A 'SMAD' Tool for Nano and Micro Satellites

SSC21-P2-07

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Abstract

Most of the Space Mission Analysis and Design (SMAD) tools available in the industry are geared towards small and large satellites. The relationships for satellite mass, power, pointing accuracy, design life, redundancy versus cost available in the literature are primarily from satellite platforms 100 kg and higher, built for 3+ mission design life. Nano and microsatellites use a very different design philosophy leveraging Commercial-Off-The-Shelf (COTS) components, minimal redundancy, higher risk, rapid development times and shorter mission durations. Here, we would like to present a nano and microsatellite mission design tool built on a database containing about 200 earth-orbiting micro and nanosatellites. The database also contains different subsystem component parameters based on a survey of commercially available nano and microsatellite products. We also include component level items with space heritage in our database. The analysis estimates relationships between parameters such as satellite mass, volume, power, sensor and actuator type, pointing accuracy, transmit power, data rate and cost. These parameters can all be plotted against a choice variable such as cost or satellite mass. The tool also facilitates easy scaling of a parameter to estimate first-order calculations of satellite mass, size, power, data rate, pointing accuracy, etc., which can be used for mission concept design. The tool is built in python and helps in the nano and microsatellite systems engineering process.

Introduction

Table 1: Satellite Classification based on different mass in kg[1]

Satellite Class	Mass (kg)
Pico Satellite	Less than 1 kg
Nano Satellite	1 to 10 kg
Micro Satellite	10 to 100 kg
Small Satellite	100 to 500 kg
Medium Satellite	500 to 1000 kg
Larger Satellite	Above 1000 kg

- Till now, there are no standard manufacturing procedures for nanosatellites. While building a new satellite, usually the design process starts from scratch. This increases the design time, development time and cost of the satellite.
- The user or system engineer search through the component list manufactured by the different manufacturer to find an accurate component. It takes a lot of time to do trade studies on the component.
- Hence, we focuses on developing a Space Mission Analysis tool (SMAD) tool for nano and microsatellite design with the objective of accelerating the design process by arriving at satellite conceptual designs faster.
- The estimation relationship link the input and the output based on an extensive satellite database of about 200 earth observatory satellites in the mass range of 1 to 10 kg and 10 to 100 kg.

Table 2: CubeSat Classification based on different Dimension

CubeSat	Dimensions	Mass (kg)
0.5U	10 cm x 10 cm x 5 cm	0.88 kg
1U	10 cm x 10 cm x 11.35 cm	1.33 kg
2U	10 cm x 10 cm x 22.70 cm	Almost 2 kg
3U	10 cm x 10 cm x 34.05 cm	Almost 3 kg
6U	20 cm x 10 cm x 34.05 cm	Less than 10 kg
12U	20 cm x 20 cm x 34.05 cm	Almost 15 kg

Methodology - SMAD Tool

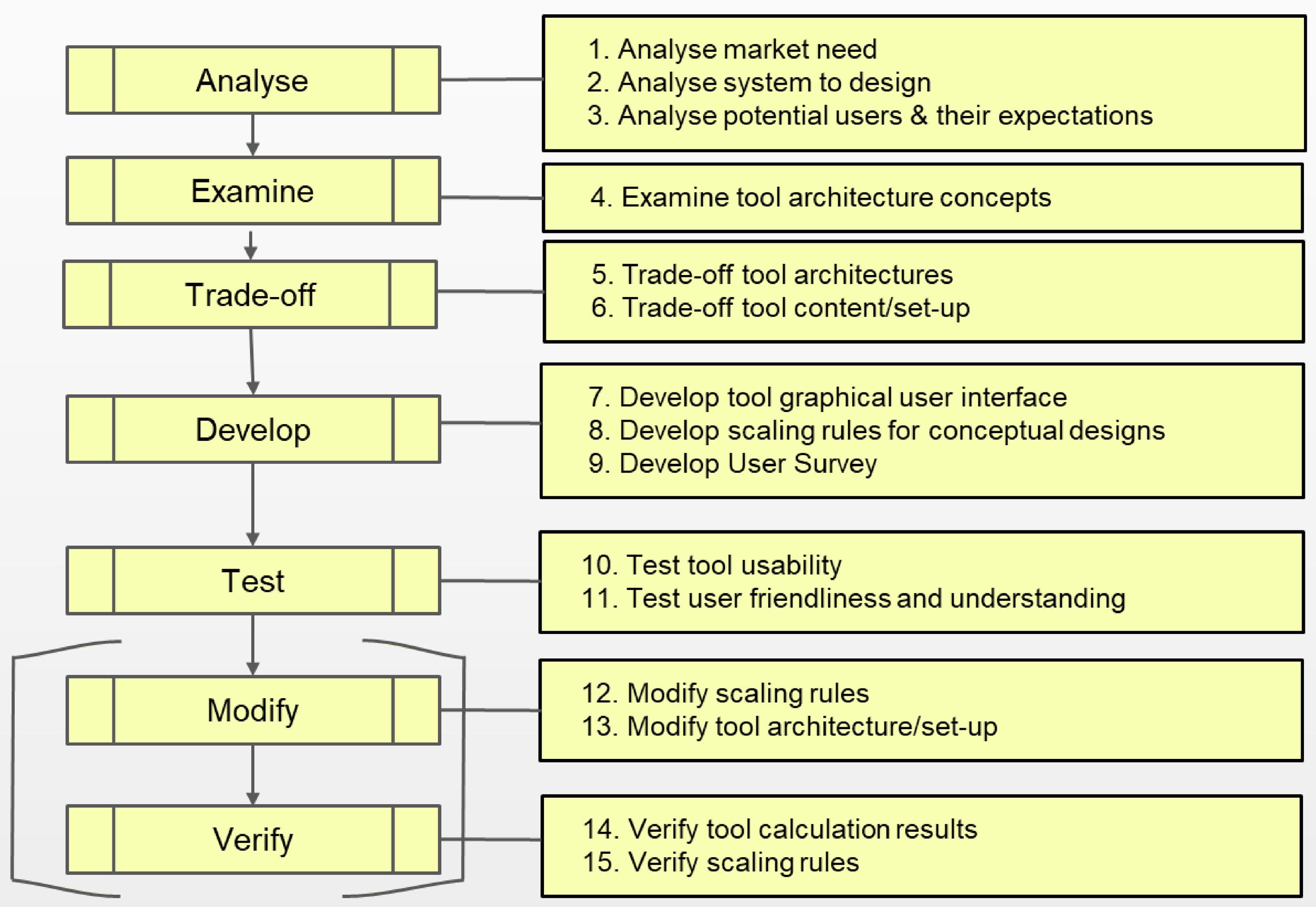

Figure 1: SMAD Tool Development Process

KNN Model or Algorithm

- K Nearest Neighbor (KNN) Algorithm
- A supervised machine learning algorithm used to solve classification problem.
- The Euclidean distance helps to determine the nearest neighbor.
- $Min\ dist(d) = \sqrt{(x-a)^2 + (y-b)^2}$, where x and y are the actual values and a, b are the net data set value.

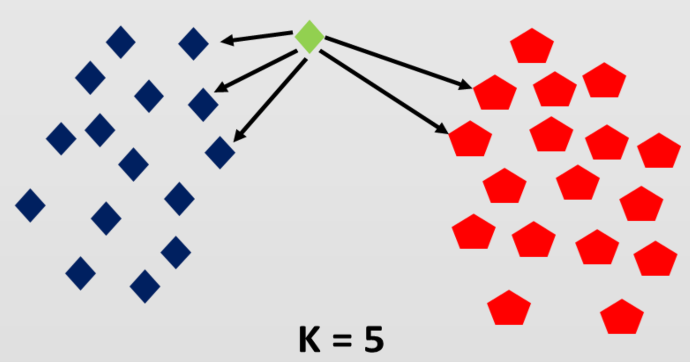

Figure 2: KNN Algorithm

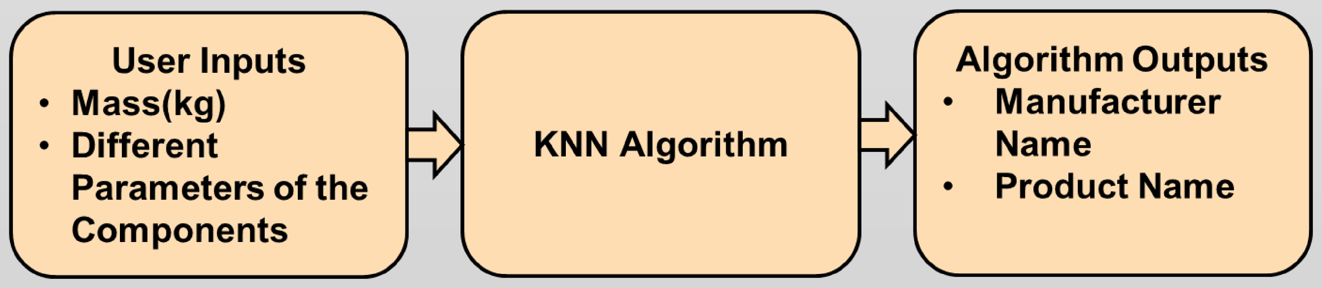

Figure 3: KNN Model

- A Graphical User Interface (GUI) is developed in python.
- This GUI accepts input from the user based on user choice which is unknown data and perform KNN algorithm and list out the nearest manufacturer and product.

Results

Nano Satellite Volume estimation

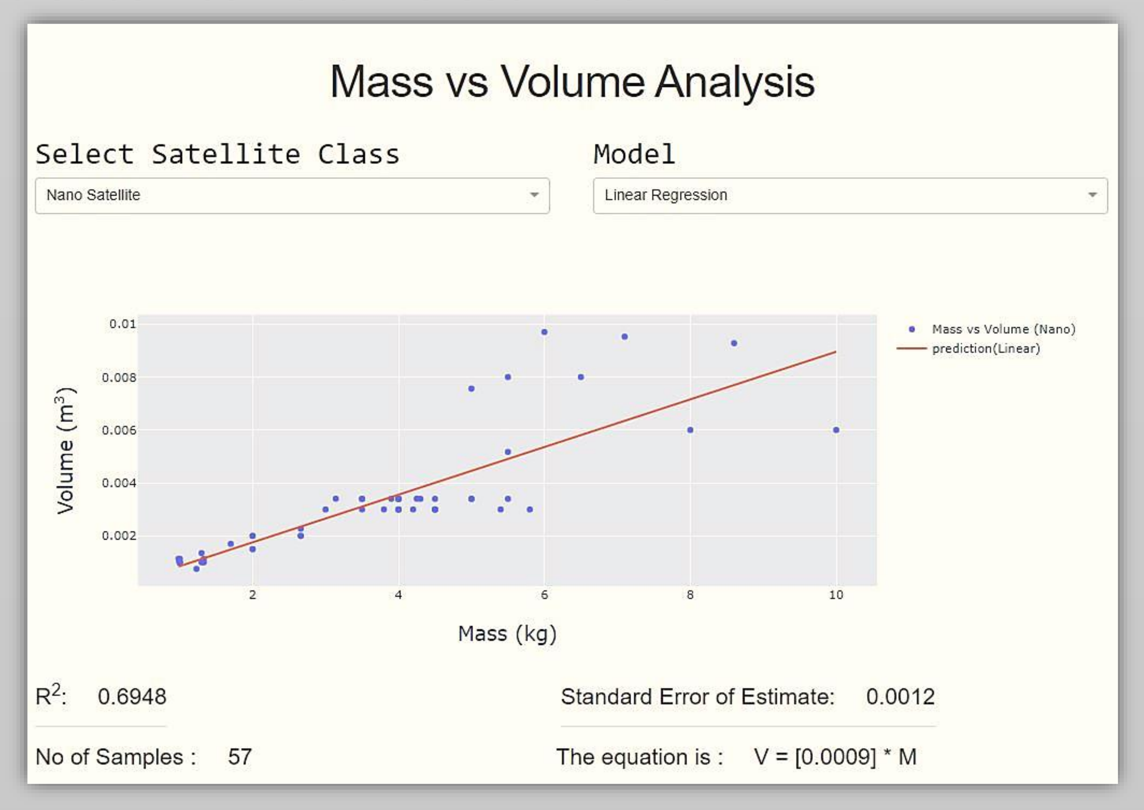

Figure 4: Mass vs Volume Analysis for Nano Satellite

- The equation for the Nanosatellite Volume and Mass is

$$V_{S/C} = 0.0009\ M$$

- It estimates a mean spacecraft density equals to $833\ \mathrm{kg/m^3}$ for nano satellites

Micro Satellite Volume estimation

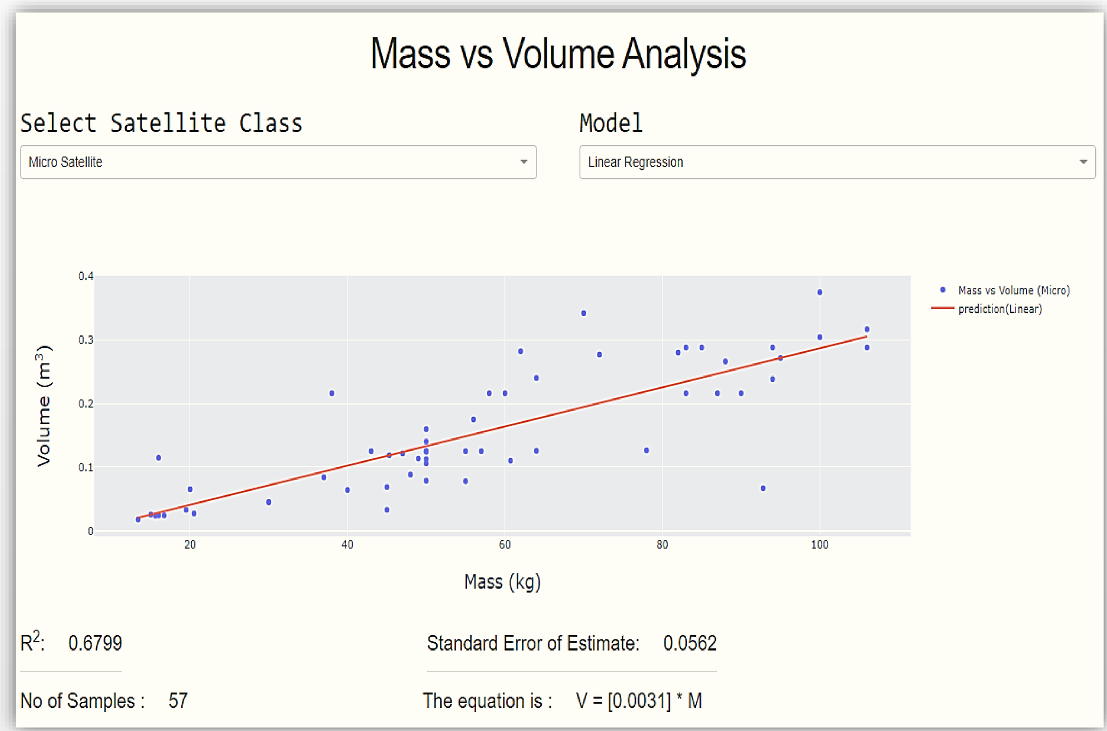

Figure 5: Mass vs Volume Analysis for Micro Satellite

- The equation for microsatellite mass and volume is

$$V_{S/C} = 0.0031\ M$$

- It estimates a spacecraft mean density equals to $323\ \mathrm{kg/m^3}$ for micro satellites.
- The estimation relationship for larger satellites available in literature is [2]

$$V_{sc} = 0.01\ M$$

- It estimates a spacecraft density of $100\ kg/m^3$ for larger satellites[2].
- The reason for higher mean spacecraft densities for nano/ micro satellites than larger satellites is due to the miniaturization of components, electronics, and tighter system integration.
- It optimize the usage of space and all their subsystem fit in very small volume.

KNN model to select the components

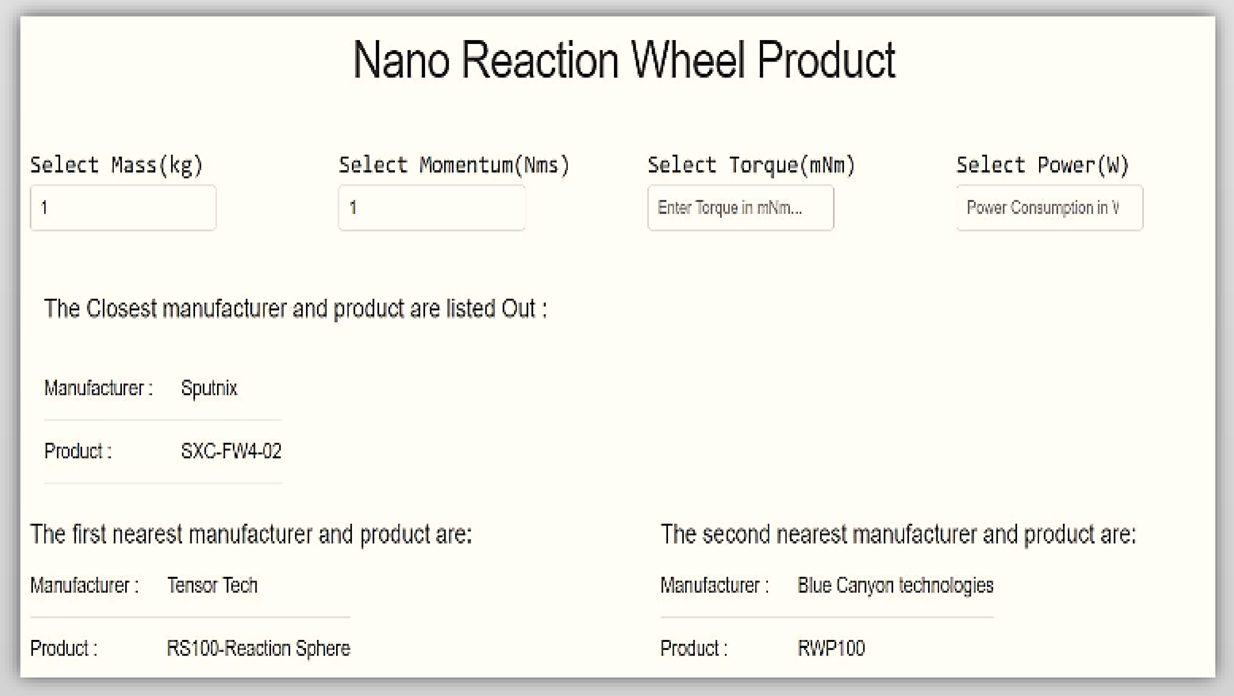

Figure 6: Nano reaction wheel component selection

- The Figure 6 shows how to select a particular reaction wheel component based on the user input parameters.
- •The tool helps the system engineer to get a feasible satellite design. Based on the user input constraints such as satellite cost, mass, power, volume, pointing accuracy, data rate and so on, the tool will be used to frame algorithms to define the whole satellite subsystems and components autonomously from the database.
- The tool will be further extended to check the interfaces, protocols and other parameters to ensure feasibility and go through an automated iterative process to give a final feasible satellite design.

Acknowledgements

The author would like to thank NTU SaRC for the funding and staff for their contribution.

References

[1]. Fortescue, P., G. Swinerd, and J. Stark, Spacecraft systems engineering. 2011: John Wiley & Sons.

[2]. Larson, W.J. and J.R. Wertz, Space mission analysis and design. 1992, Torrance, CA (United States); Microcosm, Inc