How do satellite failures relate to the space environment?

Space is a harsh environment

Satellites orbit the earth in a space environment completely different from the environment down on earth. When satellites fail, the failures can often be attributed to certain features of the space environment in which they operate. Statistically speaking, an estimated 20 to 25% of all satellite failures take place in outer space. The biggest problems are the influences of "cosmic radiation (refer to page 5)" and "plasma" (Fig. 1).

The space environment affects not only artificial satellites, but also astronauts. The International Space Station (ISS), an extraterrestrial facility to be completed in 2010, is manned by two or three astronauts at all times. Their chief occupation on the station is to conduct experiments and observations. The space agencies jointly managing the ISS have recently decided to set the occupancy rate of the station at six astronauts. A precise understanding of the space environment will be essential to ensure their safety.

Gathering data on the space environment

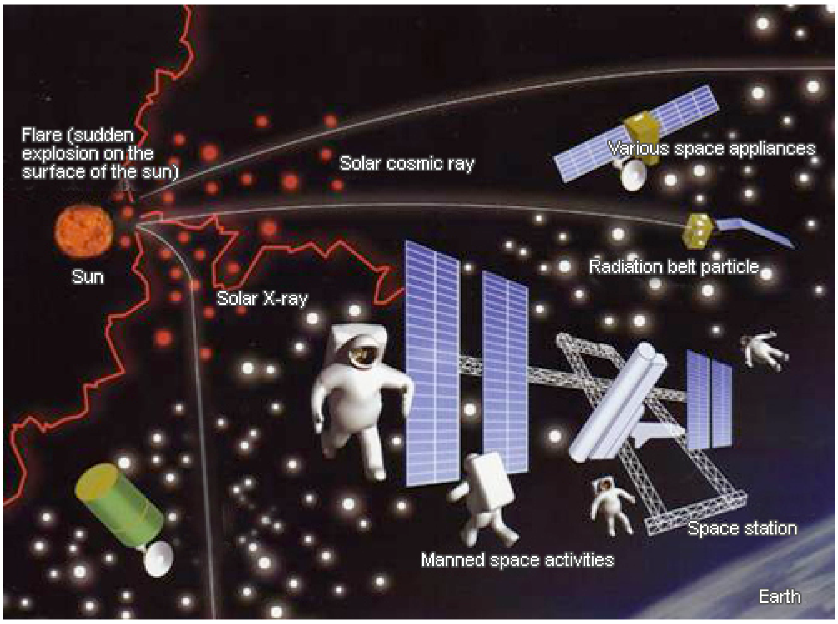
One way of understanding the conditions of space is to equip an artificial satellite with sensors to acquire data on the space environment directly. Since the launch of Kiku No. 5 (Engineering Test Satellite V) in 1989, a number of satellites have been fitted with different types of equipment for the assessment of the space environment. One of the most significant recent examples has been the French satellite Jason-2, launched in 2008. Soon, in June 2009, the Space Environment Data Acquisition system (SEDA) will be placed on board the ISS (refer to page 3). The fabrication of the measuring equipment for SEDA is the work of the Space Environment Group.

The Space Environment Group has developed many types of equipment, including a radiation particle counter to measure space radiation. The group is also constructing a model of the space environment based on data collected via sensors on board satellites Once this model is complete, anyone will be able to access it as a source of real-time information on the space environment.

Fabricating a satellite tolerant to the harsh space environment

The space environment near the earth is greatly affected by the activities of the sun. When an event such as a solar flare (a sudden explosion on the sun surface) takes place, the sun releases a tremendous dose of high-energy radiation particles (solar cosmic rays). With current technologies, satellites have no way of escaping bombardment by these particles. If equipped with technologies to monitor the condition of the space environment constantly in real time, we will be able to detect phenomena such as solar flares and magnetic storms(*) more quickly. This, in turn, will help us establish methods to mitigate the risks of huge doses of incoming radiation particles induced by solar flares, magnetic storms, and increases solar wind (plasma).

In preparing satellite guidelines suited for the actual space environment,



The cosmic rays radiating from the sun and more distant realms of outer space scarcely reach the surface of our planet. Both radiation belts and atmosphere block the rays. Yet at altitudes of 80 km and higher, the atmosphere is much thinner than the atmosphere below. This upper atmosphere is ionized with positive and negative charges, what is described as a plasma state. The electric activity can generate electrical interference in the satellites operating in orbit. The radiation exposure to astronauts cannot be dismissed as negligible.

Space is a harsh environment

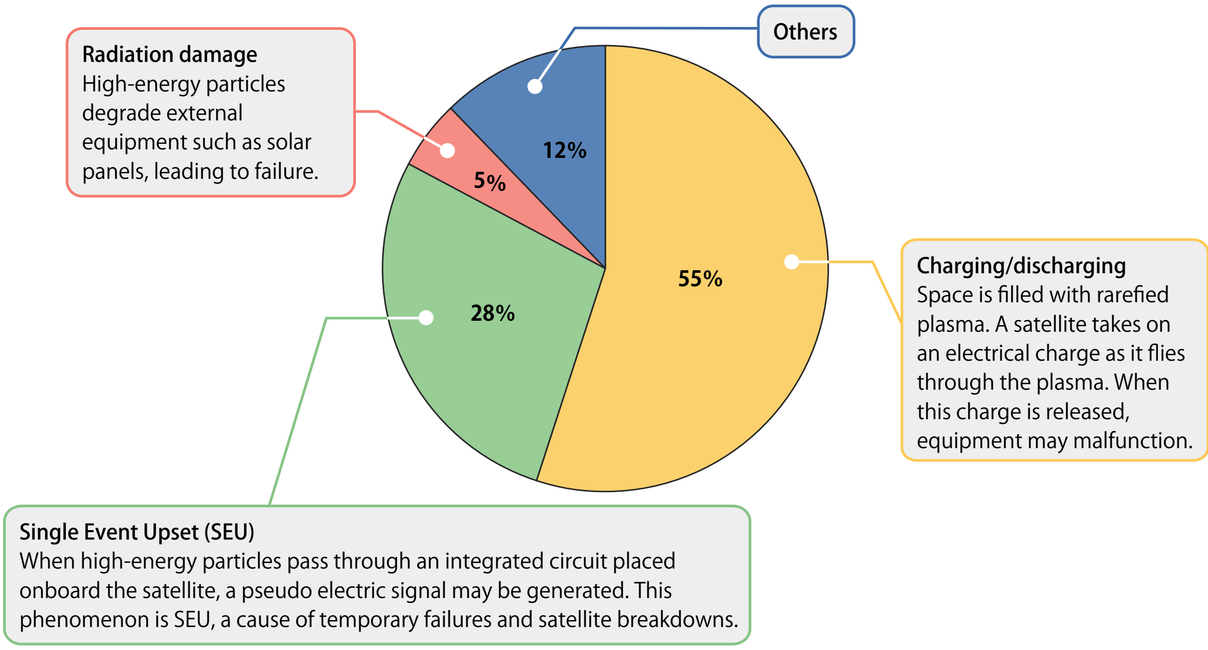
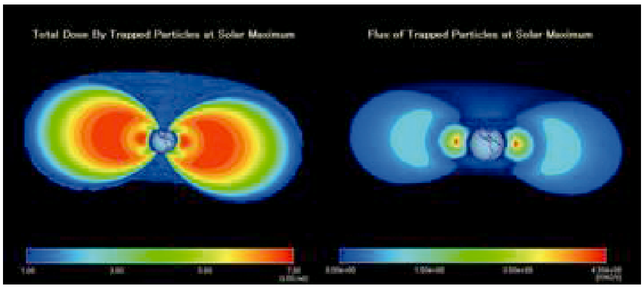


Fig. 1. Satellite failures caused by the space environment

it will be essential to consider sudden environmental changes and other factors. To collect detailed data for the preparation of guidelines, the Space Environment Group is striving aggressively to refine its measuring equipment and collect more sophisticated data.

(*) Magnetic storm: The earth can be likened to a large magnet surrounded by magnetic fields. When a magnetic storm takes place, the magnetic fields around the planet are weakened. The magnetic fields surrounding earth protect the planet from solar wind, a constant flow of plasma released from the sun. When a magnetic storm weakens the magnetic fields around the earth, the amounts of plasma in orbit may increase, affecting satellites.



This is a model of a radiation belt (Van Allen Belt) prepared based on data obtained so far. The total dose[◆1] appears on the left and flux[◆2] appears on the right. The red indicates high intensity under both conditions.

◆1 Total dose: The dose of radiation energy exposed to a substance per unit of mass.

◆2 Flux: Intensity of radiation

Fig.2 Example of a space environment model

[Space Environment Group]

(from left) Nana Higashio, Kazuhiro Terasawa, Kiyokazu Koga, Takahiro Obara, Haruhisa Matsumoto, Hideki Koshiishi, Tatsuto Komiyama

RESEARCH INTRODUCTION

Clarify the state of space

Recent success in acquiring data

In June 2008, the French space agency launched a satellite called Jason-2 (See issue No.27 of "Sora to Sora"). Eight months later, in February 2009, JAXA launched its Greenhouse gases Observation SATellite, Ibuki (See issue No.16 of "Sora to Sora"). Each of these satellites carries a radiation counter smaller and lighter than the conventional type.

The radiation to which a satellite is subjected will vary according to the type of radiation particle and range of energy. The new radiation counters on the French and Japanese satellites are designed to detect radiation particles within a wider energy range than before.

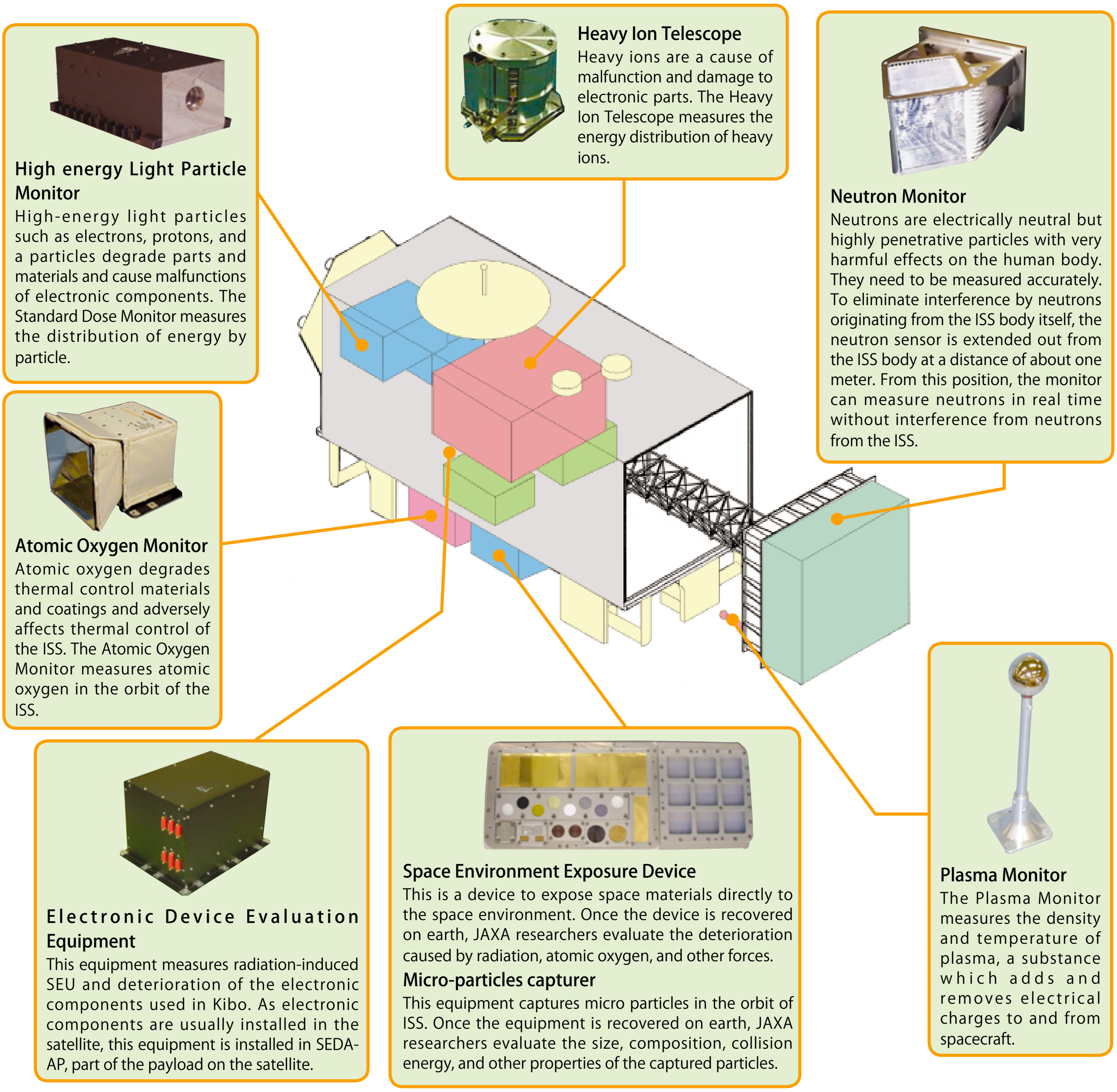


Fig. 1. Space Environment Data Acquisition mission equipment-Attached Payload (SEDA-AP)

Conventional devices measure the space environment with a single sensor, regardless of whether radiation particles measured have high or low energy. Yet the scope of their measurement sensitivity is too narrow. The new equipment from JAXA uses two sensors and a measuring method suitable for each type of radiation particle. Thus, energy particles within a wider energy range can now be measured.

SEDA-AP: a tool to examine the state of space

In March 2009, the astronaut Koichi Wakata was launched into outer space and flown to the International Space Station to begin an extended stay there. The extravehicular experiment platform is the last part of Kibo, the Japan experiment module in the ISS. In June 2009, Wakata assembled the platform and installed a sophisticated data-acquisition system equipped with eight types of instruments. JAXA calls this system the "Space Environment Data Acquisition mission equipment-Attached Payload (SEDA-AP)" (Fig. 1).

SEDA-AP will have the first neutron monitor, plasma monitor, and atomic oxygen monitor ever to be placed onboard a JAXA satellite. With the data collected by these monitors, JAXA will be constructing a detailed model of the space environment. Measurement of neutrons coming from the sun will help clarify the accelerating mechanism of the solar flare. If this measurement system succeeds, the achievement will be unprecedented.

Space in our hands

How and which parts of a satellite are affected by the space environment? Simulations are an effective way to find answers to these questions (Fig. 2). Actual satellites are developed with the results obtained from simulations. To design a satellite with strong resistance to the space environment, an engineer must have a clear and complete picture of the space environment.

Advanced onboard instruments have already begun collecting data on Jason-2, Ibuki, and the Advanced Land Observation Satellite Daichi, a satellite launched in 2006. Data collection by SEDA-AP will start soon. JAXA is planning to construct a "Comprehensive Space Environment Simulator," a configuration of supercomputers which will use these measurement results to simulate the actual space environment.

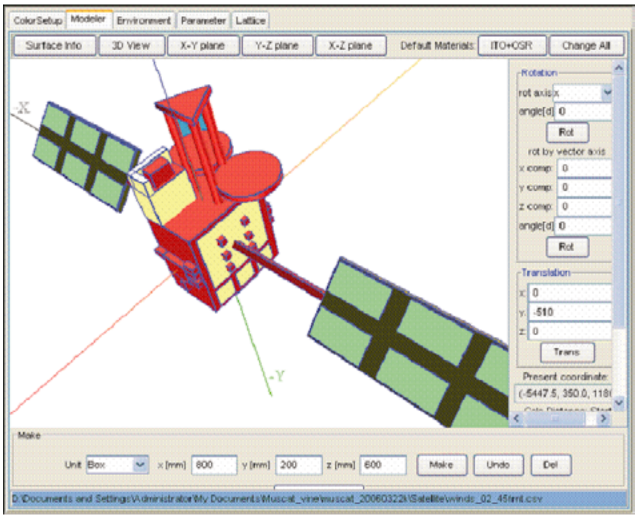


Fig.2 Spacecraft charging analysis simulation

[SEDA-AP Team]

(from left) Syoichi Ichikawa, Yugo Kimoto, Haruhisa Matsumoto, Tateo Goka, Takahiro Obara, Kiyokazu Koga

Intermission Break

What is an uchusen?

Uchusen flying about in space. Did you know that there are two kinds of uchusen?

When Japanese people hear the word "uchusen," most of them associate it with a space "ship," the type of space vehicle they read about in science fiction novels. Many people don't realize that uchusen also means cosmic "rays," imperceptible particles of energy which surround us every moment of our lives.

Cosmic rays (cosmic radiation) are high-energy particles that fill space. Earth, a part of the universe, is showered with cosmic rays from without. While the protective veil of the earth's atmosphere filters out much of the cosmic radiation to which it is exposed, extremely high-energy particles penetrate the atmosphere and reach the surface of the planet. A hands-on exhibit with visual imagery of actual cosmic rays is open to the public at the Tsukuba Space Center.

Space radiation near the earth can be classified into three types, depending on where it is generated (See the figure).

・Radiation belt (Van Allen Belt) particles

A self-created magnetic field around the earth constantly captures high-energy charged particles over a wide altitude range from about 1,000 to 20,000 kilometers. This area consists of inner and outer belts. The inner belt extends from about 1,000 to 3,000 km above the surface of the planet; the outer belt, to about 20,000 km. Particles captured in this area are called "radiation belt particles." Once captured, these particles revolve around the earth, moving from south to north along field lines. The radiation belt is called the Van Allen belt, taking its name from Dr. Van Allen, who discovered it in 1958.

・Galactic cosmic rays

When a star explodes into a supernova, a cascade of extremely high-energy particles jettisons towards the earth from beyond the solar system at almost light speed. These particles are called "galactic cosmic rays." Most galactic cosmic rays have extremely high energy. Some of them reach the earth's surface by penetrating the atmosphere and eluding the magnetic fields.

・Solar cosmic rays (solar energetic particles)

When the energy in a magnetic field stored in sunspots (sunspot groups) is released by a flare (a sudden explosion on the sun's surface) or coronal mass ejection (CME)(*), charged particles around the sun are accelerated toward the earth. These particles from the sun are called "solar cosmic rays" (solar energetic particles).

JAXA is researching space radiation particles and their very significant effects on spacecraft.

(*) Coronal mass ejection (CME): The corona is the atmosphere at the outer edge of the sun. The corona consists of plasma, which may be released when a flare occurs. This phenomenon is called coronal mass ejection.

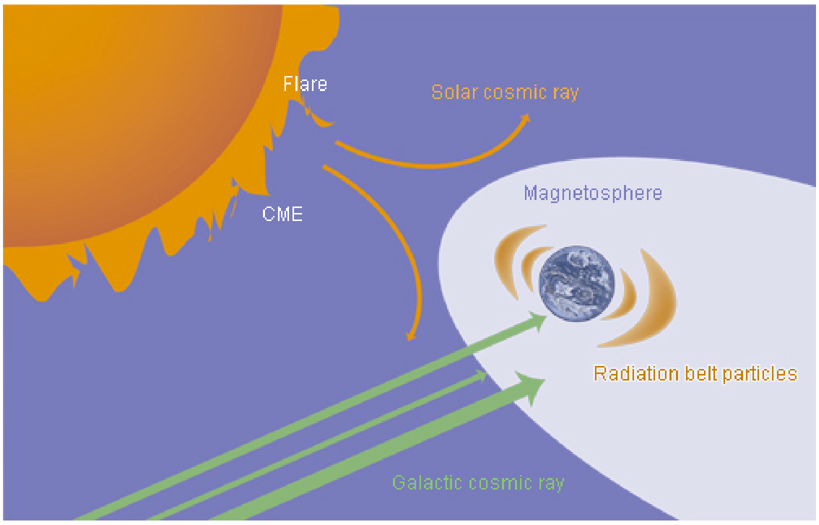


Fig. Space radiation environment near