Simulation Development and Analysis of Crew Vehicle Ascent Abort

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NASA's Commercial Crew Program is an integral step in its journey to Mars as it would expedite development of space technologies and open up partnership with U.S. commercial companies. NASA reviews and independent assessment of Commercial Crew Program is fundamental to its success, and being able to model a commercial crew vehicle in a simulation rather than conduct a live test would be a safer, faster, and less expensive way to assess and certify the capabilities of the vehicle. To this end, my project was to determine the feasibility of using a simulation tool named SOMBAT version 2.0 to model a multiple parachute system for Commercial Crew Program simulation. The main tasks assigned to me were to debug and test the main parachute system model, (capable of simulating one to four main parachute bodies), and to utilize a graphical program to animate the simulation results.

To begin tackling the first task, I learned how to use SOMBAT by familiarizing myself with its mechanics and by understanding the methods used to tweak its various parameters and outputs. I then used this new knowledge to set up, run, and analyze many different situations within SOMBAT in order to explore the limitations of the parachute model. Some examples of parameters that I varied include the initial velocity and orientation of the falling capsule, the number of main parachutes, and the location where the parachutes were attached to the capsule. Each parameter changed would give a different output, and in some cases, would expose a bug or limitation in the model. A major bug that I discovered was the inability of the model to handle any number of parachutes other than three. I spent quite some time trying to debug the code logically, but was unable to figure it out until my mentor taught me that digital simulation limitations can occur when some approximations are mistakenly assumed for certain in a physical system. This led me to the realization that unlike in all of the programming classes I have taken thus far that focus on pure logic, simulation code focuses on mimicking the physical world with some approximation and can have inaccuracies or numerical instabilities.

Learning from my mistake, I adopted new methods to analyze these different simulations. One method the student used was to numerically plot various physical parameters using MATLAB to confirm the mechanical behavior of the system in addition to comparing the data to the output from a separate simulation tool called FAST. By having full control over what was being outputted from the simulation, I could choose which parameters to change and to plot as well as how to plot them, allowing for an in depth analysis of the data. Another method of analysis was to convert the output data into a graphical animation. Unlike the numerical plots, where all of the physical components were displayed separately, this graphical display allows for a combined look at the simulation output that makes it much easier for one to see the physical behavior of the model. The process for converting SOMBAT output for EDGE graphical display had to be developed. With some guidance from other EDGE users, I developed a process and created a script that would easily allow one to display simulations graphically.

Another limitation with the SOMBAT model was the inability for the capsule to have the main parachutes instantly deployed with a large angle between the air speed vector and the chutes drag vector. To explore this problem, I had to learn about different coordinate frames used in Guidance, Navigation & Control (J2000, ECEF, ENU, etc.) to describe the motion of a vehicle and about Euler angles (e.g. Roll, Pitch, Yaw) to describe the orientation of the vehicle. With a thorough explanation from my mentor about the description of each coordinate frame, as well as how to use a directional cosine matrix to transform one frame to another, I investigated the problem by simulating different capsule orientations. In the end, I was able to show that this limitation could be avoided if the capsule is initially oriented antiparallel to its velocity vector.

This short, yet packed 10 week internship has been a wonderful experience that has taught me many new things. In particular, this internship provided me with the opportunity to explore the digital simulation of complex physical systems and the analysis thereof. My experience working with simulators persuaded me towards exploring more about the topic of simulation, especially about how each component in a simulation works in concert as a system to create an accurate representation of nature. This internship has also consolidated my love for programming, as working with the various technologies required to change the simulator (BASH, VIM, UNIX, etc.) made me feel at home. Having two more years until I graduate with a Bachelors of Science in Computer Science & Engineering, I am working towards the goal of obtaining another internship at NASA or a JSC Pathways position to explore other great areas of study and contribute meaningful work to awesome projects.