

Title page

Changemakers: Creativity and Value Creation

Module code: ACCA5033

Assignment 1: Innovation and Research

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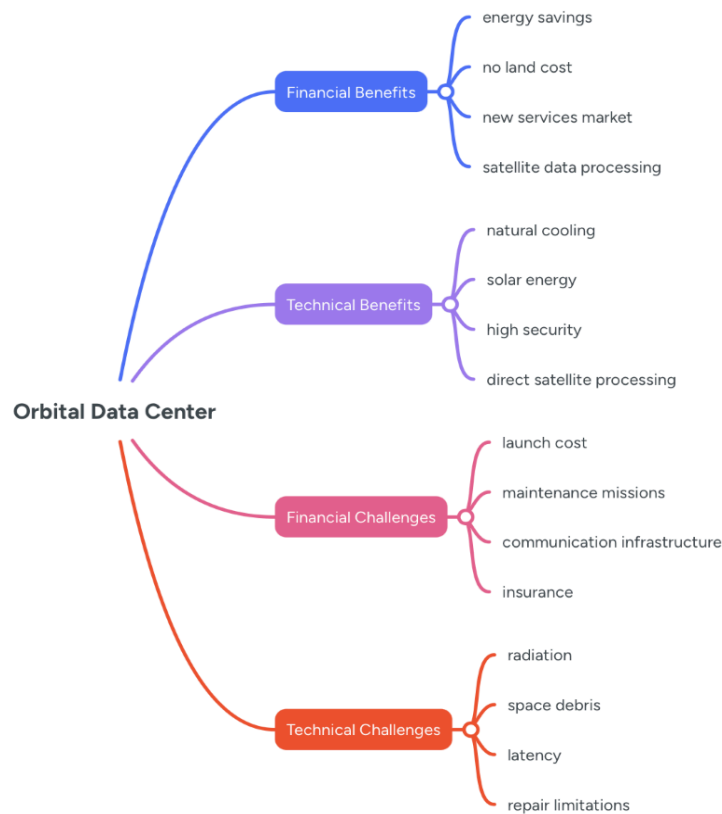
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Task 1



Ideation & Mind Map

Project Idea: Orbital Data Center

An orbital data center is a computing infrastructure located in Earth orbit rather than on the planet's surface. The idea is to place servers and data-processing systems on satellites or space platforms where they operate using solar energy and the natural vacuum of space. Researchers and aerospace companies are currently exploring this concept as global data demand and energy consumption of terrestrial data centers continue to increase [2], [6].

The main objective is to reduce the environmental impact and energy requirements of traditional data centers while enabling new capabilities such as direct processing of satellite data in space. However, the concept also introduces significant technical and financial challenges due to launch costs and the harsh conditions of the space environment [3].

1. Financial Benefits

Orbital data centers could provide several economic advantages compared with traditional ground-based facilities.

First, energy savings may be achieved. Data centers consume large amounts of electricity, particularly for cooling and server operation. Using solar energy in orbit could reduce dependence on terrestrial power systems and lower long-term operational costs [1], [6].

Second, there is no land acquisition cost. Building data centers on Earth often requires expensive land purchases, construction permits, and infrastructure development. Orbital systems eliminate these land-related expenses [3].

Third, orbital infrastructure may create a new services market, particularly for industries that rely on satellite data such as Earth observation, environmental monitoring, and defense systems [6].

Finally, in-orbit data processing could reduce the need to transmit large volumes of raw satellite data to Earth. Instead, satellites could send data directly to an orbital computing platform where it is processed before transmission to ground stations [2].

2. Technical Benefits

Orbital data centers may also provide several technical advantages.

One important benefit is natural cooling. In space, heat can be dissipated through thermal radiation into the vacuum environment, potentially reducing the need for complex cooling systems used in terrestrial data centers [3].

Another advantage is continuous solar energy generation. Satellites equipped with solar panels can produce electricity directly from sunlight, which can support computing infrastructure in orbit [6].

Orbital platforms may also provide higher physical security because direct physical access to hardware is extremely limited. This reduces risks related to physical intrusion or sabotage [3].

In addition, orbital data centers allow direct satellite data processing, where data collected by satellites can be analyzed immediately in orbit without requiring large data transfers to Earth [2].

3. Financial Challenges

Despite the potential benefits, orbital data centers face major financial barriers.

The most significant cost is launch expenses. Sending computing hardware into orbit remains expensive even with modern reusable launch vehicles [6].

Another financial challenge involves maintenance missions. If equipment fails or requires upgrades, additional servicing missions may be required, which significantly increases operational costs [3].

Orbital systems also require specialized communication infrastructure to transfer processed data between space and Earth. Developing high-capacity satellite communication networks adds further costs [2].

Finally, space infrastructure requires expensive insurance coverage due to risks associated with launch failure, equipment malfunction, or orbital collisions [6].

4. Technical Challenges

Operating computing infrastructure in space introduces several technical difficulties.

One major issue is radiation exposure. High-energy particles in space can damage electronic systems, leading to hardware degradation or data errors. This requires radiation-hardened components, which are more expensive and complex [5].

Another challenge is space debris. Thousands of objects orbit Earth, and collisions with debris can damage satellites or orbital platforms [4].

Communication latency may also become a concern depending on the orbit and the distance between the data center and ground stations [3].

Finally, repair limitations present a major challenge. Unlike terrestrial facilities where hardware can be replaced quickly, repairing equipment in orbit is difficult and may require specialized servicing missions [3], [6].

References:

- [1] T. Davenport and R. Bean, "Data Centers and the Energy Challenge," MIT Sloan Management Review, 2022.
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- [2] European Space Agency, "Space-based Cloud Computing," ESA Technology Report, 2023.
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- [3] A. Rinaldi, "Orbital Data Centers: A New Frontier for Cloud Computing," IEEE Spectrum, 2023.
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Task 2

Aim & Objectives and Research Area

Aim and Objectives

The rapid growth of digital technologies such as artificial intelligence, cloud computing, and satellite systems has significantly increased the global demand for data storage and processing. Traditional terrestrial data centers require large amounts of electricity and complex cooling systems, which increases operational costs and environmental impact [5]. For this reason, researchers and space agencies have begun exploring the concept of orbital data centers, which would place computing infrastructure in Earth orbit where solar energy and the natural vacuum of space could be used for power generation and cooling [1].

Orbital data centers could also allow direct processing of satellite data in space, reducing the need to transmit large volumes of raw data to Earth. This could improve efficiency and reduce communication bandwidth requirements [3].

Aim

The aim of this project is to investigate the feasibility, benefits, and challenges of orbital data centers as a potential future solution for sustainable and efficient global data processing infrastructure.

Objectives

To achieve this aim, the following objectives are defined:

1. **To analyse the concept and operational principles of orbital data centers**, including how computing systems could function in Earth orbit.
2. **To evaluate the potential financial and technical benefits** of orbital data centers compared with traditional ground-based data centers.
3. **To identify the major financial challenges**, including launch costs, communication infrastructure, and maintenance missions required for space-based systems.
4. **To examine the key technical challenges**, such as radiation exposure, space debris risks, latency, and equipment repair limitations in orbit.
5. **To review existing research and technological developments** related to space-based computing infrastructure and evaluate its potential future applications.

These objectives provide a structured framework for analysing both the advantages and limitations of orbital data centers.

Research Philosophy

Research philosophy refers to the beliefs and assumptions about how knowledge is generated and how research should be conducted [2]. It influences how data is collected, analysed, and interpreted.

For this project, the most appropriate research philosophy is positivism.

The positivist philosophy is based on the idea that knowledge should be derived from observable facts, scientific evidence, and measurable data [2]. This approach is commonly used in engineering and technology research where objective analysis of existing studies and technical reports is required.

In this project, the research focuses on analysing existing scientific literature, technical reports, and industry publications related to orbital computing infrastructure. These sources provide factual information about satellite technologies, space environment risks, and energy consumption of traditional data centers.

Using a positivist research philosophy allows the study to evaluate the feasibility of orbital data centers using objective evidence rather than subjective interpretations.

Search Tools and Research Databases

To identify reliable research related to orbital data centers, several academic search tools and databases were used.

One of the main tools used in this research is Google Scholar, which provides access to a wide range of academic sources including journal articles, conference papers, and technical reports. Google Scholar is useful for identifying highly cited research and recent publications related to space technologies and computing infrastructure.

Another important database is IEEE Xplore, which contains peer-reviewed engineering and technology research. IEEE publications include studies on satellite communication systems,

space electronics, and distributed computing technologies, which are relevant to orbital data center research [3].

In addition, official publications from space agencies such as NASA and the European Space Agency (ESA) provide valuable information about space infrastructure technologies and risks such as orbital debris [4].

To identify relevant research efficiently, several search strategies were applied. These included the use of keywords and Boolean operators.

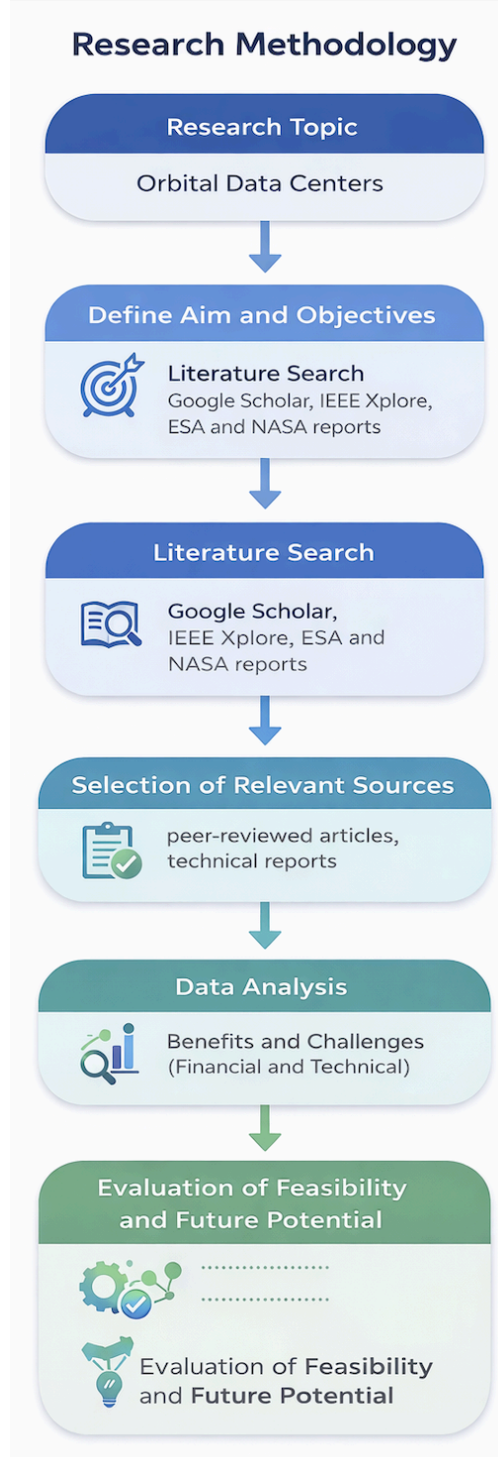
Examples of search keywords include:

- orbital data centers
- space-based cloud computing
- satellite data processing
- space computing infrastructure
- data center energy consumption

Boolean operators such as **AND** and **OR** were used to refine search results. For example:

- “space computing AND data centers”
- “orbital infrastructure OR space-based cloud computing”

Using multiple research tools and structured search strategies helps ensure that the information used in this project is **credible, relevant, and based on academic research**.



References:

- [1] European Space Agency, "Space-Based Cloud Computing," ESA Technology Report, 2023. <https://www.esa.int>
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Task 3

Research Strategies

Validity, Reliability, Generalisability and Ethical Considerations

In academic research, it is important to ensure that the results are credible and scientifically sound. Four key principles that support research quality are **validity, reliability, generalisability, and ethical considerations** [1].

Validity refers to how accurately the research measures what it is intended to measure. In this project, validity will be enhanced by using credible academic sources such as peer-reviewed journals, engineering publications, and reports from recognized organizations such as the European Space Agency (ESA) and NASA. Using multiple sources allows the research findings to be supported by established scientific evidence related to satellite systems, energy consumption, and space infrastructure [4].

Reliability refers to the consistency of research results if the study were repeated under the same conditions. Reliability in this research will be improved by using clearly defined research procedures and systematic literature review methods. For example, specific keywords and databases such as Google Scholar and IEEE Xplore will be used consistently when searching for sources. This ensures that the research process can be replicated by other researchers [2].

Generalisability refers to the extent to which research findings can be applied to broader contexts. Although orbital data centers are still an emerging concept, analysing a wide range of studies on data centers, satellite technologies, and space infrastructure helps identify general trends and technological limitations. These findings can provide insights into how orbital computing systems might develop in the future [3].

Finally, **ethical considerations** are essential in academic research. This project will follow ethical research practices by properly citing all sources, avoiding plagiarism, and ensuring that all information is obtained from legitimate and publicly available research publications. In addition, when collecting pilot feedback from participants, their responses will be anonymous and voluntary to protect their privacy and confidentiality [1].

Research Strategies and Data Collection Methods

This project primarily uses **secondary research methods**, which involve analysing existing literature, technical reports, and academic publications. Secondary research is appropriate because orbital data centers are still largely conceptual, and most available information comes from scientific studies and industry reports [3].

However, to complement the literature review, a small pilot data collection method will also be conducted. The pilot study aims to gather opinions from individuals with some technical background about the feasibility and potential benefits of orbital data centers.

The selected data collection method is a **short questionnaire survey**. The questionnaire will include both closed and open-ended questions to gather quantitative and qualitative data.

Example questions used in the pilot survey include:

1. How familiar are you with the concept of orbital data centers?
2. Do you believe space-based data centers could reduce energy consumption compared to terrestrial data centers?
3. What do you think is the biggest challenge for orbital data centers? (e.g., cost, technology, space environment)
4. Do you think orbital data centers could become commercially viable in the future?

The pilot survey will be distributed to a small group of participants such as university students or professionals in engineering or technology fields. Their feedback will help refine the research focus and identify which aspects of orbital data centers require deeper investigation.

The results of this pilot survey and participant feedback will be included in the **Appendix section** of the research proposal.

Quantitative and Qualitative Analysis

Research analysis methods can generally be divided into **quantitative** and **qualitative** approaches.

Quantitative analysis focuses on numerical data and statistical evaluation. In this project, quantitative analysis may include evaluating measurable data such as energy consumption of data centers, launch costs, and communication bandwidth requirements. Statistical data from industry reports and research papers can be used to compare terrestrial data centers with potential orbital infrastructure [5].

Quantitative methods may also be applied to the pilot questionnaire results by calculating response percentages or identifying trends in participant opinions.

Qualitative analysis focuses on understanding concepts, opinions, and themes within research data. In this study, qualitative analysis will be used to examine the advantages and challenges of orbital data centers described in academic literature.

One common qualitative method is **thematic analysis**, which involves identifying recurring themes across multiple research sources. For example, themes such as sustainability, cost barriers, technological feasibility, and space environment risks may emerge during the literature review.

Combining quantitative and qualitative analysis allows the research to provide both **numerical evidence and conceptual understanding** of orbital data center development.

References:

- [1] M. Saunders, P. Lewis, and A. Thornhill, *Research Methods for Business Students*, 8th ed., Pearson, 2019.
- [2] J. W. Creswell, *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*, 5th ed., Sage Publications, 2018.
- [3] A. Rinaldi, "Orbital Data Centers: A New Frontier for Cloud Computing," *IEEE Spectrum*, 2023.
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- [5] McKinsey & Company, "The Future of Space Infrastructure and Services," 2022.

Appendix

► Pilot Survey Questionnaire

1. How familiar are you with the concept of orbital data centers?
 - Very familiar
 - Somewhat familiar
 - Not familiar
2. Do you believe orbital data centers could reduce the energy consumption of traditional data centers?
 - Yes
 - No
 - Not sure
3. Which potential benefit of orbital data centers do you consider the most important?
 - Renewable solar energy
 - Natural cooling
 - Direct satellite data processing
 - Security advantages
4. What do you think is the biggest challenge for orbital data centers?
 - Launch cost
 - Space radiation
 - Space debris
 - Communication latency
5. Do you think orbital data centers could become commercially viable within the next 20 years?
 - Yes
 - No
 - Possibly
6. Please briefly explain your opinion about the future of orbital data centers.
