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DSS For Small Satellite vehicle

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INTRODUCTION

The document provided is a comprehensive research paper titled "DSS for selecting Small Satellite launch vehicle provider"

What are small satellites

Small satellites are a category of spacecraft that are significantly smaller and lighter than conventional satellites. Small spacecraft (SmallSats) focus on spacecraft with a mass less than 180 kilograms and about the size of a large kitchen fridge. [1]

Applications of smallsats

These satellites are used for myriad applications ranging from education, scientific research and Earth observation to communication and navigation. Their reduced size and mass allow for more cost-effective launches and often enable organizations to deploy constellations of smallsats for broader coverage or more complex missions.

Why is selecting the launcher provider important?

Selecting a launch provider is a critical decision because it is impacting significantly the cost and mission success. This is because the launch costs are a substantial portion of the total mission expenditure. Reliability is another crucial factor, as the provider's track record influences the likelihood of the satellite reaching its designated orbit, thus affecting the mission timeline and potential revenue generation. Additionally, the ability to meet specific launch windows and orbital insertion accuracy are vital for the satellite to perform its intended functions, particularly for Earth observation applications. With the increasing concern over space debris, selecting a provider that implements sustainable launch practices is also of growing importance. These factors make the selection process complex and multi-dimensional, emphasizing the need for a meticulous approach to choosing a launch provider that aligns with the mission's goals and constraints.

SCOPE

The Decision Support System (DSS) is a tool that facilitates an informed decision-making process by taking into account multiple criteria during the selection of a small satellite vehicle launch provider. This system will ensure the best fit between mission requirements and launch provider capabilities.

METHODOLOGY

Data Collection and Integration: Gather data on available small satellite launch providers, including their launch history, cost, reliability, and technical capabilities.

Integrate this data into the DSS for analysis.(Asking Industry leader, suppliers and historic prices for to gather such data)

-Criteria and Scoring System: Develop a comprehensive set of criteria for evaluating launch providers, such as launch cost, payload capacity, launch success rate, and geographic location. Create a scoring system to objectively compare providers based on these criteria.

-**User Interface Design and Develop:** Design an intuitive user interface for the DSS, making it accessible to a wide range of users, including satellite operators, mission planners, and project managers.(Usability for multiple stakeholders) based on various criteria and constraints.

-Simulation and Optimization: Implement simulation algorithms that allow users to explore different scenarios and optimize their launch provider selection based on their specific mission requirements and budget constraints.(Using monte-carlo simulation)

-Recommendation Engine: Develop a recommendation engine that suggests the most suitable launch providers based on user inputs and preferences.(The suggestion would be as good as the DSS)

UNDERSTANDING THE DESIGN ATTRIBUTES AND ALTERNATIVES.

The data we used consists of information about various space launch vehicles. Here's an overview of the columns in the dataset:

1. **Vehicle**: Name of the launch vehicle.
2. **Country**: Country of origin.
3. **LEO Capacity (kg)**: Payload capacity to Low Earth Orbit in kilograms.
4. **SSO Capacity (kg)**: Payload capacity to Sun-Synchronous Orbit in kilograms.
5. **LEO Price ($K/kg)**: Price per kilogram for launching to LEO in thousands of dollars.
6. **SSO Price ($K/kg)**: Price per kilogram for launching to SSO in thousands of dollars.
7. **Total Launches**: Total number of launches.
8. **Reliability (%)**: Reliability percentage of the vehicle.
9. **Frequency**: Launch frequenc

- Launch Vehicles: 28 unique vehicles from 7 different countries.
- LEO Capacity: Average 8,461 kg, ranging from 300 to 63,800 kg.
- SSO Capacity: Average 2,116 kg, ranging from 161 to 7,960 kg.
- LEO Price: Average $13.05K/kg, with a range from $1.41K to $43.10K per kg.
- SSO Price: Average $30.01K/kg, with a range from $2.80K to $100.40K per kg.
- Total Launches: Average 47.8, ranging from 3 to 289.
- Reliability: Average 90.62%, ranging from 33.33% to 100%.
- Frequency: Average 368, ranging from 24 to 1,270 (based on 27 entries).

This summary provides an overview of the key statistics related to space launch vehicles in the dataset.

DSS DEVELOPMENT STRATEGY

DSS develppment Structure

1. **Data Loading**: The script reads data from an Excel file named 'launchers.xlsx' into a DataFrame **launchers_df**.
2. **Data Cleaning**: Converts specific columns to numeric types, handling non-numeric values as errors.
3. **User Inputs**: The script prompts the user for the following:
   - Total mass of the satellite(s) in kg.
   - Country of preference for the launcher (Japan, China, USA, India, New Zealand, Russia, Europe, or any).
   - Type of orbit (LEO/SSO).
4. **Data compiling**: Based on user inputs, the DataFrame is compiled to match the criteria (country preference, orbit type, and capacity).
5. **Launcher Selection Logic**: The script seems to implement a Multi-Attribute Utility Theory (MAU) approach for launcher selection. This involves:
   - Defining utility functions for different attributes like price, reliability, and frequency.
   - Calculating a combined utility score (MAU value) for each launcher.
   - Selecting the launcher with the highest MAU value.
6. **Output**: The script outputs the best launcher based on the calculated MAU value.
7. **Risk Analysis**: In addition to recommending a launcher, the script performs a risk analysis based on reliability percentages. It categorizes risk into 'Low', 'Medium', and 'High' based on predefined impact levels.

Results and Use

The script provides a user with a recommended satellite launcher based on specific criteria (mass, country, orbit type) and evaluates the risk associated with each launcher option. It is useful for decision-making in scenarios where choosing an appropriate satellite launcher is necessary, taking into account various attributes like capacity, price, and reliability.

DSS DEVELOPMENT STRATEGY

The results generated by this script can be categorized into two main sections: Launcher Recommendation and Risk Assessment. Here's a detailed look at each:

Launcher Recommendation

1. Best Launcher Selection: Based on the user's input regarding the satellite's mass, preferred country, and orbit type (LEO or SSO), the script filters out launchers that don't meet these criteria.
2. MAU Value Calculation: For each of the remaining launchers, the script calculates a Multi-Attribute Utility (MAU) value. This value is a weighted sum of different attributes like price, reliability, and frequency. Each attribute has a utility function associated with it that converts the raw value (like price per kg or reliability percentage) into a utility score.
3. Output: The launcher with the highest MAU value is recommended to the user. This is the launcher that best balances the various attributes according to the script's utility functions and the user's criteria. The output includes the name of the recommended launcher and its corresponding MAU value.

Risk Assessment

1. Reliability-Based Risk Analysis: After recommending a launcher, the script performs a risk analysis focusing on the reliability of each launcher option. This analysis uses predefined impact levels to categorize risk.
2. Risk Categorization: The script categorizes risk into 'Low', 'Medium', or 'High'. This categorization is based on the reliability percentage of each launcher. For example, a launcher with a reliability of 95% or higher might be categorized as 'Low' risk.
3. Risk Assessment Output: For each launcher, the script provides a risk assessment that includes the launcher's name, its reliability percentage, the likelihood of failure (based on the reliability), and the assigned risk level. This output helps users understand the potential risks associated with each launcher option.

DSS DEVELOPMENT STRATEGY

Overall Utility of the Results

- Decision Making: The combination of the MAU-based recommendation and the risk assessment gives users a comprehensive view of their options, helping them make more informed decisions.
- Customisation: Since the script bases its calculations on user inputs and predefined utility functions, it can be tailored to different priorities and scenarios.
- Insightful Analysis: By providing both a recommendation and a risk analysis, the script goes beyond simple data filtering, offering a deeper insight into the strengths and weaknesses of each launcher option.

Limitations

- Data Dependency: The accuracy and relevance of the results are highly dependent on the quality and up-to-dateness of the data.
- Model Assumptions: The utility functions and risk categorization are based on assumptions that may not perfectly reflect all real-world scenarios.
- User Knowledge: Users need to have a certain level of understanding of the attributes (like what constitutes a good price or reliability percentage) to fully appreciate the results.

CONCLUSION:

THE DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR SELECTING SMALL SATELLITE LAUNCH PROVIDERS IS CRUCIAL FOR ENHANCING THE EFFICIENCY AND EFFECTIVENESS OF SATELLITE MISSIONS WHILE MAXIMIZING THE VALUE OF INVESTMENT. THIS PROJECT PROPOSAL OUTLINES THE OBJECTIVES, METHODOLOGY REQUIRED TO SUCCESSFULLY DELIVER A USER-FRIENDLY AND VALUABLE TOOL FOR ORGANIZATIONS INVOLVED IN SMALL SATELLITE DEPLOYMENTS. THE DSS WILL EMPOWER USERS TO MAKE INFORMED DECISIONS WHILE CONSIDERING VARIOUS CRITERIA AND CONSTRAINTS, ULTIMATELY LEADING TO SUCCESSFUL SATELLITE MISSIONS AND COST OPTIMIZATION.

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