INTEGRAL

Science Operations Centre

Announcement of Opportunity for Observing Proposals

(AO-4)

Mission Overview, Policies and Procedures

INT/SDG/06-0250/Dc

Issue 4.0

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Prepared by ISOC

Authorised by A.N. Parmar

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1 Introduction

1.1 Purpose of this document

This document fulfils two purposes. Firstly it introduces the INTEGRAL satellite, with brief descriptions of its instruments, observations modes, orbit, and ground system. Secondly, it describes the procedures that should be followed by the observers when preparing proposals to observe with INTEGRAL, the policies that ESA will follow with respect to the proposals, proposal submission and proposal evaluation and the form in which the proposals should be submitted to ESA. The observers are advised to follow these procedures, since otherwise the proposal will not be accepted by ESA for evaluation.

This document replaces two earlier manuals "*INTEGRAL Manual Issue 3*" and "*Policies, Procedures and Forms Issue 3*" which were part of the AO-3 documentation.

1.2 Schedule and scope for AO-4

The following is the schedule for INTEGRAL AO-4:

- **13 March 2006: release of INTEGRAL AO-4**
- **21 April 2006, 15.00 CET (14.00 GMT): deadline for proposal submission**
- **30 May - 02 June 2006: INTEGRAL Time Allocation Committee (TAC) meetings**
- **16 August 2006 (revolution 469): Formal start of AO-4 programme.**

This AO for INTEGRAL is open to proposers from the ESA Member States, and the countries participating in INTEGRAL (Russia, USA, Czech Republic and Poland), but proposals from other countries will also be considered by the Time Allocation Committee.

1.3 US Proposers

Proposers at institutions in the United States may respond to this AO either as Principal Investigators or as co-Investigators on non-US proposals. Accepted US investigators should request funding from NASA via a separate solicitation.

1.4 Overview of the Call for Proposals

This call for INTEGRAL proposals consists of a number of documents, a proposal submission tool and other software tools to help preparing proposals. The following documents are available:

- *"Mission Overview, Policies and Procedures"* (this document)
- "*IBIS Observer's Manual*" (describes the IBIS instrument)
- "*SPI Observer's Manual*" (describes the SPI instrument)
- "*JEM-X Observer's Manual*" (describes the JEM-X instrument)
- "*OMC Observer's Manual*" (describes the OMC instrument)
- "*INTEGRAL Guaranteed time*" (gives details on the INTEGRAL Core Programme)
- "*AO-4 Key Programme*" (gives details on the INTEGRAL AO-4 Key Programme)
- "*Annexe: INTEGRAL Science Data Rights*" (describes the data rights policies)
- "*PGT User's Manual*" (describes how to use the Proposal Generation Tool)

- "*TVP User's Manual*" (describes how to use the Target Visibility Predictor)
- "*OTE User's Manual*" (describes how to use the Observation Time Estimator)
- "*Glossary of Terms*" (gives a list of all acronyms used in the documents)

All these documents are available on line at ESA's INTEGRAL Science Operations Centre (ISOC) home page: http://integral.esac.esa.int/. On the same homepage the observers can find links to download the Proposal Generation Tools (PGT) and links to access the Observing Time Estimator (OTE) and the Target Visibility Predictor (TVP). Note that OTE and TVP run remotely through the web, whereas PGT needs to be downloaded and installed on the users' local machine(s). For more details we refer to the respective user's manuals.

1.5 Extended Mission and Future AOs

The nominal operational mission had a duration of 24 months and commenced two months after launch on December 17, 2002. Therefore, the nominal mission ended on December 16, 2004. The extended mission is currently approved by the Science Programme Committee (SPC) until December 2010, subject to a further scientific review in approximately two years time. The current plan is that the AO-5 will be published about six months after the start of AO-4 observations.

1.6 Available observing time

AO-4 will last for twelve months from August 17, 2006 until August 16, 2007. About 24 x 10^6 seconds of integration time are available for scientific observations for this fourth cycle of INTEGRAL operations. This time is divided between the Guaranteed Time (used for Core Programme observations, see separate document "*INTEGRAL Guaranteed Time*" for details), which is 25% of the total, and the Open Time (used for General Observer Programme and Key Programme observations), which is 75% of the total. For AO-4 this means that about 18×10^6 seconds are available for Open Time proposals (available to the scientific community at large), out of which 2×10^6 seconds have been reserved for the AO-4 Key Programme (see Section 1.7 and the "*AO-4 Key Programme*'' document). Note that this estimate of the available observing time does not include the instrument calibrations, which need to be done regularly during the operational phase. Also, some unfinished observations from AO-3 will be carried forward into the AO-4 timeframe. Therefore the numbers given above represent the maximum available time for scientific observations.

On the other hand, the main instruments IBIS and SPI have large fields of view. Therefore multiple targets can often be observed simultaneously, increasing the scientific efficiency of the observatory. For this ISOC will amalgamate observations of different sources, see also the "*Annexe: INTEGRAL Science Data Rights*".

1.7 AO-4 Key Programme

Newly introduced in AO-4 is the INTEGRAL Key Programme (KP). This is a scientific investigation which requires a very significant fraction of the observing time (available per AO cycle) in order to achieve its scientific objectives and which could in principle cover a time span exceeding that of one AO cycle ("multi-year" proposal).

Since INTEGRAL can study multiple targets at once in its large field of view, various scientific requirements can be accomodated, combining ultra-long deep observations with shorter observations of individual sources which are contained in those large fields.

ESA has therefore decided to implement one Key Programme (as a pilot project) within the current AO-4 cycle, and intends to release, later in 2006, a special Announcement of Opportunity calling for new KP proposals to be implemented in the AO-5 cycle. The pilot KP is targeted at the Galactic Center region for 2 Ms total exposure, please see the "*AO-4 Key Programme*" document for details.

2 The INTEGRAL Mission

2.1 Overview of the INTEGRAL Mission

The INTErnational Gamma-Ray Astrophysics Laboratory INTEGRAL was successfully launched with a PROTON launcher from Baikonour/Kazachstan on October 17, 2002 at 04:41 UTC. The PROTON launcher injected the satellite into a transfer orbit and INTEGRAL's own propulsion system brought the satellite into its 72 hours operational orbit with an apogee of 153600 km and an inclination of 52.2^{o}.

INTEGRAL is a 15 keV - 10 MeV gamma-ray observatory mission with concurrent source monitoring at X-rays (4 - 35 keV) and in the optical range (V, 500 - 600 nm). All instruments, co-aligned with large field of views, cover simultaneously a very broad energy range for the study of high energy astrophysical sources. The payload consists of the two main gamma-ray instruments, the spectrometer SPI, the imager IBIS and of two monitors, the X-ray monitor JEM-X and the optical monitor OMC. In addition a particle radiation monitor measures charged particle fluxes of the spacecraft orbital environment.

The scientific goals of INTEGRAL are attained by high resolution spectroscopy with fine imaging and accurate positioning of celestial sources of gamma-ray emission. High resolution spectroscopy over the entire energy range permits spectral features to be uniquely identified and line profiles to be determined for physical studies of the source region. The fine imaging capability of INTEGRAL within a large field of view permits the accurate location and hence identification of the gamma-ray emitting objects with counterparts at other wavelengths, enable extended regions to be distinguished from point sources and provide considerable serendipitous science which is very important for an observatory-class mission. In summary the scientific topics address:

i) **compact objects:** *white dwarfs, neutron stars, black-hole candidates, high-energy transients and GRB's.*

ii) **extragalactic astronomy:** *AGN, Seyferts, blazars, galaxies and clusters, cosmic diffuse background.*

iii) **stellar nucleosynthesis:** *hydrostatic nucleosynthesis (AGB and WR stars), explosive nucleosynthesis (supernovae and novae).*

iv) **Galactic structure:** *mapping of continuum and line emission, ISM, cosmic-ray distribution.*

v) **Galactic Centre:** *cloud-complex regions, mapping of continuum and line emission, ISM, cosmic-ray distribution.*

vi) **particle processes and acceleration:** *trans-relativistic pair plasmas, beams, jets.*

vii) **identification of high energy sources:** *unidentified gamma-ray objects as a class.*

viii) **unexpected discoveries**.

Each of the two main gamma-ray instruments, the spectrometer (SPI) and the imager (IBIS), has both spectral and angular resolution, but they are differently optimised in order to complement each other and to achieve overall excellent performance. The two monitor instruments (JEM-X and OMC) provide complementary observations of high energy sources at X-ray and optical energy bands.

Details of the INTEGRAL spacecraft, instruments and scientific aims can be found in A&A Vol. 411 (2003): a special issue dedicated to INTEGRAL.

2.2 The INTEGRAL spacecraft and its orbit

The INTEGRAL spacecraft consists of two main components, which are the service module and the payload module. The payload module comprises the scientific instruments performing the actual observation. The service module fulfils the classical spacecraft task, such as attitude control, communication with the ground and providing the necessary infrastructure for the payload module. Both modules are described in more detail below.

2.2.1 The service module

The service module of the INTEGRAL spacecraft is a re-build of that developed for the XMM-Newton project and is composed of the following key sub-systems:

- *Mechanical Structure:* It consists of the primary structure (central cone and shear panels) supporting primarily the launch loads and a secondary structure basically consisting of panels carrying the sub-system units and the tanks.
- *Thermal Control System:* The thermal control is achieved by means of active (heaters etc.) and passive (MLI) means.
- *Attitude and Orbital Control Subsystem (AOCS):* This subsystem provides control, stabilisation, and measurements about the 3 satellite axes using star and sun sensors for primary attitude measurements and Reaction Wheels for torque actuation and momentum storage. The AOCS also controls the Reaction Control System, which with its thrusters provides the capability of reaction wheel momentum dump and for orbit maintenance. A hard-wired Emergency Sun Acquisition Mode is implemented to acquire a safe sun-pointing attitude in case that an AOCS failure results in uncontrolled attitude conditions.
- *Electrical Power System:* It comprises the functions of power generation (solar arrays), storage (batteries), control and conditioning, distribution to provide all users with the required power on a regulated 28 V main and redundant power bus.
- *Radio Frequency Function:* This subsystem ensures the permanent up- and down-link of telecommands and telemetry using a quasi omni-directional antenna and two redundant S-band transponder.
- *Data Handling System:* This sub-system provides the capability to acquire, process and format data for the down-link. It consists of a single failure tolerant Command and Data Management Unit (CDMU – the central on-board computer) and two Remote Terminal Units, one on the service and the other on the payload module, for data acquisition from peripheral units. Spacecraft telemetry is down-linked in real-time; there is no on-board data storage. Early in the mission after it was confirmed that the link RF margin was sufficiently

large, it was decided to increase the telemetry clocking frequency and thus to increase the bit rate by ~25%. The data rate for science data was increased from 86 kbps to 108 kbps.

- *Launcher Adapter:* it connected the service module with the Russian PROTON launcher. A special adapter was designed, which included the separation system.

2.2.2 The payload module

The INTEGRAL payload module consists of an equipment platform accommodating the detector assemblies and an empty box supporting the "upper floor" at a height of about 3.5 m. There the so-called coded masks are installed, a key feature of INTEGRAL's instruments.

The detector bench provides the interface to the service module cone upper flange and carries the spectrometer (SPI) units, the IBIS detector and the relevant electronic and data processing units. System units (Payload module power distribution unit and remote terminal unit) are accommodated on the lower side. The vertical panels carry the OMC, IBIS calibration unit, the IBIS lead shields and the star trackers. They also support the IBIS mask and the JEM-X mask support panel. Sun acquisition sensors (part of AOCS) are accommodated on dedicated brackets. The detailed instrument descriptions can be found in the "*Instrument Observer's Manuals*".

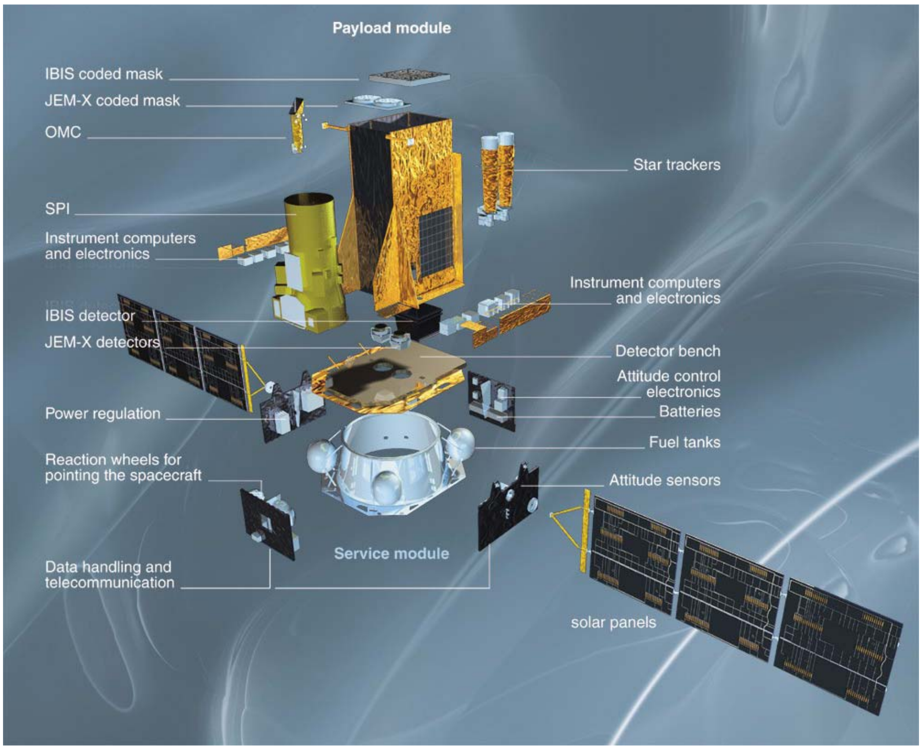

Figure 1: Exploded view of INTEGRAL service and payload modules

2.2.3 The INTEGRAL orbit

INTEGRAL is in a highly elliptic 72 hrs orbit with an apogee of 153600 km and a perigee of 9000 km. The orbital parameters are slightly changing with time. For example the perigee height increases from 9050 km in November 2002 to 12400 km 4 years later, while in the same time period the apogee height evolves from 153600 km to 150300 km. The inclination increases constantly from 52^o in November 2002 to 85^o in December 2007. Out of the 72 hrs of an orbit 65 hrs are spent above 40000 km.

In order to allow undisturbed scientific measurements and guarantee maximum science return, it is required to optimize the time spent outside the Earth's radiation belts (proton and electron belts). The real-time nature of the INTEGRAL mission requires full ground station coverage of the operational orbit above 40000 km with maximum use of available coverage below.

Nominally, scientific observations can be carried out while the spacecraft is at least at an altitude of 40000 km. However, analysis of the on-board radiation environment monitor is used to adjust this limit. Currently, the scientific observations are currently performed between an altitude of 40000 km (ascending leg of the revolution) and 60000 km (descending leg of revolution). Based on data from the radiation monitor, instrument operation is interrupted in case of a higher radiation environment, e.g. during a strong solar flare.

Ground station coverage of the orbit above 40000 km is achieved by the combined use of Redu (ESA station) and Goldstone (NASA DSN station). Simultaneous visibility from Redu and Goldstone exists during a large part of the orbit. The requirement for maximum visibility from ESA's European ground stations imposes high inclination and an apogee position in the northern hemisphere. For critical operations (like orbital manoeuvres) simultaneous coverage from two stations is required. The orbital period is almost a multiple of 24 hours (i.e. 23^h 56^s) to keep an optimal coverage pattern for all revolutions and to allow repetitive working shifts on ground.

The satellite requirements on the orbital scenarios are dictated by power, thermal and operational considerations. In order to guarantee sufficient power throughout the mission, the Solar Aspect Angle (SAA) has to be constrained. The Solar Aspect Angle of the spacecraft is SAA = +/- 40^o at the moment. This viewing constraint implies that the spacecraft cannot point to celestial sources which are closer than 50^o to the sun and to the anti-sun. The maximum duration of eclipses (umbra plus penumbra) is not exceeding 1.8 hours for thermal and energy reasons.

2.3 Overview of Scientific instrument capabilities

The design of the instruments was largely driven by the requirement to establish a scientific complementary payload. Each of the main gamma-ray instruments (SPI, IBIS) has both spectral and angular resolution but they are differently optimised in order to complement each other and to achieve overall excellent performance. The payload complementarity is summarised in Table 1.

Table 1: INTEGRAL science and payload complementarity.

Instrument	Energy range	Main purpose
Spectrometer SPI	18 keV - 8 MeV	Fine spectroscopy of narrow lines
		Study diffuse emission on >1^{o} scale
Imager IBIS	15 keV - 10 MeV	Accurate point source imaging
		Broad line spectroscopy and continuum
X-ray Monitor JEM-X	4 - 35 keV	Source identification
		X-ray monitoring of high energy sources
Optical Monitor OMC	500 - 600 nm (V-band)	Optical monitoring of high energy sources

The key performance parameters of the payload are summarized in Tables 2 and 3 below; for details of the instruments and the sensitivities we refer the reader to the "*Instrument Observer's Manuals*".

Table 2: Key parameters SPI & IBIS

	SPI	IBIS
Energy range	18 keV - 8 MeV	15 keV - 10 MeV
Detector	19 Ge detectors (each 6 × 7 cm), cooled @ 85K	16384 CdTe dets (each 4×4×2 mm), 4096 CsI dets (each 8.55×8.55×30 mm)
Detector area (cm^2)	500	2600 (CdTe), 3000 (CsI)
Spectral resolution (FWHM)	3 keV @ 1.7 MeV	8 keV @ 100 keV
Field of view (fully coded)	16^{o} (corner to corner)	8.3^{o} × 8^{o}
Angular resolution (FWHM)	2.5^{o} (point source)	12'
Source location (radius)	< 1.3^{o} (depending on source strength)	30"@100 keV (50 σ source) 3' @100 keV (5 σ source)
Absolute timing accuracy (3σ)	<200 µs	<100 µs
Mass (kg)	1309	746
Power [max/average] (W)	385/110	240/208

Table 3: Key parameters JEM-X & OMC

	JEM-X	OMC
Energy range	3 keV - 35 keV	500 nm - 600 nm
Detector	Microstrip Xe/CH_4-gas detector (1.5 bar)	CCD + V-filter
Detector area (cm^2)	500 for each of the two JEM-X detectors [1]	CCD: (2055 × 1056) pixels Imaging area: (1024 × 1024) pixels
Spectral resolution (FWHM)	2.0 keV @ 22 keV	--
Field of view (fully coded)	4.8°	4.979° × 4.9979°
Angular resolution (FWHM)	3'	23"
10σ source location (radius)	1' (90% conf, 15 σ source)	6"
Absolute Timing accuracy	~1 ms	> 3 s
Mass (kg)	65	17
Power [max/average] (W)	68/37	26/17

[1] Currently only one of the two JEM-X cameras is operated.

2.4 Overview of INTEGRAL Observing Modes

Table 4 summarizes the instrument observing modes which are available to the observer. Instrument modes shown in italics are used in only special circumstances. See the separate instrument user manuals for details. For details and choices to be made by proposers, readers are referred to the "*Instrument Observer's Manuals*". This especially applies to JEM-X due to the adjusted operation strategy with one JEM-X camera operated at any time.

Table 4: INTEGRAL observing modes

Instrument	Modes
SPI	Photon-by-photon
IBIS-ISGRI	Photon-by-photon
IBIS-PICSIT	Histogram
JEM-X	Full Imaging *Restricted Imaging* *Spectral Timing* *Timing* *Spectrum*
OMC	Normal *Fast*

3 Observing with INTEGRAL

3.1 Overview

All four instruments on-board INTEGRAL are co-aligned (Figures 1 and 2) and are operated simultaneously. Normally, observers receive from the INTEGRAL Science Data Center, ISDC (see Section 4.4.9, Data Delivery), all data from all instruments pertinent to their observation together with auxiliary data including output from the particle radiation monitor. Typical INTEGRAL observations range in duration from ~1 day to a few weeks, the former being for studies of the softer (< 500 keV) end of the spectrum, the latter for narrow - line studies and studies at MeV energies. A proposal may contain several observations.

Details of the observation types, spacecraft modes and amalgamation of observations are described below.

The reader is further referred to the AO document on "*Annexe: INTEGRAL Science Data Rights*".

3.2 Observation types

There are four classes of INTEGRAL observations which can be applied for in the open time of the General Programme (see Section 0, Proposals). Each class has implications for the science operations of INTEGRAL.

3.2.1 Normal observations

These are the majority of scientific observations which do not require any special boundary conditions apart from the normal ones, e.g. constraints on sky visibility. These observations lead to the most efficient observing schedules.

3.2.2 Fixed time observations

Fixed time observations have special scheduling requirements - for example, phase dependent observations of a binary system, or co-ordinated observations with other (ground- or space-based) facilities. The exact scheduling requirements for a fixed time observation may not be known at the time of proposal submission. Note that a sequence of observations separated by a time interval (e.g. three observations, with the observations separated by 2-3 weeks) are considered as fixed time observations as well. The proposer has to make sure this is flagged when submitting a proposal and that the *Observation Type* is set to *Fixed Time* in the *Observation Details Panel* of PGT.

Once the proposal is approved, ESA will liaise with the observer to determine the best time when to schedule such an observation. Fixed time observations reduce the observing efficiency since INTEGRAL is forced to observe a particular region of the sky at a particular time and they tend to drive the schedule.

3.2.3 Targets of Opportunity (TOO)

"Target of Opportunity'' (TOO) observations are observations in response to "new" phenomena, like X-ray novae in outburst, AGN flaring, SNe, galactic micro-quasar in high state. TOOs can be already known sources (e.g. 3C 279, GRS 1915+105, GRO J0422+32, ...) or unknown sources (supernovae, novae, ...), i.e. identified by class.

TOOs can have either internal or external triggers. Internal triggers come from the ISDC by screening the incoming science telemetry. External triggers are alerts based on observations from other missions or observatories. All triggers are being forwarded to ISOC via the INTEGRAL TOO Notification Web page at

http://integral.esac.esa.int/isoc/html/too/my_too_alert.html.

The Project Scientist then decides on declaring a TOO observation. Implementation of the updated command schedule following ISOC's request will subsequently be performed by Mission Operations Centre (MOC) in Darmstadt, Germany.

TOO observations require interruption of the pre-planned schedule, re-pointing of the spacecraft and schedule re-planning. They imply therefore a very heavy load on the scheduling system and, like fixed time observations, reduce significantly the mission efficiency. The analysis of various situations involving all elements of the INTEGRAL ground segment (ISOC, MOC, and in the event of an internal trigger, ISDC) leads to a typical turn-around time for TOO (follow-up) observations, from detection until re-pointing of the spacecraft, ranging from 20 hours to a maximum of 36 hours. It is to be noted that the ISDC and ISOC are not manned outside normal working hours. The same does apply for those MOC staff involved in re-planning activities. However, the ISDC has an automatic TOO detection system and ISDC scientists are available on call outside working hours. Also ISOC and MOC provide an on-call service outside working hours and during weekends and non-working days.

In general, the following rules and guidelines are applicable for TOO proposals:
Proposals[2] for TOO observations can be made in response to this AO.

- The Time Allocation Committee (TAC) is advised to accept no more than a few proposals for TOO observations per year, although no priorization shall be given for standard observations vsersus TOO ones; all proposals shall receive a ranking based on scientific merit.
- In contrast to AO-1, AO-2 and AO-3 the INTEGRAL Science Working Team (ISWT) has not included any TOO events as part of the Core Programme [see the AO-4 document *INTEGRAL Guaranteed time*].
- A TOO observation will displace another observation, which can be rescheduled by the ISOC and MOC if at all feasible. In some cases the displaced observation has to wait for a next AO round.
- It is up to the proposer to request[2] a TOO observation if their trigger event occurs.

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[2] A ***proposal*** for a TOO observation can be submitted during the normal AO process, in anticipation of the event. A ***request*** for TOO observation is understood to be made after a scientific event occurred which may justify an INTEGRAL TOO observation. The occurrence of this event may or may not match an existing proposal.

- Requests for TOO observations are made by submitting a TOO Notification using the ISOC Target of Opportunity Alert Web page (see above). The Project Scientist or an appointed deputy is then responsible for the submission of that request to be included in the ISOC proposal database. This will allow tracking and documenting TOO requests and including them in the time-line, as for the normal proposals accepted by TAC during the AO cycle.
- The Project Scientist or an appointed deputy will decide on the declaration of a TOO, after determining whether the overall science of the mission will be enhanced by the TOO. It is possible that the TOO observation would conflict with a time-critical observation and/or another TOO observation or other high priority observations. In such situations the Project Scientist will determine priorities. The Project Scientist will inform the scientific community on declared (approved) TOO observations.

In principle, gamma-ray bursts (GRBs) are considered as a subset of TOOs. GRBs occur randomly in time and space, therefore both inside and outside the FOVs of the instruments.

Typically one event per month occurs inside the FOV and its data will be contained in the normal science data of INTEGRAL instruments operating in the modes selected for the on-going observation. The ISDC processes the near real-time science telemetry stream in order to detect and localize these events and to alert the scientific community – see Section 4.5 for more information. We refer the document "*Annexe: INTEGRAL Science Data Rights*" for details concerning GRB proposals and data rights in this case.

GRB data from events occurring outside the INTEGRAL field of view can be obtained from the anti-coincidence shield of the SPI instrument – see also the "*SPI Instrument Observer's Manual*" and Section 4.5.2.

Due to the brevity of GRBs, no dedicated follow-up observations are done with INTEGRAL. Afterglow or counterpart observations with INTEGRAL are possible if (i) the GRB event occurs inside the FOV of the on-going observation and will be covered during the on-going nominal dithering manoeuvres, or (ii) if the event occurs outside the FOV but the spacecraft will dither onto that position during the nominal dithering manoeuvre of the observation during which the event occurred[3].

3.2.4 AO-4 Key Programme observations

Section 1.7 introduces the new concept of Key Programme (KP). The document entitled "*AO-4 Key Programme*" contains full details of the planned KP observations. PIs may propose for the data rights for individual point or extended sources which will be observed during the AO-4 KP. The proposals should be flagged as being associated with the AO-4 KP as described in Section 7.8. The PI will not have to give observation times and instrument modes for these proposals, but the proposal must still be submitted via the Proposal Generation Tool together with a full scientific justification and technical feasibility. See the "*PGT User's Manual*" for more details.

It is important to understand that no extra time or observations will be allocated or scheduled as a consequence of these proposals. All that is being requested is data rights for objects visible in the already agreed AO-4 KP.

[3]Note that in case (i) all three high energy instruments and OMC will provide data, while in case (ii) data will be provided by SPI, IBIS, and JEM-X.

3.3 Calibration observations

Dedicated payload calibration observations are occasionally executed during the normal operation phase. Observations of the Crab are intended every visibility period in order to continuously assess, verify and to complete the database describing the scientific performance of the instruments, specifically after annealing of the SPI detectors or after strong solar flare events. An initial long Crab calibration observation took place in February 2003. Thereafter, typically up to one revolution per viewing period has been used for Crab calibration observations. OMC flat field calibration sequences are performed about once a month with a duration of ~4.5 hours to characterize the OMC flat field response. Additionally, observations are performed to verify the performance of the spacecraft itself, such as AOCS calibration observations. Proposers should take note of this planning by preparing open time proposals which should avoid duplicating these observations.

In AO-3 public observations of the Earth were performed, whereby the Earth drifted through the field of view of the INTEGRAL instruments. Results from this observation will help in separating the cosmic and instrumental backgrounds and so ultimately lead to improved background subtraction.

Proposers are referred to the AO document on “*Annexe: INTEGRAL Science Data Rights*” which specifies the proprietary data rights for calibration observations during the normal operations phase.

3.4 Spacecraft observing modes

The INTEGRAL spacecraft provides stable pointings with errors typically less than 7.5″ around the pointing direction.

In order to minimize systematic effects due to spatial and temporal background variations in the spectrometer (SPI) detectors and the imager IBIS, a controlled and systematic spacecraft dithering manoeuvre is required (see also “*SPI Observer’s Manual*”). This manoeuvre consists of several off-pointings of the spacecraft pointing axis from the target in steps of about 2 degrees. The integration time for each pointing (all instruments) on the raster is flexible in the range between 0.5 hour to 1 hour. The integration time is adjusted in a way so that always multiples of a complete dither pattern are executed for each observation. The spacecraft will continuously follow one dithering pattern throughout one observation. Two different dither patterns and a staring mode (no dithering) are used as operational baseline and are described in the remainder of this section. Note that from AO-4 the hex dither pattern is implemented differently than in AO-1, AO-2 and most of AO-3.

3.4.1 Rectangular dithering

This mode is used for multiple point sources in the FOV, sources with unknown locations, and extended diffuse emission which can also be observed through combination (“mosaic”) of this pattern. It is strongly recommended to use this mode as the default for observations.

During AO-1 and most of AO-2 this mode consisted simply of a square pattern centred on the nominal target location, as shown in Figure 2. In this implementation there was 1 pointing with the source on-axis, 24 points with the source off-axis, each 2^{o} apart, in a rectangular pattern, fixed on the sky. For each single pointing the roll angle is always 0^{o}. However, since AO-3 this mode has been implemented differently to further reduce systematic artefacts in the IBIS images. For observations which are long enough to require several dither cycles, the centre of each dither cycle is offset from the others in the observation. This ensures there will only be one pointing to any location on the sky during an observation. The centre of a dither pattern (COP) will therefore itself move around in a pattern during an observation. This COP pattern consists of 7x7 points centred on the target and is parallel to the original 5x5 dither pattern (see Figure 3). The step size of this COP pattern is 0.3^{o}, so the whole COP pattern fits within the inner 3x3 points of the original dither pattern. The 49 points in the COP pattern allows for an observation time of 2.2 Msec before repetition of an individual pointing.

In addition to the COP move, since June 2005 the orientation of the 5×5 pattern is set such that the axis of the dither pattern makes a 11.3^{o} angle with respect to the instrument axes. This value has been optimized to even further minimize systematic structures in the IBIS images. As the instrument axes depend on the relative position of the Sun, the exact dither pattern positions depend on the time of execution of the observation.

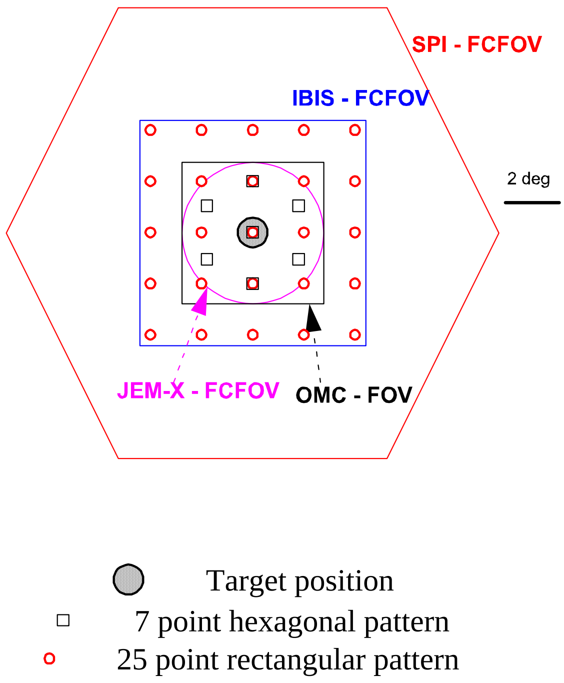

Figure 2: Schematic view of dithering patterns and instrument fully coded field of views.

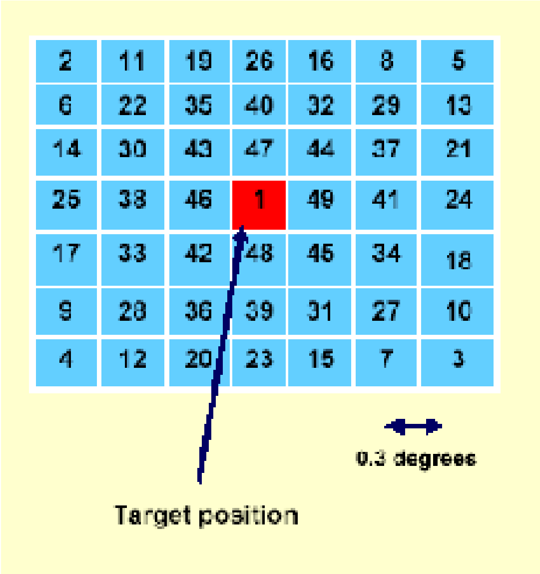

Figure 3: COP Offset Pattern for 5x5 dither pattern.

3.4.2 Hexagonal dithering

This mode consists of a hexagonal pattern centred on the nominal target location (1 source on-axis pointing, 6 off-source pointings, each 2^o apart, in a hexagonal pattern). This mode should generally only be used for a single known point source, where no significant contribution from out-of-view sources is expected: experience from earlier observations has shown that this is not very often fulfilled (e.g. because of transient sources) and the observers are generally discouraged from using this mode, except if their scientific goals require continuous monitoring of the main target by the JEM-X instrument. See the "*SPI Observer's Manual*" for further details.

This mode has been altered since the middle of AO-3 (2nd November 2005) to allow for a wandering COP offset to the hexagonal dither pattern. This COP pattern consists of two hexagons (red dots in Figure 4) around the original centre point of the (blue) dither pattern. Hence the COP pattern will consist of the centre point plus 2 x 6 points and the centre is the same for all hexagons.

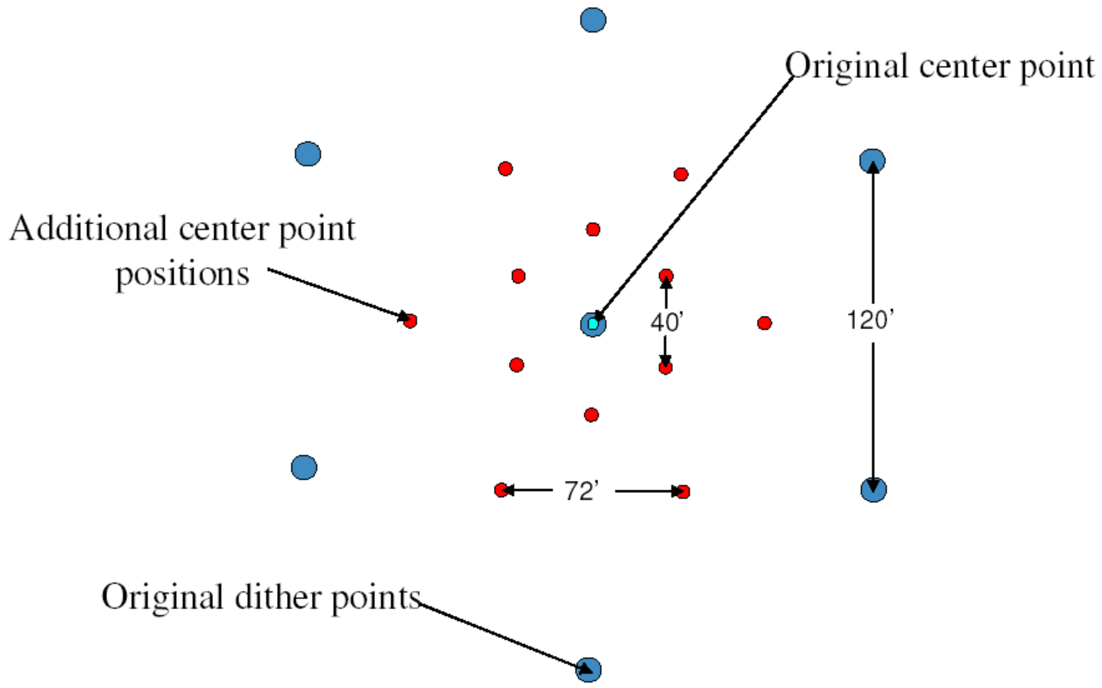

Figure 4: COP Offset Pattern for Hexagonal Dither Pattern.

3.4.3 Staring observations

If scientific requirements exist to observe a source with a single pointing position for long uninterrupted periods of time (e.g. for studies of time variability or QPOs) then the dithering modes can be disabled ("Staring Mode"). Observers should be aware that in this mode the SPI imaging capabilities are strongly compromised; consequently IBIS must be the prime instrument for these observations.

3.5 Amalgamation

The (prime) INTEGRAL instruments have large FOVs and show generally very little off-axis degradation of sensitivity and resolution, at least in the fully coded FOV. Therefore it is quite possible that more than one approved observation (source) can be covered in the same field of view. The ISOC has the capability to combine ("amalgamate") these into a single observation, thus saving observing time and increasing operational efficiency (decreasing oversubscription), while still respecting the original goals of each approved observation (instrument modes, signal-to-noise ratio).

Basically, amalgamation is the process by which several (independent) observations with similar attributes (sources in the same FOV, instrument configuration etc.) can be linked within the ISOC database such that the scheduling of a single observation, the so-called "core observation", is regarded as the scheduling of all of the originally approved observations.

The following criteria and steps to create a proposed amalgamation will be used by ISOC:

- After the TAC process, the proposal database will be scanned to find candidates for amalgamation.
- The target (pointing or dither) for the "core observation" is that for the longest observation of a group of candidates.
- The duration of the "core" observation is that requested for the longest candidate, and is sufficiently long so that off-axis corrected durations for all observations (included in the amalgamation) are consistent with their requested on-axis duration, i.e. there will be no degradation in signal-to-noise.
- The TAC recommended scientific grade of the "core" observation will be as high as or higher than the grades of all other observations in the amalgamation.
- All sources are within the fully coded FOV for the main instruments (SPI, IBIS).
- There are identical modes for all four instruments (JEM-X: primary mode only), except where the observer has set "data not required" or deselected "prime" (see Proposal Generation Tool PGT in Section 5.1). Then the selected mode for that observation and instrument can be ignored.
- There are restrictions in the combination of dither patterns which can be amalgamated with each other. They are described in Table 5.
- Fixed time observations may not be amalgamated with each other.

ISOC will generate a list of proposed amalgamations from the database of accepted proposals. These will be presented to the Project Scientist for endorsement. However, it should be noted that during routine operations, the ISOC may have to de-amalgamate observations if an observing mode of an observation has been modified and then re-amalgamate afterwards. Proposers will be notified by the ISOC if their observations have been amalgamated. The reader is also referred to the AO document "*Annexe: INTEGRAL Science Data Rights*" for data rights on multiple sources in the FOV.

Table 5: Allowed combinations of dither patterns in amalgamation.

S/c observing mode	Hexagon	Rectangular	Staring	No preference [4]
Hexagon	No	No	No	**Yes**
Rectangular	No	**Yes**	No	**Yes**
Staring	No	No	**Yes**	**Yes**
No preference [7]	**Yes**	**Yes**	**Yes**	**Yes**

[4] "No preference" means that the observer has not specified a dither pattern or staring mode. Although this is technically possible it may not be useful from a scientific point of view.

4 The INTEGRAL Science Ground Segment

4.1 Introduction

The INTEGRAL science ground segment consists of the ISOC and ISDC and is shown in the lower part of

Figure 5.

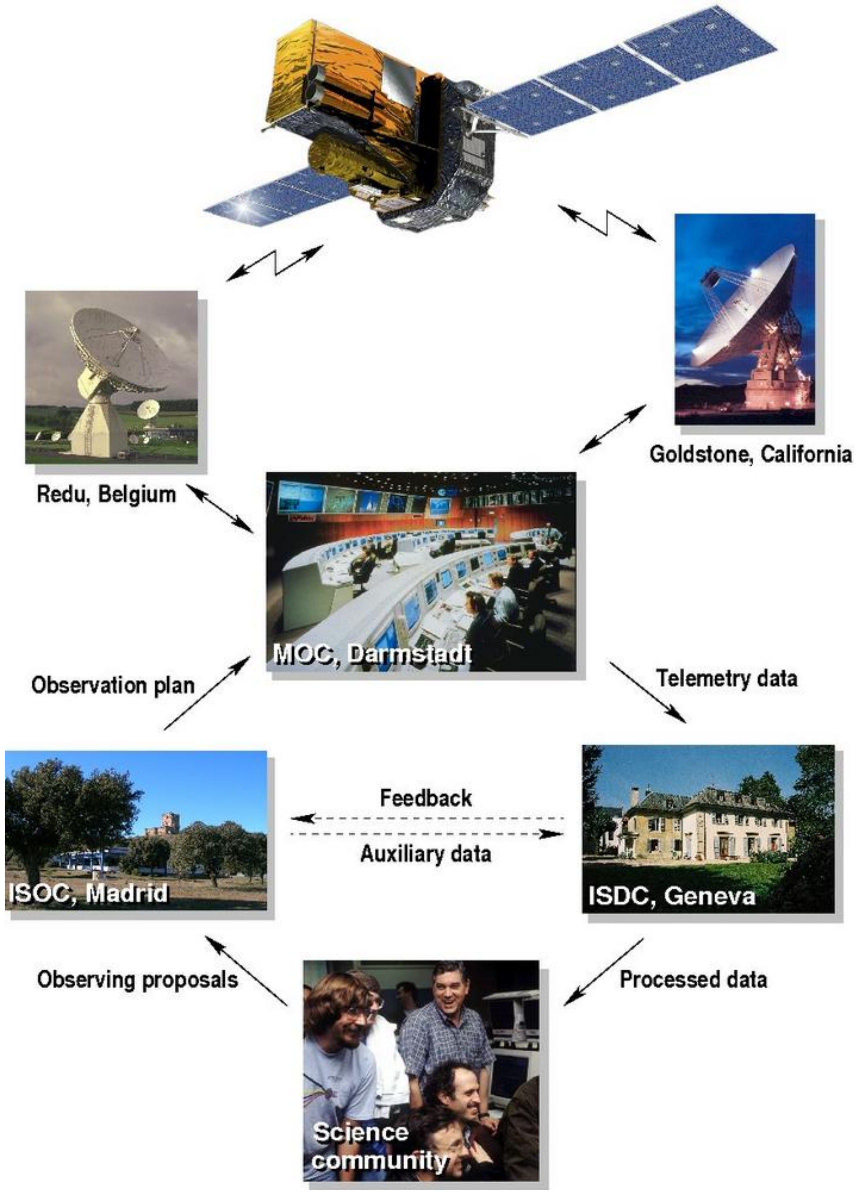

Figure 5: The INTEGRAL ground segment.

Basically, the ISOC receives observing proposals and processes the accepted proposals into an optimised observation plan which consists of a time line of target pointings plus the corresponding instrument configurations. The ISDC receives the science telemetry plus the relevant ancillary spacecraft data from the MOC. MOC's prime responsibility is the operations of the spacecraft and payload. Taking into account the instrument characteristics the ISDC converts these raw data into physical units and generates standard data products. ISDC archives the data and products and distributes them to the science community. ESA also maintains a copy of this archive at the ISOC.

4.2 Science ground segment support for proposers and observers

The INTEGRAL ISOC WWW site at http://integral.esac.esa.int/ provides access to important information for proposers and observers, in particular on:

- INTEGRAL Announcement of Opportunity (AO)
  - AO Announcement
  - AO Documentation
  - Proposal support tools: Proposal Generation Tool (PGT), Observing Time Estimator (OTE), Target Visibility Predictor (TVP)
  - Links to (mainly high-energy) astronomical catalogues.
- INTEGRAL Target and Scheduling Information
  - Scheduling Information
  - Long and short term scheduling
  - Approved Target List
  - ISOC & ISDC data archive.
- INTEGRAL Helpdesk and Frequently Asked Questions.

There is one central helpdesk handling all questions (received via e-mail at inthelp@sciops.esa.int or submitted on the web from http://integral.esac.esa.int/helpdesk/) related to the INTEGRAL mission. The INTEGRAL helpdesk is organized such that those questions on proposals, observing modes, scheduling and on INTEGRAL in general are handled by ISOC staff and questions on INTEGRAL data, analysis software, instrument calibration and data shipment are handled by ISDC staff. This split is transparent to the user of the help desk, however. A list of frequently asked questions (FAQ) will be maintained on the ISOC and ISDC WWW pages.

The INTEGRAL science analysis software is available together with documentation and test data for download from the ISDC Web page at http://isdc.unige.ch/index.cgi?Soft+download. Further information on ISDC user support is provided in Section 4.4.

4.3 From proposal to observation: ISOC

4.3.1 ISOC responsibilities

The INTEGRAL Science Operations Centre ISOC (**http://integral.esac.esa.int**/) was relocated to the European Space Astronomy Centre (ESAC), Villafranca, Madrid, Spain at the beginning of 2005. ISOC is responsible for the definition of scientific operations including the instrument configuration for each observation, the mission planning and implementation of the observing programme. In summary, ISOC:

- is preparing AOs for observations, receives the proposals and assess their technical feasibility and makes technical assessments available to the Time Allocation Committee.
- is responsible for the mission planning (scheduling) and implementation of the observing programme.
- is responsible for the definition of scientific operations including the instrument configuration for each observation.
- decides on TOO follow-up observation upon the receipt of an alert for Targets of Opportunity in order to change/interrupt the observing program (responsibility of Project Scientist).
- keeps an archival copy of all scientific data as created and maintained by the ISDC.

The ISOC newsletter (http://integral.esac.esa.int/newsletters/) is an important communication link between the ISOC and the user community.

4.3.2 Proposals

4.3.2.1 Observing proposals and proposals associated with the Key Programme

General Observers submit their proposals in response to a Call for Observing Proposals, or Announcement of Opportunity ("AO"), issued by ESA (i.e. ISOC) at regular intervals during routine in-orbit operations. For the available observing time and their distribution among the various programmes, we refer to Section 1.6. Proposals written in response to an AO must reach ISOC before the calendar deadline announced in the AO documentation (see Section 1.2); the only exception is for requests to observe newly identified "Targets of Opportunity" which can be submitted to the ISOC at any time (see Section 3.2.3).

As noted in Section 1.7, new in AO-4 is the Key Programme. Therefore, we now distinguish between normal observing proposals (as in AO-1 to AO-3) and proposals associated to the Key Programme.

4.3.2.2 Observing proposals

An observing proposal must contain details of the proposed observations (e.g., target information, instrument modes requested and observation duration) as well as a scientific justification. The TAC will evaluate each proposal on the basis of its scientific merit using also the entries entered with the Proposal Generation Tool (PGT). Each proposal is evaluated against the observation duration entered by the PGT and not what is written in the scientific justification. In case zero or unrealistically small observation durations (so called “hitch-hiker” observations) are specified, the scientific goals won’t in general be achievable and the proposal would have to be rejected. This applies also to “survey proposals”, which are of the nature “*I want the data of all observations with sources from the supplied list/or from all observations with sources of type X in the FOV, but do not request any extra observation time*”, unless the proposer has a very convincing justification, why this kind of research cannot be done using public data from the archive. Each requested observation for each target of a proposal must be entered into the proposal by the PGT, otherwise it is not considered by the TAC for evaluation. This means, targets only listed in the scientific justification and not entered into the proposal by PGT are not considered during the TAC evaluation. General Observers (i.e. the PIs) can request a PGT compatible version of their own proposal submitted in response to an earlier AO via the INTEGRAL helpdesk. This is very useful in case of long lists with targets and saves re-entering all the observation information

Instructions on downloading and using PGT and other supporting tools are given in Section 5.

4.3.2.3 Proposals associated to the Key Programme

Proposals which are to be associated with the Key Programme (see Sections 1.7, 3.2.4 and 7.8) are not treated exactly the same way as the normal observing. Once a proposal has been selected within PGT to be associated to the Key Programme some choices are blocked (see Section 7.8 and the “*PGT User’s Manual*”. The targets one wishes the data rights for, must be entered into PGT, their location is crucial for acceptance (see the “*AO-4 Key Programme*” document). Targets only listed in the scientific justification and not entered into the proposal by PGT are not considered during the TAC evaluation.

As for normal observing proposals, a science justification is required, which will be evaluated by the TAC mainly on its scientific merit. The science case must demonstrate that the time accumulated during observations of the Key Programme at the target’s location meets the scientific objectives, and why this kind of research cannot be done using public data from the archive.

For further details we refer to the document “*AO-4 Key Programme*”.

4.3.3 Proposal handling and Time Allocation Committee (TAC)

After the deadline for an AO, ISOC will perform a technical feasibility of the submitted proposals using the Target Visibility Predictor and the Observing Time Estimator, and forward the proposals to the Time Allocation (TAC) for scientific assessment.

The proposals are reviewed by a single international Time Allocation Committee (TAC). This committee consists of three panels, covering the range of scientific topics addressed with INTEGRAL:

- Compact objects: including black-hole candidates and neutron-star binaries, pulsars, isolated neutron stars and galactic jet sources.
- Active Galactic Nuclei: including AGN, Seyferts, Blazars, quasars, but also normal galaxies, clusters of galaxies and cosmic background.
- Nucleosynthesis and miscellaneous: including supernovae, supernova remnants, novae, Wolf-Rayet stars, diffuse (line) emission, inter-stellar phenomena, gamma-ray bursts, gamma-ray burst sources and anything not in the two categories given above.

Based on the results of the assessments, TAC will recommend approval of either an entire proposal (i.e. all requested observations), or part of a proposal (some of the requested observations, and possibly with reduced observation time), or rejection of the entire proposal. In addition, all accepted observations (normal, fixed-time and TOO) will receive from the TAC a scientific grade (A is the highest, C is the lowest) and, within each grade, a final mark (100 is the highest, 10 is the lowest). The TAC will be advised to allocate time for an oversubscription of about 1.5 to increase scheduling efficiency. This means that not all proposals accepted by the TAC can be scheduled within the AO. Where possible, preference will be given to higher graded proposals.

GRB proposals and proposals associated with the AO-4 Key Programme (Sections 1.7 and 3.2.4) will be evaluated normally by the TAC (see previous Section). However, they only receive a final mark and will not be graded A-C, as they have no scheduling priority of their own.

The TAC will be advised to accept only a limited number of proposals for Targets of Opportunity (about 1 per month). The reason for this is that the scheduling of TOO observations will reduce the efficiency of the mission, since it upsets the pre-planned schedule of the observatory (see also Section 3.2.3).

Following the TAC assessment, and endorsement of the TAC recommended observing programme by the ESA Director of Science, a database of approved observations and associated details is created and maintained by ISOC. This data base contains both GO and Core Programme observations. A subset of these data is made available to the ISDC. ISOC will communicate to the proposer the ESA endorsed decision of the TAC, and in particular, for the successful proposer, ISOC will communicate the TAC approved observations.

4.3.4 Scientific mission planning

This section describes the scientific mission planning including execution of observations, scheduling and re-scheduling.

During routine observations, ISOC generates and maintains detailed observing schedules based on the approved observations (both from the Core Programme and the General observing Programme), and delivers these schedules to MOC for uplink and execution. The ISOC scheduling takes into account: celestial viewing constraints; the need for high efficiency (i.e. time spent usefully observing versus slewing); the need for high scientific value observations (as determined by the TAC-assigned grade); and any special requirements (e.g. fixed-time observations). One important feature is that a number of INTEGRAL observations may be rather long, in fact too long to be scheduled as an unbroken block of time, and ISOC has to schedule them as several separate exposures. In addition, both ISOC and MOC provide details of the "live" schedules to ISDC.

Re-scheduling is usually associated with the need to drastically change the pre-planned sequence of observations/operations which is foreseen in cases of:

- instrument/spacecraft anomaly
- declaration of a TOO
- previously unforeseen (planned) ground station outages.

Re-planning at MOC is foreseen at a maximum frequency of once per orbit. The MOC reaction time of (typically) 8 hours from receipt of the ISOC request and execution of the related command schedule applies only for re-planning due to TOO's (see Section 3.2.3) and anomalies. Any other re-planning, e.g. optimization of instrument configuration, is generally implemented by MOC in the next revolution following the request from ISOC, assuming that this revolution will start more than 8 hours in the future.

When an exposure has been performed on-board the spacecraft, MOC forwards the telemetry to ISDC for processing. There is a return loop for ISDC to inform ISOC if any or all of a scheduled exposure did not yield useful scientific data, in which case re-scheduling can be considered by ISOC. Note that an abnormally high background level (due to e.g. solar activity) will not be regarded as a reason to regard the data as "bad". However, if the prime instrument is switched off for any reason then that time will be regarded as "bad", and re-scheduling will be considered if "bad" time makes up a significant fraction (>15% of the total approved time) of the observation.

ISOC regularly informs ISDC which fraction of a full observation has been completed by successful exposures. When a certain fraction of an observation (usually the whole) has been completed, and the data have been processed, ISDC ships those data to the observer.

An observer has sole proprietary data rights to his/her source for one full year after those data have been shipped (see also AO document "*Annexe: INTEGRAL Science Data Rights*" for further details). After that period, the data are public and anyone may request access to them via the ISDC archive.

4.3.5 INTEGRAL archive at ISOC

ISOC offers an alternative and complementary method of accessing public INTEGRAL data to the already established archive maintained by the ISDC, see Section 4.4.8. The ISOC Science Data Archive (ISDA) can be found at http://integral.esac.esa.int/isda. It uses the same browser technology as that developed for the XMM-Newton Science Archive (XSA) and the ISO Data Archive (IDA). It is a highly flexible system of browsing and downloading the data and products, either at the level of observations, individual dither pointings, or so-called observation groups. A choice of interactive tools are available for examining data from the original FITS image file and performing simple analysis. ISOC continues to make more high-level data products available as well as improved tools to visualize these products.

4.4 From observation to data products: ISDC

4.4.1 Introduction

The INTEGRAL Science Data Centre (ISDC) (http://isdc.unige.ch/) is the link between the scientific output of the instruments on board INTEGRAL and the astronomical community. It has the task to receive, analyse and archive all INTEGRAL data and to distribute them to the observers worldwide.

The ISDC is based in Versoix, near Geneva, Switzerland since 1996. Its staff consists of about thirty scientists and engineers funded by an international consortium of twelve institutes with support from the European Space Agency (ESA). The ISDC works in close collaboration with the INTEGRAL instrument teams to ensure that the software they develop and maintain is integrated in a coherent data analysis system. The ISDC is also in contact with the ISOC and MOC.

4.4.2 ISDC responsibilities

The ISDC receives all the INTEGRAL telemetry and auxiliary data. One of its tasks is to detect gamma-ray bursts and to alert interested scientists. The ISDC is also responsible for monitoring the scientific instruments on board INTEGRAL and for finding solutions with the instrument teams to problems that might occur. By performing a quick-look analysis of the data, the ISDC is able to inform the astronomical community about the detection of unexpected features and events.

The ISDC is responsible for the calibration and conversion of raw data products into physical units. It also processes the observed data with the best set of instrumental responses in order to derive source properties in the form of images, spectra and light-curves. Finally, the ISDC is responsible for the archiving and distribution of all data and for supporting users of INTEGRAL data.

4.4.3 Data flow

The ISDC receives the telemetry of the INTEGRAL spacecraft in real-time from the MOC at a rate of ~ 113 kbits per second. This on-line telemetry is used for the real time and the quick-look analysis (Real time and quick-look analysis). Every few days, the telemetry is sent again to the ISDC on CD-ROM, as so called “consolidated data” in which all telemetry losses (e.g. at station handover) that can be recovered, have been corrected. The consolidated data are used for the standard scientific analysis (Section 4.4.5). Apart from the telemetry, the ISDC receives auxiliary data from MOC and in particular the current observing plan from the ISOC.

4.4.4 Real time and quick-look analysis

The INTEGRAL Burst Alert System (IBAS) is designed to detect and locate gamma-ray bursts (GRBs) in the field of view of the instruments within a few seconds, see Section 4.5.

Within a few hours of receipt, the data are used for instrument monitoring and a scientific quick-look analysis (QLA). The QLA compares the INTEGRAL data with the expected position and flux of known sources. The aim of the QLA is to rapidly detect bright transient sources, large flux changes in known sources and instrument anomalies. QLA results are communicated to the observers/owners of that particular observation (see "*Annexe: INTEGRAL Science Data Rights*"). The ISOC will be contacted if the detected event might be of interest for an INTEGRAL Target of Opportunity (TOO) follow-up observation (see Section 3.2.3).

4.4.5 Data analysis

The ISDC performs a Standard Analysis (SA) of each observation. This analysis results in deconvolved images of the gamma-ray sky in pre-defined energy bands, spectra of individual sources and light-curves of variable objects. The SA is designed as an automatic process, which should be completed within three weeks after consolidated data have been received by the ISDC. It is based on high level analysis software especially developed in collaboration with the INTEGRAL instrument teams and integrated into the ISDC system in order to function automatically. The results of the SA are included in the INTEGRAL Archive (see Section 4.4.8).

4.4.6 INTEGRAL data

An INTEGRAL revolution of three days (72 hours) results in a telemetry volume of 2.7 GBytes. This telemetry stream is processed and analysed at the ISDC and results in about 17 Gbytes of uncompressed data products per revolution. These data are stored in FITS files and consist of:

- **raw data** (4.5 GBytes), which are reformatted data with the same information content as the telemetry sent by the spacecraft,
- **prepared data** (7.2 GBytes) including additional timing information,
- **corrected data** (2.7 GByte) including gain corrected event energy, and
- **high-level products** (2.7 GBytes) which are the results of the scientific analysis in the form of images, spectra, light curves etc.

All these data are distributed in a compressed format (~ 9 Gbytes per revolution) to the observers (Data distribution). Proposers should be therefore aware that they need more than 10 Gbytes of disk-space to store INTEGRAL observations that last about one revolution.

The INTEGRAL data flow is cut into a series of contiguous "science windows". A science window usually corresponds to a pointing (30-60 minutes in dither modes) or a slew of the spacecraft. An entire observation consists usually of the order of some 10's to some 100's distinct science windows. Raw and prepared data are stored by science window, whereas corrected data, intermediate results of the analysis and high level data products are stored per observation. The instruments generate many types of data during each science window: these will use the hierarchical grouping convention of FITS, which is transparent to the ISDC data analysis system. Since the data will be stored in FITS files, they are not only accessible through the ISDC scientific software, but also through any other astronomical software package, provided that the data organization and the above convention are well understood.

4.4.7 Calibration overview

Although the ISDC has to deliver well calibrated results, the instrument teams are formally responsible for the calibration of their instruments (see Section 3.3). The instrument teams analyse the calibration data and their results are used by the ISDC data processing. All calibration and response files are accessible through the INTEGRAL Archive (Section 4.4.8). Concerning data rights on calibration data, the reader is referred to the AO document on "*Annexe: INTEGRAL Science Data Rights*".

4.4.8 INTEGRAL archive at ISDC

The main INTEGRAL archive, located at the ISDC, contains all INTEGRAL data from raw telemetry to the results of the SA (Section 4.4.5), as well as calibration and response files, auxiliary data and catalogues of sources. A second archive located at the ISOC contains the same data (see Section 4.3.5).

Public data in the complete ISDC archive are on-line and accessible both via an archive browse utility with a dedicated WWW interface and more directly through anonymous FTP. For FTP data retrieval, the exact name or location of the archived data has to be known. The WWW interface allows indirect querying of the ISDC database by specifying object names, coordinates, time intervals or similar parameters to identify corresponding sets of data. These data are then extracted from the archive in tar files, compressed and made ready for FTP retrieval. Data might also be distributed on hard media (Section 4.4.9). Private science data will not be accessible from the INTEGRAL archive until they become public after the proprietary period of one year (see AO document "*Annexe: INTEGRAL Science Data Rights*").

4.4.9 Data distribution

Guest observers, at the time of proposal submission, can choose if they want to receive their data via Internet transfer (FTP) or on hard media. Experience has shown that the typical download rate for data from ISDC is 1 Gbyte/hour via FTP and that the data transfer via FTP is generally smooth. Consequently, the use of hard media is strongly discouraged and re-distribution of hard media is not foreseen unless the media is defective or was lost in the mail. The data distribution occurs after ISDC has received the consolidated data from ESA, processed and archived these data off-line. The whole process takes about one month.

Note that ISDC cannot assume any responsibility for the public network capacity that might (or might not) be available to support very large data volume transfers.

It is possible for observers visiting the ISDC to have a first view of the data from their observations within a few hours. The ISDC can indeed (with the permission of ESA, note that in the case of amalgamated observations ESA will request the approval of all PIs) provide the observers access to the data of their observation at the ISDC. This possibility can be used by any observer wishing to have a first view of the data content before the distribution of the data.

4.4.10 User support and communication

The ISDC provides support to the observers with their data analysis. The INTEGRAL science analysis software is available together with documentation and test data for download at the

ISDC Web pages at http://isdc.unige.ch/index.cgi?Soft+download. Alternatively, observers are welcome to visit the ISDC for local support and direct access to data analysis tools.

The ISDC software includes scripts to repeat the standard analysis and applications to visualize the data and to manage off-line analysis. The software is available for SUN/Solaris, Mac OS/X and Linux. Due to limited resources, it is not possible to provide software running on other operating systems.

ISDC organizes regular INTEGRAL data analysis workshops. Their aim is to discuss issues on calibration and on data analysis methods, software and results.

The ISDC newsletter (http://isdc.unige.ch/Newsletter/) is an important communication link between the ISDC and the user community. Subscription to the distribution list receiving information about new releases can be done via the WWW pages.

4.5 Gamma-ray burst (GRB) handling

This section describes how gamma-ray burst (GRB) events are handled by the INTEGRAL ground segment. The entire data from GRBs are collected and treated as any TOO event described previously (Section 3.2.3), however three areas connected with the GRB phenomenon are treated specially:

- GRB position, trigger time, if available duration and flux estimate to facilitate rapid follow-up observations.
- GRB time histories from the SPI ACS subsystem to support the Interplanetary Network (IPN).
- Fast uplink of special OMC sub-window.

These areas are described below in more detail.

4.5.1 GRB position and trigger time

INTEGRAL has no GRB detection and triggering system on board. However, it continuously downlinks its acquired data to Earth allowing for constant, near real-time, monitoring. At the ISDC all data are automatically analysed to detect any transient events. In addition, a fast analysis is performed by the INTEGRAL Burst Alert System IBAS. This “on ground” approach to detections not only allows for the application of larger computational power than available on-board a spacecraft, but also permits the implementation of several detection algorithms running in parallel.

After receiving the INTEGRAL telemetry at ISDC, the IBAS relevant data are extracted and fed into the attitude determination and into the several detection processes running in parallel.

As soon as a GRB candidate event is detected, it must pass a verification process and a final screening, which is additionally in charge of spawning a more detailed off-line analysis of the burst. The GRB position, trigger time, flux and duration then reach the alert generation process, and the information is broadcast electronically. The rate of GRBs is about one burst per month within the IBIS and SPI FOVs. Localization accuracy is a function of the event’s S/N ratio, the spacecraft attitude and stability (e.g. during slews), the angular resolution, and whether the event took place in the fully or partially coded FOV. Naturally, the first alert broadcast message has rather crude information, e.g. the positional information is based on predicted attitude information rather than the reconstituted one. Therefore subsequent alert messages are sent out to subscribers with improved information, both on position and source characteristics. In order to facilitate rapid follow-up observations (e.g. using XMM and Chandra), data describing the GRB peak (2-200 keV, 1 sec), fluence (20-200 keV), lightcurve (20-200 keV, plot only) and GRB duration (sec) are also publicly available. For further details, see http://isdc.unige.ch/index.cgi?Soft+ibas.

Alerts with the coordinates of GRBs are distributed through internet sockets for robotic telescopes using the UDP transport protocol. The required software can be requested from ISDC. Email alerts are distributed via GCN circulars. The typical uncertainty is smaller than a few minutes. The IBAS GRB detection and alert distribution are mostly based on automatic processes. The interactive analysis, to confirm the event and to derive the most accurate GRB position, is generally performed within a few hours after the automatic delivery of the first alert message(s) with the preliminary coordinates.

In operating an automatic GRB alert system, there is a trade-off between the requirement to react in the shortest possible time and the desire to get the most accurate results (e.g. reality of the event, dimension of error region, etc.). Considering that the main users of the IBAS Alerts are robotic telescopes with large fields of view, specifically devoted to GRB afterglow searches, the fast alert time requirement is favoured. Users must be aware that this implies that some of the IBAS alerts might subsequently be found not to be related to real GRB events. Users not interested in the fastest reaction time can decide to subscribe only to particular Alert Types.

4.5.2 GRB data from the SPI anti-coincidence (veto) subsystem

INTEGRAL is a satellite well suited as the Interplanetary Network’s near-Earth node providing large area detectors. As an optimised input to the IPN, SPI’s anti-coincidence shield (ACS, see *Instrument Observer’s Manual (SPI)* for more details) collects GRB data in time bins of 50 ms, time-tagged to an accuracy of 1 ms at energies above ~ 50-100 keV. Thus the data of about 300 (5σ) bursts per year, located mainly perpendicular to the instruments’ FOV usefully contribute to the IPN.

These time series (contained in the instrument housekeeping data stream) are also provided via the ISDC GRB alert system to the scientific community and are as such immediately publicly available.

4.5.3 OMC window handling in case of a GRB alert

Due to the limitation of the downlink data rate, it is not possible to down-load all OMC data. Thus it is necessary to pre-define specific OMC CCD sub-windows for routine observations (see "*OMC Observer's Manual*" for details). It is possible that a GRB (detected by IBIS via the ISDC alert system) is in principle observable by the OMC as it is taking place in its FOV, but that the pre-selected sub windows (selected prior to the observation) do not cover it. To enable GRB monitoring by the OMC it is necessary to rapidly command one special sub-window (covering the GRB location) that replaces all pre-defined sub-windows for the duration of the on-going (dither) pointing only (i.e. <= 60 minutes), i.e. until the next set of pre-defined OMC sub-window commands (for the next dither pointing) will be uplinked. Because GRB events are short-term events, the number of involved ground-segment elements has to be minimized in this process.

In order to allow a near real-time implementation of the required new OMC window commands the required functions are split between ISDC and MOC only. In summary the ISDC software:

- identifies a GRB from IBIS near real-time science data
- identifies a GRB location within IBIS detector co-ordinates
- converts IBIS detector co-ordinates to OMC detector co-ordinates
- checks whether location is within OMC FOV
- provides necessary input to MOC only if previous check is positive

Upon receipt of this message, MOC

- accepts and checks (syntactical) correctness of input
- generates necessary telecommands
- uplinks necessary telecommands

The whole process has been successfully used in flight.

The size of the new uplinked OMC sub-window is (91 × 91) pixels. The data collected from all other pre-defined sub windows during that pointing (only) are lost. It is estimated that the new OMC sub-window will be effective about one minute after the detection of the event (nominal case). It is noted that this mechanism has been established only to provide the described functionality for the OMC. As it violates some of the basic mission principles including safety related features it can not be applied for other cases. No other commands (especially to AOCS) are being sent in response to a GRB.

5 Proposal Submission Procedure and Tools

5.1 Proposal generation tool (PGT)

Proposals must be prepared and submitted electronically (no paper copies) using the Proposal Generation Tool (PGT) software. Other formats will not be accepted!

ISOC makes PGT available through its WWW pages (http://integral.esac.esa.int/). The PGT software allows the preparation, editing, printing and submission of INTEGRAL proposals. The scientific justification for the proposals should be attached (through a PGT button) to the proposal, and submitted electronically together with the rest of the proposal. The scientific justification should not be more than five A4 pages, including figures and tables. The PGT software is written in JAVA and must be downloaded and run locally on the observer's computer. Installation scripts are provided with the software. The user should make sure that the correct version of the JAVA run time libraries are installed (see PGT readme file for details).

Prospective proposers may wish to 're-use' their old proposals from earlier AO's, updating them as necessary for AO-4. However, PGT has been modified for AO-4 and the old proposals are no longer consistent with the new software. To support the community in this, the ISOC will, on request only, generate a copy of an old proposal in the new format (consistent with the AO-4 PGT), and send it to the proposer. A proposer should send such a request to the INTEGRAL helpdesk, quoting the Proposal ID of the relevant proposal. *ISOC will only send a proposal back to the original PI.*

5.2 Observing Time Estimator (OTE)

The Observation Time Estimator (OTE) is available via the same ISOC WWW webpage (http://integral.esac.esa.int/) as PGT.

The OTE is the only official way to calculate the observing times for the two main INTEGRAL instruments (SPI and IBIS). It is also used by the ISOC for the check of the technical feasibility for all observations (see Section 4.3.3). Observers are therefore strongly advised to use the OTE to calculate requested observing times, since it is imperative that sufficient information is provided in the proposals to allow feasibility checks to be performed by ISOC.

5.3 Target Visibility Predictor (TVP)

In principle, any point on the sky is visible for INTEGRAL, however due to the constraints listed below, not at any point in time. The INTEGRAL Target Visibility Prediction (TVP) tool can be used to calculate visibility constraints for each celestial source taking the below constraints into account with exception of the SPIBIS effect, which is only considered at the scheduling level. The TVP tool is available via the same ISOC WWW webpage (http://integral.esac.esa.int/) as PGT and OTE.

5.3.1 Sun and anti-sun viewing constraints

TVP respects the constraints on the solar aspect angle (SAA) of the spacecraft, which are described in Section 2.2.3. As a consequence of this constraint, the sun cannot be observed, at any time.

5.3.2 Earth and Moon viewing constraints

In order to ensure correct functioning of the spacecraft star trackers (see Figure 1), which are co-aligned with the instruments pointing axis, the spacecraft has to point at least 15^{o} away from the Earth and 10^{o} away from the Moon limb during normal observations. TVP therefore includes these constraints.

Note that observations of the Earth have been performed in AO-3, but such observations require elaborate non-standard mission planning and execution and cannot be performed as part of the routine operations.

5.3.3 Other constraints

Nominally, scientific observations will be carried out while the spacecraft is at least at an altitude of 40,000 km. However, analysis of the on-board radiation environment monitor is used to adjust this constraint as described in Section 2.2.3.

No observations will be performed from 30 minutes before an eclipse (i.e. when INTEGRAL is in the Earth shadow with respect to the Sun) until 30 minutes after an eclipse.

A special constraint is imposed on the scheduling of observations by IBIS. If a very bright source (Crab, Cyg X-1 and Galactic Centre) is positioned 30-50 degree off-axis within a narrow azimuth angle range around the spacecraft Z-axis the bright source casts a shadow of the SPI mask onto the IBIS detectors. This so-called `SPIBIS' effect can be avoided for the specific observation by excluding time periods from scheduling, where the bright source lies within the critical area. Currently, the ISOC avoids scheduling observations during periods where the SPIBIS effect occurs. More details can be found in the "*IBIS Observer's Manual*".

5.4 Software Updates

Proposers are strongly recommended to verify that they always work with the latest version of this software in addition to the latest versions of the entire AO documentation. The ISOC will try to avoid any updates to these software tools (PGT, OTE, and TVP) and the documentation between the issue of the AO and the deadline for proposals. However it cannot be excluded that an update is necessary. Users are therefore strongly advised to sign into the email distribution list for updates of the ISOC provided software and documentation. Signing up to this list can be done by sending an email to the INTEGRAL helpdesk (inthelp@sciops.esa.int) containing the text "update distribution list" in the subject line. Observers who have signed up to this list in earlier AOs do not need to re-apply. For questions on the instruments, the AO and any other query that has to do with INTEGRAL, observers can make use of the INTEGRAL helpdesk mentioned above (see Section 4.2).

5.5 Proposal Deadline

Proposals must reach ISOC by **Friday April 21, 2006 at 15.00 CET (14.00 GMT)** at the latest.

In order to aid proposal submission, in Section 7 we provide a description of the proposal format, and a checklist of scientific questions and proposal submission procedures.

5.6 Proposal evaluation and selection

The INTEGRAL proposals will be assessed mainly on their scientific merit by a single international Time Allocation Committee (TAC). Details of the TAC panels and decision making process are given in Section 4.3.3.

The TAC is advised not to accept observations that simply duplicate (as opposed to enhance) the scientific results obtained from the Core Programme, or the executed AO-1, AO-2 and AO-3 programmes. Proposers are thus strongly advised to carefully check any possible duplication of their observations. This can be done by accessing the INTEGRAL target list. The list can be accessed via the ISOC home web page, by clicking on either ‘Observing Programme’ or ‘Approved Target Lists’.

The TAC recommends the AO-4 programme to the ESA Director of Science, who will take the final decision on acceptance. Then ESA will notify the proposers of the decisions. The decisions on acceptance or rejection of a proposal are final and non-negotiable. Reasons for the rejection of a proposal can be provided on request to the INTEGRAL helpdesk.

5.7 Ongoing modifications to the observing programme

During in-orbit operations changes to the instrument performances may occur. In addition, the instrumental background varies with the Solar cycle since, at Solar minimum, the Sun’s magnetic field can propagate more easily into the inner Solar System. These changes may influence the integration time required for the observations. The effects of any such changes on the instrumental performance are routinely monitored. If the expected changes in integration time or signal to noise are significant, the observers will be notified, the TAC chairman will be consulted, and the integration times modified by ISOC. In principle once an observation is approved it would not be subsequently rejected if the required integration time increases, provided of course that the observation is still feasible.

Note that not all changes will be allowed after the proposal has been approved. Examples of changes that are not allowed are (see Section 2.4 for a description of the observation modes):

- Change of source or pointing for an observation.
- Change from normal observation to fixed time observation.
- Change from normal or fixed time observation to TOO observation.
- Change from TOO observation to normal or fixed time observation.

6 INTEGRAL Data

6.1 Data products and distribution

The ISDC will be in charge of the processing and distribution of INTEGRAL data (see Section 4.4.9). The data will be distributed either on hard media or (preferably) via the internet. The proposer can specify his/her preferred means of data distribution in the "Admin details" panel of the Proposal Generation Tool. The selection of a data distribution medium is mandatory. The proposer also should specify here the address the data should be sent to, if it differs from the PI's address.

6.2 Data rights and publication

In accordance with ESA's policy for scientific missions, all scientific data remain property of the observer for one year, and they will be publicly available through the archives one year after they have been processed and dispatched to the observer by the ISDC. However, due to some important science objectives addressed by INTEGRAL (e.g. Targets of Opportunity) and because of some design aspects of the payload in particular, i.e. the large field of view of the INTEGRAL instruments and the nature of coded mask instruments (all data of the entire field are needed to reconstruct the image of the sky), the data rights for INTEGRAL have been detailed for a number of cases, including amalgamations and multiple sources in the field of view, and in line with INTEGRAL's Science Management Plan. These are described in a separate document ("*Annexe: INTEGRAL Science Data Rights*").

Proposers are informed that publications making use of INTEGRAL data should acknowledge via a footnote to the title, on the title page containing a text as shown below:

"Based on observations with INTEGRAL, an ESA project with instruments and science data centre funded by ESA member states (especially the PI countries: Denmark, France, Germany, Italy, Switzerland, Spain), Czech Republic and Poland, and with the participation of Russia and the USA."

6.3 Source Naming Convention

A unique source naming convention for new sources detected by INTEGRAL has been established in agreement with the IAU. Source designation are IGR J*HHMMm+DDMM* or IGR J*HHMMm-DDMM* (equatorial coordinates, epoch J2000), where *HHMMm* is the right ascension of the source in hours, minutes and fractions of a minute, and *DDMM* is the declination of the source in degrees and arcminutes. Coordinates must be truncated, not rounded, to comply with this convention.

7 Appendix: Proposals - format and checklists

7.1 Introduction

The only interface for submission of proposals is the PGT software. Since the PGT software formats the proposal, based on the inputs given by the observer, no specific format will be given here. Instead some general information and rules for the inputs to PGT are given here that may help the observer writing a proposal. For more details we refer to the "*PGT User's Manual*".

7.2 PGT inputs

The PGT inputs are split into several screens:

- The main screen, where the Proposal ID can be entered.
- The Admin Details screen, where the administrative details of the PI and Co-Is need to be entered (e.g. names, addresses etc.)
- The Proposal Details screen, where detailed information for the entire proposal is given (title, abstract, category and scientific justification). The scientific justification (see below) is to be added as an attachment to the proposal.
- The Observation Details screen, where the detailed information for each observation is given.

The Proposal ID is only needed when re-submitting proposals (because of updates). The Proposal ID is assigned by the Proposal Handling System at ISOC and will be sent to the observer by email upon first time submission and successful reception of a proposal.

7.3 Target coordinates

While ISOC will perform some checks on the fidelity of the source coordinates, it is the ultimate responsibility of the proposer to make sure that the (epoch J2000) coordinates entered into PGT for the target are correct. (PGT performs a validation of the coordinates using SIMBAD given the source name entered in the proposal; a warning only is given if the values of the coordinates do not match those returned by SIMBAD). Since changes to the source or pointing are not allowed after TAC approval (except obvious errors discovered by the proposer), observations for which target coordinates are wrong could be lost. Proposals for new (unknown) TOOs or GRBs in the field of view may use coordinates (0,0) in PGT.

7.4 Scientific justification

The scientific justification has to be written in English and should be attached to the proposal in the Proposal details panel (using the "New Attachment" button at the bottom of the page). The attached file should preferably be a PDF file. In case PDF format is not possible, a postscript file is also acceptable. The justification should use A4 paper format, and a maximum of 5 pages is allowed (including figures and tables). In addition, the font size must not be smaller than 10-point.

The Observation Details panel in PGT allows only a small amount of information on the source flux to be entered in the proposal. In many cases this may not be sufficient information to judge the technical feasibility of the proposal. In those cases the proposer is advised to give details on fluxes, spectral shape, line strength, line width etc. for his sources in the scientific justification. These details will be taken into account by ISOC when doing the technical feasibility check.

Only targets included in the PGT input will be considered for approval. Observations mentioned in the text of the justification or abstract but not entered into PGT will not be accepted.

7.5 Integration times and gamma ray burst observations

For all observations other than association to a Key Programmes (see Section 1.7) proposers have to specify an integration time in PGT (this is a mandatory field in PGT and cannot be left blank). In general the integration time should be calculated using the Observing Time Estimator software (OTE), which will calculate how much time is required to achieve a given significance for a given flux. ISOC will use the same software to perform the technical feasibility checks on the proposals.

The situation is different for observations of gamma ray bursts in the field of view. The duration of these events (of the order of 100 seconds), and the possible afterglow (few hours), is short compared to the typical duration of an INTEGRAL observation. Also these cannot be treated as normal TOO follow up observations, since no re-pointing of INTEGRAL is possible on these very short time scales. Observers interested in data of gamma-ray burst sources in the field of view therefore cannot estimate their integration times using the OTE, since they are basically interested in receiving data for a period of time around the gamma ray burst event. However, OTE can still be used to estimate the minimum detectable flux in a given energy band with the SPI and IBIS instruments, thus giving a possibility to predict the detectability of a gamma-ray burst. When proposing for gamma ray bursts in the field of view proposers therefore should specify in PGT the period of time for which they want to receive the data of the gamma ray burst. This can be before and after the event (the split between the time before and after the event needs to be specified in the scientific justification).

7.6 TOO and fixed time observations

For Targets of Opportunity (TOO) and Fixed Time observations, the proposer has to fill in a short justification for each observation in PGT in addition to the scientific justification for the proposal. These justifications must be entered in the appropriate window in the PGT observation details screen. For TOOs this should specify why this observation should be regarded as a TOO, and when the TOO should be triggered (flux levels etc.). Note however that it is ultimately the responsibility of the proposer to inform the Project Scientist that the TOO target has become active and should be observed (for TOOs discovered in the field of view of INTEGRAL and for which a proposal exists, the proposer will be informed that this TOO is active, after which the proposer decides whether to activate the TOO follow-up observation or not). The TOO alert form on the ISOC web site should be used only to request that a TOO be scheduled. The form can be found at the 'Target of Opportunity Alert' link on the ISOC home page, or directly via the URL:

http://integral.esac.esa.int/isoc/html/too/my_too_alert.html.

For fixed time observations the proposer needs to specify in the justification, why a fixed time observation is required, and when the fixed time observation should be performed, if already known. This information will be used by ISOC to determine when to schedule the observation. Note that for fixed time observations, for which a time or date for the observation is already known, it is imperative that the proposers check the visibility of their sources using the Target Visibility Predictor for the dates and times they want their observation to be performed.

The reader is also referred to the discussion on TOOs in Section 3.2.3.

7.7 Coordinated observations with other facilities

ISOC will support coordinated observations with other facilities. Proposers are particularly encouraged to apply for coordinated observations with XMM-Newton where appropriate.

Proposers who want their observation to be coordinated with another facility should enter it as a fixed time observation, specifying as reason for the fixed time that it is coordinated with another observatory (specifying also which observatory). Through contact with the observer the ISOC will try to accommodate the coordinated observation. Necessary contacts with other observatories are ultimately the responsibility of the proposer; however the ISOC mission planners are in regular contact with mission planners on other missions such as RXTE, XMM-Newton, Suzaku and Chandra. Note however that due to visibility, scheduling and other constraints it may not always be possible to accommodate fixed time observations. Also, since INTEGRAL observations are in general long, it may be easier for other observatories to follow the INTEGRAL scheduling (especially ground based observatories).

7.8 Association with Key Programme

Proposers who wish their proposal to be associated with an INTEGRAL Key Programme (KP) should check the checkbox “Associate with Key Programme”. Note that in AO-4 there is only one KP, but it is expected that in future AOs several will be available.

The KP pointings and instrument configurations are pre-defined so the only information the user has to provide is related to the target source he requests data from. Therefore certain information in the “Observations Details Panel” will be blocked for this type of proposal, e.g. instrument settings and dither pattern selection.

7.9 Checklist for the proposal

The proposal text must contain at least the following three items:

- the scientific case
- the observation strategy
- demonstration of the feasibility of the observations

The proposal should be checked against the following questions:

- Is your science justification complete? Does it contain the mandatory three sections mentioned above?
- Have you filled in the Observations Details Panel for *all* observations of *every* source in the proposal?
- If your observation has any scheduling constraints, have you marked it as a fixed time observation in PGT?
- If your proposal is for gamma-ray burst data, have you supplied the trigger criteria and the time interval of the data you request?
- If your proposal is for Key Programme data have you selected the button labelled "Submit as Key Programme Association"?
- If you are not using the standard 5 x 5 dither, have you justified the use of the alternative dither pattern?
- If you plan to observe a region of the sky which will be observed in the Core Programme, or has been observed in the Core or Open Time programmes, have you explained what new science will be addressed by your proposed observations?
- Why can your programme only be done with INTEGRAL? If so, why can't it be done using archival data?
- Have you checked the latest news on the INTEGRAL WWW?