How Beta Angle Determines CubeSat Mission Development

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Background

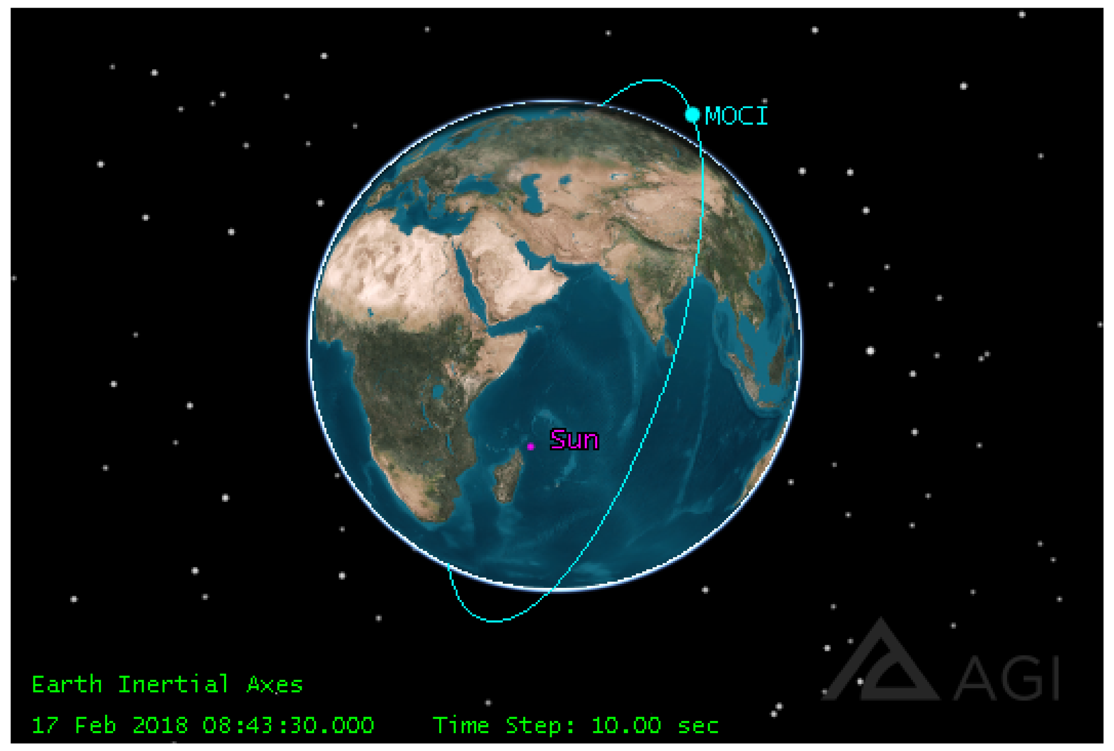

Figure 1: Illustration of MOCI in orbit in relation to the Sun.

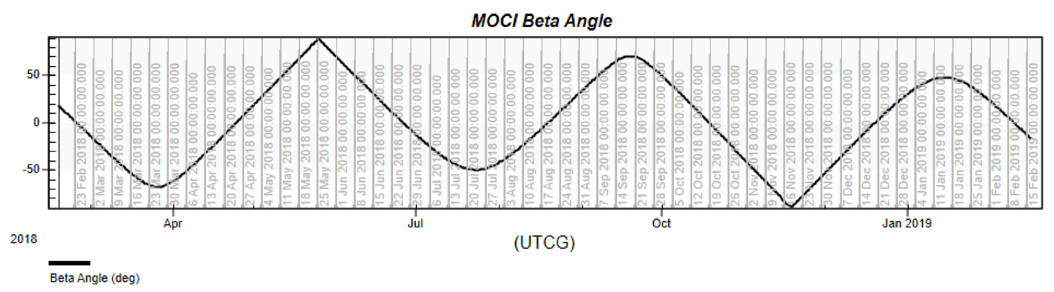

Figure 2: Beta angle of MOCI over a period of several months.

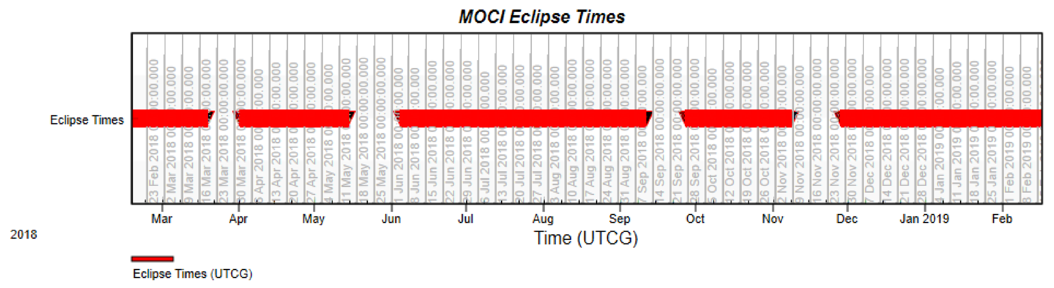

Figure 3: Projected eclipse times for MOCI over a period of 1 year. Beta angle is not the sole determinant of eclipse. Periods of partial and full eclipse are shown.

What is MOCI? The Multiview Onboard Computational Imager (MOCI) is a 3U CubeSat which will will use Structure-from-Motion to produce 3D terrain maps of image targets on the ground. Data will be sent directly to the UGA Center for Geospatial Research. Launch is anticipated in 2020.

What is Beta Angle? A satellite's beta angle is the angle between the incoming Sun vector and the satellite's orbital plane. It determines the percentage of time the satellite spends in direct sunlight. At a 0 degrees, MOCI experiences maximum eclipse. Over 70 degrees, MOCI experiences a period of intense Sun exposure ("full sun"). Beta angle changes cyclically due to

- Precession of the satellite's orbit
- Rotation of Earth about the Sun

and thus, periodic variation is partially (but not completely) seasonal. It ranges from 0 to 90 degrees.

ADCS

MOCI precisely determines its attitude with a fine sun sensor, which permits the actuators to adjust the satellite's spatial orientation. Attitude knowledge allows the satellite to

- Slew over a target
- Point camera at an image target
- Point antenna to downlink
- Direct more delicate hardware components away from the Sun

Thus, interference with attitude determination and control systems (ADCS) is equivalent to interfering with nearly all mission operations. One way to mitigate this is to depend on some component besides a fine sun sensor for attitude determination, like a star tracker, which does not rely on sunlight.

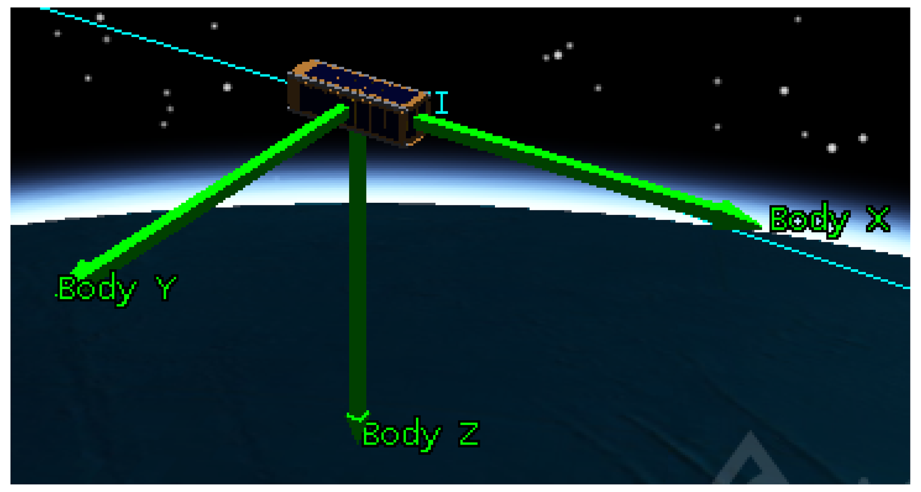

Figure 4: MOCI body axes

Target Feasibility

MOCI depends on direct sunlight in two ways to be able to image.

1. The body of the satellite must be in sufficient light to point.
2. The ground target must be sufficiently sunlit.

For a pass to be feasible, both conditions must be met. As long as MOCI depends upon a fine sun sensor, in times where the beta angle approaches zero, the number of passes which are feasible imaging opportunities will decrease.
Furthermore, the periods of MOCI's orbit, of orbital precession, of the shifting beta angle are all different. For the ideal (but unlikely) scenario in which a target is regularly imaged in consistent lighting conditions (i.e. at the same time of day), we need to find intersections of the actual orbit and orbital precession, and verify that the beta angle will be within the acceptable range at those times.

Methodology

Analysis was conducted using Systems Tool Kit 11, using a basic 3D model file (courtesy of Graham Grable) to represent MOCI. The orbit was set to the ISS orbital parameters (altitude, orbital radius, etc.) using two-line element (TLE) files from AGI's server. Scenarios were usually set over one year (February 2018 to February 2019).

Solar Power Generation

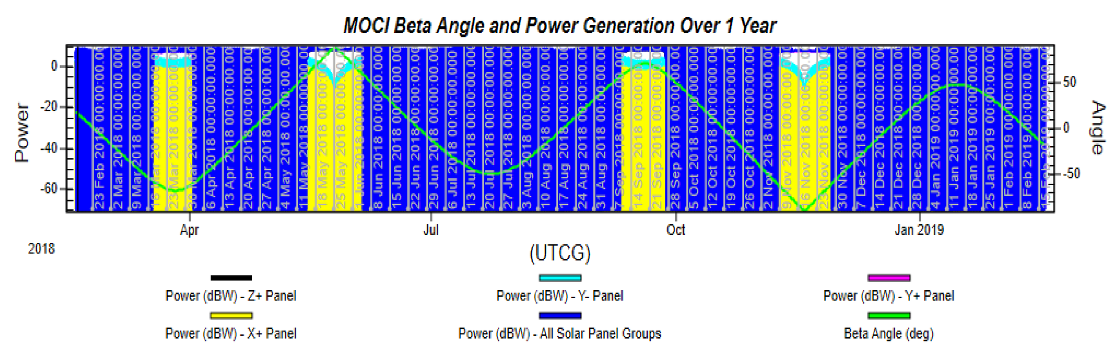

Figure 5: Beta angle and power generation over one year.

MOCI will rely upon power generation by at least 3 solar panels, which must be exposed to sunlight for power to be generated. Thus, during eclipse, it cannot be assumed that MOCI will generate enough power to carry out its operations. Periods of eclipse occur when the beta angle is close to 0 degrees. This occurs 2-4 times a year.

Conclusion

Because beta angle determines the amount of time MOCI has access to sunlight, it impacts crucial satellite operations such as

- Power generation
- Attitude adjustment
- Target imaging
- Communication with ground station

The beta angle changes cyclically, and we can predict periods of eclipse. Beta angle must be considered for a LEO Earth-imaging mission like MOCI.

References

1. Leicher, Grable, Copenhaver, King. (March 2018) MOCI Concept of Operations, v4. UGA Small Satellite Research Laboratory
2. Bar-Sever, Y. E. (1996). A new model for GPS yaw attitude. Journal of Geodesy, 70(11), 714-723.

Future Research

- Determine periods of extreme beta angle values
- Optimize design in anticipation of extremes (i.e., switching to star tracker)
- Verify ability to fulfill mission success criteria during beta angle extremes
- Generate periodic operational schedules while MOCI is in orbit

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