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Poster
Satellites are vulnerable to high radiation from solar storms, making it essential to monitor and predict solar flares and coronal mass ejections (CMEs) that damage satellite electronics, while solar radiation heats the atmosphere, increasing satellite drag leading to increased orbital uncertainties. AI and machine learning (AI/ML) advancements can significantly enhance empirical methods for solar forecasting by leveraging vast datasets and complex algorithms to dramatically improve accuracy. Despite these advancements, current models still face limitations, such as high computational demands and difficulties in predicting rare events.

Indirect measurements of extreme ultraviolet (EUV) radiation often fail to capture the full spectrum of solar dynamics that impact the atmosphere. These methods typically rely on empirical models and approximations resulting in forecasts that may not fully account for the complex interactions between solar activity and atmospheric density. Our approach, leveraging direct observation of high-fidelity EUV imagery from NASA Solar Dynamics Observatory (SDO), offers a comprehensive and accurate representation of these solar events. This leads to more accurate predictions and a deeper understanding of how solar dynamics influence atmospheric conditions. At Booz Allen we are developing an MLOps pipeline called Sun2OD, that fuses multimodal foundation model ensembles of solar events, Space Weather, and Orbit Determination for Space Battle Management.

The lowest latency information impacting the space environment is light from the sun, therefore the first component of the Sun2OD pipeline that we present is a deep learning-based solar weather foundation model trained on solar imagery, called SDOViT. To achieve this, we successfully developed this vision transformer architecture to extract an information-dense solar feature space from 12-channel SDO imagery. Secondly, we fuse the resultant SDOViT latent space with atmospheric model drivers, such as F10.7, F30, Dst, Kp, and Ap, augmenting historical model driver data to train a multimodal space weather forecast model called SWFCast. Preliminary SWFCast results showing 30% improvement in accuracy in F10.7, F30, Dst, Kp, Ap, Hp30, and Hp60 compared to the NOAA 27-day forecast over the last solar cycle; and the 27-day forecast accuracy is drastically improved within the 5-day horizon.

The future direction of Sun2OD includes several key model enhancements. First, we will integrate additional datasets, such as radio and particle flux, geomagnetic indices, and coronographs, to enrich our models and expand coverage of learned solar dynamics. We will develop solar flare and CME prediction capabilities to provide early warnings to satellite operations. Finally, we will develop deep learning models to improve anomaly detection and maneuver planning based on high-fidelity satellite ephemerides, ensuring robust and adaptive space operations. Together, these advancements form a comprehensive AI-enabled Space Battle Management solution.

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