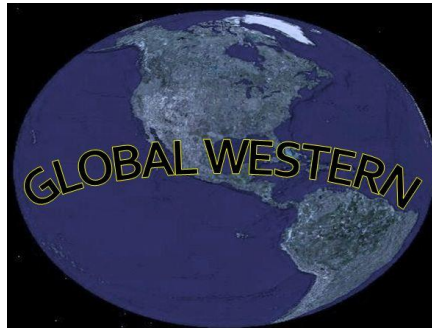




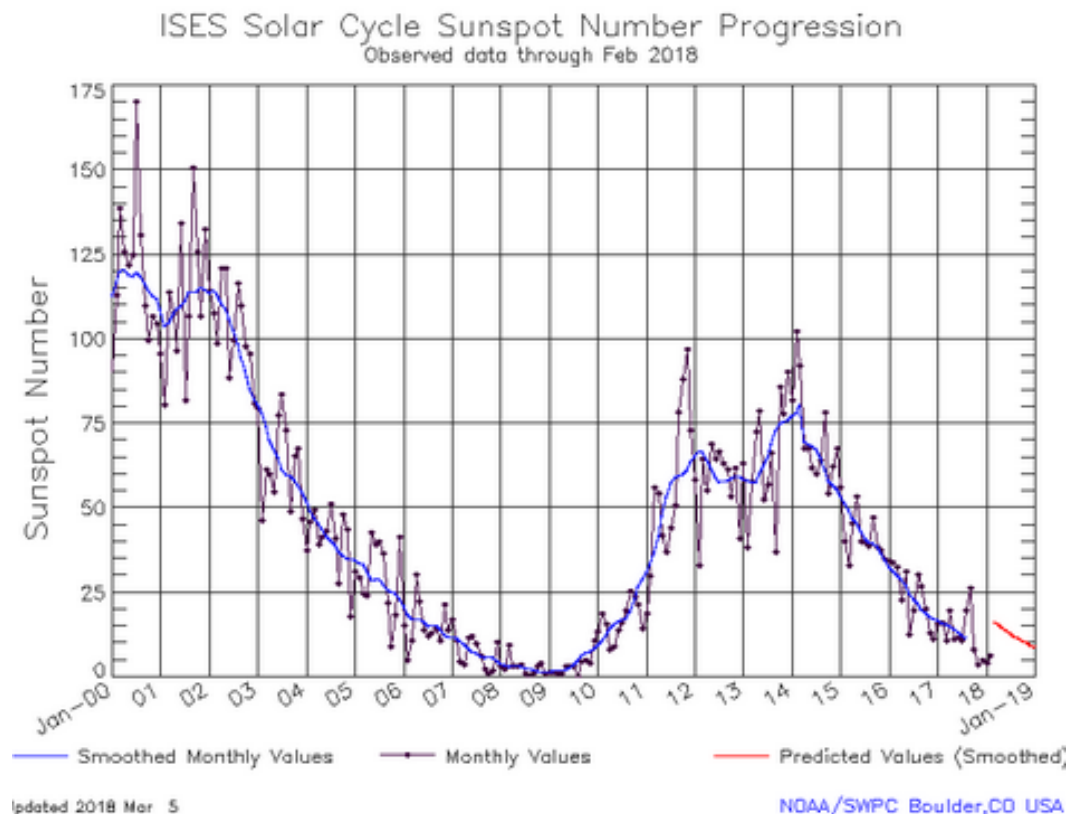
OR Sat Drag and Orbital Decay Issues

5/7/2018

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Background and Summary: OR Sat is to be delivered into 575 km 97° inclined sun-synchronous orbit. OR Sat is to have a minimum operational life of 60 days. Continuous undamped tumbling (maximum drag) results in a mission endurance of 75 days. Partially damped tumbling equivalent to a continuous 20° Angle of Attack (AoA) (nominal drag) results in predicted 140 days endurance. Due to the strong mass concentration at the SC end of the vehicle when deployed, the drag-induced pitching moments overwhelm the weak gravity gradient stabilizing torque. Therefore there is no possibility of gravity-gradient stabilized 90° Angle of Attack (AoA) nadir-pointing attitude being continuously maintained.

Factor 1, Spacecraft drag correlates to the F10.7cm activity number. The F10.7cm activity number somewhat correlates to the Sunspot number. This F10.7cm ranges from lows of ~65 to highs over 350. We're currently approaching a minima which will likely last for a couple years. The current (May 10, 2018) number is 70, the current 45 day prediction (for June 23, 2018) is 68.



Graph 1. Sunspot activity from Jan 2000 through February 2018

Sunspot number

Minimums can last about **2 years**.

Current F10.7cm Flux Forecast is at: <https://www.swpc.noaa.gov/products/usaf-45-day-ap-and-f107cm-flux-forecast>

....And is currently near absolute lows (68-70). We anticipate continuation of very low F10.7 flux through the entire mission.

Our assumptions:

- SC mass 2.229 kg
- Minimum Cross Sectional Area = 1.97 m²

- Solar Cycle – 10.7 cm Solar Radio Flux 11 year cycle- as of 3/27/2018 NOAA reports current value is 69 stu (used as surrogate for total X-ray flux). Currently close to minimum. Minimum is 65, maximum is over 300. Maximum will be reached in about 5 years.
- Initial Orbital Injection = 575 km altitude, circular
- Balloon deployment may occur in any direction, but damping to minimum cross sectional area ('streamlined') orientation occurs in a *negligible period of time*.
- Drag and Decay Calculated in accordance with Satellite Orbit Decay Calculations author Australian Space Weather Agency for current conditions yields 370 days endurance before decay.

Factor 2, SC attitude, Angle of Attack

The operational concept for OR Sat is either continuous undamped tumbling or partially damped tumbling equivalent to 20° angle of attack. Numerous experts were polled for input of the question of 'how fast will tumbling damped out?' and no consensus was reached. Additionally, we were requested to consider 10° angle of attack and 20° angle of attack, results are presented in Chart 1. We reject the possibility that the SC can fly for any extended period of time at a maximum drag, 90° angle of attack attitude- at 575km deployment altitude the gravity gradient forces are far weaker than the drag induced pitching moment. As the mission proceeds, some drag will reduce the SC altitude and the ratio between gravity gradient forces and pitching moment become higher. The worst case possibility for Angle of Attack and resulting drag and orbital decay situation is that the SC performs undamped continuous tumbling. In such a scenario, mission endurance for the lightweight ~2.2kg SC configuration drops to 48 days.

Comprehensive Resolution

The addition of a single ballast plate panel comprehensibly extends mission endurance to in excess of the required 60 day longevity metric.

Mass, kg	Orientation	lifetime, days
3.5	streamlined, 0 deg AoA	586
3.5	10 deg AoA	273
3.5	20 deg AoA	140
3.5	continuous tumbling	75

Not realistic

Not realistic

Chart 1. OR Sat orbital endurance predictions with four possible drag values (with one ballast plate)

Summary:

OR Sat in a medium mass ~3.3 kg configuration with one ballast panel will comprehensibly achieve mission endurance requirements under all realistically conceivable mission scenarios.