We live in the extended atmosphere of an active star. While sunlight enables and sustains life, the Sun's variability produces streams of high energy particles and radiation that can harm life or alter its evolution. Under the protective shield of a magnetic field and atmosphere, the Earth is an island in the Universe where life has developed and flourished. The origins and fate of life on Earth are intimately connected to the way the Earth responds to the Sun's variations. Understanding the Sun, Heliosphere, and Planetary Environments as a single connected system is the goal of the Science Mission Directorate's Heliophysics Research Program. In addition to solar processes, our domain of study includes the interaction of solar plasma and radiation with Earth, the other planets, and the Galaxy. By analyzing the connections between the Sun, solar wind, planetary space environments, and our place in the Galaxy, we are uncovering the fundamental physical processes that occur throughout the Universe. Understanding the connections between the Sun and its planets will allow us to predict the impacts of solar variability on humans, technological systems, and even the presence of life itself. There are three primary objectives that define the multi-decadal studies needed:

- To understand the changing flow of energy and matter throughout the Sun, Heliosphere, and Planetary Environments;
- To explore the fundamental physical processes of space plasma systems; and
- To define the origins and societal impacts of variability in the Earth-Sun System.

A combination of interrelated elements is used to achieve these objectives. They include complementary missions of various sizes; timely development of enabling and enhancing technologies; and acquisition of knowledge through research, analysis, theory, and modeling.

**Subtopics**

**S5.01 Voltage Supplies and Charge Amplifiers for Solar Science Missions**

Lead Center: GSFC
For success of future solar science missions, it is critical to develop future enabling technologies which are modular, compact and efficient. This subtopic focuses on innovations for two technology areas: (1) The first area is compact, sealed and efficient high voltage supplies for space use; (2) The second technology area is high gain, wide dynamic range charge amplifiers. Specific module details are provided as below.

High voltage power supplies can be divided into 3 kilovolt categories: low (The charge amplifier ASIC shall be of low power, high gain and low noise. The ASIC shall be developed for at least 16 channels, with capability to daisy chain the amplifiers. Individual channels shall contain offset correction, gain correction and input capacitance tuning. The ASIC shall be designed for optimum operating temperature, radiation tolerance and ESD safe inputs.

The proposer shall describe the innovation and specific improvement over the current state of the art.

S5.02 Sensors for Measurement of Particles and Fields

Lead Center: GSFC

Understanding the connections between the Sun and its planets will allow us to predict the impacts of solar variability on humans, technological systems, and even the presence of life itself. This requires remote and in situ sensing of upper atmospheres and ionospheres, magnetospheres and interfaces with the solar wind, the heliosphere, and the Sun. Improving our knowledge and understanding of these requires accurate in situ measurements of the composition, flow, and thermodynamic state of space plasmas and their interactions with atmospheres, as well as the physics and chemistry of the upper atmosphere and ionosphere systems. Remote sensing of neutral atoms is required for the physics and chemistry of the Sun, the heliosphere, magnetospheres, and planetary atmospheres and ionospheres. Because instrumentation is severely constrained by spacecraft resources, miniaturization, low power consumption, and autonomy are common technological challenges across this entire category of sensors. Specific technologies are sought in the following categories:

Plasma Remote Sensing (e.g., neutral atom cameras)

This may involve techniques for high-efficiency and robust imaging of energetic neutral atoms covering any part of the energy spectrum from 1 eV to 100 keV, within resource envelopes less than 5 kg and 5W.

- Miniaturized, radiation-tolerant, autonomous electronic systems for the above, within resource envelopes of 1 - 2 kg and 1 - 2 W.

In Situ Plasma Sensors
Improved techniques for imaging of charged particle (electrons and ions) velocity distributions as well as improvements in mass spectrometers in terms of smaller size or higher mass resolution;

Improved techniques for the regulation of spacecraft floating potential near the local plasma potential with minimal effects on the ambient plasma and field environment;

Low power, digital, time-of-flight analyzer chips with sub-nanosecond resolution and multiple channels of parallel processing; and

Miniaturized, radiation-tolerant, autonomous electronic systems for the above, within resource envelopes of 1 - 2 kg and 1 - 2 W.

**Fields Sensors**

- Improved techniques for measurement of plasma floating potential and DC electric field (and by extension, the plasma drift velocity), especially in the direction parallel to the spin axis of a spinning spacecraft;
- Measurement of the gradient of the electric field in space around a single spacecraft or cluster of spacecraft;
- Improved techniques for the measurement of the gradients (curl) of the magnetic field in space local to a single spacecraft or group of spacecraft;
- Direct measurement of the local electric current density at spatial and time resolutions typical of space plasma structures such as shocks, magnetopauses, and auroral arcs; and
- Miniaturized, radiation-tolerant, and autonomous electronic systems for the above within resource envelopes of 1 - 2 kg and 1 - 2 W.

**Electromagnetic Radiation Sensors**

- Radar sounding and echo imaging of plasma density and field structures from orbiting spacecraft; and
- Miniaturized, radiation-tolerant, and autonomous electronic systems for the above within resource envelopes of 1 - 2 kg and 1 - 2 W.