[17] McCall 2019
[18] USA 2019

Mars Science Laboratory mission since 2011: The Mars Rover *Curiosity* is active on Mars since 2012 in search for past or present life.
The **James Webb Space Telescope (JWST)** as successor of the *Hubble* telescope is planned to start in 2021
Lunar Gateway: planned new space station in orbit about the Moon, instead of the Earth for temporary human habitation.

Due to security concerns, all researchers from the *NASA* are prohibited from working with Chinese citizens affiliated with a Chinese state enterprise or entity since 2011 (**China exclusion policy**).

3.2.2 Europe

The European Commission released a *Space Strategy for Europe* in 2016[19]. Note that the *European Space Agency ESA* is an organization that was founded separately from the EU, but is closely linked to it. This detail is important as the United Kingdom will leave the EU by the Brexit in 2020 but will stay in the ESA.

So 'Europe' in Space Policy consists of:

- the Member States,
- the *European Space Agency (ESA*),
- the *European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)*
- and the EU.

Of the member states, France plays a special role, as this is hosting the headquarter of ESA, owns the launching base in Kourou in French Guiana, and has founded in 2019 (from precursor organizations) a new *Space Command*, where defensive measures already exist (including powerful radars to observe space).

The *European Space Agency (ESA)* is the key European Space organization with of 22 member states. ESA participates in the ISS conducts unmanned exploration missions to other planets and the Moon and is active in earth observation, science and telecommunication. The major spaceport is the *French Guiana Space Centre* at Kourou and its main launch vehicle *Ariane 5* is operated through *Arianespace* with ESA.
ESA cooperates also with other space agencies such the NASA (see ESA website)[20].

Goals of the *European Space Strategy* include to maintain Europe's autonomous access to space, to cooperate with space industry and to enhance security for the critical space infrastructure.

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[19] European Commission 2016
[20] ESA units are: Headquarters (HQ) European Space Operations Centre (ESOC) European Space Research and Technology Centre (ESTEC) European Space Astronomy Centre (ESAC) European Centre for Space Applications and Telecommunications (ECSAT) European Astronaut Centre (EAC) ESA Centre for Earth Observation (ESRIN) Guiana Space Centre (CSG) European Space Tracking Network (ESTRACK) European Data Relay System.

Key activities are three satellite programs[21]:

- *Copernicus*, the EU's Earth Observation program: free, full and open access satellite data used to provide services in six areas: land monitoring, marine environment monitoring, atmosphere monitoring, climate change, emergency management and security.
- *Galileo*, the EU's global satellite navigation system: providing positioning and timing information for autonomous and connected cars, railways, aviation and other sectors.
- *EGNOS*, the EU's regional satellite navigation system: Monitors and corrects satellite navigation signals for aviation, maritime and land-based users over most of Europe
- The *European Global Navigation Satellite System (GNSS) Agency (GSA)* is an EU agency responsible for the exploitation of EGNOS and *Galileo*.

In the next 10-15 years the EU plans to launch more than 30 satellites for its *Galileo* and *Copernicus* programs, notably in the class of the future European-built launchers such as *Ariane 6* and *Vega C*, making the EU the largest European institutional customer[22].

The security concerns are planned to be addressed by the *European Defense Agency (EDA)* which will evaluate the situation.

For intelligence purposes, the EU already operates since many years the *EU Satellite Center EU SatCen* which collects Imaging Intelligence for security assessments in the *Joint Situation Center SitCen*. Meanwhile, the SitCen is part of the *European External Action Service EEAS* and now called *Intelligence Center (INTCEN)*, which according to the EEAS Org Chart from 01 Feb 2019 is organized in 4 units *Intcen 1*-4 for analysis, open source intelligence (OSINT), situation room and consular crisis management.

For space defense, the EU has implemented the *EU space surveillance and tracking (SST) support framework* which has now started delivering operational services based on a pool of Member States' capacities and it is planned to extend its scope to other threats and vulnerabilities, for example cyber threats or the impact of space weather on satellites and on ground infrastructure such as transport, energy grids and telecommunication networks.

3.2.3 China

China has a long-term strategy to expand its space program[23]:
After building a cost-effective launch capacity a first step, a space station should be constructed to allow expansion in cislunar space. A lunar base, deep space exploration and asteroid mining are later goals.

[21] European Commission 2016, EU 2019
[22] European Commission 2016
[23] Goswami 2019

The space program of the People's Republic of China is directed by the *China National Space Administration (CNSA)*, an agency within the *Commission of Science, Technology and Industry for National Defense*. The *Long March* rocket is produced by the *China Academy of Launch Vehicle Technology*, and satellites are produced by the *China Aerospace Science and Technology Corporation*.

In 2003, the first Chinese crewed space program was a flight with the *Shenzhou 5* spacecraft. In 2007, a ground-based anti-satellite (ASAT) missile was successfully tested.
Important current programs are:
Project 921 since 1992: starting with *Shenzhou* program which brought first Chinese into space, followed by stepwise launch of *Tiangong* modules as space labs with the ultimate goal to build a permanent Space station in the 2020ies.
Lunar landing: In 2013, China landed the space probe *Chang'e-3* on the Moon, followed by the *Chang'e-4 Moon Rover* landing on the far side of the moon in 2019 with water expeditions and some planetary science experiments, in line with the Chinese government's goal of sustaining a human lunar outpost, possibly with international partners[24].
The project included a growth experiment on the moon with a small lunar biosphere in a box (air, water and soil): a cotton plant managed to grow under these conditions while certain other plants failed to grow[25].
Future projects include:
Robotic Mars mission

- **Zheng He**: to launch an asteroid sample return mission
- **Xuntian**: space telescope, later on maybe coordinated with a proposed space station
- **eXTP**: x-ray astronomy in cooperation with European countries

3.2.4 Russia

Russia's civilian space agency is the *Roscosmos State Corporation for Space Activities (Roscosmos, RKA)*.
Important elements of the Russian space program are:

- the GLONASS navigation satellite system
- the activities on the *International Space Station ISS* where *Roscosmos* is responsible for expedition crew launches by *Soyuz* spacecraft and supplies with *Progress* space transporters and
- the provision of Earth Observation and Remote Sensing satellites
- The *Soyuz* rocket and the large *Proton* rocket are used for transportation, a new rocket system, *Angara*, is under development.
- *ExoMars* (Exobiology on Mars) is an astrobiology program *by the European Space Agency (ESA)* and *Roscosmos*.
- The next aim is the successful landing of unmanned space probes on Moon, Mars and Venus.

[24] Pekkanen 2019, p.94
[25] Devlin 2019

The military is organized in the *Military Space Forces (VKO)* with the *Plesetsk Cosmodrome* (launch facility) while the RKA and VKO use together the *Baikonur Cosmodrome*.
The Russian space program suffered from financial shortage and efficiency matters in particular after the collapse of the Soviet Union, but the Russian government is aware of the problems, so reforms and new efforts can be expected in the 2020ies.

3.2.5 India

The *Indian Space Research Organization (ISRO)* is the space agency of India. Important activities are:

- **Rockets**: After initially several Indian satellites were transported by foreign countries such as the Soviet Union, India uses now own reliable launching systems, the *Polar Satellite Launch Vehicle (PSLV)* for launching satellites into polar orbits and the *Geosynchronous Satellite Launch Vehicle (GSLV)* for geostationary orbits. The *new GLSV-Mark III* can carry larger objects.
- The **satellite program** includes communication, Earth observation, Remote Sensing, Radar Imaging, and Satellite navigation systems (*GAGAN and IRNSS/NAVIC*).
- *Chandrayaan-1* was a robotic **lunar exploration mission** with a lunar orbiter and an impactor called the *Moon Impact Probe* and discovered lunar water as ice in the polar regions in 2008.
- The second lunar mission *Chandrayaan-2* to study the lunar geology and the distribution of lunar water in 2019 ended with a landing failure.
- The **Mars Orbiter Mission** (*Mangalayaan 1*) entered Mars orbit in 2014.
- India plans in the 2020ies a first **crewed flight** with a spacecraft called *Gaganyaan* and the Mars Orbiter Mission 2 (*Mangalyaan 2*).

3.2.6 Japan

In 2015, Japan's Prime Minister Shinzo Abe emphasized the need for a shift in Space Policy[26] and a new 10-year basic plan for Space Policy was released. More attention is now given to security-related matters.
Japans wants to maintain autonomous launching capacities and will modernize its rockets for this reason to the new *H-3* model.
Japan's Aerospace Exploration Agency (JAXA) has also expanded the *Quasi-Zenith* satellite navigation system to enhance connectivity with the GPS system and an Earth observation satellite with a missile warning sensor was also released. JAXA is also researching on high-speed planes for use on Earth.
The *Japan Aerospace Exploration Agency* will now also cooperate with the Ministry of Defense with a focus on reconnaissance and surveillance activities. In particular, China is seen as competitor in Space Policy and it was mentioned that it is assumed that China develops anti-satellite laser beam weapons. The main cooperation partner in this plan is the United States.

[26] Rajagopalan 2015

Japan has developed its legal Space Law framework by the

- *Remote Sensing Data Act*: Act concerning Ensuring Adequate Handling of Satellite Remote Sensing Data to regulate appropriate data usage and the
- *Space Activities Act*: Act concerning launch and control of satellites[27] which regulates authorization for satellite launches and the handling of commercial actors.

A specialty of Japan's Space activities are **asteroid landing missions**.

Japan's *Hayabusa* probe returned to Earth in 2010 after a seven-year and 6 billion kilometers journey with samples from an asteroid, and new asteroid missions are planned with *Hayabusa 2*. Japan's *space dialogue* with India, which sent a geologic survey probe now orbiting Mars, includes collaboration on exploration of the lunar polar zone. [28]

Japan's plans for the 2020ies include lunar landers and a lander on the Martian Moon Phobos.

[27] Hara 2017
[28] Pekkanen 2019, p.94

4. Military Space Policy

4.1 Space Weapons

The arms race in space is already going on. The *US Congressional Research Service* noted that “China, Russia, and other nations are pursuing capabilities to target U.S. space systems using jammers, lasers, kinetic-kill, and now cyberattack capabilities” [29].

4.1.1 Anti-Satellite Weapons

Established weapons are anti-satellite missiles which however cause a lot of space trash which brings all other space objects into danger.
For testing purposes, satellites in low earth orbit have been destroyed by ballistic missiles launched from earth by Russia, the United States, China and recently India.
The space debris matter would be a good argument for a convention that forbids testing of space weapons in outer space. This may even have a chance for acceptance, as the orbits are already overfilled with waste particles which go around the earth with high speed. During cold war, US and Soviet Union agreed on a test stop for atmospheric nuclear explosions as the contamination of the atmosphere with radioactive particles increased rapidly.

4.1.2 Laser Weapons

It is nowadays no problem to produce high-precision long-range beams, but it is currently still not possible to produce sufficient kinetic energy to hit larger objects, anti-drone and anti-missile testing with Laser is still in early stage. Laser weapon research is e.g. done by the United States, but also in Germany.
The drone defense research in Germany is going forward to the use of laser weapons. In May 2015, a small quadrocopter drone could be destroyed after application of 20 Kilowatt over 3.4 seconds[30]. However, for larger objects energy levels up to 200 Kilowatt will be needed, the technology is in development.
In 2021, the US Navy plans to set up the much stronger laser weapon HELIOS on destroyers which is able to downing drones and boats[31]. Such a laser would have the technical potential to damage satellites as well.
Japan assumes that China develops anti-satellite laser beam weapons[32].

4.1.3 Satellite Hacking

Another weapon that is widely unknown is satellite hacking. Little is published, but one can say that direct takeover of satellites in space is cumbersome and has little effect, while hacking of space control centers on earth has led to a substantial increase of satellite hacking activities. Satellite hacks of US satellites were already reported since a decade and

[29] CRS 2019
[30] Marsiske 2016
[31] Mizokami 2019
[32] Rajagopalan 2015

China was suspected by the *US-China Economic and Security Review Commission* since a longer time already[33]. In June 2018, *Symantec* reported successful breaches of satellite and defense companies by a new espionage hacking group (Advanced Persistent Threat APT) called *Thrip* which has been active since 2013.
This APT may have overlaps with the APT40 (*Temp.Periscope/Temp.Jumper/Bronze Mohawk/Leviathan*). APT40 is active since 2013 and attacks preferably industries involved into military ship construction. It uses a variety of tools, including spearphishing, spoofing (of *Thyssen Krupp Marine Systems*) and unexpectedly seemed to have taken over TTPs from the Russian groups *Dragonfly* and *APT28* in 2017 and 2018. The group used the *Foxmail* system which was used earlier by another Chinese group named *Luckycat* in 2012[34]. The German Space Center *Deutsches Luft- und Raumfahrtzentrum DLR* was hacked in April 2014, presumably for technology espionage[35].

While in the past people thought that future wars on earth would be decided in space, it seems now that future wars in space may still be decided on earth: the hacking of space control centers could be used for sabotage, i.e. by sending false commands to move satellites resulting in damage, collision or loss. However, as seen from the practice of cyber conflicts in critical infrastructures, large cyber powers abstain from sabotage of other large powers as they know that their own infrastructure would be also vulnerable for retaliatory measures.
Due to the low received signal strength of satellite transmissions, satellites are also vulnerable by jamming by land-based transmitters, e.g. to disturb GPS navigation satellites.

4.2 Space Defense

Space Defense can have various goals: early warning and detection of missile attacks, but also of Near-Earth Objects such as asteroids. Already in the 20th century, it was discussed e.g. in the US *Strategic Defense Initiative SDI* whether satellites could help to destroy attacking missiles, but the high speed of the missiles including the development of **hypersonic weapons** makes this difficult in practice. Russia announced in 2020 the readiness of the hypersonic nuclear system *Awangard* which is transported with an intercontinental ballistic missile to space and can then fly in space with extreme speed[36].

The *European Space Agency ESA* has approved in November 2019 the *HERA* Mission for asteroid defense, which will be done in a cooperation with the NASA. In 2021, a NASA probe will fly to the asteroid pair *Didymos/Didymoon* and hit it in 2022. Thereafter, an ESA probe will evaluate the impact[37].

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[33] Menn 2018
[34] Insikt Group 2018
[35] Die Zeit online 2014
[36] Hemicker 2020
[37] Spangenberger 2019

5. Challenges for Space Policy

5.1 Space Debris

The space activities in the past 60 years have created an estimated 23,000 pieces of uncontrolled debris that can disable or destroy a satellite[38]. The testing of anti-satellite weapons by China in 2007 and recently by India in 2019 caused additional debris to the space environment[39].

This led to the development of **Space debris collectors**: *e.Deorbit* satellite of the ESA planned for the mid 2020ies.

US has released in December 2019 stricter Space Debris Standards and includes all kinds of space activities.[40]

In addition to the Space Debris as such, old satellites which are still in earth orbit as well as the rapidly growing number of satellites create problems for telescopes which are also affected by '**light pollution**' on earth caused by large cities. In addition, tens of thousands of small satellites are projected to launch in this decade[41].

5.2 Space Weather

Space weather caused by solar variability is a potential threat to space systems, human space flight and ground- and space-based infrastructures upon which societies increasingly depend.[42]

Modern electronic devices can be destroyed by electromagnetic waves as they occur during a so-called **electromagnetic pulse EMP**. An EMP could be caused by nuclear weapons, but may also naturally occur as an effect of strong solar storms[43].

5.3 Space Travel and Settlement

For travel and transportation, all leading Space Nations have meanwhile strong and reliable launching systems and spacecraft propulsion systems.

It is important to differentiate between the launching phase where strong engines are needed to escape from earth gravity and the space activity where e.g. satellites need to be kept in orbit.

The launching phase is typically done by rocket engines that use stored rocket propellants as reaction mass for forming a high-speed propulsive jet of high-temperature gas. The rocket engines are thus chemically powered. All other types of rocket engines are in early stage, hypothetical or not strong enough. An intensely discussed alternative for long-term space travel are ion thrusters and other electromagnetic thrusters.

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[38] CRS 2019
[39] CRS 2019
[40] Hitchens 2019
[41] Pekkanen 2019, p.93
[42] United Nations 2019, note 145
[43] Morschhäuser 2014, p. 1-2

While it is technically no problem to travel to the moon in a few days, they key problem of Space Policy is that all rocket engines are by far too slow to reach other celestial bodies in an acceptable time. A travel to Mars would take more than 500 days and it is still not clear whether human beings are really physically and psychologically stable enough for such travelling (note that the back travel would require another 500 days).
In reality, a visit to Mars would currently only be a (very risky and costly) symbolic act without any chance to be repeated or to be expanded to settlement in the next decades, i.e. factually the Mars is almost out of reach for human mankind with the exception of robotic research engines.

To overcome this problem, nuclear engines are planned to be used for space travel who could provide much more power and acceleration than current rockets. The respective UN Treaty does not forbid the use of nuclear engines, but requires cautious handling due to the enormous damage (including contamination of large areas) which could result from launching or landing failures or explosions.
While NASA gave up the plans for the *NERVA* nuclear engine in the 1970ies, President Trump has now released (in line with the US Space Policy of 2010) the *Presidential Memorandum on Launch of Spacecraft containing Space Nuclear Systems* from 20 August 2019 which states that the use of nuclear power is vital to keep US dominance in space.
US authorities are required to evaluate low uranium-enrichment systems with a very low probability of accidents and exposure of human to radiation. Such systems could continue to accelerate rockets in deep space and drastically reduce travel duration to Mars, thus making Mars missions much more realistic.
Note that in military submarines nuclear engines are already used in practice, i.e. there is a lot of practical experience with nuclear engines which could be utilized for space research.

While US is focused on uranium-based technology, China is currently evaluating an alternative concept of nuclear energy, the **thorium-based molten salt reactors**. This technology has the major advantage that the nuclear process is self-limited in case of thermal expansion, i.e. no risk of severe nuclear accidents of the Chernobyl or Fukushima type. Thorium is far more common and cheaper than Uranium. Thorium-Fluoride (ThF_4) salt is very stable. Further, thorium reactors create less nuclear waste with substantially shorter half-life times of radioactivity, i.e. is promoted by its supporters as clean and safe nuclear energy[44]. The discussion to use thorium is as old as nuclear reactors are, but historically the chance to gain material for nuclear weapons was seen as key advantage of uranium-based technologies.
There is also criticism of this concept, the construction of thorium reactors is seen as difficult and the cost-efficacy estimates of thorium reactors are perceived as too optimistic. However, after decades of fruitless theoretical discussion, China is now testing two thorium molten salt reactors in the Gobi Desert region.

If this test would be successful, it would have significant impact on space policy: Thorium is available in Moon and Mars dirt on the surface and probably easy to collect. Establishing thorium-based nuclear energy may make collection of moon dirt profitable and form an

[44] Cannara 2011

economic platform and local energy source for moon settlements. Further, it could be a technology platform for a high-speed, but low-risk rocket engine which brings Mars into direct reach of human space travel.

However, irrespective whether uranium- or thorium base nuclear engines will succeed, if one space power starts using this, the others would be forced to use this as well if they do not want to leave the space, in particular the Mars to the others, i.e. the 2020ies and the next decade may bring a **nuclear race**.

Outer space would have big opportunities for resources, outsourcing risky productions, later on maybe settlement, here the discovery of water on Moon and Mars is a big step forward.

Another problem is the current **all-in-one concept**, i.e. astronauts and materials fly together to the target in a non-stop flight with a huge rocket. NASA engineers suggest that materials, e.g. for space stations could be sent upfront to reduce weight and risk for the astronaut travel[45]. Reduced weight may also result in more travel speed.
The recent development of flexible solar collector materials[46] would also allow to send packets with solar collection materials ahead, so that astronauts would have an easy-to-handle energy source on the moon or Mars.
Another issue is the non-stop flight. Once a settlement on the Moon is established, it could be used a low-gravity launching point for Mars missions.

5.4 Life in Outer Space

5.4.1 LUCA and Deep Carbon

Recent research on life on earth provided new insights in function and location of life. Originally, there seemed to be a common ancestor cell for all life on earth, known as *LUCA (last universal common ancestor)*.
LUCA is the precursor cell of three cell lines, the *bacteria*, the *archaea* and the *eukaryotes* (cells with a nucleus) which are the basis of higher life forms including the human beings[47].
The analysis of LUCA based on common genes between the three cell lines, shows that LUCA was an anaerobic cell (i.e. can exist without oxygen) that fixated carbon from gas[48], i.e. which are relatively low hurdles for emergence of life.
The LUCA genome shows the importance of ribosomes, i.e. nucleic acid (RNA)-protein complexes which drive metabolism and form the link between genes and protein synthesis. Meanwhile it was shown that even today phosphorus-rich lakes exist which would be ideal for emergence of such cells[49].

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[45] BBC 2019
[46] Husain AAF et al. 2018
[47] Weiss et al. 2018
[48] Weiss et al. 2018, p.7
[49] University of Washington 2019

The *Archaea* have been shown to exist as 'extremophiles' in environments with more than 100 degrees Celsius and under other very harsh conditions which makes it more likely that life also could have emerged on Mars in its early age when it still had an atmosphere.

Other research has demonstrated that our biology is not the only possible way to exist, other nucleic acids and amino acids could be sufficient as well[50]. In other words, life on other celestial bodies does not necessarily to share our biology, but it should be noted that for an 'infection' the same biology is not needed, it would be sufficient if the other organism could utilize some of our biomass or metabolism for its own purposes after contact (touching, inhalation, digestion).

After a massive research effort of more than 900 of scientists in the last decade, the *Deep Carbon Observatory (DCO)* showed in 2018 that 70% of *bacteria* and *archaea* on Earth are located a few kilometers in the underground and under the seabed as **Deep Carbon**[51]. This also shows that life can be resistant to high pressures and temperatures as well.

Going further, this may indicate that the primary location of life is the underground and not the surface, because exposure to the surface is much more risky (asteroids, natural disasters, climate changes including ice ages, changes of the atmosphere [initially, no oxygen, then much oxygen, since 60 million years less oxygen], volcanoes, and in modern times nuclear wars) while the underground is a safe continuum.

For life on Mars, this means that the smallest hint for ancient surface life increases the chance that in the underground small residuals of life may still exist (an issue that could be a problem for mining activities).

5.4.2 Biomex and Contamination Risks

The *Biomex* experiment on *EXPOSE-R2* attached outside on the *Zvezda* module of the *International Space Station (ISS)* exposed various life forms (a variety of pigments, cell wall components, lichens, archaea, cyanobacteria, iron bacteria, snow alga, black fungi and bryophytes) to open space and in particular, the above-mentioned *Archaea* were able to survive long-term exposure to open space[52].

This increases the likelihood that cells from earth could survive in space until landing on Moon/Mars/asteroids or in future on the Saturn Moons *Titan* and *Enceladus* which seem to have modest environments which would make survival easier.

This however means that human missions and in particular human biowaste from missions and settlements could inadvertently contaminate other celestial bodies with life, in particular the lunar and Martian water reserves which are vital for settlement plans. While spreading life may be seen as something positive, the microbes are exposed to cosmic radiation which massively promotes mutations. This means that visitors who return later on the same place could be confronted with lunar and Martian strains of known microbes.

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[50] Wang/Zhang 2019, p.23
[51] DCO 2018
[52] DLR 2014

In other words: there is a risk that human missions inadvertently create extraterrestrial microbe variants instead of discovering new life.

On behalf of the United Nations, the *Committee on Space Research (COSPAR)* stated that for certain space mission/target body combinations, controls on microbial contamination must be imposed in order to avoid or minimize the biological cross-contamination of the visited target body[53].

In practice, the new Mars Rover *ExoMars* for search of life on Mars was systematically sterilized before launch in 2019[54].

5.4.3 (Sub)Cellular Life

On the first look, it seems to be obvious that all life on Earth are either single cell or multi-cell organism.
But looking closer, this may not be the complete picture. Human beings for example appear on the subcellular level as composite life from of three different cell types.

Sub-cellular level:
Within the human cell, there are small units knows as mitochondria. These units allow the use of oxygen for production of energy. Historically, the mitochondria have been separate life forms which were integrated into a precursor cell to the modern cell.
They have a separate genome as a DNA ring <u>in addition</u> to the human genome and replicate differently by fusion or fission, the so-called mitochondrial DNA (mtDNA). Theoretically, the DNA ring could have been a split-up from human genome, but the close genetic relation to *Proteobacteria* indicates that the takeover of mitochondria could have been a chronic infection which appeared to be advantageous in a symbiotic manner. They replicate with cell cycle by binary fission, but can also do outside cell cycle in case of increased energy needs[55].

Mitochondria are only of maternal origin, because during insemination the sperms are destroyed and only the maternal mitochondria of the maternal oocyte are used for the child. Genetic analysis has shown that all mitochondria seem to have appeared from a single woman only who lived approximately 150,000 years ago which means that all humans beings have a common ancestor.
In reference to the Bible, this woman is sometimes called **Mitochondrial Eve**, but the finding did not mean that she was the first or only woman on earth, but the only women whose successors managed to survive until today.
So, the mitochondria from this woman undergo fissions already for 150,000 years.

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[53] Giuliani et al. 2009
[54] ESA 2019
[55] An easy-to-read introduction to Mitochondria is provided by Wikipedia

Cellular level:
While mitochondria and the surrounding cell exist together now as 'human cell', it should be known that cellular life is not always the same as the life of the whole organism.

Humans beings are born when released after pregnancy and doing the 'first cry' (i.e. unfold lungs and start to breathe) and die when brain and heart have stopped working. Of course, embryos and fetuses are already living as well, but dependent from maternal supplies. It can happen that a fetus may exist for some time despite genetic (e.g. cardiac) malformations, but could never survive independently. These cases appear as dead born children. Thus, it is reasonable to define 'birthday' as the first day of independent life. The maximum life span seems not to be longer than 120 years[56] (evident from many documented oldest human beings of the world, who typically die latest around the 116th birthday)

On the cellular level, the life span is much longer than this. The first day as independent cell is the birth of the own mother, because the first cell of any human being is then present and stored in the maternal oocytes already, i.e. cellular life starts decades *before* the own birth.
Also, sometimes cells can survive the death of its human being, because there is a phenomenon called **microchimerism**, i.e. some maternal cells pass the placenta during pregnancy and exist then in the baby instead.
This explains the strange finding that sometimes males have some female immune cells in their lymph nodes. Theoretically, these cells can survive for decades, until death of the child which carries these cells, i.e. the cellular life span of a certain human being can come close to 200 years.

The microbiome:
Human beings can only exist in the long run with a bacterial settlement, the **microbiome**[57].
It is vital for supply of some vitamins, supports the digestion and prevents infections with malicious bacteria. A significant portion of stool consist of bacteria leaving the gastrointestinal tract.
Directly after birth, bacterial settlements start and co-exists with human cell in a sometimes-difficult balance with the immune system. After death, the balance collapses and the bacteria utilize the biomass of the human being and continue to exist in environment.
The human life has thus different levels.

[56] Interestingly, the Bible already mentioned exactly this 120-year life span in *Genesis 6*: „1 When human beings began to increase in number on earth and daughters were born to hem, 2 the sons of God saw that the daughters of humans were beautiful, and they married any of them they chose. 3 Then the LORD said: „My Spirit will not contend with humans forever, for they are mortal, their days will be a **hundred and twenty years**." Note that Bible editions slightly vary in wording due to difficult translation, but with consistent meaning of text, see Biblehub.com
[57] Hair/Sharpe 2014

Table 2: Levels of human life

	Pre-birth	Birth	Death	Time after death
Multi-cell organism	[embryo 3 months fetus 6 months]	x	X (max 120 years)	----
Single Human Cells	Maternal oocyte (for decades)	x	Microchimerism (for decades in children)	
Microbiome	---	Settlement	may continue in environment outside the body	
Mitochondria	Fission of same maternal line since approx. 150,000 years			

Source: own presentation

Conclusion: in popular science, life is considered to be appear as single- or multi-cell organism.
However, life can also be a composition of elements which alone may not be able to live. If the Mars Rover find organic elements that could not support life alone, it is still possible that this is only a part of something more complex that still exists /existed.

5.4.4 Microgravity

Life in Outer Space is confronted with many obstacles: extreme temperatures, cosmic radiation, vacuum and low or no gravity (**microgravity**). While it is technically possible to protect humans and maybe other organism from extreme temperatures, cosmic radiation and vacuum by shields and artificial atmosphere, it is difficult to protect organisms against low or no gravity. Multi-cell organisms have to maintain a complex structure and transportation systems for metabolism which are both vulnerable for changed gravity.
The problem is that microgravity has massive impact on the physiological functions such as the cardiovascular system, but also in the musculoskeletal system, where reduced gravity leads to underusage resulting in muscular atrophy and reduced bone density.
Even for well-trained astronauts, return to earth after long-term presence in space is challenging.
While the problem is currently solved by frequent exchange of humans on the ISS, it is questionable how human beings should be able to survive long-term settlements (and then with much more difficult problems, such as pregnancies).

Thus, microgravity experiments with living organisms are underway to evaluate the effects of microgravity on organisms[58]. China landed the *Chang'e-4 Moon Rover* on the far side of the moon in 2019 and included a growth experiment on the moon with a small lunar biosphere in a box (air, water and soil): a cotton plant managed to grow under these conditions while certain other plants failed to grow[59]. If natural plants cannot grow on the Moon, settlements may only be possible with modified plants instead; a future challenge

[58] DLR 2019
[59] Devlin 2019

would then be to identify genes or gene variants that could increase **microgravity resilience**.

Progress in the area of **synthetic biology** may help to modify plants in a way that they are robust enough for growing under low gravity on Moon or Mars dirt.

Since 2010, Craig Venter and his team worked to develop a **minimal genome** cell, this is the smallest possible genome that allows autonomous life and replication[60]. *Mycoplasma* was the smallest known autonomous cell type and thus used as model organism since 1984. In 2016, a new cell, called *Syn 3.0*, was created by replacing the genome of *Mycoplasma capricolum* with the genome of *Mycoplasma mycoides*, with removal of unessential DNA. It had only 473 genes, but still the function of 149 genes was unknown[61]. After it was found that a slightly larger genome leads to improved cell growth, a modified minimal cell was created which allowed to reduce the number of genes with unknown function to 30 in the year 2019[62].
If the function of these 30 genes could be clarified, the basic mechanisms of living cells are identified and could then be used to create **freely designable artificial cells**.

The other matter is **synthetic genomes**[63]. Genomes of larger organisms are organized in units called Chromosomes, e.g. 46 Chromosomes (23 pairs) for human beings. The rapid technical progress of DNA synthesis allows meanwhile a synthesis of artificial *Yeast (S. cerevisiae)* chromosomes. Also, 16 natural chromosomes of *S. cerevisiae* were successfully fused into a single chromosome; the artificial *S. cerevisiae* still has normal cellular functions.
Together with designable cells this technology may allow large-scale genomic variation and optimization, potentially useful for adapting plants from earth to grow them on Moon and Mars.[64]

5.4.5 Summary

Recent research has shown that the hurdles for life in Outer Space and other planets may be lower than expected. For life on Mars, this means that the smallest hint for ancient surface life increases the chance that in the underground small residuals of life may still exist. There is a risk that human missions inadvertently create extraterrestrial microbe variants instead of discovering new life and may contaminate lunar and Martian water reserves. Life is considered to be appear as single- or multi-cell organism, but can also be a composition of elements which alone may not be able to exist. Low or no gravity (microgravity) was identified as largest hurdle for long-term settlements and space travel, further research on microgravity resilience is needed.

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[60] Kastilan 2010
[61] Danchin/Fang 2016
[62] Lachance et al. 2019
[63] Wang/Zhang 2019, p.23
[64] In the late 2020ies, given the current progress, **synthetic human genomes** may be possible. In 2016, the Human Genome Project-Write (HGP-Write) was initiated with the goal of synthesizing a complete human genome within 10 years. But note that human chromsomes are much more than ‚naked‘ DNA, so this would not be the step to ‚synthetic‘ human beings with computer-designed, machine-produced genomes.

6. Concluding Remarks

The review of UN Space Law has shown that the framework is challenged by plans to start exploitation and settlements of celestial bodies, in particular Moon and Mars.

An overview on space activities, where unmanned satellite and research probes are standard, was followed by a summary of policies and strategies of the leading actors (US, Europe, China, Russia, India and Japan) and a review of military and security issues in Outer Space: Anti-Satellite Weapons, Laser Weapons and Satellite Hacking were identified as key challenges.

Environmental problems also exist in Space policy: space debris and protection of lunar and Martian water reserves appear to be the most urgent ones.

A key problem are the long travels to other planets. A nuclear space engine race may be seen in the 2020ies to solve these problems.

Recent research has shown that the hurdles for microbial life in Outer Space and other planets may be lower than expected. There is a risk that human missions inadvertently create extraterrestrial microbe variants instead of discovering new life and may contaminate lunar and Martian water reserves. Life may also be a composition of elements which alone may not be able to exist. Low or no gravity (microgravity) was identified as largest biologic hurdle for long-term settlements and space travels.

7. Literature

7.1 Literature References

BBC (2019): New engine tech that could get us to Mars faster. BBC News 25 Dec 2019

Cannara, A. (2011): Presentation Thorium-Based Molten-Salt Reactors. Sbcglobal.net

CRS (2019): “Space Force” and Related DOD Proposals: Issues for Congress. Congressional Research Service CRS Paper 08 April 2019

Danchin A., Fang, G. (2016): Unknown unknowns: essential genes in quest for function. Microb Biotechnol. 2016 Sep;9(5):530-40. doi: 10.1111/1751-7915.12384. Epub 2016 Jul 20.

DCO (2018): Deep Carbon Observatory Website. Results summary from December 2018 https://deepcarbon.net

Devlin, H. (2019): Battlefield Moon: how China plans to win the lunar space race. The Guardian Jan 2019

Die Zeit online (2014): Cyberangriff: Hacker spionierten Luft- und Raumfahrtzentrum aus. 13 Apr 2014

DLR (2014): BIOMEX: Biology and Mars Experiment. Deutsches Luft- und Raumfahrtzentrum DLR

DLR (2019): Microgravity Research and Life Sciences. Deutsches Luft- und Raumfahrtzentrum DLR

ESA (2019): Heat sterilisation of ExoMars parachute – ESA. www.esa.int › ESA_Multimedia › Images › 2019/03

European Commission (2016): Space Strategy for Europe in 2016. Brussels, 26.10.2016 COM(2016) 705 final

EU (2019): EU Space Policy Fact Sheet of the European Commission.

Giuliani, M. et al (2009): Contamination Control of Exomars Mission. Article on ESA.int

Goswata, N. (2019): China’s future space ambitions: What’s ahead? The Diplomat 04 Nov 2019

Hair, M, Sharpe, J. (2014): Fast Facts about the Human Microbiome. The Center for Ecogenetics and Environmental Health, University of Washington, 1/2014

Hara, K. (2017): Current Status of Japan’s Space Policy and Development of Legal Frameworks. Ministry of Foreign Affairs (MOFA) of Japan LSC#56

Hemicker, L. (2020): Putins Wunderwaffe. Frankfurter Allegmeine Zeitung 03 Jan 2020, p.8

Hitchens, T. (2019): US tightens Space Debris Standards, keeps 25-year cap. Breakingdefense.com 09 Dec 2019

Husain, AAF et al. (2018): A review of transparent solar photovoltaic technologies. Renewable and Sustainable Energy Reviews 94 (2018) 779-791

Insikt Group (2018): Chinese Threat Actor TEMP.Periscope targets UK-based engineering company using Russian APT techniques. Recorded Future Blog 13 November 2018

Kastilan, S. (2010): Vier Flaschen für ein Heureka. Frankfurter Allgemeine Zeitung 21 May 2010, p.33

Lachance JC, Rodrigue S., Palsson BO (2019): Minimal cells, maximal knowledge. Elife. 2019 Mar 12;8. pii: e45379. doi: 10.7554/eLife.45379.

Lohse, E. (2016): Krieg der Sterne. Frankfurter Allgemeine Zeitung 206/2016, p.4

Marsiske, HA (2016): Bei Strahlenwaffen liegt Deutschland vorn. Artikel 3117433 Heise.de 25 Feb 2016, 2 pages

McCall SM (2019): Military Space Reform: FY2020 NDAA Legislative Proposals. Congressional Research Service CRS Paper 02 October 2019

McLeod, CL, Krekeler MPS (2017): Sources of Extraterrestrial Rare Earth Elements: To the Moon and Beyond. Resources 2017, 6, 40; doi:10.3390/resources6030040

Menn, J. (2018): China-based campaign breached satellite, defense companies: Symantec. Reuters online 19 June 2018

Mizokami, K. (2019): The Navy plans to put NELIOS Laser Weapon on Destroyer in 2021. Lookheed Martin

Morschhäuser, T. (2014): Heftiger Sonnensturm verfehlt Erde nur knapp. Frankfurter Rundschau online version 25 July 2014, p.1-2

Pekkanen, SM (2019): Introduction to the Symposium on the New Space Race. Governing the New Space Race. Ajil Unbound. doi:10.1017/aju.2019.16

Rajagopalan, RP (2015): Japans Shift in Space Policy Reflects New Asian Realities. 23 Feb 2015

Spangenberger, U. (2019): Asteroiden-Abwehr und eigene Mond-Mission. Tagesschau online 30 Dec 2019

United Nations (2017): International Space Law: United Nations Instruments. New York, 2017. UN Office for Outer Space Affairs

United Nations (2019): Report of the Committee on the Peaceful Uses of Outer Space. Sixty-second session (12–21 June 2019), General Assembly Official Records Seventy-fourth Session Supplement No. 20, 75 pages

University of Washington (2019): Life could have emerged from lakes rich of phosphorus. Phys.org 30 Dec 2019

UNOOSA website (2020): United Nations Office for Outer Space Affairs (UNOOSA)

USA (2010): National Space Policy of the United States of America 28 June 2010

USA (2019): The Presidential Memorandum on Launch of Spacecraft containing Space Nuclear Systems from 20 August 2019

Wang F., Zhang W. (2019): Synthetic biology: Recent progress, biosafety and biosecurity concerns, and possible solutions Journal of Biosafety and Biosecurity 1 (2019) 22–30

Weiss MC, Preiner M, Xavier JC, Zimorski V, Martin WF (2018): The last universal common ancestor between ancient Earth chemistry and the onset of genetics. PLoS Genet 14(8):e1007518. https://doi.org/10.1371/journal.pgen.1007518

7.2 Further Readings

2017 Modern Geostrategy - Methods and Practice
https://repositorium.ub.uni-osnabrueck.de/handle/urn:nbn:de:gbv:700-2017121216405

2019 Cyberwar-methods-and-practice
https://repositorium.ub.uni-osnabrueck.de/handle/urn:nbn:de:gbv:700-201907091696