NASA SBIR 2021 Phase I Solicitation

S5.03 Accelerating NASA Science and Engineering through the Application of Artificial Intelligence

Lead Center: GSFC

Participating Center(s): ARC, JPL, LaRC

Scope Title:

Accelerating NASA Science and Engineering Through the Application of Artificial Intelligence

Scope Description:

NASA researchers are increasingly using artificial intelligence (AI) and machine learning (ML) technologies across science and engineering to address questions that previously could not be studied, in order to open up new insights. From both the Government and commercial sectors the volume and variety of datasets is increasing at an exponential rate, making it more of a challenge to NASA science and engineering. This subtopic is looking for innovative proposals using AI/ML to address the following unique problems across NASA. Proposals MUST specify and be in alignment with existing and/or future NASA programs to address or extend a specific need.

This subtopic has the following three critical areas: (1) AI/ML at the Extreme Edge, (2) Rapid Detection of Land Coverage Change, and (3) Rapid Identification of Events in High-Resolution Earth System Model Data. This goal is accomplished by more completely specifying smaller, better defined areas that rest squarely within Focus Area 13 (Information Technologies for Science Data). Proposals for fault management should be addressed in S5.05 Fault Management Technologies (Focus Area 3 Autonomous Systems for Space Exploration). Further, proposals for small spacecraft trajectory control should be addressed in Z3.02 Artificial Intelligence (AI)/Machine Learning (ML) for Small Spacecraft Swarm Trajectory Control (Focus Area 11 Spacecraft and Platform Subsystems), and proposals for autonomous systems should be addressed in the STTR Topic T4 Autonomous Systems for Space Exploration (subtopic - Integrated Data Uncertainty Management & Representation for Trusted Autonomy in Space).

Proposals should address one of the following focus areas:

- AI/ML at the Extreme Edge
  - With the increase in data rates for instruments, there is an increasing need to compute at the edge, often in constrained computing environments.
  - NASA is interested in the application of AI/ML on spacecraft, rovers, within a constellation of SmallSats, or other remote sensing platforms where the latency and bandwidth between the remote platform and the ground station are not sufficient to adequately download all data. An example of
this is the Magnetospheric Multiscale (MMS) mission where a fraction (approximately 2%) of the
data taken will be transferred back to Earth.
- How can training of models be done efficiently at the edge to detect anomalies, perform
classifications, segmentation, or run other types of AI/ML models?

- Rapid Detection of Land Cover Change
  - Remote-sensing data of the Earth (both from NASA and commercial sources) is also continuing to
    increase at dramatic rates, and NASA is interested in using AI/ML to enable the rapid detection of
    changes in the land use and anomalies across multiple data sets.
  - This will require the potential fusion of multiple satellite datasets, intersensor calibration,
geolocation, and more.

- Rapid Identification of Events in High-Resolution Earth System Model Data
  - The Global Modeling and Assimilation Office (GMAO) uses a general circulation model (GCM)
called the Goddard Earth Observing System (GEOS) high-performance application to produce
model output for instrument design. These nature runs are free-running atmospheric models that
are driven by sea surface temperatures with resulting datasets being very large (on the order of
petabytes).
  - Instrument teams then use the GEOS output to study the potential impact of additional observations
on specific weather phenomena such as hurricanes, weather fronts, mesoscale convective cells,
and more.
  - NASA is interested in models that can be trained to rapidly identify these various weather
phenomena in the GEOS nature run data. This will be used to create a searchable catalogue of
these events for use in observing system simulation experiments (OSSEs).

Research proposed to this subtopic should demonstrate technical feasibility during Phase I, and in partnership with
scientists and/or engineers, show a path toward a Phase II prototype demonstration, with significant communication
with missions and programs to later plan a potential Phase III infusion. It is highly desirable that the proposed
projects lead to solutions that will be infused into NASA programs and projects.

Expected TRL or TRL Range at completion of the Project: 4 to 6
Primary Technology Taxonomy:
Level 1: TX 11 Software, Modeling, Simulation, and Information Processing
Level 2: TX 11.X Other Software, Modeling, Simulation, and Information Processing

Desired Deliverables of Phase I and Phase II:
- Prototype
- Software
- Research

Desired Deliverables Description:
Data products developed under this subtopic may be developed for broad public dissemination or used within a
narrow scientific community. It is expected that the training sets, models, and resulting data products will be
publicly accessible.

In general, the desired outcomes for this subtopic include: (1) new or accelerated science and engineering
products, (2) training data sets and trained models specifically for a given problem but that can also be used as a
basis for furthering other science and engineering research and development, and (3) resulting data products that
can be used and infused in NASA science projects and potentially used to develop new missions.

More specifically,
- Phase I should be used to establish a proof of concept with deliverables including a final report, any
  software developed, training sets, etc.
Phase II will expand on this proof of concept to a full prototype with a very similar set of deliverables, including a final report, software, training sets, etc.

**State of the Art and Critical Gaps:**

NASA science and engineering is making large strides in the use of AI technologies (which includes both machine learning and deep learning). However, the datasets and requirements are growing so rapidly that additional support is needed to fill in gaps. In addition, emerging computational platforms now provide significant improvements in computing capabilities to enable AI to be applied to a wide variety of applications in science and engineering. These emerging computational capabilities have the potential to dramatically speed up AI calculations, and these systems are even being used as the reference architecture for exascale high-performance computing systems.

**Relevance / Science Traceability:**

Broad applicability across throughout the decadal surveys and satellite development requirements. Specific missions include the Europa Lander, Mars 2020, and more:

- Spacecraft, rovers, constellation of SmallSats, or other remote sensing platforms.
- Global Modeling and Assimilation Office (GMAO) assimilation: Augment Earth system modeling or data assimilation.
- Carbon Cycle Ecosystems Office (CCOE): Wide variety of applications given the diversity of data sets from sparse in-situ to global satellite measurements.
- Earth Observing System Data and Information System (EOSDIS)/Distributed Active Archive Centers (DAACs): Harnessing the potential for new discoveries across the wide array of observation data.
- Computational and Information Sciences and Technology Office (CISTO - Code 606): Technologies used for new data science.
- NASA Center for Climate Simulation (NCCS - Code 606.2): Building applications toward exascale computing.

**References:**

- NASA Goddard Institute for Space Studies: [https://www.giss.nasa.gov/](https://www.giss.nasa.gov/)
- NASA Earth Science Data: [https://earthdata.nasa.gov/](https://earthdata.nasa.gov/)
- NASA Center for Climate Simulation: [https://www.nccs.nasa.gov/](https://www.nccs.nasa.gov/)
- NASA High-End Computing (HEC) Program: [https://www.hec.nasa.gov/](https://www.hec.nasa.gov/)

In addition, proposers are encourage to search the NASA Technical Report Server (NTRS) for additional information to help guide potential solutions:

- [https://ntrs.nasa.gov/](https://ntrs.nasa.gov/)