Meeting: September 6, 2005
Attendees: Chahé Adourian, Prof. Hans Vangheluwe
Subject: Current overall objective of master's thesis

Discussed two possible options and a third one, which may be a mix of first two. The current consensus is to go with option 2. Here are the three options:

Option 1: Focus on design optimization issues from a system's point of view, as would be beneficial to system engineers in the satellite industry; the following alternatives are to be considered:

a. Given a design, perform parameter optimization
b. Explore various alternative designs automatically, as well as parameter optimization
    a. Based on existing partial template designs, full designs could be constructed …

What is required is an environment in which to do this. Current state of affairs would allow the simulation of spacecraft Attitude & Orbit Control Systems (AOCS) without too much effort. Thus research into optimization could be started if the domain is restricted to this.

The following considerations may be useful to observe:

a. Optimization should consider the feasible range for the parameters given existing products. As such a database of existing parts must be maintained (at least enough to demonstrate that further scaling is possible)
b. Test-benches to evaluate the design should be created such that they are as reusable as possible, and, as much as possible, independent of the particular design instances under test. This would reduce the number of test benches required to generate all the performance numbers needed.
c. Test-benches must be comprehensive enough to cover most of the aspects of interest to system engineers. We will need to list these.
d. The satellite operates under various modes (general conditions), and optimization for one set may not be optimal for another; As such multi-criteria optimization may be necessary.

The following considerations are essential:

a. The user requires a Design Specific Modeling environment (DSM). The advantages are many
    i. Search space is reduced
    ii. Most/all generated designs are meaningful, even if not desirable or useful.
    iii. A DSM environment is simpler to use than a non-DSM environment where the user would be required to fill-in all the design specific information.
b. The DSM should allow/support the natural increase in complexity that occurs for each subsystem during the design process as it becomes more and more detailed. The DSM should allow replacing one set of models with another that is more complex and possibly belonging to another modeling paradigm, and all the while maintain links with the rest of models that haven't changed.
c. Integration of scientific approaches in doing design. Example: use of a Design Structure Matrix to determine which parts of the system should be designed first, so as to minimize the number of dependencies among the parts, and thus reduce costly redesign.

Option 2: Concentrate on the development of a multidisciplinary design and simulation environment geared towards satellites. This DSM environment would be composed of a multitude of established tools, such as CAD, FEM (Finite Element Modeling), Visualization and finally simulation tools; the aim would be to integrate all of these tools such that a coherent description of the model is maintained across all interfaces. In other words, there should not be conflicted information originating from two different tools and that require harmonization by the user manually during integration phase.

The tools under consideration for integration are the following:

- For CAD: SolidEdge
- FEM Thermal and Mechanical: Ansys Multiphysics
- Visualization: Virtools
- Simulation: Dymola

A typical design effort would proceed as follow

1. Using Dymola only, start by using the spacecraft subsystem models, to create a subsystem or system model of a spacecraft; The parameters of the models may be extracted from a database reflecting the characteristics of real components;
2. Run the created model through a series of performance gaging benchmarks. These benchmarks are carried out using test benches created in Dymola itself.
3. User can modify the parameters or the actual structure of the systems and repeat step 2.
4. Once the design is satisfactory, try and come up with the physical representation of the model based on manufactured parts. This is done using the CAD tool and libraries of 3d models representative of the manufactured parts.
    a. Note: given that in step 1, the user filled the parameter of the models using a database, the physical shape of the models might already be deduced from this same database;
5. After the physical representation has been completed, the performance measuring tests can be carried further; for example:
    a. The mass properties of the spacecraft can be recalculated. This will have an impact on the AOCS and its performance.
    b. Solar Radiation Pressure and Atmospheric drag effects can be modeled more accurately given that shape of spacecraft is now more detailed. This will have an impact on the AOCS and its performance.
    c. Thermal analysis can be initiated to determine thermal influx over the various surfaces (we still don’t need a FEM model, but simply the shape of the spacecraft); This can allow to detect areas that are subjected to high thermal stresses, and in some cases even to determine their temperatures.
    d. Illumination of solar panels and the impact of self-shadows on them by the spacecraft can be evaluated to improve assessment of power available. Temperature of the arrays can also be evaluated, with a direct impact on their power generation efficiency.
    e. Obstruction of (visual) sensors such as sun-senor, earth sensor etc, by the spacecraft itself, including moving components (e.g. rotating solar panels) can be evaluated;
    f. Etc.
6. Implementation of a FEM. The following performance measures can be performed
    a. Detection of maximum and minimum temperatures
    b. Evaluation of structural deformations, with an impact on the pointing accuracy of some sensors (such as an observation camera which needs a to operate within some range of pointing accuracy).
    c. Etc.

Challenges:

- The design processes and their flow must be understood. As such, a design flow/graph needs to be developed;

- The impetus is, first and foremost, on supporting the systems engineer; As such, every capability that is built/developed must be evaluated to determine its use by the system engineer;
- Proper tools to carry out this process must be integrated/developed.
- Spacecraft Design procedures as described in books such as the *Space Mission Analysis and Design* (SMAD), by Wertz, must be understood and a guide explaining how to conduct those processes in the DSM explained. In fact, the DSM should be constructed in order to allow the application of SMAD procedures.

Option 3: Develop part of Option 2, and then some of Option 1
In detail, this would entail in the following tasks to be performed:

1. Develop enough models of spacecraft subsystems using Dymola to allow a variety of realistic satellite simulations, covering most subsystems, to be developed.
2. Integrate Dymola with the Virtools visualization environment, to provide some of the dymola models with the visual informations they need to function properly (e.g Sun Sensor models, Solar panel illumination information, Planet horizon sensor, etc.)
3. Demonstrate various optimization techniques;