"OPTOS: A pocket-size giant"
(MISION, OPERATION & EVOLUTION)

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Small platforms following the Cubesat standard have been of great use to allow space access to academic institutions; however most of these small platforms do not provide enough reliability or operability for larger purposes such as Earth observation, scientific research or communications. Due to this, there has been identified the need to develop a space system that counts with the benefits of size and budget of nano/pico-satellites, but with improved payload capacity, system reliability and mission life time for more ambitious projects. Such system is under design currently, and its demonstrator will be launched in Q3 2009 under the name of OPTOS. This project counts with several payloads that will investigate fields within magnetism, radiation, and optics. The platform counts with an innovative OB-Com, based on wireless optical communications between boards, a distributed OBDH subsystem, as well as a 3-axis stabilized ADCS. This project will be a milestone in space platform design philosophy as it will enable state of the art features with the low cost, size and development time intrinsic to Cubesat missions. This will allow further development into fields such as Cubesat satellite constellations (early warning, astrophysics research, mapping, communications...) and fast chain production capabilities for space access.

INTRODUCTION

Figure 1: OPTOS external lay out and dimensions

The Spanish National Institute for Aerospace Technology (INTA) has focused a great deal of resources for over a decade on the development of small satellite platforms and technologies (Minisat, Nanosat...). One of the latest developments of this line of production is based on a small platform (3U Cubesat – 30x10x10 cm) that counts with state of the art technologies serving its subsystems, enabling a high efficiency low cost multipurpose satellite, which will allow industrial/agency level research applications at manageable budgets. As a demonstrator, OPTOS will be launched in Q4 2009 housing four payloads on board oriented towards scientific research of materials, technologies and space environment in the fields of magnetism, radiation and optics.

The goal of this project is to allow easy and rapid access to space to the national or international scientific community. For this reason, only a platform with maximized reliability and operability can be accepted in order to implement in it the various high end engineering concept developments and cutting edge scientific research undertaken at INTA to be tested in space. This design concept will allow INTA availability to research technology and science in orbit in a platform whose cost will be increasingly lower and times of development shorten at every launch.

This first satellite of an upcoming family, counts with advanced subsystems that should enable a smooth operability, including innovative concepts such as On Board Communications based on wireless optical signals (being the first satellite world wide to use this system solely); a concept developed by INTA and already tested in space (NanoSat, Photon...) with an excellent behaviour. This OB-Com design is complemented with a distributed OBDH along the different boards of the satellite, based on programmable devices such as CPLDs and FPGAs. Refined subsystems for satellites of this class can be found all throughout, such as a 3 axis stabilized ADCS that optimizes thermal and power capabilities, while enabling the use of the camera on board (payload APIS) to be oriented as desired. This system counts with a reaction wheel, magneto-torquers, sun sensors, sun presence sensor and a 3axis magnetometer.
In order to maximize the options of success, the satellite does not only relay on robust subsystems, but benefits from a careful design philosophy. OPTOS is managed and engineered under ESA standards (ECSS) and the satellite is treated as if it were a more expensive larger satellite type, going through intensive qualifications; every unit is certified and rigorously tested. This approach may not seem cost efficient, as a large portion of the budget is oriented towards qualification and verification; however, this becomes the best insurance for the project. Further satellite developments will see its cost reduced as each component and subsystem has been already intensely tested in this first demonstrator.

![Figure 2: Axis references in OPTOS](image)

INTA has identified a need in the space industry that sooner or later was to be addressed by an agency: Fit high end technology in small platforms that can be re-launched for constant access. Further more, constellations of small platforms will provide new capabilities in space applications.

using a platform adhering to the Cubesat Standard, counting on board with a camera, hence requiring certain attitude control.

![Figure 3: Mission segments](image)

Using the Cubesat standard (developed by CalPoly University at San Luis Obispo) is not an arbitrary choice. This standard is used world wide primarily by universities and some corporations, such as Boeing, enabling a wide network of supplier for various parts that form the satellite. These suppliers have the capability of catering components at reduced price (since the design for component in a CubeSat is likely to be replicated for another one). INTA as well as the CubeSat community can benefit from the developments of components produced in mass. Standardization of components works on our benefit.

One of the challenges found when analyzing the mission is the dependence on launcher opportunities in order to define the orbit geometry (as a small satellite like OPTOS will piggy back a larger load). Different orbit types (circular, GTO...) were considered and altitudes swept throughout different options. It has been identified the need of an orbit that provides similar light conditions over any region at every pass in order to study the optics degradation of the camera on board, condition fulfilled with helio-synchronous orbits, hence this geometry has been set as a requirement in order to choose a launcher. Additionally, launchers offer this opportunities to this orbit quite often, increasing our chances to be selective on a launch that satisfies our needs.

During the first phases of the development, it was required to design for any RAAN or possible altitude since the final orbit configuration was not frozen at that point. It was determined to base our analysis and designs on worst case scenarios from a power point of view (LTDN 12:00), as well as for thermal control (LTDN 6:00) and communications (High orbits – bad for power consumption / Low orbits – bad for contact times) and developed a system that in preliminary
phases could fulfill the mission requirements within any of these scenarios.

As an example: If the orbit were to be a dusk-dawn (RAAN 6:00) the satellite will be stabilized with spinning to dissipate the incoming energy from the Sun, whilst if the orbit was noon-midnight (RAAN 12:00) the satellite will be positioned stable with respect to Sun, using the sunlit faces to warm up and the shaded ones to radiate energy. In the first scenario, the instantaneous power obtained through solar panels would be lower than the second, however no eclipse would exist whilst in the second scenario there would, therefore, total energy received during an orbit would be similar either way. Any other option in between these 2 RAAN would be considered and one solution or the other will be given.

Figure 4: Different RAANs analysis

Further in time and as the design was coming into detail, a more precise orbit had been identified based on a number of launch opportunities, freezing the analysis in an orbit with the following configuration:

<table>
<thead>
<tr>
<th>Orbit Type</th>
<th>Helio-synchronous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude</td>
<td>670 km</td>
</tr>
<tr>
<td>LTDN</td>
<td>10.15</td>
</tr>
</tbody>
</table>

Table 1: Basic orbital elements

This orbital configuration enables an orbit of 90 minute duration out of which 30 minutes are in eclipse and remaining in the Sun region. Analysis foresee no problems related to orbit decay in such conditions (estimated orbit life time: 14 years).

Freezing an orbit has enabled detail design and budgets, such as attitude control algorithms based on measurements of the magnetosphere with correlations of sun position vector (both parameters measurable through our ADCS components).

With a more defined orbit target, the orientation of the satellite was set in order to maximize one of the most critic resources of the mission: power. This satellite holds numerous payloads and demanding subsystems, hence a correct attitude with respect to the Sun became an important concern. Additionally, operational modes have been designed in order to optimize the power consumption thorough out an orbit and throughout the day, enabling the usage of resources by everyone at specific times. Operational modes are discussed further on this paper.

Although this paper will focus primarily on the Space Segment of the Mission, it is important to make note of certain characteristics of the ground segment. This segment is based around a ground station located at INTA’s main campus, in Torrejón de Ardoz (near by Madrid). The main functions of the ground will be the following:
- Tracking the satellite to determine times of contact.
- Telemetry reception and processing to know status of all the satellite (platform and payloads).
- Telemetry and transmission operations to control the different functions of the satellite, both platform and payload operations.
- Scientific data pre-processing operations and sending of scientific data to the users, in the format specified.

The general structure of Satellite Control Centre is:

Figure 5: SCC Configuration

**SUBSYSTEMS**

The platform is composed by a set of subsystems that allows a comfortable operation throughout the mission life time for all payloads on board. The design and development of most of components that form the platform has been produced at INTA, with the exception of some units who have been contracted or purchased from the private industry, in which case it will be mentioned in the document.

Attitude Determination and Control

Counting with precise attitude determinators and controllers are of importance since OPTOS counts with an Earth observation camera on board (APIS,
discussed in next chapter), hence it is required a subsystem that allows orientation to picture areas of interest and to avoid direct lighting of Sun to the lenses (light sensors would be damaged). Also, stabilization is needed to obtain pictures as clear as possible.

Our ADCS counts with the following components:

**Reaction Wheel:** Used for inertial stabilization during observation and nominal mode, avoiding direct Sun pointing. This small reaction wheel (Ø 21mm, h 12mm) has been supplied by AstroFrein (Germany)

**Magneto-Torquers:** 5 Magneto-torquers (2 x, 2 y, 1 z) provide freedom of rotation, with variant torque vector depending on time of actuation and sign of voltage used (+/-). Used for attitude transitions (observation-navigation) and to un-saturate the reaction wheel, they are installed embedded in the solar panel's PCBs, hence obtaining a considerable space saving. These components are supplied by Clyde Space (UK/Scotland).

**Sun sensors:** The subsystem counts with 2 Sun sensors placed on \(-y\) and \(-z\) faces of the satellite, allowing the Sun position determination. The location of this sun sensors have been carefully selected to assure Sun location determination constantly through our operation. These are supplied by TNO (Netherlands).

**3-Axis magnetometer:** This component gives the system the knowledge of its position relative to Earth's magnetic field. Although it is developed at INTE, this component is an improved design based on a HMC 2003, Honeywell (USA).

**Sun presence sensor:** Placed in \(+z\) axis, by the camera opening, as an alert device in case Sun incidence start occurring in that region, endangering the integrity of the camera.

The control algorithms for this subsystem are being developed by SENER (Spain)

**Electrical Power**

This satellite is power demanding due to its complexity; hence a proper power design is of essence. A way of optimizing the power generation is to orient the satellite in the most convenient way.

Different attitudes of the satellite with respect to the Sun were considered: spinning, one face to the Sun and 2 faces to the Sun (45° each). This last one proved to be the most efficient thanks to the cosine rule: 

\[
1 \times \cos(45°) + 1 \times \cos(45°) = 1.4 \text{ sides,}
\]

hence 40% more solar panel efficient area than a single face pointing to the Sun, and 17% more energy than a spinning satellite.

![Figure 6: Body axis with respect to Sun vector](image)

In nominal operations (no observation) the satellite will fly with its elongated \(+z\) axis (where camera is oriented) perpendicular to the ecliptic and contained in orbit plane, while the \(+x\) and \(-y\) (where sun sensor is installed), with a 45° incidence to the Sun each. This orientation, with the solar panels installed, will produce 7.2 W of energy at EOL.

The EPS counts with 4 solar panels (Clyde Space) with GaAs triple junction cells that transfer the energy received to the battery charge regulator board (also Clyde Space), where power is distributed to the system and battery. Electrical power feeds the system with 7 voltages: +3.3V, +4V, +5V, +5.5V, +/-12V and unregulated, making use of converters for the regulated powers.

**On Board Communications.**

This subsystem relies in a sophisticated technology based on wireless communications via optical signalling. This implies that there is no need of cable usage between boards to communicate data, as almost every board counts with an emitting and a receiving diode that can pulse light at different frequencies into an optical channel as well as reading the signals coming from other boards. These units are called OWLS (Optical Wireless Link System) and are independent intelligent units based on CPLDs. It implements CAN Drivers, derived from CAN Core ESA, so the On-Board Communication Protocol is a Reduced Bus CAN customized by INTE.

This design allows easy integration of the boards (no need to assemble and disassemble cables).

**On Board Data Handling**
The OBDH has a distributed architecture based on two types of units:

- **EPH.** Based on a FPGA VIRTEX II-1000 that includes the TTC processor. On-Board SW Controller, ADCS SW and TTC Control SW run on the EPH. It has an interface with the TTC subsystem for receiving TC frames and subsystem status information, as well as for sending TM frames. It also interfaces with the rest of satellite through the CAN bus.

- **DOT.** Based on a CPLD Cool Runner II. They are oriented to control the subsystems of the platform (PDU, ADCS actuators and sensors, Thermal sensors) and payloads. They include a CAN Bus interface for receiving commands, sending data and contributing to hold the On-Board Bus Time. By default they provide:
  - Eight digital lines that can be configured as discrete outputs or clock signals.
  - Three analog channels and one AD Converter to analog-digital conversion of 10 bits.

All the DOTs work by switching on and off periodically in order to save energy and minimize SEU, and only remaining switched on continuously when they detect some orders directed to them or when they need to transmit.

![Figure 7: OBDH/OBCOM diagram](image)

**On Board Software**

The control architecture of the OPTOS satellite is a distributed architecture. Therefore, the On-Board SW S/S of OPTOS shall be a distributed subsystem. The **On-Board SW Controller** shall be in charge of managing all S/C Subsystems and Payloads operation. It **will run on the EPH** and includes:

- **CAN Drivers**
- **TTC Drivers** Low level software for implementing the CAN Bus protocol used by OWLs communications.
- **Operating System Kernel** Low level software for controlling interface lines with the TTC subsystem.
- **ADCS Software** Periodic execution algorithms for attitude determination and definition of corrective actions over actuators (RW, Magneto-torquers), using ADCS sensor data measured.
- **Application Software** High level Software that uses functionalities provided by the previous software and it is in charge of tasks like Operational modes control, TM Management, TeleCommands execution and distribution, maintenance of SpaceCraft Time.

In addition, there will be several **On-Board SW components**, every one running on a DOT and performing a little SW functionality (CPLD). In concrete:
- Execute commands on the subsystems or payloads under its control.
- Reading TM data of the subsystems or payloads connected to the own DOT.
- Communicating with the EPH and the other DOTs through the CAN Bus.

**Structures & Mechanisms**

The satellite's structure is double-some, counting with an aluminium external casing, provided by Pumpkin (USA) and an internal carbon fibre structure.

The external structure provides radiation shielding and support for external components such as the solar panels, antennas and deployment mechanisms, while the internal one is conceived as a harness for all boards and internal equipment, easing the integration of the whole satellite. The carbon fibre structure has a U shape, open in the +x direction from where all boards are slide in and out thanks to aluminium guides installed on their edges. This rack provides certain electrical and thermal conductivity.
There are 2 mechanisms in the satellite that enable the opening of the camera shutter and the deployment of antennas. When the satellite is deployed from the launcher, the attitude is un-controlled at first, hence endangering the camera as it may see the Sun. A shutter is installed and only opened once navigation or nominal attitude has been achieved after de-tumbling operations and attitude acquisition. At this point Sun presence in the camera is not an issue. The antennas are flexed closed to outer structure prior to satellite deployment, and released once in orbit via burners, cutting the string that keeps them tight.

thermal control

In order to simplify the design of the system, it was required to develop a passive thermal control that would ensure comfortable temperature ranges within the satellite. This subsystem relies on paintings and conductive materials to absorb, transfer and dissipate energy fluxes.

through the development of a mathematical model using 186 nodes in a finite element environment, it has been analyzed and foreseen with tools like ESArad and EASatan that the satellite should comfortably operate within ranges between -20°C / +50°C, well within operability requirements for every component.

The satellite will count with 14 thermistors on board that will record the temperature evolution of the system. This information is not only valuable as a reference for the scientific experiments carried on board, but it will also be part of the satellite’s housekeeping, and analysis of this data will be performed regularly in order to determine the environment at which the system is operating. If this temperature becomes critical, solutions can be found from ground, such as starting a spin for thermal stabilization.

The mathematical model and its analysis have been verified via STM tests in Q3 2008, proving estimations to be correct.

Telemetry and Tele-Commands

The satellite will downlink and uplink from the ground station all telemetry, telecommands and house keeping using 4 monopoles with an omni-directional radiation diagram, at 402 MHz. The transponder will work in half duplex using Manchester pulses (SP-L) for downlink a phase with data sub-carrier (PM/PBSK) for uplink. The uplink bitrate is 4 Kbps while the downlink is configurable at 3.5 – 7 Kbps (nominal value is 5 kbps).

This subsystem uses ESA communication protocols such as EESS E 70 to communicate with the ground segment and EESS- E 41 for telecommands and telemetry.

The TTC hardware is being designed and developed by Thales-Alenia Space España (Spain).

Payloads

Subsystems described previously have the goal to allow the operation, survivability and data transferring of the science undertaken onboard. The scientific goals of the mission are performed by the payloads which are entirely developed by INTA.

Perhaps, what makes this mission most thrilling is the quantity and quality of scientific experimentation on board OPTOS.

APIs

This Athermalized Panchromatic Imaging System, is designed in order to work efficiently in environments
within a range of -20°C/20°C. The objective of this PL is to study the degradation of lenses in space environment, by picturing the same region over and over in time with same light conditions.

![Figure 10: APIS instrument](image)

The regions of interest are those that provide a picture with a constant radiance, like desert regions. The camera will have, however, the capability to picture any other terrain or region as desired. Some of the zones where the imaging studies will be carried out are African regions as the ones pictured below.

![Figure 11: Regions of interest for the APIS study. Satellite pictures of the deserts of Mauritania (left), Algeria (centre) and Mali (right)](image)

**GMR**

The Giant Magneto Resistance will study the magnetism fluxes produced by Earth’s magnetic field. The GMR relies on the effect of the change in electrical resistance experimented by a multilayer in the presence of a magnetic field. In a GMR, the multilayer is composed of magnetic and non magnetic films being the magnetic films antiferromagnetically coupled, it is, the magnetization of one film is opposed to the following.

![Figure 12: GMR effect](image)

Aside the mentioned objective, this experiment will be utilized as a study of these type of commercial materials in space as they have never been tested in this environment.

**FIBOS**

The Fibre Bragg Gratings for Optical Sensing aims to measure temperature through studying the wavelengths of a laser travelling across the Bragg Gratings. The measurement obtained will be matched with the sensed temperature of a thermistor in the same location.

![Figure 13: One of the FIBOS sensors with the optics fibre channel that will transfer the light from the laser](image)
This payload uses two sensors attached differently, to correlate different perturbation as it may be thermal expansions of materials.

**ODM**

OPTOS Dose Measurement is an instrument designed to measure radiation in space. It counts with two units on board OPTOS, whose measurements will be correlated. This experiment consists in receiving and absorbing radiative particles via commercial RAD-FETs, whose total dose will be measured repeatedly (minutes) throughout the life time of the mission. A thermistor will give the reference temperature and this data will be used to correct the measurements.

This experiment will also be mounted in other small platforms under design at INTA.

**S/C OPERATION**

The design of OPTOS Operation has supposed a challenge due to the ambitious scientific goals in spite of technical restrictions imposed by the platform:

- Low S/C power budget that even forces an EPH switch-off for 10 minutes once per orbit.
- Low data budget, due to Half-duplex TTC and downlink bit rate of 5 kbps.
- Not HW redundancy.
- Earth Observation Camera on boarded that requires an ADCS able to get a good pointing and stabilization accuracies. This means ADCS SW imposes strong real time requirements and high power consumption.
- Payloads with quite different operational requirements:
  - APIS needs good accuracy and stability in the pointing \( \Rightarrow \) ADCS SW running continuously.
  - GMR in Nominal A mode has an Operation cycle of 4 seconds, and an execution cycle of 1 second. During its execution cycle, ADCS magneto-torques must not operate.
  - FIBOS needs a controlled thermal environment. The S/C does not perform Thermal Control. For that, FIBOS Operation shall be executed as quick as possible, using all the S/C Data Bus resources. Meanwhile ADCS algorithms shall not be executed.
  - OBDH units that are automatically switched-on /off to guarantee a good behaviour in the space environments and to safe power. This causes a more complex S/C Data Bus management.

As consequence, the Operation has been designed to allow the harmonic coexistence between all elements. A proper S/C orientation shall provide an efficient power generation and a careful operation modes design should be able of optimizing its usage.

The next figure shows the identified Operational modes.

**Initial mode:** This mode is just reached after deployment and it performs the warm up and the start up of different subsystems.

**Nominal mode:** Implies a power consumption mode where all basic subsystems are functioning (OBCOM/OBDH, ADCS and EPS).

**Scientific mode:** It concerns the usage of any of the payloads while maintaining the critical components on. Some payloads shall not be operated simultaneously.

**Observation mode:** Requires changing attitude with respect to its nominal operation to seek imaging target required by the on board camera. A Sun sensor placed on its -Z axis (opposite to the camera) will determine sun position and maintain a stable attitude during this operation.

**Safe mode:** In case of an emergency in the satellite (lost of attitude, scarce power...) the satellite shall come into this saving mode, which is the least power requiring of all.

**Communication state:** Highest consumption state in any mode. During communications period, just basic subsystems operations are performed (power control and checking and reduced ADCS operations) and the main S/C resources are devoted to TTC (Rx and Tx) S/S management and on-ground data processing and sending. No Payload operation shall be executed.

![Figure 146: OPTOS Operation Modes](image-url)
QUALITY ASSURANCE & AIV

The quality assurance of this satellite is following the ESA standard ECSS thanks to which there is a thorough project control in design, test and verification, purchase follow up etc... Quality assurance is developed by an independent team from the project. INTA counts with a QA department that works as external agents for projects throughout the institute.

One way of assurance survivability of the mission, and the quality of the project as a whole, is by having a purchase politics that implies using only military components, and in some cases COTS that have flown already or have been qualified in space.

As an example: The CMOS sensors used in the optics are COTS that have been qualified by an INTA team in radiation environments, in the Accelerator Laboratory at the University of Jyväskylä, Finland (JYFL), and results point to a survivability of components over a year.

The work of QA team to assure a proficient management and design is complimented by a thorough AIV plan that would be the one used for any other satellite, regardless of their size and budget. Originally a model philosophy of STM, EQM and a final FM was considered, budgeted and planned, but date re-scheduling to fulfil mission has forced to shift into a hybrid model philosophy based on an STM, EM and PFM. Future developments will go through the stricter first philosophy conceived.

The project has passed successfully a full CDR on February 2009 where designs have been frozen and STMs results presented. The STMs results for both vibration and thermal environment have proven to be a success. The satellite design is qualified for the strictest launching conditions for rockets such as DNEPR and PSLV. The thermal test have proven our models to be accurate, which point to full operability of every subsystem and payload at all times during orbit, currently going through CDR and most subsystems have already gone through BB testing and are closing their designs. In parallel, the STM campaign is about to begin in order to test the thermal behaviour predictions at vacuum and the mechanical behaviour of the structure.

![Figure 155: Model distribution along project phases as originally planned](image)

Figure 166: Structures and Thermal Model
Subsystems have already gone through BB testing and EM for payloads and subsystems are undergoing as for February 2009.

THE FUTURE

The successful operation of this satellite will enable the possibility for INTA to launch frequently in order to test in space the different developments produced in the distinct departments ensuring a professional operability that meets the standards for any agency.

Meanwhile, the Space Programmes Department at INTA keeps on working on different small satellites, such a Xatcoboé, that will be launched in the maiden flight of Vega and will count with solar panel.
deployment system for Cubesats developed at INTA, or the feasibility study of OPTOS-2G to increase the OPTOS platform performances.

Both of these satellites follow Cubesat standards and will implement technological advancements developed through OPTOS project. INTA is and will keep on investing on these small platforms, seeking to obtain the refined characteristics implemented in the demonstrator OPTOS at budgets and development times that would enable any corporation or agency launching repeatedly and occasionally science to space in a reliable platform.

**OPTOS SECOND GENERATION (2G)**

To give continuity to the OPTOS platform developed by INTA, last year it was made a feasibility study to see the possibility of develop a new platform OPTOS 2G which increase the OPTOS performances. During the OPTOS platform development and at this feasibility study was identified that this platform has been optimized as follows:

- **TTC** full-duplex with greater capacity for data transfer.
- **Structure** (new development) to optimize the volume available to accommodate all the subsystems and the payload (bigger than in OPTOS)
- Deployable solar panels to increase the Power available on board.
- Optimizing the **ADCS** subsystem with 4 reaction wheels, a star-tracker and 5 sun sensors to increase the pointing and stability capabilities of this new platform OPTOS 2G.

Once identified these points to improve the OPOTS platform in the feasibility study of OPTOS-2G was reached following conceptual design of the above subsystems (keeping the other as OPTOS):

- **TTC**: Double-device TTC architecture (FULL DUPLEX):
  - 1 Half duplex transceiver (same than OPTOS) with 4 monopoles antennas (18 cm) for UHF 402 MHz, Bit-rate: 4 kbps uplink / 5 kbps downlink (TC and HK).
  - 1 S-Band transmitter (comercial) with 2 patches antennas for S-Band 2245 MHz, Bit-rate: 4 - 256 kbps downlink (configurable in real time), Payload & TM data.
- **Structure**: A lot of space is lost between internal – external OPTOS structure so a new "one body" structure was design to to optimize the volume available to accommodate subsystems and payloads. SSs are grouped to occupy as minimum space as possible and a "big" space (200 x 50 x 50 mm) for a PL is available.

![Figure 17: OPTOS-2G SS and PL internal distribution.](image)

- **Power**: Besides the 4 panels mounted on the sides of the estrucutura of OPTOS, in 2G are added another four 6-cells panels deployed 120°, with solar cells on both sides of the deployable solar panels consiguiendo una potencia de 18 W maximum / 8 W minimum. This “tetraedron” configuration → completely symmetrical → no matter Sun direction (isotropic configuration suitable for a wide range of missions).
OPTOS 2G to be (even) better:

- More "professional"
- More efficient
- Lessons learnt → Less errors, more efficacy
- Not demonstrator → Real tasks, professional payloads

OPTOS 2G suitable for specialized and "professional" purposes (as a "big" satellite):

- Industrial-level and professional Payloads
- Earth observation: resolutions up to 30m possible
- Any other possible scientific / technical PL under study

**ADCS**: The same than OPTOS, plus...

- 2 Sun Sensors (OPTOS) → 5 Sun Sensors (2G)
- 1 Reaction Wheel (OPTOS) → Pack of 4 Actuation Wheels (2G) (3 axis + auxiliary plane)
- 1 Star Tracker (2G)

**ACHIEVED PERFORMANCE**:

- MPE: 10 arcsec (att. knowledge)
- APE: 1 deg (att. control)
- RPE: 20 arcsec (att. stability)