# Mission Operations Concept and Ground Segment System Architecture relevant to the Instrument Operations of the INTEGRAL Mission

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## Abstract

The **INT**ernational **G**amma **R**ay **A**strophysics **L**aboratory (INTEGRAL) is an astronomical observatory satellite of the European Space Agency to be launched in the year 2001 into a highly elliptical orbit with a period of 48 or 72 hours.
The responsibility of the INTEGRAL mission control and scientific utilisation is split over three main elements, namely:

a) The INTEGRAL Science Operations Centre (ISOC), located at the European Space Research and Technology Centre (ESTEC) in the Netherlands, which will be responsible for the planning of the instruments utilisation based on inputs from the Scientific Community;
b) The INTEGRAL Science Data Centre (ISDC), located at the Geneve University in Switzerland, which will be responsible for the processing of the scientific data and their distribution to the observers;
c) The Mission Operations Centre (MOC), located at the European Space Operations Centre (ESOC) in Darmstadt, Germany, which will be responsible for spacecraft and instruments monitoring and operations execution.

The present paper, after introducing the reader to the INTEGRAL Mission and Space Segment, will provide an overview of the mission operations concept and the corresponding ground systems architecture. It will focus on the implementation of the operations concerning the instruments.

## References

1. INTEGRAL Mission Operations Concept, INT-SYS-MIS-TN-0001-OGI, 1998
2. INTEGRAL Mission Implementation Plan,INT-MOC-MGT-0101-OGI, 1997
3. INTEGRAL Mission Implementation Requirements Document, INT-SR-1593, 1997

# 1. OVERVIEW OF INTERGRAL MISSION AND SPACE SEGMENT

## 1.1 INTEGRAL Mission Characteristics

The International Gamma Ray Astrophysics Laboratory (INTEGRAL) is an astronomical observatory satellite built by the European Space Agency (ESA) to be launched in the year 2001. The mission is dedicated to the fine spectroscopy and imaging of celestial Gamma-ray sources in the energy range 15 KeV to 10 MeV with concurrent source monitoring in the X-ray and optical energy ranges.

INTEGRAL will be launched into a highly eccentric orbit with a period of 48 or 72 hrs. in order to provide long periods for continuous observations outside the radiation belts. Currently two launcher options are maintained: the Russian PROTON (baseline) and the European ARIANE-V (backup). The final mission orbit will depend on the selected launcher. The whole mission (ground and space segment) will be designed to support both options.

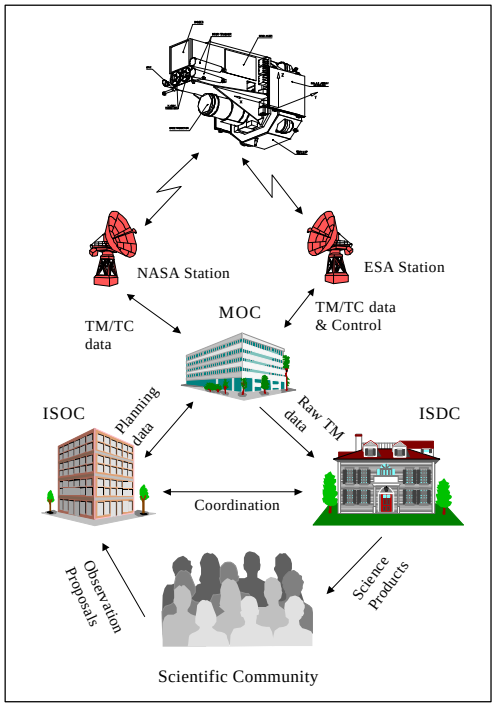
## 1.2 INTEGRAL Space Segment

The INTEGRAL space segment consists of the spacecraft (S/C), split into the service module (SVM) and the payload module (PLM), and the instruments.

The Service Module comprises the functions needed to control the satellite; such as attitude and orbit control, power generation and data handling. The SVM design is based on the bus designed for the XMM mission.
The Payload Module houses the payload, the facilities needed for data and power interface between S/C and payload and the star trackers which have to be co-aligned with the instruments' field-of-view.
The INTEGRAL payload consists of the two main Gamma-ray instruments, Spectrometer (SPI) and Imager (IBIS), and the two supporting monitor instruments, X-ray Monitor (JEM-X) and Optical Monitor (OMC).

# 2. INTEGRAL Ground Segment Architecture

## 2.1 Ground Segment Overview




The INTEGRAL Ground Segment (see figure) consists of the Operational Ground Segment (OGS) and the Science Ground Segment (SGS).

The OGS contains:
- ESA and NASA ground stations depending on the selected orbit;
- the Mission Operations Centre (MOC) located in the European Space Operations Centre (ESOC) in Darmstadt, Germany;
- associated communication facilities.

The Science Ground Segment (SGS) contains:
- the INTEGRAL Science Operations Centre (ISOC) at the European Space Research and Technology Centre (ESTEC) in Nordwijk, Netherlands;
- the INTEGRAL Science Data Centre (ISDC) at Geneva University in Versoix, Switzerland.

The Science Ground Segment is complemented by the Science Community, the Time Allocation Committee (TAC), the instrument teams of the Principle Investigators (PI) and the INTEGRAL Science Working Team (ISWT).

## 2.2 Share of Functions within Ground Segment

INTEGRAL will utilise ESA (Redu) and NASA (Goldstone) ground stations depending on the selected orbit. The ESA stations will be remotely controlled from the MOC.

The MOC is the focal point for the control of the INTEGRAL satellite. It is the only source for telecommands (TC) sent to the satellite. It performs safety and health checks of the satellite using housekeeping (HK) telemetry data (TM). It interfaces to the ISOC for the planning of the satellite operations and routes the TM augmented with auxiliary data (such as determined orbit and reconstructed attitude) to the ISDC.

The ISOC interfaces to the Science Community to receive the observation proposals from the science community. It analyses and processes the proposals, and generates an observation plan, consisting of a timeline of target pointings and the definition of the corresponding instrument configurations.

The ISDC receives the TM (Housekeeping and Science) and relevant auxiliary data from the MOC. Taking into account the instrument characteristics the ISDC will convert the raw science data into physical units and will make available the final science products to the science community via a Science Archive.

# 3. MISSION OPERATIONS CONCEPT

## 3.1 Principle Operational Rules

All INTEGRAL operations are pre-planned and executed in real-time by the MOC. Real-time changes to the operations timeline are limited to contingency recovery. No real-time interactions between the various centres are required.

The Mission Operations Concept has been defined in terms of a number of strategies. The strategies relevant to the instruments are addressed in the following sections.

## 3.2 Instrument Planning

The Science Planning starts with the Announcement of Opportunity and the generation of proposals by the observers. These proposals are reviewed and approved by the Time Allocation Committee. The approved proposals are further processed by the ISOC.

The operations related planning functions are split between MOC and ISOC. ISOC is mainly in charge of planning the sequence of pointings and the corresponding instrument configurations. The MOC is planning the relevant S/C activities and the routine Instrument activities such as activation / deactivation of the instruments before / after eclipses and perigee passages.

The MOC provides a long term planning input to ISOC in form of a batch of Planning Skeleton Files (PSF's), which covers a period of about one month. This batch is provided to ISOC one month in advance to the concerned planning period. In order to limit the necessary replanning in case of TOO's, the ISOC provides a batch of Preferred Observation Sequences (POS's) covering 2 weeks about 2 weeks in advance to the concerned period.

The MOC creates the relevant Timelines for one week about one week in advance. In addition it creates a Timeline Summary, which is sent to ISOC for approval and to ISDC to provide ISDC the means to follow the instrument operations.

## 3.3 Instrument Operations Execution

The Timeline, which consists basically of a sequence of commands with the associated planned execution times, will be loaded on the ground based command scheduler once per orbit.

The instrument related operations will be executed automatically from the ground command scheduler at MOC, i.e. the telecommands related to the instrument configurations for the planned observations are released at the predefined times. In addition an on-board Broadcast Packet, which provides general information such as eclipse times, is provided every polling cycle, i.e. every 8 seconds, to the instruments. The instruments can use this information to configure themselves automatically for special events, e.g. eclipse or perigee passages.

All safety and health related operations, which require a reaction time of less than 24 hours, are under the responsibility of the MOC and will be performed according to flight procedures, which are prepared by the MOC in form of the Instrument Flight Operations Plan (IFOP).

Since the baseline is that all instrument operations are preplanned, changes to the Instrument configurations can only be implemented for the next orbit when the new Timeline will be applied. Special support is foreseen for TOO's. In case of TOO's the Timeline can be changed within 8 hours on receipt of a change request by MOC. The MOC supports one replanning per orbit.

The instrument performance analysis is to be performed offline by ISDC. The ISDC is also to identify all instrument malfunctions, which can only be detected by analysing the Science data. Proposals for changing the instrument configurations will be generated by ISDC and sent to ISOC. ISOC will approve the requested changes and will provide the relevant information to MOC including a modification of the Observation Plan (POS) as necessary.

## 3.4 Instrument Data Processing

The satellite housekeeping data (HK), which is needed for monitoring of health and safety, is processed in real-time by the MOC.

The HK is routed together with the science TM data to the ISDC, which performs a quick look analysis of the instrument performance. This analysis is used amongst others to identify Targets Of Opportunities (TOO), which may require a re-planning of the observation schedule.

The MOC maintains an archive of all raw TM data. In case of interruptions of the data links between the ground stations and the MOC, the MOC retrieves the data from the ground stations and consolidates this archive.

Data from the consolidated archive, together with auxiliary data, is copied to CD-ROMs and sent to the ISDC for their data analysis on a weekly basis. The ISDC generates the scientific products using these CD-ROMs and maintains their archive of the scientific products. The scientific products are made available to the scientific community according to agreed access rights.

## 3.5 Instrument Maintenance

The maintenance of the Instrument configurations including the Instrument related OBS (Instrument Application S/W and Front End Processor S/W) is a task of the PI Teams. Relevant S/W images are to be provided via ISOC to the MOC. The MOC generates the appropriate Load Memory Commands and ensures a proper uplink of the commands including a check of the OBS by means of a Memory Dump.

The MOC will keep track of the relevant changes made to the on-board configuration, which will allow to reestablish the proper instrument environment after a major anomaly. ISOC will approve the instrument configuration and will provide additional inputs if necessary.

# 4. CONCLUSION

The major challenge in the design of the INTEGRAL ground segment and its internal interfaces and procedures are given by the geographical distribution of its elements and the scientific and technical requirements of the mission.

The INTEGRAL ground segment is at the time of generation of this paper in the phase of defining the S/W requirements and the architectural design of the system. By the time of launch in 2001 it will have proven its operational status in a number of simulations and integrated ground segments tests involving the actual satellite and a satellite simulator.