NASA DRIVE Science Center for Geospace Storms (CGS)

One of the critical grand challenges of Heliophysics today is understanding and ultimately predicting the dynamics of stormtime geospace – the near-Earth space environment spanning altitudes from a few tens to millions of kilometers. Stormtime geospace is a system of systems comprised of interconnected physical domains: the magnetosphere, including all of its regions; the ionosphere; the upper atmosphere in which the ionosphere is embedded; and the lower atmosphere, included as part of geospace for the first time in the proposed project. These domains are populated by neutral gases and plasmas that are immersed in electromagnetic fields and evolve on disparate temporal and spatial scales. During storms, all of these domains engage in complex, non-linear, cross-scale interactions that profoundly alter the entire system. This complexity has defied previous attempts to describe stormtime geospace with the completeness and fidelity required for comprehensive understanding and reliable space weather forecasting and mitigation. One reason is that such understanding can only be derived from simulation models that treat geospace as a whole. At the same time, there is strong evidence of the critical role of mesoscale processes in stormtime geospace dynamics (e.g., injection of plasmasheet particles into the ring current by bursty bulk flows; ionospheric polar cap patches and tongues of ionization affecting localized Joule heating and mass outflow; and preconditioning of the ionosphere by lower atmospheric waves). Therefore, a key requirement for a Whole Geospace Model is to resolve the coupled system's dynamics across a broad range of scales, which entails the conception, implementation and use of highly accurate numerical algorithms. Furthermore, it is only when models are constrained rigorously by observations and comprehensive data analysis that the degree of knowledge ultimately leading to robust predictive capability, and application to operational needs, can be achieved.

Motivated by these challenges, we propose the Center for Geospace Storms (CGS) with the vision to:

Transform understanding and predictability of geospace storms.

The specific research objectives of the CGS are as follows:

1) Build a physics-based, predictive, community model of stormtime geospace, coupling all key regions, and treating and resolving critical mesoscale processes.
2) Augment and constrain the Whole Geospace Model by ingesting heterogeneous data sources and developing rigorous validation methodologies using multivariate datasets.
3) Discover, understand and quantify the causal connections and emergent dynamics across spatiotemporal scales, domains, species, and energy populations characteristic of stormtime geospace.

The 2013 Solar and Space Physics Decadal Survey recommended implementation of the DRIVE Heliophysics Science Centers with the goal "to enable deep and transformative science" and "to address the most pressing scientific issues of heliophysics". This program finally allows tackling the grand scientific challenge of stormtime geospace which, in addition, possesses great societal importance and is prioritized as such by the Decadal Survey and by the National Space Weather Action Plan. The CGS is synergistic with and supports existing and future NASA missions, and ongoing grant programs. To empower the community beyond the lifetime of the CGS, the Whole Geospace Model will be released under an open-source license.

The complexity and the broad scope of the problem demand an interdisciplinary team approach enabled by the DRIVE Science Center program. This project will bring together a uniquely qualified team of research scientists, academics and trainees from across all geospace domains, space science disciplines, and with expertise ranging from modeling and theory to data analysis and computer science. The CGS is led by JHU/APL, the largest university affiliated research center in the Nation, in partnership with a national research center (NCAR/HAO), three major universities with space science programs (UNH, VT, Rice) and a nonprofit research center (SRI). The university teams will lead planning for future workforce development. Collaborators from minority serving and informal education institutions are involved to help develop and pilot programs for community engagement and informal science communication. Finally, the CGS leverages strong existing programs for education and public outreach at all participating institutions.