**Cubesat for Gamma-Ray Relative Navigation and Timing Test Bed**

**Background**: There are several planned future space missions which will require cubsats to operate in a formation. In these missions, the cubesats will be required to maintain:

1. A relative position solution (i.e., relative to the formation) with an accuracy of 10 meters (1 standard deviation)
2. A relative attitude solution with an accuracy of 10 mrad.
3. A clock offset or timing accuracy (relative to the formation) better than 10 µs.

For operation in low and medium Earth orbits (LEO or MEO), the Global Navigation Satellite Systems (GNSS) such as the US’s GPS or the Russian Federations GLONASS can be used to provide a position and timing solution which meets the above requirements. An inertial measurement unit aided by star trackers, horizon sensors or sun sensors can provide the required attitude accuracy.

For operation in geostationary or geosynchronous Earth orbit (GEO), GNSS signals become unreliable. For operation beyond GEO, GNSS signals are unavailable. Thus, for deep space missions, an alternate sensor for determining position, attitude and time will be required.

**Discussion**: To deal with the problem of navigation and timing in deep space, the use of gamma-ray bursts has been proposed. In this scenario, two space vehicles observing a gamma-ray burst would record the time at which the electromagnetic energy from the burst was received. The difference in time of arrival of the gamma-ray burst signal provides an indirect measurement of relative displacement and clock offset between the two vehicles.

To test out the concept of using gamma-ray bursts as a means of navigation and timing in deep space, the following cubesat mission is proposed:

1. A cubesat with a gamma-ray detector and GPS receiver will be launched into LEO
2. The cubesat makes observations of gamma-ray bursts and records the GPS time when ray was received on the vehicle.
3. A gamma-ray observatory of Earth at a precisely known location will record the time when the same gamma-ray burst were received.
4. Using the time difference of arrival, position and timing offsets are estimated.
5. The computed position and timing solution are compared to the relative position and clock offset calculated using GPS. The results are used to analyze the performance of the system.

**Design Problem**: In this design project, you will be required to complete a conceptual design of this mission. Assume that your ground-based gamma-ray observatory will be located in Minneapolis, MN. You will have to design the cubesat and its onboard systems. The gamma-ray sensor will be a payload built by someone else that you will have to integrate into your system. You will be required to analyze the data requirements for verifying the performance the gamma-ray relative positioning and timing system to an accuracy of 10 m and 10 μsec. This analysis will include analyzing the data requirements and selecting a radio (based on a link budget).