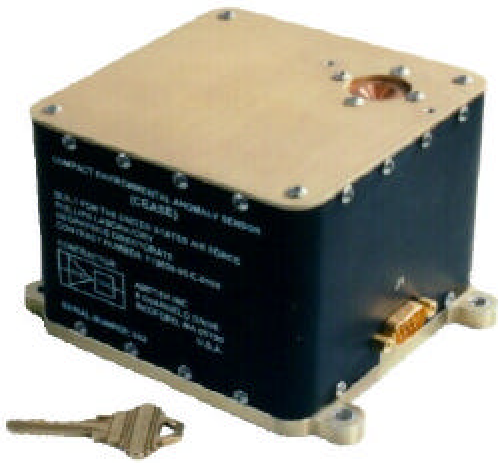
COMPACT ENVIRONMENTAL ANOMALY SENSOR

CEASE

SPACE RADIATION ALARM

Today's space systems demand high performance and reliability. However, satellites operate in a hostile environment, bombarded by ionizing radiation from a variety of sources. Ionizing radiation damages electronic components and systems, with consequences ranging from minor performance degradation to catastrophic system failure. Cost effective and simple ways to reduce this risk both in the design and operation of the spacecraft are needed. Amptek offers the answer - a multipurpose easily integrated, environmental hazard sensor package, the Compact Environmental Anomaly SEnsor (CEASE).[1]



ENVIRONMENTAL THREATS
• Total Radiation Dose • Radiation Dose Rate • Surface Dielectric Charging • Deep Dielectric Charging • Single Event Effects

Spacecraft operators are responsible for preventing degradation in performance and failure of space-borne systems. With real-time warnings that the environment is likely to cause anomalies, operators can alter spacecraft operations to minimize risk to their systems. Today, space "weather" forecasts serve as these warnings. But the forecasts do not provide the real-time local conditions required to take corrective action.

Anomalies or failures do occur, and the tools to understand their causes are needed. Space environmental effects must be isolated from other causes of system failures. When operators have to pinpoint the definitive cause of a spacecraft anomaly, real-time, in situ monitoring is needed. Without it, time, money and even satellites are lost. With such monitoring, operators can modify operations during hazardous conditions, predict performance loss and end of life, and launch replacement satellites if necessary.

CEASE IS THE SOLUTION

CEASE is a small, low power instrument that provides operators with fully processed, real time, in situ measurements and autonomously generated warnings of the space radiation environment threats. CEASE reports these threats to the host spacecraft:

- Ionizing radiation dose and dose rates
- Single event effects
- Surface and deep dielectric charging

The primary CEASE output to the spacecraft, updated once per minute, is a 10-byte *Engineering Data* packet quantifying the threat levels associated with those space environment hazards. Appropriate action may then be taken by the spacecraft or its operators to mitigate risk.

With its suite of sensors and sophisticated onboard data processing, CEASE is an extremely flexible stand-alone diagnostic instrument. CEASE is a solution to the problem of space environmental monitoring for both operational and experimental spacecraft. It is the primary instrument chosen by the US military for this task. There are two versions of CEASE available to provide the necessary monitoring *(Table 1)*. CEASE II includes an additional sensor to better characterize the surface charging in geosynchronous orbits.

Table 1 Summary of CEASE Properties

	CEASE I	CEASE II
Size	4.0 x 4.0 x 3.2 "	5.0 x 5.1 x 3.2 "
Mass	1.0 kg	1.3 kg
Power*	1.5 Watts	1.7 Watts
Standard Interface	RS422 or MIL-STD-1553B	RS422 or MIL-STD-1553B
Telemetry (minimum)	10 bytes per 60 sec	10 bytes per 60 sec
Diagnostic Sensors	Lightly Shielded Dosimeter Heavily Shielded Dosimeter SEE Detector Particle Telescope	Lightly Shielded Dosimeter Heavily Shielded Dosimeter SEE Detector Particle Telescope Electrostatic Analyzer

*Power requirements can vary for non-standard interfaces.

MEASURING SYSTEM THREATS

Radiation Dose

As electronic components are exposed to ionizing radiation dose, they suffer progressive cumulative damage. Once a tolerable dose for a given component is exceeded, its performance will degrade and the component may even fail catastrophically. The failure mechanism can depend on the total radiation dose, the radiation dose rate, or the type of particles responsible for the dose. For example, some components are particularly sensitive to a displacement damage, a specific effect caused primarily by protons rather than electrons.

With its dosimeters, CEASE measures both the integrated radiation dose (rads) and very high short term radiation dose rates (rads/hr). The particle populations primarily responsible for this are >5 MeV protons and >1 MeV electrons. The conditions at geosynchronous altitudes and in high inclination orbits following a major solar flare and in the inner radiation belt present the most hazardous ionizing radiation doses for spacecraft. CEASE also measures the integrated surface radiation dose that shortens the life of solar cells.

Single Event Effects

Very large energy deposition events create sufficient charge in an electronic device to alter its logic state, either temporarily (bit flip) or permanently (latch-up). The results are known as Single Event Effects (SEEs). SEEs can result in corrupted data processing, commanding, and telemetry. The worst cases can cause system failures. Typically, SEEs are induced by >50 MeV proton or high energy heavy ions. The SEE hazard is greatest in the inner radiation belt.

CEASE measures large energy deposition events and returns information on the probability of encountering SEEs on orbit.

Spacecraft Charging

Dielectric charging occurs when insulating materials absorb incident electrons. Surface charge can build on dielectric materials exposed to the space environment, leading to arc discharges. These discharges, in turn, generate significant noise transients that upset or damage sensitive on-board electronics. Lower energy electrons drive the surface charging. Additionally, charge can build on dielectric materials (e.g. shielded electronics, coaxial cables) in the interior of a spacecraft. This phenomenon is known as deep dielectric charging and is caused by high energy electrons. Both types of dielectric charging are predominantly a hazard in high altitude and geosynchronous orbits. CEASE monitors both surface and deep dielectric charging with its particle telescope while CEASE II includes an electrostatic analyzer to better characterize the lower energy particle environment relevant to surface charging at geosynchronous altitudes.

CEASE PROVIDES THE ANSWERS

CEASE processes the collected sensor data to quantify the environmental threat levels due to the hazards discussed above. These threat levels are provided in eight Hazard Registers *(Table 2)*. If a Hazard Register exceeds its threshold, CEASE then sets a corresponding Warning Flag. The Hazard Registers and Warning Flags are CEASE's primary output to the spacecraft.

Table 2 CEASE Hazard Registers

Name	Acronym	Description	Typical Dynamic Range
Lightly **S**hielded **D**ose	LSD	Mission integrated radiation dose behind 0.08" of Al	0.2 to 118 krad
Heavily **S**hielded **D**ose	HSD	Mission integrated radiation dose behind 0.25" of Al	0.1 to 59 krad
Lightly **S**hielded Dose **R**ate	LSR	Radiation dose rate over the last minute behind 0.08" of Al	0.04 to 27 rads/hr
Heavily **S**hielded Dose **R**ate	HSR	Radiation dose rate over the last minute behind 0.25" of Al	0.04 to 27 rads/hr
Surface Dose	SUD	Solar panel damage parameter: "effective 1 MeV electron fluence"	1.8×10^{13} to 5.6×10^{16} electrons/cm^2
Single **E**vent **E**ffect	SEE	Register value is proportional to SEE probability	0 to 15 events/minute
Surface **D**ielectric **C**harging	SDC	Electron flux responsible for surface dielectric charging (50 < E < 250 keV)	5.0×10^4 to 2.3×10^9 electrons/cm^2-sec
Deep **D**ielectric **C**harging	DDC	Electron flux responsible for deep dielectric charging (E > 250 keV)	4.2×10^3 to 1.9×10^8 electrons/cm^2-sec

CEASE provides its data on the environmental hazards in the form of one of three data packets. The *Engineering Data* packet is the minimum amount of information required to assess the environmental threat. The *History Data* contains time histories over 72 hours of selected critical data, to be used in conjunction with the *Engineering Data*. CEASE can provide the highest level of detail in space environment data in the *Science Data* packet.

The 10-byte *Engineering Data* packet contains the Hazard Registers, the Warning Flags, and CEASE state-of-health data. Operators can use these data in a variety of ways. The spacecraft can read the packet on a regular interval. Alternatively, *Engineering* packets can be read by the spacecraft only as needed, such as in the event of an anomaly. At a minimum, the spacecraft processor, or its operators on the ground, need only check a single byte in the *Engineering* packet, which contains the eight Warning Flags. If no flags are set ON, the processing of the rest of the packet may be skipped. If one or more Warning Flags are set, then the rest of the packet can be processed to determine the nature and severity of the threat. Appropriate action may then be taken by the spacecraft or its operators to avoid problems.

If CEASE has issued a warning, the spacecraft operators can then request the relevant *History Data* blocks from the instrument. The *History Data* provide more detail about the environmental threats, particle fluxes and radiation doses than the *Engineering Data*. The *History Data* consists of the previous 72 hours of data stored in a ring buffer. Each 15-minute data segment is contained in a 52-byte packet.

The most detailed space environment data available from CEASE are available in the *Science Data* packet. This packet contains the raw count rates and the raw spectra collected from the sensor suite. These are the data from which the *Engineering Data* are derived. The frequency of this *Science* output can be tailored to the specific needs of the mission but must be selected prior to instrument fabrication. The standard *Science* packet is 56 bytes, but this can also be adjusted to meet the mission requirements. *Science Data* are most appropriately obtained from CEASE on the initial satellites in a constellation or on experimental spacecraft.

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[1] Dichter, B.K, et. al., "Compact Environmental Anomaly Sensor (CEASE): A Novel Spacecraft Instrument for In-Situ Measurement of Environmental Conditions", *IEEE Trans. Nucl. Sci.*, Vol 45, No. 6, p. 2758, December 1998.