Attitude Determination System

Trade Study Number – A0003

Conducted by Rachit Singhvi

Purpose of Trade Study (Foresee)

The purpose of TS A0003 is to determine the instrumentation constituting the sensor suite of the ADS to be installed on all FireLOC CubeSats. The ADS is required to provide high attitude determination accuracy for accurately geolocation the fire and downlinking the data to ground. This trade study will focus on determining the variance of ground track error with increase in attitude determination error. We will use this result to determine the accuracy required to be met by ADS parts.

Investigation

The pointing requirements and error tolerance defined by the payload determines the type of control system and actuator suite required to constitute the ADCS. However, attitude determination requirements may tend to be more stringent due to “pin-point” accuracy needed to detect a fire on ground.

In orbital trade study O0005, it was determined that at 500 km orbital altitude, the point on Earth the payload sees will drift by a ground distance of ~8.75 km per degree of drift, which converts to 2.42 m per arcsec. We can further calculate the circular area to be covered in order to geolocate the fire, by considering a perimeter of the ground radius resulting from the angular drift.

$$A_{search} = \pi\,(R_{drift})^2$$

The smallest determination accuracy current state of the art star trackers can achieve is 0.001 degrees. Using this metric as our step value, we plot a ground search area vs angular drift graph.

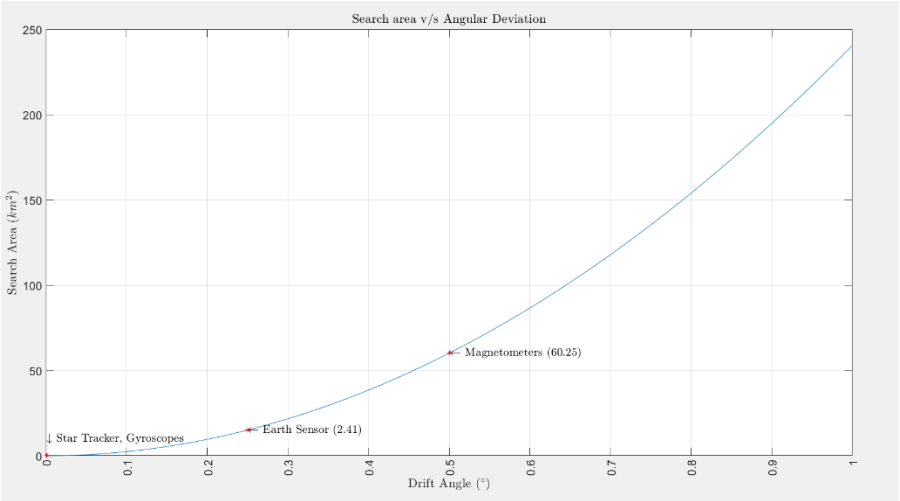

Figure 1. Fire detection accuracy based on expanding search area with increase in drift angle

We see that the ground search area increases exponentially as expected. Such an increase would result in longer fire location determination time for the ground personnel. Thus, a system that both, allows for a small margin of error as well as provides sufficient accuracy such that ground personnel can locate the fire without direct line of sight (e.g., smoke or heat sensors) is necessary. NADIR pointing requirement reduces the sensor options to those that are used for actively tracking the earth or the body frame attitude. This removes sun sensors out of the running choices. Now, we look at the accuracy we get using magnetometers, star trackers, gyroscopes and earth sensors.

Record

From our sensor performance research, we see that magnetometers provide and earth sensors provide a maximum pointing accuracy of 0.50 degrees and 0.25 degrees respectively, which correspond to over 60.25 square kilometers and 2.41 square kilometers of search area. Further, star trackers and gyroscopes provide the best attitude determination to the order of 0.001 degrees. This value corresponds to a ground distance of 80m, which is approximately 3 pixels for the payload. Hence, deriving requirements for ADS from our investigation, star trackers would be choice of sensor along with a system of 3 gyros to provide 3-axes attitude determination. The star tracker (inertial reference) would be used to accurately initialize the gyroscopes (body frame) in space.

Execute

Signatures:

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