ABSTRACT
Although satellites are getting smaller and the development duration is getting shorter, it still takes a long time to conduct a satellite conceptual design. The System Engineering Design Tool (SEDT) has been developed to effectively and efficiently design small satellites, which are in the range between 10kg (nanosatellite) and 200kg (microsatellite) to minimize the amount of labor involved. The present SEDT consists of five design blocks and has some characteristics different from system engineering tools previously developed. First of all, it adopts top-down design methodology which induces the architecture of distributed design. SEDT has also implemented the subsystem design process which is connected in series. It enables the design order of satellite system based on design parameters of satellite database constructed from over 200 small satellites launched between 1990 and 2004, which can improve the data reliability as a design reference. SEDT incorporates system budgets, mass and power, as verification parameters, and some characteristic trend equations. SEDT can do the conceptual system/subsystem design, analyze the design output, and predict the ROM development cost in accordance with user’s requirements. Specially, the SEDT implements GUI to provide convenience to the users.

1. INTRODUCTION
The System Engineering Design Tool is a software tool that provides a convenient means to perform conceptual design of a satellite system. The ultimate purpose of the tool is to cut down the program time and cost of small satellites at the beginning phase. An added value is the database, which the tool is based on, such that the result reflects the current trend in satellite designs and helps to achieve more valid designs. The function of SEDT software to compute mass and power and to estimate cost gives a rough idea of the shape of the satellite system according to the system engineer’s request, through numerous equations and algorithms. Also trade-offs can easily be carried out by system engineers by substituting mission critical factors such as mission requirements and system requirements, and analyzing the effects of these factors on the satellite design.

2. SEDT ARCHITECTURE
SEDT consists of Mission Design Block (MDB), System Design Block (SDB), Performance Verification Block (PVB), Cost Block (CB), and Visualization Block (VB), as shown in Figure 1.
The Mission Design Block (MDB) performs mission analysis and design based on user/mission requirements. The feasibility for satellite development in accordance with the mission requirements will be ensured at this stage.

The System Design Block (SDB) is divided into various different subsystems such as payload, EPS, SMS, ADCS, TCS, propulsion, TT&C, and C&DH. Individual subsystems are designed based on the analysis data flow-downed from MDB, and the design data is interacted with each other.

Payload design is limited according to the mission, and must take requirements from MDB into consideration during payload design. Currently, SEDT can only generate specifications for payloads that are based on optical sensors. This is due to the fact that optical sensor payloads have more standardized design processes and thus generates more accurate estimates according to the performance specifications of the sensors. For other types of payload, only power consumption and mass are taken into consideration for system interface due to the wide diversity of payload types and missions.

The two major categories for EPS are the solar cell and battery design. The system engineer decides on parameters such as power control method and cell properties to generate parameters such as EOL power, required solar cell area, battery capacity, and mass based on inputs from MDB and the given budget. In particular, EPS battery mass is determined by a special equation, derived by using the relationship between battery capacity and cell voltage.

SMS calculates the mass of the satellite by locking down satellite size, shape, and structure material. The result is displayed right away to ensure that the design does not exceed the budget. SMS mass estimation based on database analysis takes into account the portion of internal space taken up. In addition, SEDT runs a feasibility check on the
satellite size by checking to see if the top down power requirement is satisfied. In other words, the solar cell area of EPS directly impacts the external area of the satellite and satellite deployment of solar arrays.

ADCS takes into consideration the pointing accuracy requirements, pointing method and stabilization method. In order to maintain a “feasibility checked” state, some of the selections may be limited. Sensors and actuators design is made more realistic by using heritage information from the database. The program sizes actuators while factoring in the disturbances that affect satellites during in-orbit operation.

Previous large-size propulsion systems cannot fit under small satellite mass and power budget. SEDT implements micro electric propulsion that brings many advantages to small satellites such as low mass, low power consumption, high Isp. Therefore, SEDT provides a valid design range to aid engineers in designing the system. Propulsion design consists of function & propulsion type, ΔV calculation, and propellant mass calculation.

TT&C mainly involves link budget calculation process and estimates mass and power consumption using common small satellite components such as GPS receiver, beacon generator, and TNC as system parameters.

TCS compares maximum temperature range of satellite components and the calculated worst case hot/cold temperatures and provides this data to the system engineer so the active/passive temperature control system can be selected. The worst case temperature is calculated by considering max/min power dissipation.

C&DH determines the complexity of the system. The complexity depends on the function, architecture, hardware system, and fault tolerance, and also helps provide estimates for system mass and power consumption. Amount of telemetry data is dictated by sampling rate, quantization, and the number and types of sensors for each subsystem. Data rate is determined by contact time, downlink, and orbital period.

PVB gives the capability to adjust performance and specifications according to each subsystem mass and power consumption estimated by aforementioned systems as compared to the budget. In particular, power consumption verification is run through an Energy Balance Analysis.

Analyzing and estimating satellite production cost is becoming more important, especially during the initial phase of the design. The basic production cost for the bus and the payload is estimated according to the methods stated above while taking into account the inflation according to the production year. This calculation is carried out using CERs(Cost Estimation Relationships) developed by Aerospace Corporation.

VB is the stage where the satellite designed in SDB takes a physical configuration and each component is shaped by matching the designed mass values to a realistic sizing. This is a good aiding tool to the system engineer in providing an idea of the satellite shape and component sizes, and for visualizing general design of the satellite.

3. CHARACTERISTICS OF SEDT

Equations used by SEDT are based on those that are standard in satellite design, with additions derived from construction and production experience. The flow of the data follows calculation orders of the elements within the equations. A standard order could be established by following the above logic. This new order can also be thought of as a top-down method. For other applications, a special equation was formed through database analysis, then applied where needed. A summary of this process is shown in
Figure 1. Up to now, excel-type tools were popular due to ease of generation, but there is a limit to the complexity such tools can accommodate. SEDT solves this problem by being able to handle much more complex parameters while also adopting GUI to make the tool easy to use.

4. DATABASE, CHARACTERISTIC EQUATION, AND APPLICATION

The database includes not only the basic information such as mass and volume, but also information on each subsystem and orbital elements of more than 200 small satellites produced between 1990 and 2004. SEDT has developed a crucial mass and power consumption estimation equation based on this database. For example, Figure 2 shows the process of generating an appropriate shift using the data. Table 1 shows C&DH characteristic equation for each situation and occasion, and each SEDT subsystem uses this same categorization for application of the equations.

![Figure 2 The relationship between satellite and payload mass](image)

5. CONCLUSION

SEDT is an initial concept design tool for small satellites. It is a powerful tool where a system engineer can alone run design estimates, from mission concept to bus design, cost estimate, and even structure and component shape and size. This kind of software also contains a great value to be used as an educational tool for students interested in satellite systems. In addition, larger database information needs to be obtained and modifications made through continued usage by experts to increase reliability.

REFERENCES
