Chapter 4 – Outer Space as a Socioeconomic Field

On social impact analyses

Core PESTEL components

- Political: Government stability, policies, public spending, geopolitics, subsidies, taxation
- Economic: Growth, inflation, interest rates, energy prices, labor costs, funding availability
- Social: Demographics, public attitudes, social acceptance, lifestyle, education
- Technological: Innovation, R&D, digitalization, technology readiness, infrastructure
- Environmental: Climate impacts, emissions, resource availability, environmental constraints
- Legal: Laws, regulations, compliance requirements, standards, permitting

PESTEL+I analysis is an an expanded version of the classic PESTEL framework

- Examines the external macro-environment affecting an organization, project, sector, or policy
- The "+I" simply adds Institutional factors, which is especially common in policy analysis, public projects, energy, infrastructure, and EU-funded research

Institutional factors focus on how things actually work in practice, beyond formal laws

- Governance quality
- Administrative capacity
- Bureaucratic efficiency
- Coordination between institutions
- Enforcement of regulations
- Corruption, transparency
- Informal norms and practices

Legal = what the rules say

Institutional = how the rules are implemented

Crucial distinction is crucial in

- Energy systems
- Infrastructure deployment
- Environmental policy
- Cross-country or EU-wide projects

Why use PESTEL+I instead of plain PESTEL?

- PESTEL alone tends to overestimate policy effectiveness

Example

- A country may have strong renewable-energy laws (Legal)
- But weak permitting authorities or fragmented agencies (Institutional)
- As a result, projects may stall despite "good" policy on paper

One-sentence definition

- PESTEL+I is a macro-environmental analysis framework that evaluates political, economic, social, technological, environmental, legal, and institutional factors shaping a project or sector.

4.1. Social importance of space assets

Space research and development significantly improve life on Earth, despite general ignorance of the fact

- Healthcare and emergency services: Communication and navigation satellites, play a crucial role in modern healthcare systems, e.g. rapid emergency responses and telemedicine in remote regions
    - Spin-offs from space technology contribute to advancements in healthcare as well as energy, and various industries
    - Telemedicine allows remote consultations and diagnostics, enhancing healthcare access in isolated areas
- Disaster mitigation: Weather satellites and their imagery provide crucial data for forecasting natural calamities and coordinating effective rescue operations
    - Real-time weather data and satellite imagery are provided for effective rescue strategies
    - Remote sensing satellites assist in environmental monitoring, agriculture, and resource management
- Environmental Management: Satellites aid in soil quality management, rainforest preservation, climate change monitoring, and tracking global temperature and ice coverage data
- Technological spin-offs: Space research and development produce numerous spin-off technologies adopted on Earth for health, transportation, public safety, and other industries (e.g. flame-resistant textiles, 3D endoscopes)
- Dual-use (civil/military) nature: Many space systems are dual-use (civil and military), which can present a challenge although civil applications are crucial
    - Systems for forest fire monitoring can also be used for reconnaissance, which can complicate international cooperation

Key roles of space assets include

- Communication
- Navigation
- Resource management
- Healthcare
- Education
- Environmental protection
- Agricultural development

Space assets have significant impact on social development and living conditions on Earth

Healthcare applications

- Modern healthcare relies on communication and navigational satellites
    - Emergency services (ambulances, rescue units) use satellites for accurate location and rapid transport
- Distress signals in vehicles are enabled by satellite navigation systems
- Remote medical (education and practice) benefits from communication satellites, improving skills of local healthcare workers

    - Telemedicine allows consultations, diagnostics, and even surgeries from a distance
    - Disease monitoring is enhanced via remote sensing satellites

Natural disaster/catastrophe mitigation

- Weather satellites provide precise and real-time meteorological data
    - Data aids preparation and response to storms and other disasters
    - Navigation and imagery together enable effective rescue operations
    - Satellite imagery helps rescuers understand scope and terrain of disasters
- Space-faring nations share information for catastrophe mitigation
    - This catalyzes international cooperation
- Emergency communication via satellites works even in remote or disaster-affected areas

Some overall observations

- Space assets are integral to social well-being, both in daily life and emergencies
- Social benefits are a key argument for continued investment and development of space infrastructure

On the dual-use of space applications

- Many space technologies were originally developed for military purposes
    - Reconnaissance satellites now support soil quality monitoring, deforestation prevention, and natural resource localization
    - Satellites help farmers optimize fields, protect the environment, and locate resources efficiently
- They connect isolated populations to central regions, improving access to goods and enabling government monitoring/control
- Example: Israeli space program
    - Initially military-focused for security and peace monitoring
    - Evolved to support industrial and social development

On climate and environmental monitoring

- Satellites provide global measurements that terrestrial methods cannot reliably achieve
    - Global temperature tracking
    - Sea-level monitoring (avoids errors from tides, waves, land shifts)
    - Ice coverage and thickness measurements in polar regions — think Greenland
- Satellites are key tools in climate change mitigation and environmental observation
    - The European Copernicus system was developed to meet Kyoto Protocol requirements

On direct and indirect benefits of spin-offs (and technological impacts)

- Direct benefits: inspiration, scientific knowledge, innovation, new markets, treaties
- Indirect benefits: economy, healthcare, environmental quality, security, philosophy
- Historical examples of social benefits from space research
    - Improved solar panels
    - Human-robot cooperation skills

    - Aging research in weightlessness
    - Implantable heart monitors
    - Light-based cancer therapy
    - STEM (Science, Technology, Engineering, and Mathematics) education among youth (even in our International and European Studies department)
- NASA spin-offs: health and medicine, transportation, public safety, consumer goods, energy and environment, IT, industrial productivity
- Example applications: 3D endoscopes, ionospheric mapping software, Landsat imagery, low-cost sensors, freeze-dried food, cooling suits, kidney dialysis machines, flame-resistant textiles

Conclusions

- Space assets have enormous social and economic impact.
- Civil applications of originally military technologies contribute substantially to social development, environmental monitoring, and technological advancement
    - Their dual-use nature requires careful consideration in international cooperation.

European GMES/Copernicus program

- Primary objective: research on global climate change
- Civil project led by ESA and EU to provide accurate information for
    - Environmental management
    - Climate change mitigation
    - Civil security
- Dual-use nature
    - Provides high-quality reconnaissance capabilities
    - Strengthens EU independence in security (similar to Galileo navigation)
    - Civil-military overlap can hinder cooperation, especially in diplomatic tensions
- Future importance: dual-use vs social importance will grow as space capabilities advance

Ultimate social benefit of outer space

- Human survival: space exploration enhances the chance of survival from Earth-based catastrophes
- Two key issues
    1. Awareness of humanity's fragility
        - Apollo lunar photos highlighted the limited, isolated nature of Earth
        - Inspired global social movements (environmental protection, nuclear disarmament)
    2. Potential settlement of other celestial bodies
        - Could preserve humanity in case of asteroid strikes, pandemics, nuclear war
        - Long-term survival beyond Earth and even beyond the Sun's lifespan
- Early investment in interstellar travel may be motivated by human extinction prevention

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4.2. Space and economy

As an overview, this section explores outer space as a location of diverse economic activities, a significant and growing industry worth approximately US$300 billion annually

- The space economy has expanded since the 1980s, with private actors now generating 76% of revenue in the sector
- The commercial space industry primarily consists of satellite services, satellite manufacturing, launch services, and ground equipment
- Telecommunications was the first fully commercialized space industry and remains the most profitable sector, despite challenges like orbital overcrowding and competition from fiber-optic cables
- Other commercially profitable activities include navigation systems, remote sensing for agriculture and mineral exploration, 3D mapping, and the nascent field of space tourism
- Future opportunities include advancements in miniaturization, orbital repairs, and space tourism

Economic scope (in more detail)

- Global space industry ≈ US$300 billion/year, grew even during 2008 economic crisis
- Four segments
    1. Satellite manufacturing
    2. Launch services
    3. Satellite services
    4. Ground equipment
- Private actors now cover entire value chain: manufacture → launch → operate → terrestrial support
- Most profitable: information gathering and provision

Commercialization history

- 1980s: proliferation of new space actors → increased focus on economic returns
- First commercialized space sector: telecommunications
- State dominance, subsidies, and high-risk ventures still limit profitability

Challenges for commercial satellites

- Overcrowding / orbital slot management
    - Limited slots and increasing satellites create competition
    - Solutions: precision signal focus, new orbits, “paper satellites” to reserve slots
    - Need for regulation or market mechanisms (slot payments)
    - Example: ITU disputes over GEO slots (Iran, Pakistan)
- Competition from terrestrial infrastructure
    - Fiber-optic cables cheaper, faster, lower maintenance
    - Comsats most effective in remote or unstable regions

Other space-based economic activities

- Navigation systems (heavily state-regulated/owned)
- Remote sensing (soil data, mapping, resource management)

- Weather forecasting (saves air transport US$18B/year)
- Spin-offs for terrestrial industries: lightweight alloys, miniature cameras, miniaturization, space cargo transport, orbital repairs, space tourism

Concrete examples

- 3D maps: mobile coverage, water management
- Agriculture and forestry: soil monitoring, crop growth, illegal logging control, subsidy fraud detection
- Mineral exploration: multispectral satellite imagery aids mining and resource management
- Construction: mapping large sites, environmental risk assessment

Space tourism

- Began early 1990s (USSR Mir station, USD 20M, later ISS travel US$60M)
- Expected cost decline with private boosters and suborbital commercialization

NewSpace actors

- Drive cost reduction to achieve profitability (e.g. SpaceX, Virgin Galactic)
- Focus on new markets (space tourism, global internet via space-based systems)
- Compete with traditional state actors but also open new economic fields

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4.3. Private and commercial space actors

This important section focuses on the growing role of non-state actors in shaping the future of space utilization

- The NewSpace movement (entrepreneurial, risk-taking, cost-effective, privately funded) is challenging the state-dominated Old Space (military logic, prestige competition) paradigm (p. 12).
    - SpaceX: A leader in technological progress, focused on revolutionizing space tech with the ultimate goal of enabling human life on other planets; known for reusable rockets and cargo transport to the ISS
    - Virgin Galactic: Focused on human spaceflight and developing space tourism as a viable industry
    - Large tech companies like Google and Microsoft collaborate with space actors for services such as Google Maps

Private and commercial actors are increasingly shaping the future of space utilization, driven by innovation and competition

- Approximately 80% of global space activities involve state investment or operations
    - Commercial actors are gaining prominence
- The emergence of private companies aims to reduce costs and improve access to space.
    - Notable private actors include SpaceX, Virgin Galactic, and various satellite manufacturers.
    - Initiatives like Google's Lunar XPRIZE encourage private investment in space exploration.
- Collaboration between private companies and established space agencies is fostering new technological advancements and market opportunities.

Private companies are increasingly influential in space exploration and utilization, often surpassing state efforts.

- SpaceX (founded in 2002 by Elon Musk) aims to revolutionize space technology and enable human life on other planets (with a focus on Mars)
    - SpaceX operates three space vehicles and has over 4000 employees, achieving significant milestones like reaching Low Earth Orbit (LEO) and safely returning vehicles
    - Goal: enable human life on other planets
    - Capabilities: LEO missions, ISS resupply (Dragon capsule), GEO missions, reusable rockets
    - Key milestones: Falcon 9 (2010), Dragon connects to ISS (2012), reusable first stage tests (2014–2015), Falcon Heavy (2018)
    - Advantages: entrepreneurial drive, rapid progress, easy access to founder capital
- Virgin Galactic (founded in 2004 by Richard Branson) focuses on human spaceflight and space tourism, despite facing setbacks from accidents
    - Focus: human spaceflight, reusable piloted vehicles (WhiteKnightTwo, SpaceShipTwo)
    - Achievements: Ansari X-Prize (2004), despite setbacks (2007, 2014 accidents)
    - Future: space tourism as a major commercial enterprise

- Both companies exemplify the shift towards private sector involvement in space, potentially leading to dominance in space operations
- State actors still hold larger budgets, but may allow private companies to take over many operational aspects due to efficiency

Emergence and significance

- Commercial, non-state actors became relevant mainly after the Cold War
- ~80% of space activities involved state investment/operations; 76% of revenue now generated by commercial activity (2014 data)
- Motivation for private actors
  - Reduce cost of reaching orbit vs state capabilities
  - Lower overall government space budgets via privatization
- Globalization increased market size, making space ventures more profitable

Historical context

- Privatization trends started in the 1980s (e.g. Arianespace) → competition in Western launch markets
- New private launch capabilities (e.g. SpaceX Falcon rockets) challenge and supplement state capabilities
- Some commercial ventures can threaten revenue of states reliant on commercial launches (e.g. Russia)

Private sector involvement across space industries

- Satellite manufacturing: Boeing, Lockheed Martin, Alcatel, Tyvak Nano-Space
- Cyber/IT integration: Google, Microsoft collaborating with Virgin Galactic, Bigelow Aerospace (e.g. Google Maps)
- Space Data Association (SDA): database of GEO objects, links private companies and governments
- Incentives and prizes
  - Google Lunar XPRIZE (US$30M for Moon rover achievement)
  - Hawking-Milner project (Starshot, probes to Alpha Centauri)
- Privatized institutions: Intelsat (2001) → largest global communications provider

Impact on space geopolitics and economy

- Private actors increasingly shape space utilization, potentially dominating non-security aspects
- States retain dominance over security-related operations
- NewSpace movement
  - Entrepreneurial, risk-tolerant actors breaking away from Old Space military/prestige logic
  - Focus: single-issue solutions, cost-effectiveness, efficiency
  - Effect: encourages cooperation, reduces hierarchical control, shifts geopolitical dynamics

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4.4. Resource extraction and energy from space

As an overview, this section discusses the potential for natural resources and energy sources in outer space

- Natural resources: The Moon and asteroids contain valuable resources like platinum-grade metals (PGMs) for export to Earth, and water ice, silicon, and iron for building and fueling future space settlements and infrastructure
- Two main energy resource solutions are explored
  - He-3 fusion: Helium-3 (He-3), rare on Earth but abundant on the Moon and gas giants, could fuel clean nuclear fusion generators if the technology is mastered
  - Beamed solar power: Collecting solar energy in space and beaming it to Earth via microwaves or lasers is a potential nondepletable and eco-friendly solution, though it faces economic and logistical challenges

The Moon and asteroids present valuable resources for future space mining and energy production.

- Proximity and feasibility of the Moon ~ 3 days from Earth, with piloted and robotic missions technologically feasible
- The Moon is a primary target for mining operations, particularly at its poles, which are accessible within three days from Earth
- Lunar resources can be categorized into indigenous (available on Earth) and alien (from asteroid impacts), with varying economic values
- Platinum group metals (PGMs) and titanium are highlighted as valuable for export, while water and other materials are crucial for space habitation
  - Platinum-group metals (PGMs): high-tech industry, catalysts, electronics
  - Titanium: military hardware, linked with He-3 deposits
- Asteroids also hold significant resources, including PGMs and water, which are essential for space development
- Helium-3 (He-3) is identified as a potential energy source for nuclear fusion, with the Moon being a probable extraction site.
- Other earth-scarce or environmentally expensive minerals make lunar extraction commercially interesting

Geopolitical and geoeconomic perspective

- Space resources are strategically valuable
  - The geographic distribution of centers of resources assigns value to locations according to their strategic importance
- Key focus: inner solar system — Moon, asteroids, Mars — for natural and energy resources

Resources for lunar settlement/space operations

- Water: critical for life support, radiation shielding, oxygen, and fuel
  - Sources: permanently shadowed areas (PSAs) and near-surface deposits
  - PSAs: temperatures near absolute zero, potential trillion kg of ice, ~17,700 km^2 coverage
- Metals and oxides: silicon (solar panels), aluminum, iron, copper, zinc, magnesium
- Volatiles: hydrogen, nitrogen, carbon for life support

- Lunar soil/regolith: potential building material (cement, microwaving into strong structures)
- Economic model: Moon as a manufacturing site for space infrastructure due to low gravity and available resources

Asteroids and Mars

- Asteroids: PGMs, gold, germanium (exportable), water and iron (for space industry)
- Mars: water, ores, minerals, volatiles crucial for self-sustaining settlement
    - Mars as a stepping stone for asteroid belt exploitation
- Economic viability depends on
    - Resource presence and accessibility
    - Mining feasibility (orbit, travel time, extraction technology)
- Near-Earth Objects (NEOs) could be mined or brought closer, but challenging

Helium-3 (He-3) for nuclear fusion

- Second and third-generation fusion reactors aim to use He-3 (rare on Earth, abundant in solar system)
- Sources: Moon (bound to titanium ores), asteroids, Martian moons (Phobos, Deimos), atmospheres of gas giants
- Potentially environmentally clean terrestrial energy, fuel for deep-space missions

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Space-based solar power

- Concept: orbiting or lunar solar farms beam energy to Earth (laser/microwave)
- Advantages: high efficiency, eco-friendly, globally available
- Orbital satellites: best at GEO for constant sunlight and consistent energy transmission
- Lunar solar farms: use Moon as stable platform, avoid some orbital assembly challenges
- Challenges
    - High cost of installation and assembly
    - Legal uncertainties
    - A Lunar farm would require ~15% of the Moon's surface for sufficient output!
    - Day/night cycles on the Moon reduce efficiency

Summary

- Space resources — both energy and non-energy — are essential for
    - Lunar and planetary settlement
    - Development of space industry
    - Future terrestrial energy needs
- NewSpace actors (e.g. Deep Space Industries, Planetary Resources) are already entering the domain
- Investments in technology and infrastructure are critical to unlock commercial viability

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4.5. The future of space economy

Overall, this section explores the long-term possibilities for economic activity across the solar system

- Terra-centric system: The economy will likely remain centered on Earth as the primary importer of space resources and producer/exporter of high technology
- Mars as a hub: Mars is positioned as a potential stepping stone and processing base for utilizing resources from the asteroid belt
- Interstellar trade speculation: Hypothetical trade with alien civilizations (!) would likely involve intangible goods like information due to the vastness of space and speed-of-light limitations

In more detail, on the inner solar system economy

- Earth remains central, as:
  - Leading importer of solar system resources
  - Producer of advanced technologies
- Economic activity will focus on celestial bodies where extraction and operations require less energy (taking advantage of gravity wells)
- Technological solutions to reduce travel cost
  - Space elevators (more feasible on Moon or smaller bodies)
  - Carbon nanotube-based structures
  - Other future propulsion/launch innovations

Mars as a strategic hub

- Large enough for permanent settlement and indigenous industrial capabilities
- Close to asteroid belt → first stop for mining missions
- Resource processing may occur in Mars orbit to save energy when sending materials back to Earth
- Mars may play an export role as an intermediate destination for processed resources

Helium-3 (He-3)

- Likely a major trade commodity and energy source for space economy
- Energy crucial for operations further from Sun (solar power less effective at distance)

Space tourism

- Predicted to grow alongside accessibility of new sites
- Likely to become a viable industry in the inner solar system economy

On the outer solar system

- Potential revenue from:
  - He-3 harvested from gas giants (floating mining platforms)
  - Natural resources from Jupiter (Trojan and Greek) asteroids, comets, and other small bodies
- Requires
  - Advanced technologies
  - Established inner solar system infrastructure

- Commercial viability increases with scale of operations

Interstellar trade with alien civilizations

- Highly speculative; major uncertainties
  - Existence of nearby industrialized civilizations
  - Potential for intelligent life to evolve
  - Self-destructing civilizations or cosmic hazards
  - Willingness to communicate or trade
- Likely first contact via electromagnetic signals rather than physical travel
- Trade of physical goods across interstellar distances is practically impossible due to
  - Vast distances
  - Limits of light-speed travel
- Possible interstellar exchange of intangible goods (information, music, knowledge)
- Primary motivation for interstellar travel: survival or exploration, not commerce

Summary on a future space economy:

- Earth-centric, expanding to Moon, Mars, and asteroid belt
- He-3 and other resources drive interplanetary trade
- Advanced technologies needed to enable sustainable resource extraction
- Outer solar system development remains long-term, high-investment scenario
- Interstellar commerce largely speculative, limited to information exchange

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4.6. Outer Space as a Socioeconomic Field

This final summary reiterates the dual nodes of social benefit and economic potential that define space utilization

- The progress driven by space research and development, with assets ranging from daily communication to future resource potential, will continue to profoundly impact human life

The dual nature of space activities

1. Social benefits
    - Enhances quality of life, often independent of profit
    - Examples
        - Communication satellites: connect remote populations, enable telemedicine, education, and skill development
        - Remote sensing and weather satellites: disaster early warning, rescue operations, improved agriculture and soil management
        - Spin-off technologies: everyday life improvements through satellite-derived innovations
2. Economic importance
    - Commercial potential and profit-driven activities
    - Initially focused on space launch industry and competition (e.g. Arianespace vs NASA)
    - Privatization of communication satellites: first truly economically viable space ventures
    - Current space-related markets
        - Space-based services: navigation, weather, remote sensing, communication
        - Terrestrial industries: satellite and launch vehicle manufacturing
    - New private actors (e.g. SpaceX, Google) pushing innovative markets and human spaceflight initiatives

Future potential

- Resource extraction
    - Outer space may become Earth's ultimate source of rare minerals, ores, and energy resources
    - Resource-rich NEOs and asteroid belt accessible via Mars as a stepping stone
    - Valuable materials: PGMs, gold, and other strategic metals
- Energy resources
    - He-3-based nuclear fusion
        - Requires advanced reactors beyond current technology
        - He-3 deposits available on Moon, Martian moons, asteroids, Mercury, and outer solar system bodies
        - Mining challenges remain significant
    - Space-based solar power
        - Solar panels on lunar surface or in orbit

        - Issues: cost, infrastructure, assembly, and lunar night cycles
        - Commercial projections exist, but economic feasibility still debated

Multiplier effects

- Space activities generate human progress and spin-off technologies
- Benefits return to Earth beyond direct economic or material gains
- Current utilization is only the beginning; potential future impact is massive

The inner solar system economy is expected to evolve with a focus on resource utilization and technological advancements

- Earth will remain central to space activities, primarily as an importer of solar system resources and a producer of advanced technologies.
- Mars is positioned as a key site for human settlement and resource processing, facilitating access to the asteroid belt.
- He-3 may become a primary trading commodity, powering the solar system economy.
- Space tourism is anticipated to grow as more destinations become accessible.
- Future economic activities will extend beyond the inner solar system, with potential revenue from He-3 and resources from outer solar system bodies.

Outer space has significant social and economic implications for life on Earth and future advancements

- Current space activities improve quality of life through communication, remote sensing, and disaster response capabilities
- The economic landscape includes satellite operations, launch industries, and emerging private space markets
- Future developments in space could yield abundant resources and energy solutions, enhancing life on Earth
- Technologies like He-3 fusion and space-based solar power hold promise for addressing energy needs
- The socioeconomic utilization of space is still in its infancy, with vast potential for growth and innovation

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Summary of Chapter 4: Outer space as a socioeconomic field

- Social importance: Space assets enhance healthcare, disaster response, and environmental management, improving living conditions on Earth
- Economic importance: The space economy, valued at $300 billion, includes satellite services, manufacturing, and launch services, with private actors increasingly involved
- Resource extraction: Potential for mining resources like platinum and He-3 from the Moon and asteroids
- Future prospects: Space tourism and energy solutions (e.g., solar power, nuclear fusion) may revolutionize terrestrial economies and ensure human survival

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One-paragraph summary

- Outer space has a dual role as both a social enhancer and economic frontier. While current benefits are significant—especially through satellites and spin-off technologies—the future promise lies in resource extraction, advanced energy generation, and expansion of human presence in the solar system. Space is poised to become both a driver of human progress and a central element of the Earth-centric economy