A Geostationary Equivalent Polar Observation System

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ABSTRACT

This paper presents a novel polar observation architecture to provide geostationary equivalent observations of the Earth's high-latitudes. This system, known as a Taranis orbit, can provide polar observations at a lower cost to current solutions and to a higher quality than proposed systems.

Space-based remote sensing is vital for global weather forecasting, ranging from nowcasting through medium to longer term forecasts, climatic trend analysis, prediction of extreme climatic events, natural disaster recovery and much more. Data users are progressively requiring an increasingly wide coverage, consistency and quality of product from space-based assets whilst also seeking to maximize the temporal resolution at minimum data latency.

A fleet of satellites monitor the Earth's weather on a routine basis from two orbital positions; near-polar low-Earth orbits (LEOs) at around 800-900 km altitude and geosynchronous orbits at 36000 km altitude. Each orbit used currently offers advantages and disadvantages. LEO provide high-resolution images although narrow swaths of data mean there is a lack of large scale contextual information; large numbers of spacecraft are required to provide continuous or near-continuous imagery. Conversely, GEO offer higher temporal resolution around equatorial regions of the Earth, however, observations are critically limited beyond 55 degrees latitude due to the rapidly decreasing horizontal resolution with increasing latitude. Consequently, many products are not available beyond 55 degrees latitude, such as the retrieval of atmospheric motion vectors and bi-directional reflectance distribution functions resulting in a critical data deficit at the polar regions.

Recent research has developed a highly-elliptical orbit (HEO) concept, known as the Taranis orbit, to provide geostationary equivalent observations of the polar regions. Electric propulsion is used to negate the secular drift in the argument of perigee of the Taranis orbit caused by the non-spherical nature of Earth and the deviation of the orbital inclination from the ‘critical’ value of 63.43 degrees to 90 degrees. Notably, continuous coverage above 55 degrees latitude can be achieved by two spacecraft on a 12 hour Taranis orbit requiring only one launch. This is a significant reduction in the number of spacecraft required in LEO and a decrease in the number of launches required for spacecraft employed in other HEO systems, such as a Molniya orbit, which requires three spacecraft on three separate orbit planes, to provide continuous coverage of the same region. The Taranis orbit is therefore a lower cost solution to the high-latitude data deficit than existing solutions.

This paper will classify relevant applications of the Taranis orbit detailing the current maximum observable latitudes from GEO for the data products considered and identify possible instrumentation for a future Taranis mission. Further analysis of the Taranis orbit concept will also be presented including visibility analysis to determine the level of coverage to the selected latitude limits from spacecraft on 12 and 16 hour Taranis orbits of varying inclinations. By identifying the minimum inclination to provide continuous coverage a reduction in the required acceleration is possible. Various launch vehicles will be considered and the subsequent effect on the available payload mass for a range of mission lifetimes determined.