GSFC Computational and Information Sciences and Technology Office (CISTO)

Program: Computational and Information Sciences and Technology Office (CISTO)

Research Title: Computational and Technological Advances for Scientific Discovery

Research Overview:
SMD requests that EPSCoR include research opportunities in areas of a) Artificial Intelligence and Machine Learning (AI/ML), b) High Performance Computing, c) Augmented Reality/Virtual Reality/Mixed Reality (AR/VR/MR), and d) Citizen Science to enable and accelerate scientific discovery and technological innovations for NASA's scientific missions. NASA's scientific lines of business include Earth Sciences, Planetary Sciences, Astrophysics, and Heliophysics.

a) Artificial Intelligence and Machine Learning (AI/ML)
Advent of new technologies such as Clouds and GPUs for storing and processing massive data sets has significantly increased adoption of AI in the past decade even though many of the AI technologies originated in 1950s. Similarly, in recent years AR/VR consumer-friendly software and hardware tools have become available at affordable prices. Internet tools and technologies have also enabled ordinary citizens to participate in the scientific process via various Citizen Science applications and games. At the same time, NASA scientists are faced with large volumes of data from various missions on a daily basis. This makes it essential to take advantage of the latest technological and computational advances, as outlined in this call, for their analysis and scientific discovery.

Recent advances in AI infrastructure and tools calls for development of AI algorithms for various, yet unexplored, scientific data *classification, search, prediction, feature selection, and modeling* problems in different NASA scientific areas. Some past work includes classification of supernova to better measure cosmic distances and understand expansion of universe, classification of Planets to better predict probability of life, finding craters on moon, search for gravitational waves, and search for exoplanets. Similar techniques can be applied for finding different phenomena (e.g. feature detection for identifying safe landing sites, finding faint moving objects, etc.), environmental feature recognition (forest patches, water bodies, agriculture fields, etc.), or to other fields such as Earth Science and Heliophysics data. Another topic of interest is to apply AI/ML techniques to NASA data in time domain, or time-series analysis (e.g. when studying solar winds or various Earth observations).

While these techniques are often applied on the ground, there are compelling reasons for benefitting from AI capabilities onboard the spacecraft in deep space. Drivers for onboard AI capabilities include data transmission and downlink limitations, the desire to have near real time results (e.g. for spacecraft safety, planetary defense, etc.), or the nature of mission itself (e.g. in interferometry missions an image cube is constructed from data of multiple satellites via complex image registration and reconstruction algorithms).

b) High Performance Computing; Evolving Applications to Exascale
High Performance Computing (HPC) applications across NASA have seen a significant increase in computational capability over the past decade using cluster systems with traditional CPU-only based capabilities. The architectures being deployed across the US and abroad to reach the next milestone of computing, Exascale, have a significantly different architecture based on accelerated computing using Graphical Processing Units (GPUs). NASA applications, such as atmospheric models, will require Exascale computational capabilities over the next decade. Research investigations addressing the porting and scaling of HPC applications on accelerated based HPC are encouraged. Furthermore, the use of

Domain Specific Languages (DSLs), such as Kokkos or GridTools, to create portable and optimized applications for different architectures is of high interest.

In addition to scaling applications using accelerator based computing platforms, NASA is interested in replacing model components and augmenting models with artificial intelligence. In General Circulation Models of the atmosphere, components are written based on physical models and algorithms are then written to compute those physics or chemistry based models. In some cases, the computational requirements for these physical based algorithms take too many resources for current HPC platforms. Replacing these model components with trained algorithms has the potential to dramatically reduce the computational requirements for these models while not reducing accuracy beyond acceptable limits. Research investigations addressing the replacement of model components with trained models for use in HPC applications is of high interest as well.

c) Augmented Reality/Virtual Reality/Mixed Reality (AR/VR/MR)

AR/VR applications allow scientists to experience being in environments that are hard, impossible, or too costly in person. For example, existing NASA AR/VR applications enable immersive exploration of places deep in the ocean, to distant planetary surfaces and galaxies or to experiment with various robotic or spacecraft assembly and integration processes in AR/VR before taking high risks on the actual expensive hardware.

d) Citizen Science

Various NASA projects have used Internet tools and technologies not only as a public outreach and education tool but as a means to engage ordinary citizens in their projects and most importantly to contribute to their scientific discoveries. Examples of such NASA citizen science projects are GLOBE Observer (https://observer.globe.gov), Planet Hunters (www.planethunters.org), Backyard Worlds: Planet 9 (www.backyardworlds.org), Moon Zoo (www.moonzoo.org) and Galaxy Zoo (www.galaxyzoo.org).

Research investigations addressing more than one of the above-mentioned areas (hybrid solutions) are encouraged. Examples include: onboard HPC AI/ML data processing and volume reduction algorithms; Citizen Science applications for generating labeled training data as input to AI/ML software, or to validate AI/ML output results.

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Intellectual property management:

Additional Information:
NASA GSFC CISTO will provide NCCS support as needed.

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