

Development status and performance estimation of MAXI

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ABSTRACT

Monitor of All-sky X-ray Image (MAXI) is an X-ray all-sky monitor, which will be delivered to the International Space Station (ISS) in 2008, to scan almost the whole sky once every 96 minutes for a mission life of two years. The detection sensitivity will be 7 mCrab (5σ level) in one scan, and 1 mCrab for one-week accumulation. At previous SPIE meetings, we presented the development status of the MAXI payload, in particular its X-ray detectors. In this paper, we present the whole picture of the MAXI system, including the downlink path and the MAXI ground system. We also examine the MAXI system components other than X-ray detectors from the point of view of the overall performance of the mission. The engineering model test of the MAXI X-ray slit collimator shows that we can achieve the position determination accuracy of <0.1 degrees, required for the ease of follow-up observations. Assessing the downlink paths, we currently estimates that the MAXI ground system receive more than 50% of the observational data in “real time” (with time delay of a few to ten seconds), and the rest of data with delay of 20 minutes to a few hours from detection, depending on the timing of downlink. The data will be processed in easily-utilised formats, and made open to public users through the Internet.

Keywords: X-ray Astronomy, All-sky X-ray Monitor, ISS, JEM, Kibo, MAXI

1. INTRODUCTION

The Japanese Experiment Module (JEM) “Kibo” is a multi-purpose laboratory of the International Space Station (ISS). The Exposed Facility of JEM can be used as a site of space observatories. Considering advanced space sciences which can be performed under several limited conditions of the ISS, all-sky monitoring experiments are the best solution. Since the ISS always faces the bottom side to the Earth, the sky view from the ISS is rotating all the time. Moreover, there will be a small vibration in attitude. Thus the ISS is not a good base for precise pointing observations. Therefore the mission has become an all-sky monitor. The rotating sky enables us to scan almost the whole sky in every orbit without having any moving mechanism. The fields of view are free from the Earth occultation, which makes the observation efficient.

The X-ray sky is very variable and is only observable above the atmosphere. MAXI is to perform the systematic survey of the X-ray variabilities to study the nature of the active celestial objects. MAXI can detect the X-ray transient phenomena and rapidly inform the world about them.

2. MAXI MISSION

Monitor of All-sky X-ray Image (MAXI) is an all-sky X-ray monitoring mission, which was proposed by the X-ray astronomy group of the Institute of Physical and Chemical Research (RIKEN) in 1996, and was selected in 1997

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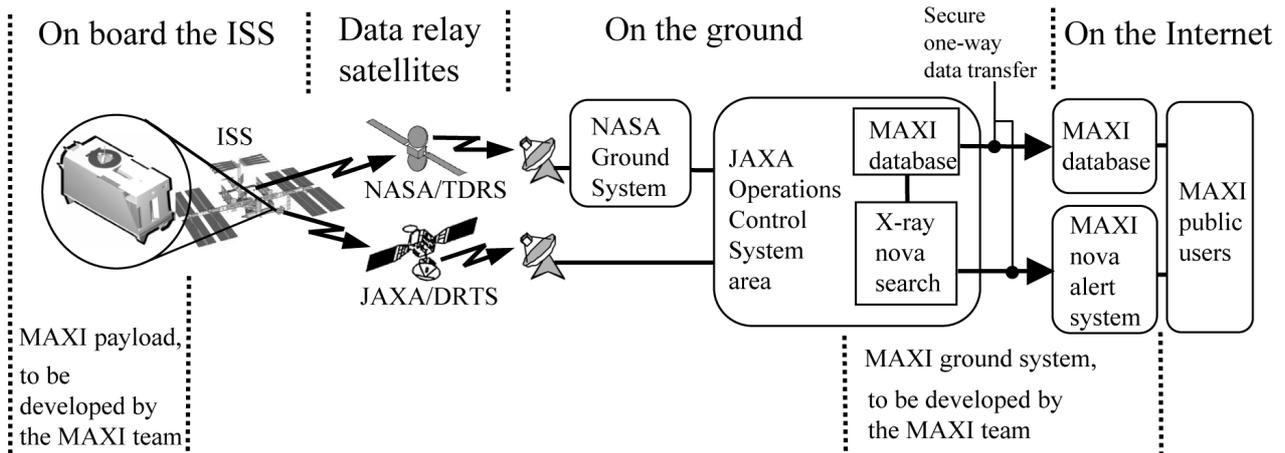


Figure 1. The MAXI system. We have two downlink paths for the MAXI data. The MAXI team is responsible for the MAXI payload and its ground system. The MAXI mission, including the rapid distribution of observational results, requires us to study the nature of downlink paths between the payload and the ground system in detail. The MAXI data will be transmitted to the Internet through a secure one-way path. The cultivation of public users is also an important task of the MAXI team.

as a first-generation payload for the Exposed Facility of the Japanese Experiment Module “Kibo” (JEM “Kibo”), part of the International Space Station (ISS). In the development of the MAXI system (Fig. 1), we have already finished the preliminary and critical design reviews of the payload, and partially started the fabrication and the calibration of its flight hardware. On the other hand, most components of the MAXI ground system are still in the design phase. In our current schedule, MAXI will be delivered to the ISS by a Japanese H-IIA Transfer Vehicle (HTV) launched in 2008. The mission life is at least two years, and might be extended depending on its performance, cost, and resource availability on the JEM “Kibo”.

3. MISSION OBJECTIVES

MAXI will detect thousands of active X-ray emitting sources in the 0.5 to 30 keV band and monitor them with twenty times higher sensitivity than previous all-sky X-ray monitors. The 5σ detection sensitivity will be 7 mCrab for one scan and 1 mCrab for one week. This will be the highest sensitivity ever achieved for an all-sky monitor observation. The mission objectives of MAXI are:

- 1) to make a time-resolved catalog of thousands of X-ray sources;
- 2) to search for time variability of active galactic nuclei (AGN);
- 3) to make complete light curves of X-ray novae;
- 4) to find and monitor transient objects;
- 5) to make a spectral mapping of galactic hot gas with the X-ray CCD camera;
- 6) to detect Gamma-ray bursts and their afterglows;
- 7) to monitor long-term variation of flaring stars;
- 8) to study the distribution of distant AGN.

Objectives 1) through 5) are solid goals with the MAXI sensitivity, Regarding Objective 6), the probability of Gamma-ray bursts (GRB) occur in the MAXI fields of view is rather low (about five GRB a year), because MAXI views less than 2 % of the whole sky at any given moment. Yoshida et al (1999)¹ still estimates that MAXI will detect about 25 GRB afterglows a year. To reach Objectives 7) and 8) requires the precise calibrations of effective areas over the field of view, and the accurate determination or reproduction of instrumental background levels.

The MAXI ground system will transmit an alert through the Internet on detecting any significant transient phenomenon, so that other observatories or satellites can turn their telescopes on the source to make follow-up

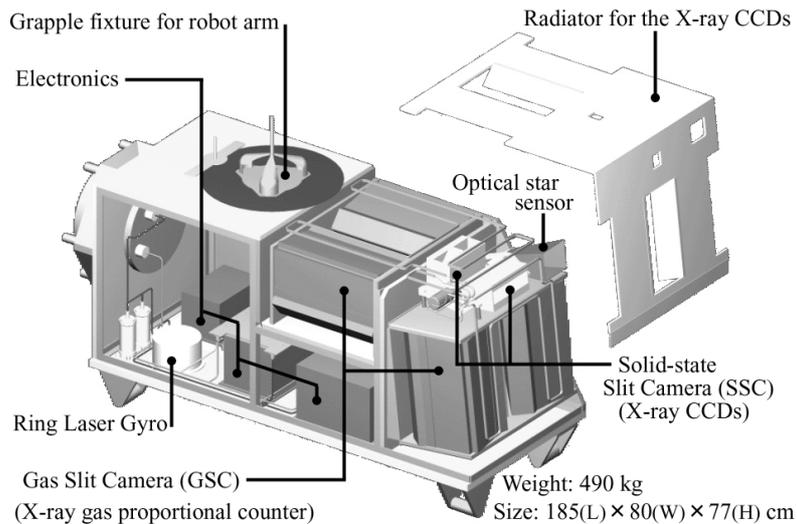


Figure 2. The Monitor of All-sky X-ray Image (MAXI) payload, which will be attached to the International Space Station in 2008.

observations. A frequently asked question is how rapidly MAXI will distribute the observation results, including X-ray nova alerts. It depends on characteristics of the MAXI downlink paths, which are assessed in Subsection 6.3.

4. MAXI PAYLOAD AND COMPONENTS

4.1. The MAXI Payload

Fig. 2 shows the MAXI payload, which weighs 490 kg with dimensions of 185 cm (length) \times 80 cm (width) \times 77 cm (height). It carries simple X-ray eyes, eight combinations of a slit and orthogonally arranged collimator plates, which produce one-dimensional X-ray images along sky great circles on twelve position-sensitive proportional counters (Gas Slit Camera; GSC) in the 2–30 keV band and two X-ray CCD units (Solid-state Slit Camera; SSC) in the 0.5–10 keV band. (See Appendix A to find what we mean by “sets”, “units”, and “counters” of GSC and SSC.)

MAXI will be attached to one of the ten ports of the JEM “Kibo” Exposed facility (Fig. 3). The attachment port, called the Equipment Exchange Unit (EEU), has a mechanism to hold a payload, and provides various resources such as electricity, communication channels, and fluid of a single-phase heat pipe. The resource assigned to MAXI is electricity power of maximum 400 W (120 VDC), survival power of maximum 100 W (120 VDC), data transmission rates of 25 kbps (through the MAXI MIL1553B port) and 200–600 kbps (through the MAXI Ethernet port), and coolant Perfluorocarbon (FC72) with the flow rate of 155 kg/hr. The CCD camera (SSC) is cooled with the Loop Heat Pipe and Radiator System (LHPRS) carried by MAXI itself, and the rest parts of MAXI are cooled by the coolant FC72 circulated by the JEM.

4.2. Gas Slit Camera (GSC)

We have started the fabrication and the calibration of the flight model of GSC counters. We plan the counter-level calibration for 2004, and the camera-unit-level calibration, in combination with slit collimators, for 2005.

Table 1 presents the characteristics of GSC. The GSC has detection thresholds of 2 mCrab for one day and 0.6 mCrab for 10 days in the 2–30 keV band. The GSC has two fields of view toward two directions, 84 degrees apart from each other: a horizontal and a zenithal fields of view (see Fig. 3). The directions of the fan-shaped fields of view are fixed on the International Space Station (ISS). Since the ISS orbits with its bottom side always facing the Earth, MAXI automatically scans almost the whole sky every orbit with a period of about 96 minutes.

Table 1. Characteristics of the MAXI X-ray cameras.

	Gas Slit Camera	Solid-state Slit Camera
Detector	Proportional Counter Xe+CO ₂ (1%) gas	X-ray CCD
Energy Range	2–30 keV	0.5–10 keV
Detector Area	5350 cm ²	200 cm ²
Field of View	1.5 × 160 degrees	1.5 × 90 degrees
Energy Resolution	18 %	<150 eV at 5.9 keV
Position Resolution	1 mm	0.025 mm (pixel size)
5- σ detection limit for one scan	7 mCrab	20 mCrab

While MAXI is inside high background regions such as the South Atlantic Anomaly, it cannot make no useful observations. The sky region missed by either of the horizontal or the zenithal field of view due to such high background environments will be covered by the other field of view within one orbit.

Fig. 4 shows one of six GSC units, and illustrates how to produce one-dimensional position sensitive field of view with a slit and collimator plates. Each GSC unit consists of two counters and a slit collimator, and has a field of view of 1.5 degrees × 80 degrees. Three GSC units cover 1.5 degrees × 160 degrees together (Fig. 3). The X-ray entrance window of each GSC counter is made of a 100 micron Be sheet with dimensions of 272×190 mm (446 cm²). The counter is filled with Xe and CO₂ (1%) gas mixture at 1.4 atm (0°C). In each counter, six carbon wires are used as anodes surrounded by ten veto cells. The incident X-ray position is obtained by the charge division method. Each GSC counter carries a radioactive source (Fe55) as an X-ray energy calibrator.

4.3. Solid-state Slit Camera (SSC)

The performance of the SSC electronics, CCD and its readout and drive circuits, have been verified using the engineering model. We make some modification in the thermal design to keep pre-amp temperature within the permitted temperature range in the cold case of the MAXI thermal environment. We will start the fabrication of the flight hardware after the modification of thermal design in 2004.

Table 1 presents the characteristics of SSC. The performance of SSC is presented in detail by Katayama et al (2005).² The SSC consists of two units: a horizontal and a zenithal ones. Each unit consists of a slit collimator providing a 1.5×90-degree field of view, and 16 CCD chips as a one-dimensional position sensitive detector. Each CCD chip is 1-inch square of a format of 1024 × 1024 pixels with pixel dimensions 24×24 μ m. Its architecture is full frame transfer. To achieve the energy resolution of 143 eV FWHM at 5.9 keV, the CCDs must be operated below -60°C. To cool CCD chips, a one-stage Peltier cooler is attached to the backside of each CCD chip to produce a temperature gradient of $\Delta T = -40^\circ\text{C}$ between the chip and a SSC unit body. Each Peltier cooler consumes typically 1 W (in total 32 W for two SSC units). The heat from the Peltier coolers are transported by a Loop Heat Pipe (LHP) from the SSC units to two radiators on MAXI (this system is called Loop Heat Pipe and Radiator System, LHPRS). The JEM “Kibo” provides an active thermal control system (ATCS), but its coolant temperature is 16 to 24°C, which is not suitable to cool the SSC unit bodies. LHPRS has a thermal diode function, which is suitable in the ISS thermal environment where sky sink temperature for the MAXI radiators changes with a large amplitude and a short period (96 minutes). Each SSC unit carries a radioactive source (Fe55) as an X-ray energy calibrator.

4.4. Onboard Data Processor (DP)

The test of the Data Processor (DP) is ongoing using a prototype and its software. The prototype does not have interfaces with the support sensors, such as a star sensor and a ring laser gyro unit.

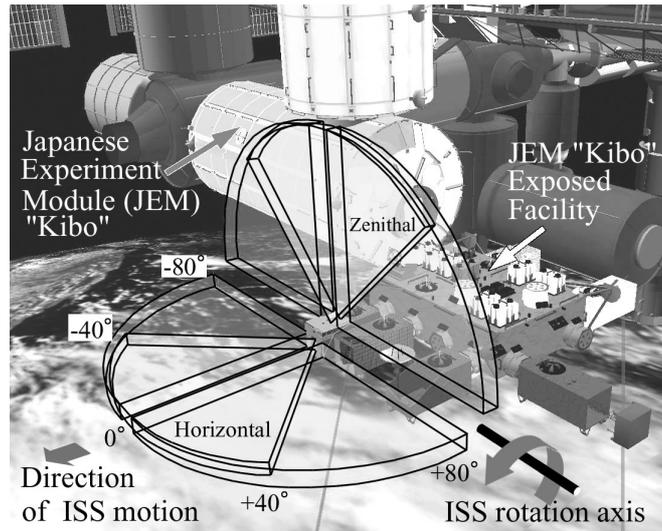


Figure 3. The computer graphic picture of the Japanese Experiment Module(JEM) overlaid with visualised fields of view of the MAXI Gas Slit Camera (GSC). Position angles are shown along the fields of view. The rotation and the orbit motion of the International Space Station are synchronised at the same period of about 96 minutes. Not shown are the fields of view of the other type of camera, the MAXI Solid-state Slit Camera (SSC). The fields of view of SSC covers a smaller position-angle range from -45 deg to $+45$ deg.

The DP will have communications with the MAXI ground system and the MAXI components, such as GSC, SSC, a star sensor, a ring laser gyro unit, and a GPS receiver. The DP formats the X-ray observation data from GSC and SSC into photon event data, in which a minimum unit is a set of properties of a single photon detection (detection position, arrival time, and photon energy). The DP does not perform any scientific analysis, such as X-ray nova search. It downlinks the event data to the MAXI ground system.

There are two communication interfaces on the MAXI DP: a medium-bit-rate interface (10Base-T Ethernet) and a low-bit-rate interface (MIL1553B). In the MAXI mission design, we suppose that the low-bit-rate connection is more reliable than the medium-bit-rate one in many aspects. Thus we use the low-bit rate channel to downlink essential part of the MAXI data, and use the medium-bit-rate channel to downlink the full set of data. The low-bit data enable the MAXI ground system to perform the X-ray nova search to issue alerts. The medium-bit-data enable us to conduct further analyses, including the diagnostics of the MAXI instruments.

The DP is constructed on the VME bus and consists of four CPU modules. When one CPU module fails, the other CPU modules can continue the task of the failed CPU with a reduced observation capability. Every CPU is a RISC chip, R3081 (25MIPS). The four CPU modules share a memory module to store the observation parameters and the information about the CPU module configuration.

5. MAXI GROUND SYSTEM AND ITS DEVELOPMENT STATUS

The MAXI ground system will be made of the following four components (see Fig.1):

1. Database inside the JAXA Operations Control System (OCS) zone, storing time-sorted event data for quick look and nova search;
2. Nova search system inside the JAXA OCS zone, searching for significant X-ray transient events, such as X-ray novae;
3. Database on the Internet, providing images, spectra, and light curves in response to the public user access using web browsers;

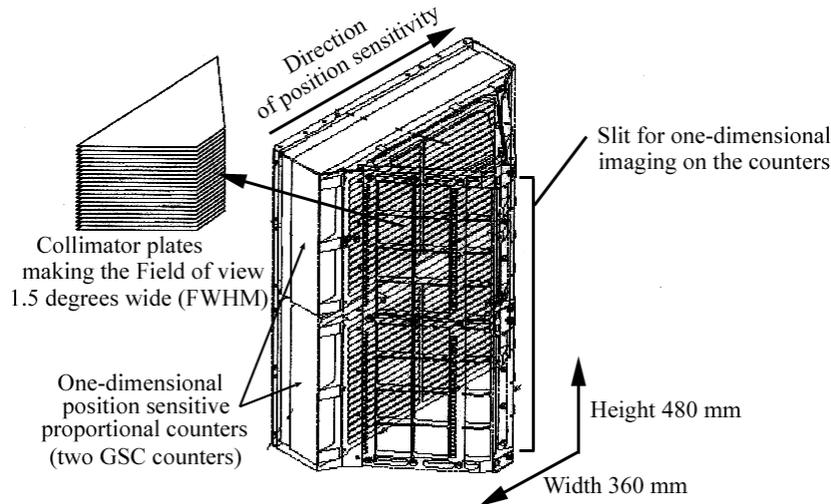


Figure 4. One of the six Gas Slit Camera units (GSC units). Each GSC unit has a field of view of $1.5 \text{ deg} \times 80 \text{ deg}$. A set of collimator plates defines the 1.5-degree width (FWHM) with no imaging capability across it, and a slit produces an 80-degree long one-dimensional image of the sky on the counter along its position sensitive direction.

4. Nova alert system, issuing alerts on detecting significant transient events to registered users.

Components 1 and 2 are connected to the Operational Control System network, isolated from the Internet for security reasons. To transfer the MAXI data to Components 3 and 4 on the Internet efficiently, we are planning to use a secure one-way data path. The candidates are a two-port hard disk and a photocoupler. We have tested a two-port hard disk, which introduces acceptable time delay of a few seconds in data transfer.

Of the four components listed above, Components 2–4 are still in the conceptual design phase. We have already coded Component 1 as software in advance to the other components, so that we can start an interface test with the OCS, an external system that the MAXI team is not responsible for. Component 1 has five tasks:

- Data reception from the Operating Control System (OCS);
- First reduction of the raw data, and the storage in a database;
- Distribution of the first reduction data to other computers;
- Data backup;
- System diagnosis.

Component 1 takes 0.2 – 0.3 seconds to process one-second data in the 20-kbps data stream, with PC-Linux Vine-2.5 (kernel 2.4.20) on a DOS/V machine with a Pentium-4 2.2-GHz CPU and 512 MB memory.

6. MAXI PERFORMANCE

6.1. Performance Evaluation Based on Simple Photon Statistics

By Monte Carlo simulation, Mihara et al (2002)³ have already evaluated the performance of the MAXI GSC observations based on photon number statistics. Fig. 5 shows the simulated all-sky images of GSC. In the simulations, all the MAXI structure were assumed to be in the positions as designed in drawings. In other words, the simulation has not predicted any systematic errors possibly caused by misalignments of parts, especially collimator plates and slit, and by limitations of our ground and in-orbit calibrations.

In the rest of this section, we examine the collimator and its calibration from the point view of the MAXI performance. We also mention the MAXI system ability of quick data distribution.

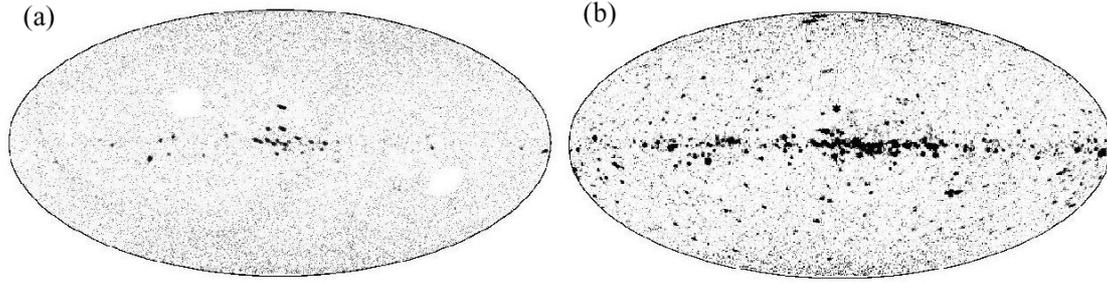


Figure 5. Simulated images of the MAXI Gas Slit Camera (GSC) plotted in the Galactic coordinates. Panel (a) is for 90-minute (one-orbit) data accumulation; panel (b) for two-month data accumulation.

6.2. Estimation of Position and Flux Determination Accuracy

6.2.1. Collimator

The MAXI slit collimator (Fig. 4) was thought to be a source of systematic errors against position and flux determination accuracy. The 100- μm thin collimator sheets are supported in place using spring coils, which provides tension to keep the sheets flat. Even with the tension, the sheets bend by their own weight if the collimator is placed with the sheets parallel to the ground. Thus we have tested the engineering model, with the sheets vertical to the ground, in the laboratory using an X-ray beam line.⁴

Of the 64 collimator sheets over a GSC counter, every pair of adjacent sheets makes a triangular response of X-ray transmission with width of 1.5 degrees (FWHM at position angle of 0 deg). At every position angle examined in the field of view, the X-ray transmission directions of plate pairs are misaligned with a 3σ deviation of 0.12 degrees. The directions of the X-ray transmission, averaged for all collimator plates at each position angle, should be on a single great circle in the sky. The 3σ deviation of the field of view from a great circle is measured to be 0.03 degrees for the engineering model. With an estimated attitude determination accuracy of 0.05 deg (3σ) for the GSC and SSC units, the collimator quality is good enough to achieve position determination accuracy of 0.1 degrees in the scanning direction. On the other hand, the accuracy in the position angle direction depends on the quality of the slit and the X-ray counter. We also achieve the accuracy of 0.1 deg in this direction.

Preliminary results of the slit collimator test imply that the ground calibration provides the ratios of effective areas, with accuracy of a few percent, for different position angles of a slit collimator. This means that, even when MAXI can determine absolute flux with worse accuracy (for example, 10%), it still has potential to monitor the flux variation of a given object with accuracy of a few percent.

6.2.2. In-orbit calibration

For MAXI, the in-orbit calibration is crucial to achieve a position determination accuracy better than 0.1 degrees and a flux determination accuracy better than 10%.

Some astronomical satellites can point to desired calibration sources in the sky. As noted above, however, we cannot control the MAXI attitude, hence the direction of the fields of view. The ISS orbits with the period of 96 minutes, the orbit inclination of 51.6 degrees, and the precession period of about two months. Thus every celestial source change its detected position in the MAXI field of view cyclically with a period of two months. The source is detected in a limited region of a field of view, depending on its declination angle in the equatorial coordinate system.

Fig. 6 shows the coverage of field of view with a given celestial source (Panel a) and the frequency of Crab Nebula's crossing the MAXI field of view at a given position angle (Panel b). To calibrate the whole field of view of MAXI in orbit, we need more than one celestial source as flux and position calibrators.

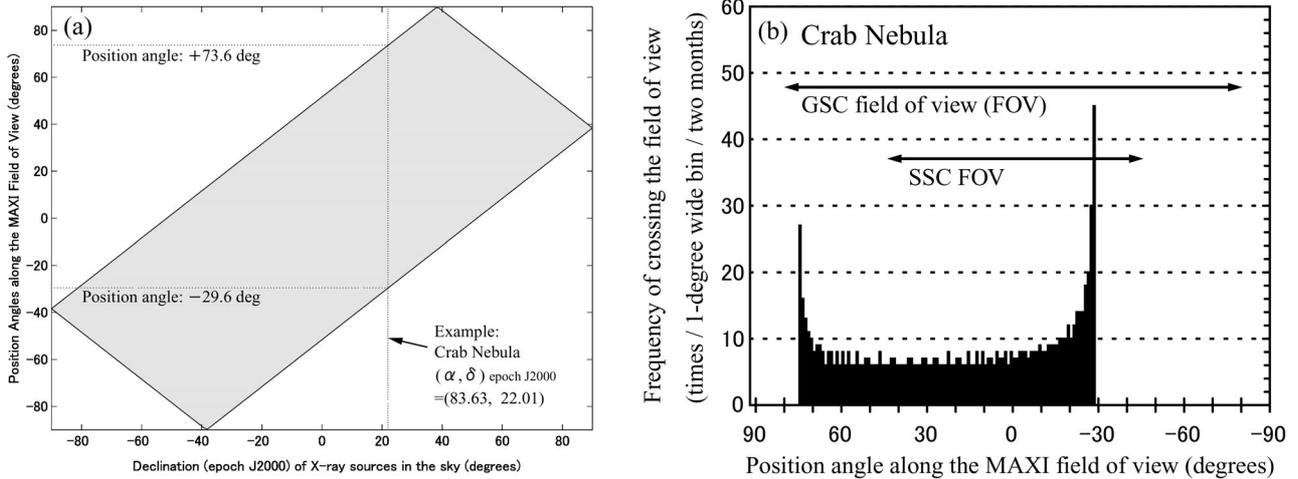


Figure 6. The coverage of the field of view with a given celestial source.

Panel (a): The declination angle of a given celestial X-ray source, and its coverage of the MAXI field of view (FOV). For example, Crab nebulae, a useful calibration source in X-ray astronomy, moves across the FOV at the position angles between -29.6 degrees and $+73.6$ degrees.

Panel (b): Frequency of crossing the field of view for Crab Nebula

6.3. Quick Distribution of Observation Results

One of the MAXI objectives is the quick distribution of observation results, including the transmission of X-ray nova alerts to the Internet. If we have a real-time connection 24 hours a day from the MAXI payload to the ground system, the place of data analysis does not matter to realise the quick distribution. It is not the case for MAXI.

On average, the 50–70% of the observational data will be downlinked in real time (with delay of a few to ten seconds). The rest of data, stored on the ISS for next downlink, takes 20 minutes to a few hours to arrive the MAXI ground system, depending the timing of data transmission. The fastest way to distribute nova alerts is to perform nova search onboard the MAXI payload, and downlink the results with priority whenever a real-time connection is established. Instead, the MAXI team has chosen to perform an X-ray nova search on the ground using more flexible hardware and software environments.

Fig. 7 shows the low-bit-rate downlink path, which is essential for the MAXI mission. The medium-bit-rate path is not shown. The MAXI data are duplicated, and the identical data set is output to both the NASA link and the JAXA link. The NASA link provides real-time connection with the ground system for more than 50% of a day using a fleet of data relay satellites, and the JAXA link provides it for about 20% of a day with a single data relay satellite. The duration of the real-time connection depends on the operation plans of the data relay satellites, which are not dedicated to the ISS, but shared with other satellites. When the ISS is out of real-time contact, data are stored in the onboard recorders, and then replayed during next contact. Channels 2 and 3 in Fig. 7 are for real-time data, and Channels 1 and 4 are for the data stored in the onboard recorders during communications outage. The MAXI ground system receives the real-time data through Channel 5. The stored data in the onboard recorders can be already 0–200 minutes (two orbits) old at the beginning of downlink. The NASA-stored data are collected by the MAXI ground system through Channel 6 at a very slow transfer rate, one-second observation data per second. The JAXA-stored data is received through Channel 7 from the Data Archives and Retrieval System (DARS) which spends 20 minutes to a few hours preparing data files for the MAXI ground system. To make the data distribution as fast as possible, we are considering the following modifications:

1. We modify the DP software to perform onboard attitude determination using Visual Star Camera (VSC) and Ring Laser Gyro (RLG). We planed to downlink raw data of VSC and RLG, and determine the attitude

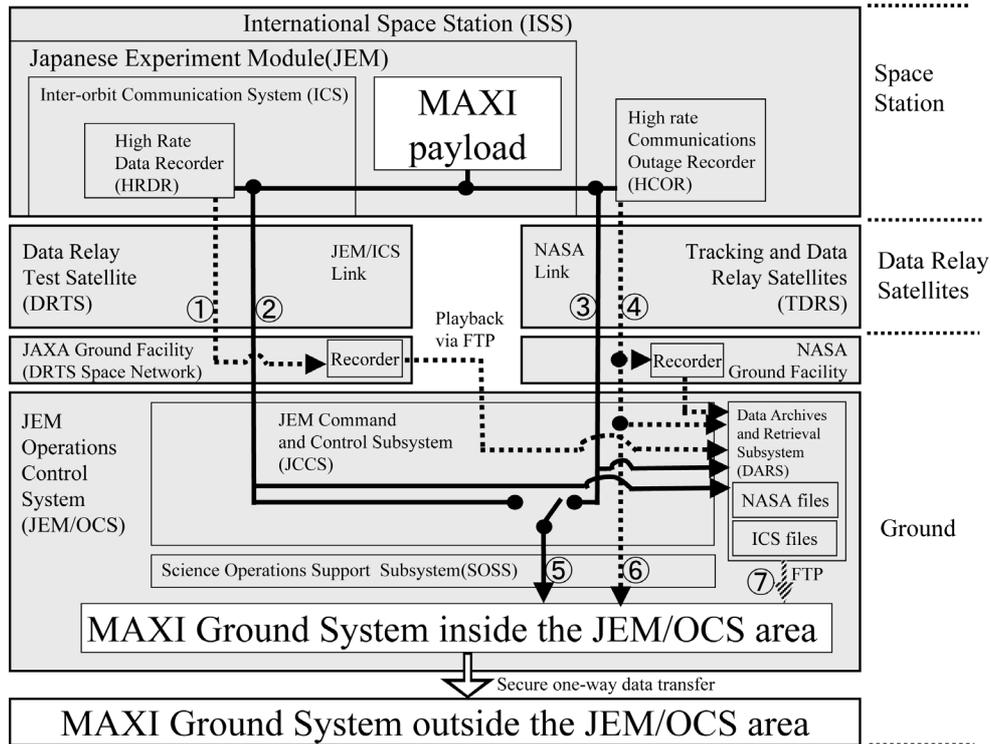


Figure 7. The downlink channels of the MAXI low-bit-rate data, which is primary data used in X-ray nova search. The MAXI data are duplicated on board the ISS, and the identical data set is output to both the NASA link and the JAXA link (JAXA link is shown as JEM/ICS link). Both links utilise data relay satellites in the geostationary orbit. Channels 2 and 3 are for real-time downlink data. Channels 1 and 4 are for the data sets stored in on-board recorders during the communications outages of the ICS and the NASA link, respectively.

of MAXI on the ground. The RLG data are used to extrapolate the VSC absolute attitudes during the periods of no VSC visibility. However, we noticed that this method introduces a delay in nova search, because there is a case that the MAXI ground system has received the latest X-ray event data and RLG data, but has to wait for the VSC data to determine the sky positions of X-ray events, when the phase of no VSC visibility overlaps the beginning of the real-time downlink;

2. We consider asking the modification of DARS (the data source of Channel 7 in Fig.7) to speed up its file preparation of the JAXA stored data (at present, it takes 20 minutes to a few hours);
3. We consider a way to obtain the NASA stored data quickly (at present, very slow at one-second observation data per second through Channel 6 in Fig.7).

6.4. Photon Arrival Time Accuracy

We have evaluated that the accuracy of the GPS time tag on each X-ray photon is $120 \mu\text{s}$. The breakdown is $55 \mu\text{s}$ from the photon absorption to the collection of the ADC signal, $50 \mu\text{s}$ for the least significant bit of the GSC clock, $0.1 \mu\text{s}$ for latching the GSC clock on the GPS PPS signal arrival, and $15 \mu\text{s}$ for the GPS PPS signal distribution to the GSC data processor.

The time resolution of SSC is limited by the CCD readout speed, ranging from 2 to 16 seconds depending the readout patterns.

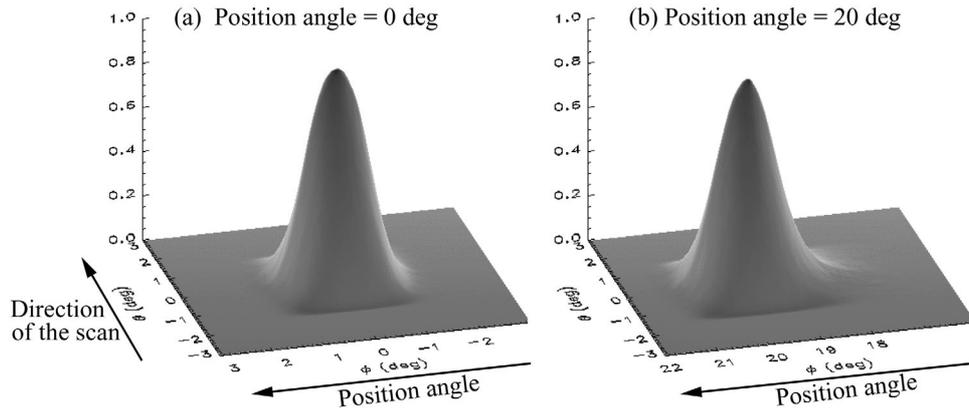


Figure 8. Point spread functions (PSF) of the MAXI Gas Slit Camera. Panel (a) is for the point source at the position angle of 0 degrees along the field of view; Panel (b) is for 20 degrees. Along the position angle axis of Panel (b), the PSF shows asymmetry caused by slant incidence of photons into the gas cells.

7. FUTURE PLAN

7.1. Studying Data Analysis Methods

We need to study the data analysis methods using simulated MAXI data. For example, we have to study how to analyse a photon-accumulated image, in which photons are collected from different scans, hence with different point spread functions (PSF). Fig.8 shows the PSF of GSC at two position angles along the field of view. Panel b of 8 shows asymmetry caused by slant incident of photons into the gas cells. The shape and the position along a GSC anode wire depends on the photon energy. This means that there is no unique correspondence between the positions on the anode wire and the sky. We have to determine the correspondence and the fitting method at the same time to obtain the best position and flux accuracy.

The SSC does not show the PSF asymmetry caused by slant incident of photons, but we will have to consider various PSF for SSC as well. In the nominal ISS attitude, the sky scanning direction and the CCD charge transfer direction are the same. In the permitted ISS attitude range, however, they can be differ by ± 15 degrees, requiring us to constructing appropriate PSF according to the ISS attitude.

7.2. Analysing the MAXI mission scenarios

From the launch of MAXI to the end of the mission, there are many ISS specific issues to be assessed from the point of view of the MAXI mission success. Some of them are beyond the control of the MAXI team, and what we can do are just assessment and preparation for them. One example is the installation of the MAXI payload to the ISS with a robot arm, during which the MAXI instruments have to survive with no electricity supplied. We will make specific operation scenarios, and will verify that the MAXI mission withstands the worst cases.

7.3. Preparing for Quick Start-up of the MAXI System after the Launch

Taking account of the two-year mission life and the role as an all-sky monitor, it is essential to establish the distribution of reliable and easily-utilised data in the early stage of the MAXI mission. As we noted, the MAXI ground system for the scientific analysis and distribution is still in the conceptual design phase. We need to complete the ground system, publish the detailed specification of the MAXI system, and cultivate potential MAXI users well in advance to the launch of MAXI scheduled for 2008.

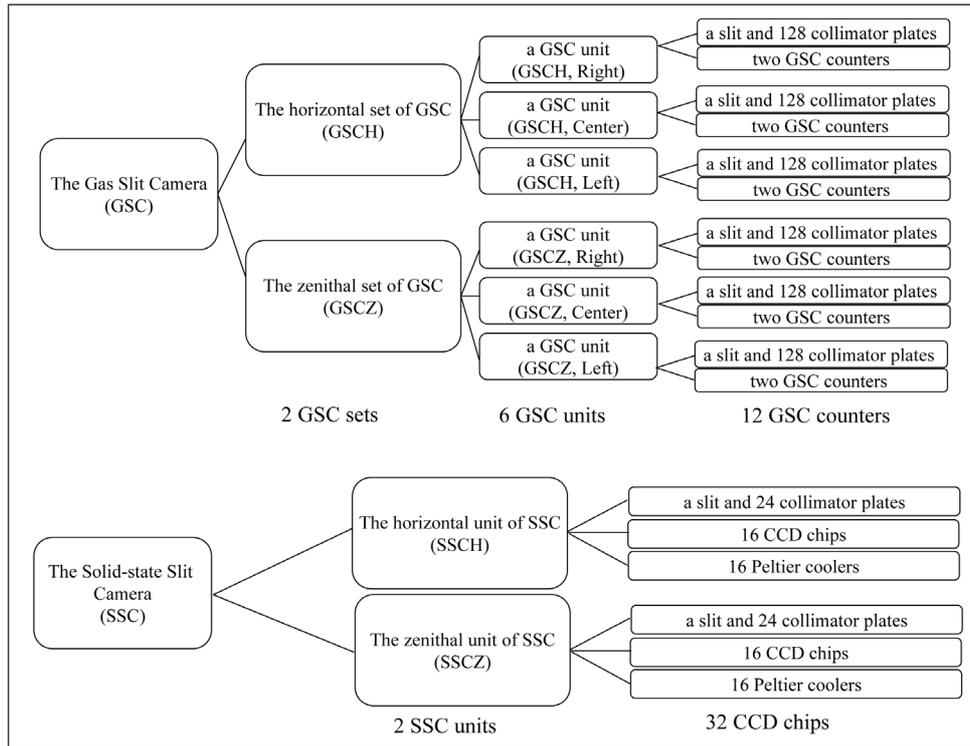


Figure 9. Components trees of the MAXI X-ray instruments.

8. CONCLUSION

We presented the overall picture of the MAXI mission system. The design and performance of the X-ray detectors of GSC and SSC are verified using the engineering models. We have finished the preliminary and critical review of the MAXI payload. The MAXI system components other than the X-ray detectors were examined from the point view of the mission performance. We confirmed that the quality of the collimator meets our mission requirement. The distribution of the MAXI data might speed up by modifications in the data transfer path to the MAXI ground system. In the 2004–2005 time frame, our workforce will be gradually shifted from the development of X-ray detectors to the calibration of them and the construction of the ground system including data analysing software.

APPENDIX A. COMPONENT TREES OF THE MAXI X-RAY INSTRUMENTS

To make clear what components we refer to by “sets”, “units”, and “counters” of GSC and SSC, we shows the component trees in Fig. 9.

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