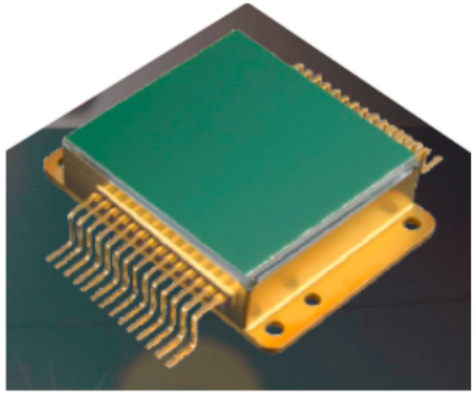
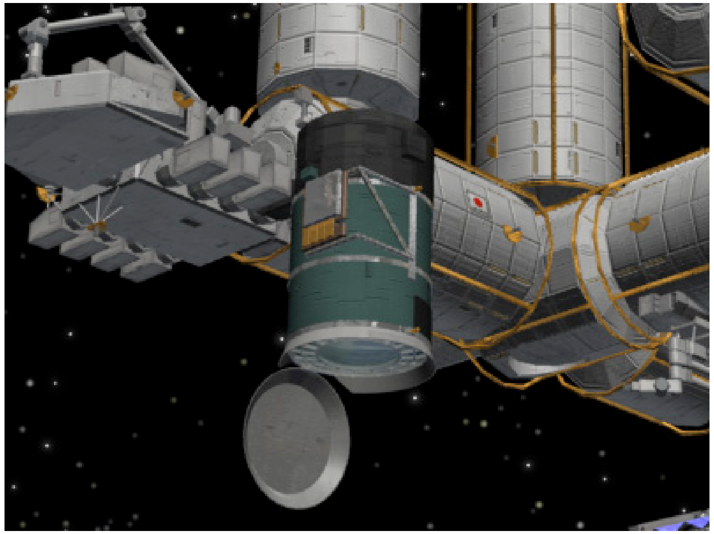


Development of an electronic control unit of a microbolometer array for space instrumentation

Javier Licandro, Enrique Jóven, Guillermo Herrera
Instituto de Astrofísica de Canarias, España

DESARROLLO DE INSRUMENTACION ESPACIAL, Madrid, 29-30 de Junio de 2011

JEM-EUSO



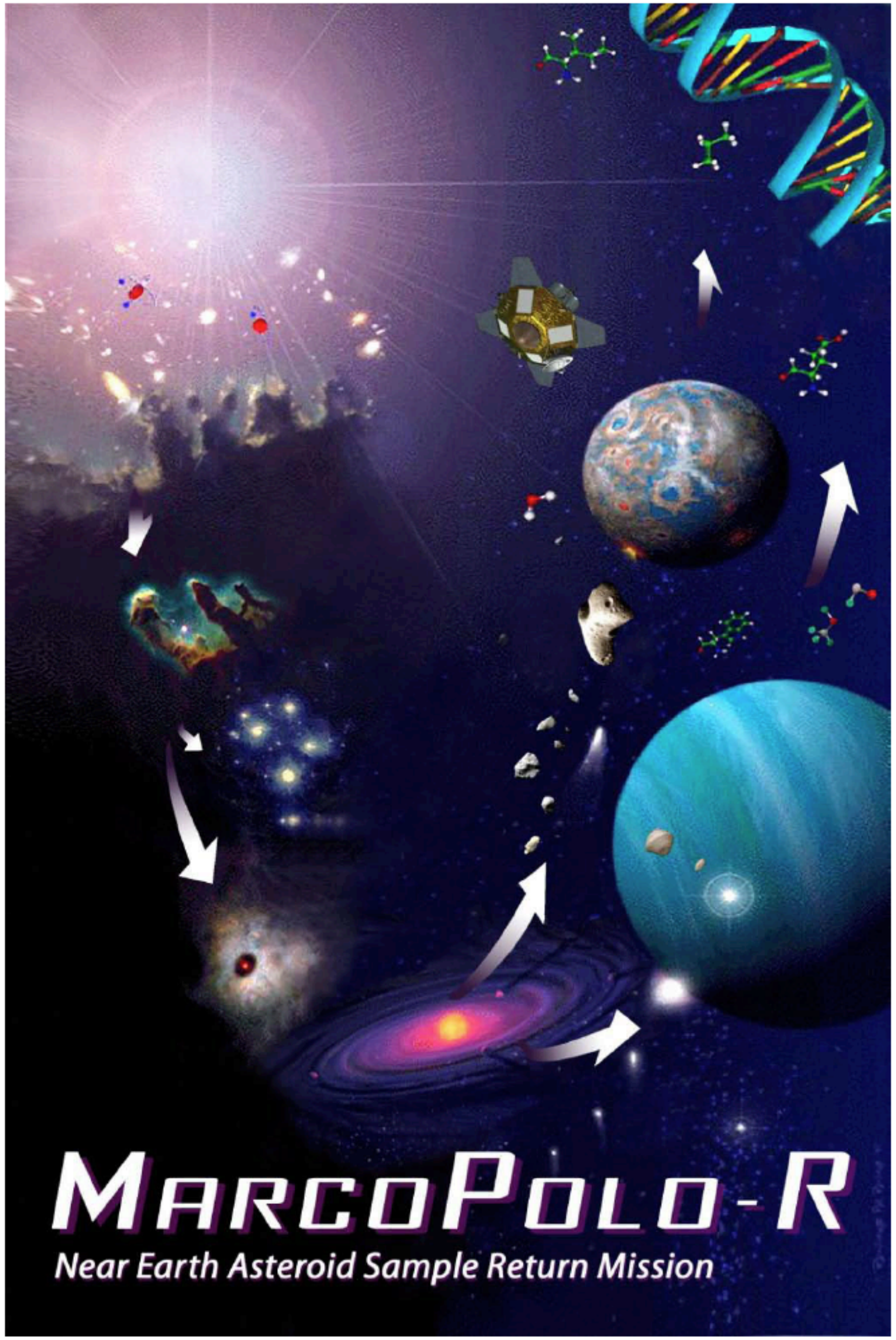
JEM-EUSO will be on orbit on the International Space Station (ISS). It observes transient luminous phenomena taking place in the earth's atmosphere caused by particles coming from space.
The sensor is a super wide-field telescope that detects extreme energy
It is facing Phase B1, the System Requirement Review (SRR) was delivered March 2011

JEM-EUSO includes an **Atmospheric Monitoring System (AMS).** to observe the Earth's atmosphere continuously providing key parameters for the optical yield determination

AMS will integrate and **Infrared Camera** used to detect the presence of clouds and to obtain the cloud top altitude during the observation period of the JEM-EUSO main instrument.

The IC is a Spanish project (leaded by M. D. Rodríguez Frías, U. Alcalá de Henares)

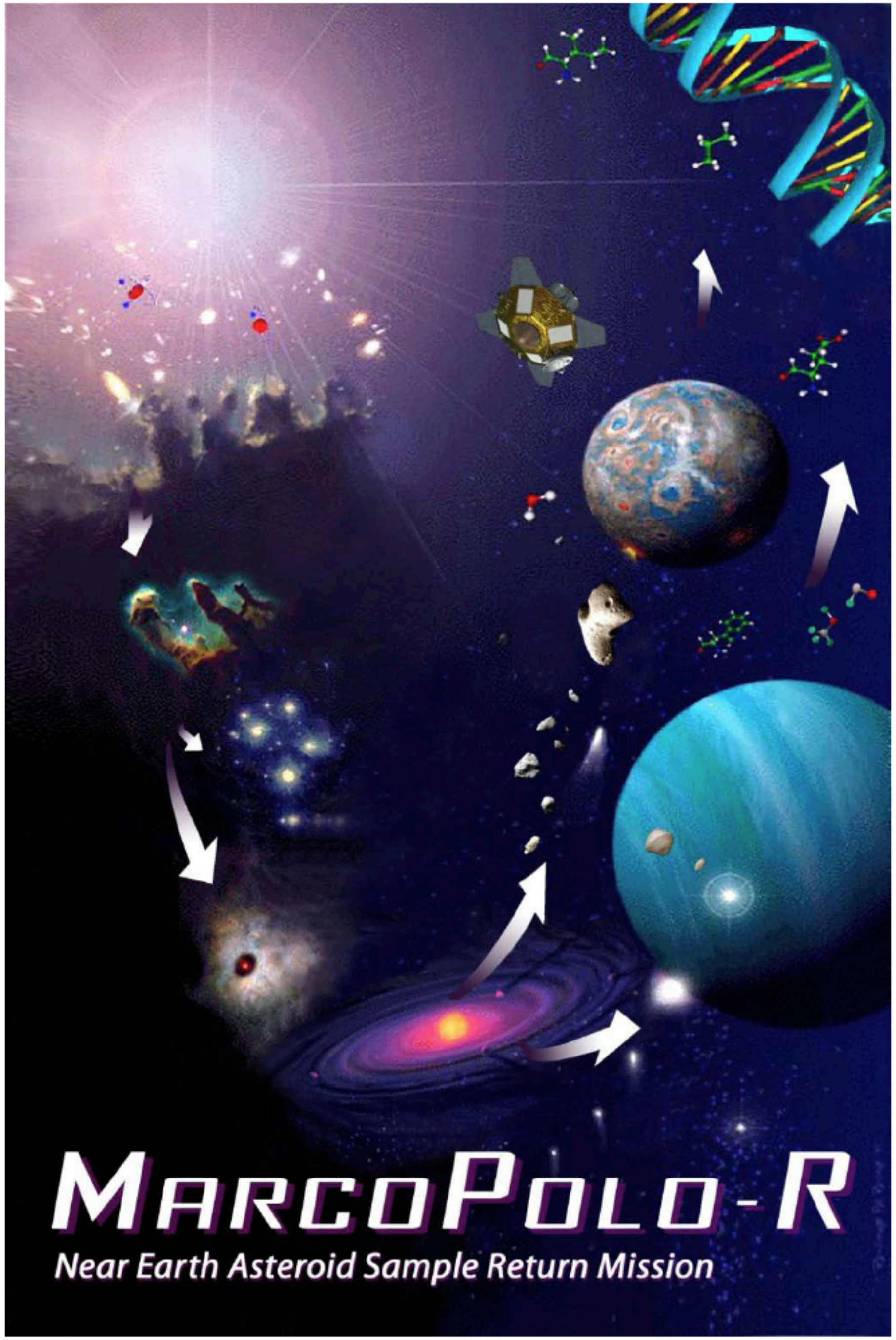
We are in charge of the detector electronic control unit (ECU) of the IC



MARCO POLO - R: a scientific and technological opportunity for Spanish researchers

Javier Licandro (IAC), Luisa Lara (IAA),
Adriano Campo Bagatin (U. de Alicante),
Josep M. Trigo (CSIC-IEEC)

II Encuentro de exploración del Sistema Solar
Bilbao, 16-17 de Junio de 2011

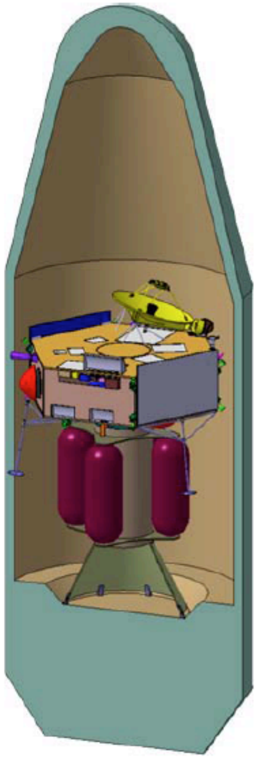


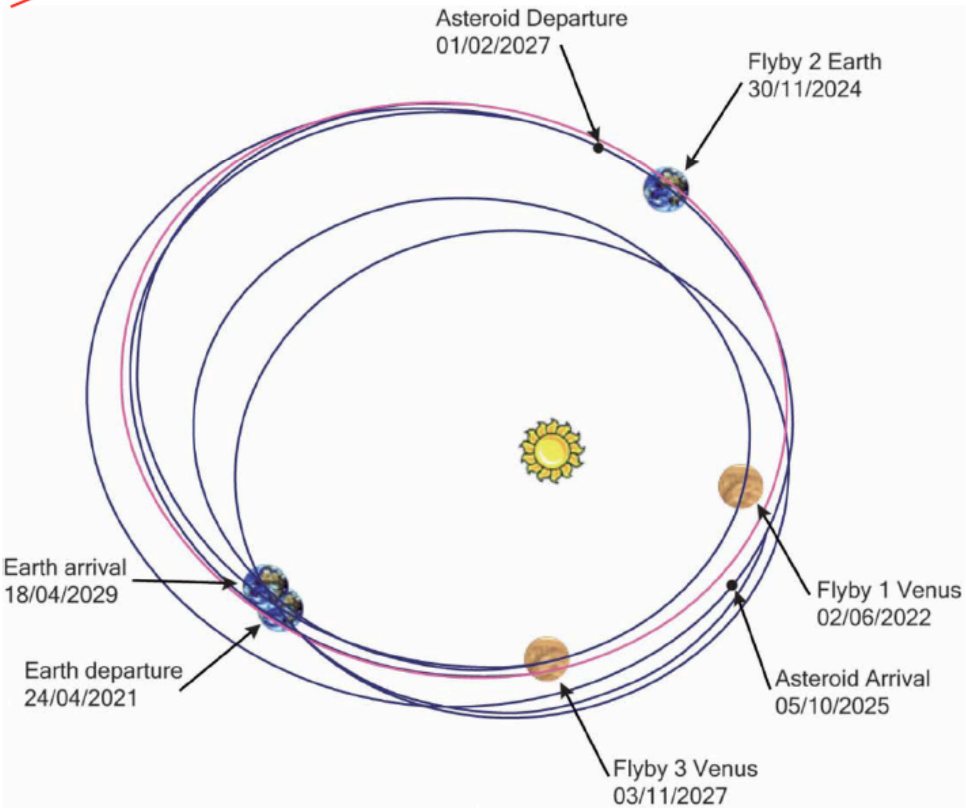
MARCO POLO - R: a scientific and technological opportunity for Spanish researchers

- Marco Polo (now Marco Polo - R) is a sample return mission to a primitive asteroid
- Will answer key about: 1) the origin of the Solar System and planets; 2) organics in the SS and the origin of life
- Technological challenge

MarcoPolo-R mission baseline *1996FG3 binary*

Launch	Mission duration (yrs)	Stay time (months)	Δv (km.s^{-1})	Entry v (km.s^{-1})
10.03.2020*	6.98	10.5	2.07	12.0
10.03.2020*	4.70	3.5	1.9	15.0
23.02.2021*	9.09	13.7	2.93	12.0
24.04.2021	**7.99**	**16.1**	**2.81**	**13.6**
09.01.2022	**7.28**	**9.3**	**2.88**	**13.6**





Other targets:

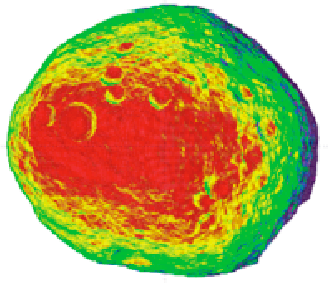
1999JU 3
1999 RQ36

Cosmic Vision ESA – M3

MarcoPolo-R Proposal core members	
Europe	
Maria Antonietta Barucci (Lead Proposer)	LESIA – Paris Observatory, F
Patrick Michel (Co-Lead Proposer)	Univ. Nice, CNRS, OCA, F
Philip A. Bland	Imperial College, London, UK
Hermann Böhnhardt	MPS, Katlenburg-Lindau, D
John R. Brucato	INAF – Obs. of Arcetri, I
Adriano Campo Bagatin	Univ. Alicante, E
Priscilla Cerroni	INAF – IASF, Roma, I
Elisabetta Dotto	INAF – Obs. of Roma, I
Alan Fitzsimmons	QUB, Belfast, UK
Ian A. Franchi	Open Univ., Milton Keynes, UK
Simon F. Green	Open Univ., Milton Keynes, UK
Luisa-M. Lara	IAA – CSIC, Granada, E
Javier Licandro	IAC-CSIC, Tenerife, E
Bernard Marty	CRPG, Nancy, F
Karri Muinonen	Univ. Helsinki and FGI, FIN
Andres Nathues	MPS, Katlenburg-Lindau, D
Jürgen Oberst	DLR Berlin, D
François Robert	MNHN, Paris, F
Raffaele Saladino	Univ. of Tuscia, Viterbo, I
Josep M. Trigo-Rodriguez	CSIC – IEEC, Barcelona, E
Stephan Ulamec	DLR RB – MC, Cologne, D
USA	
Andrew Cheng (Lead U.S. Collaborator)	JHU – APL, Maryland
Lance Benner	JPL, California
Richard P. Binzel	MIT, Massachusetts
Andrew Rivkin	JHU – APL, Maryland
Michael Zolensky	NASA/JSC, Texas

- Proposed in 2010
- 4 Spanish researchers in the proposal core group
- It is one of the 4 M missions that passed to feasibility studies (until 2013)
- MP already passed to this phase in the last call
- Funding problems detected almost solved with the participation of NASA
- A Spanish researcher, Luisa Lara (IAA) is member of the ESA Scientific Study Team (SST) of MP-R.
- NASA & JAXA already approved similar missions (OSIRIS-Rex & Hayabusa II) making even more important MP-R

THERMAP



A thermal mapper for the Marco Polo mission

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Co-Investigators:
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L. Jorda, LAM, Marseille, France
E. Kührt, DLR, Berlin, Germany
J. Knollenberg, DLR, Berlin, Germany
J. Helbert, DLR, Berlin, Germany
M. Delbó, OCA, Nice, France
E. Lellouch, LESIA, Paris, France
D. S. Lauretta, LPL, Univ. of Arizona, Tucson, USA
J. Licandro, IAC, Tenerife, Spain

Industrial partners:
EADS - ASTRIUM, Toulouse, France
ULIS, Grenoble, France

- Map the temperature to an accuracy of 5K (goal 1K) to derive the surface thermal properties (thermal inertia). A two-dimensional thermal mapper capable of recording the complete map of the body in one or a few frames in a few minutes.
- Map the surface composition. Spectroscopy with a spectral resolution of about 70 is diagnostic of the composition, in particular of minearls.
- Map of the regolith distribution. Determine the nature and distribution of regolith on the surface, important to understand the surface history of the asteroid.
- Understand the Yarkovsky and YORPS effects

We are in charge of the detector ECU of the detector

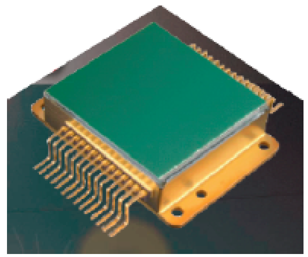
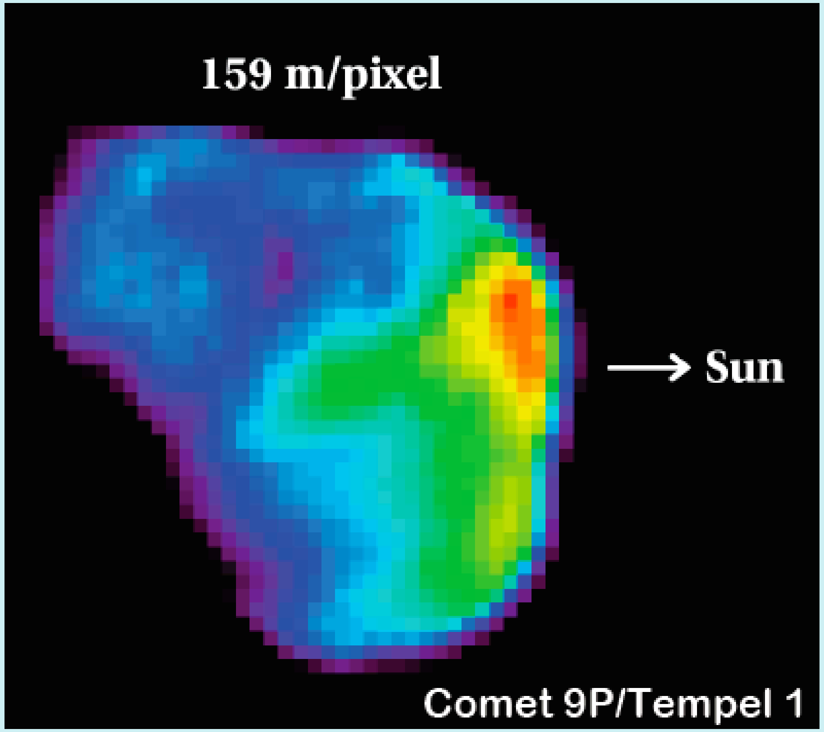
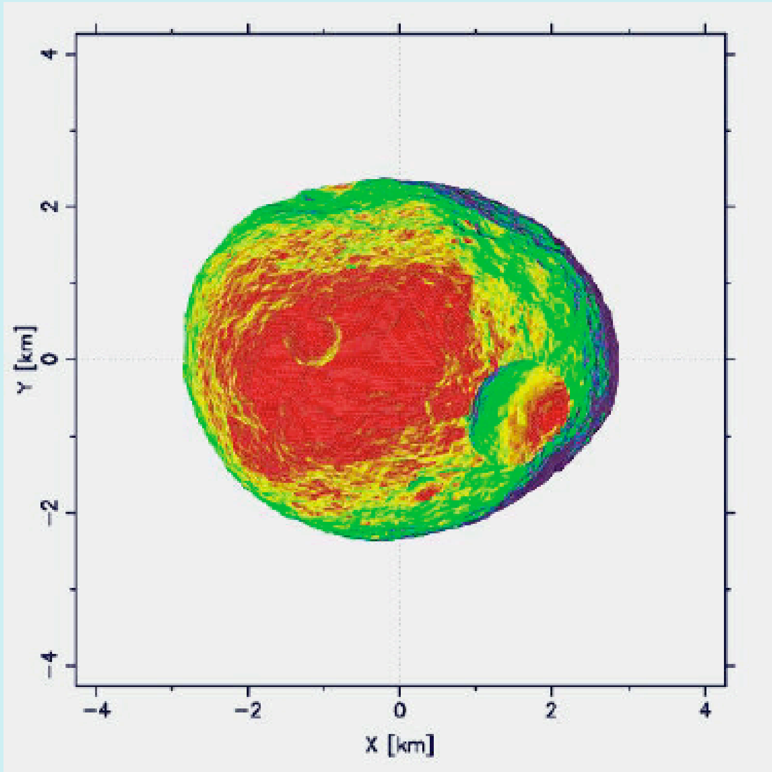


Figure 2 : Microbolometer array of 640x480 pixels from ULIS

Deep Impact mission (2005)



Marco Polo (2022)



Detector most important properties

A uncooled microbolometer array (640x480, 25μm pixels) detector from the french company ULIS

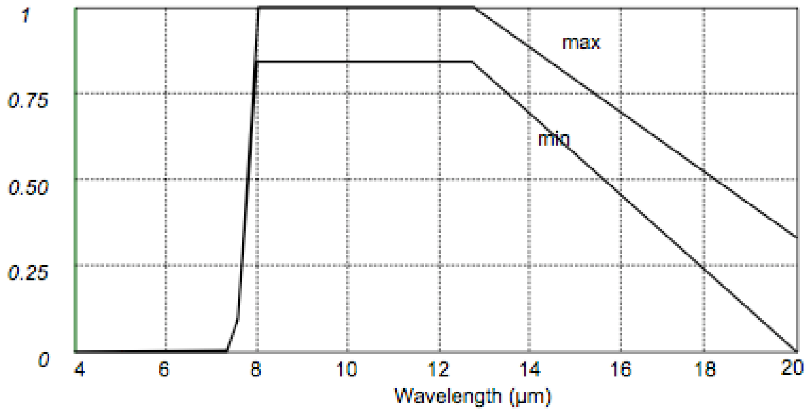
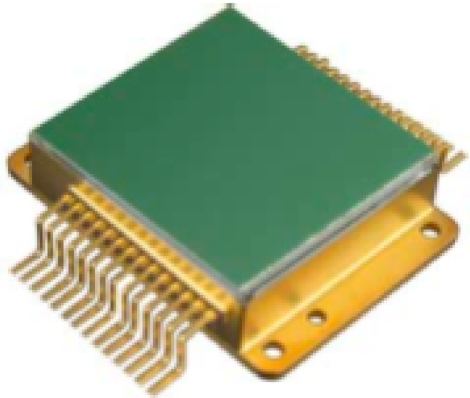


Figure 2: Normalized spectral response gauge of UL 04 17 1



- Good sensitivity, low noise level in the 8-15 microns region
- Uncooled microbolometer array NO NEED FOR COOLING
- Low mass, low consumption

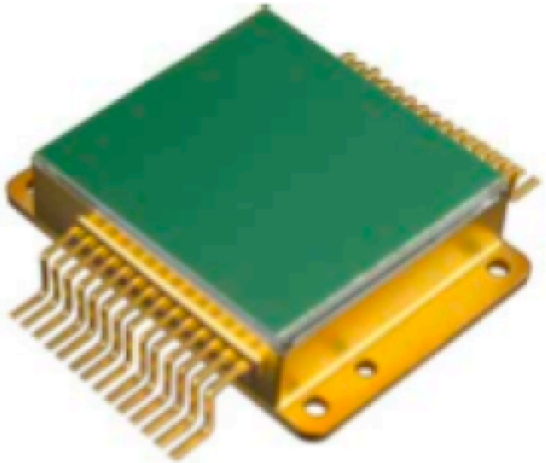
The detector is the same of the alternative instrument for MP-R the ATMS

Also the detector of an infrared camera for another mission, JAXA JEM-EUSO (a Spanish instrument, we are in charge also of its ECU)

The uncooled Microbolometer array detector

SPECIFICATIONS

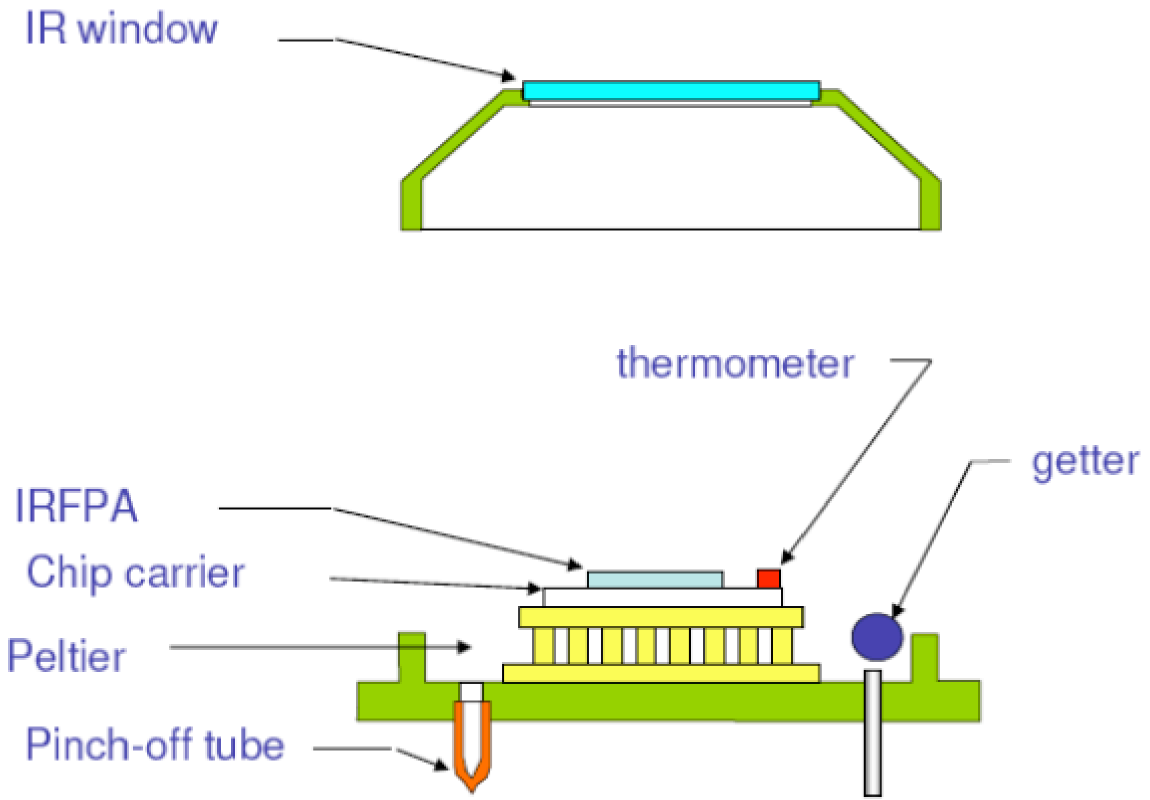
- Pixel-pitch: 25 µm
- NETD < 120 mK @ f/1, 300 K, 60 Hz
- Dimensions (LxWxH): 23.5 x 32 x 7.7 mm^3
- Power consumption < 300 mW (without TEC)
- Spectral response: LWIR
- sensitive area: 16 x 12 mm^2
- Row by row reading mode
- Weight < 25 g



FEATURES

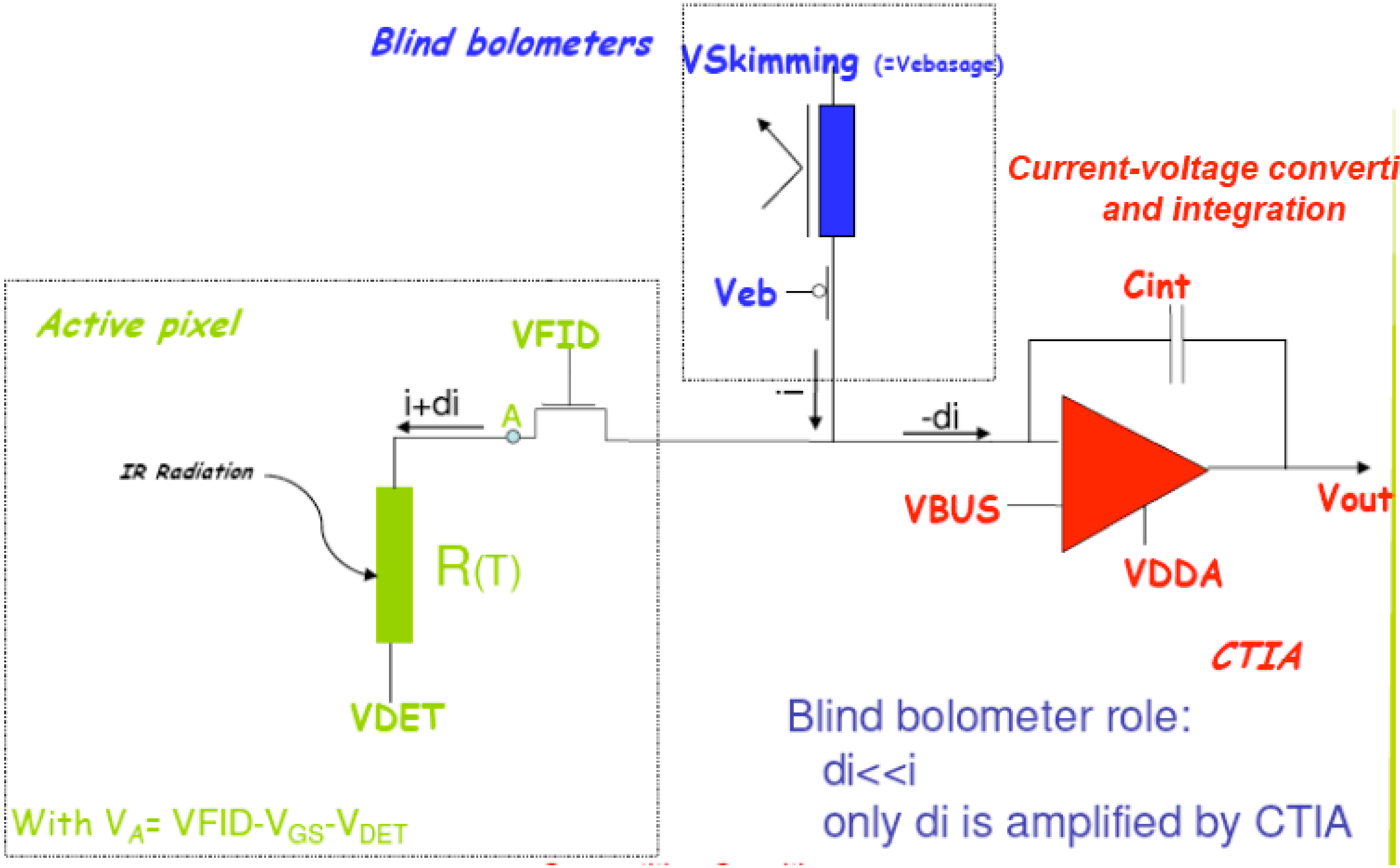
- Amorphous silicon microbolometer
- Uncooled operation (with or without TEC)
- Adjustable integration time
- 1 or 2 analog outputs available
- 640 x 480 pixel focal plane array
- Digital selection mode via a serial link
- Power supply: 5 V for analog, 3.3 V for digital
- Output dynamic range 1.0 V to 4.2 V
- H, V image flip array
- 28-lead vacuum flat-pack
- On-chip temperature sensor
- MIL STD 883-810 qualification (in progress)
- Lead free and RoHS compliant
- Typical responsivity: 5 mV/K
- Frame rate up to 60 Hz
- User defined windowing capability

The uncooled Microbolometer array detector



Uncooled IR detector packaging structure

The electrical pixel scheme

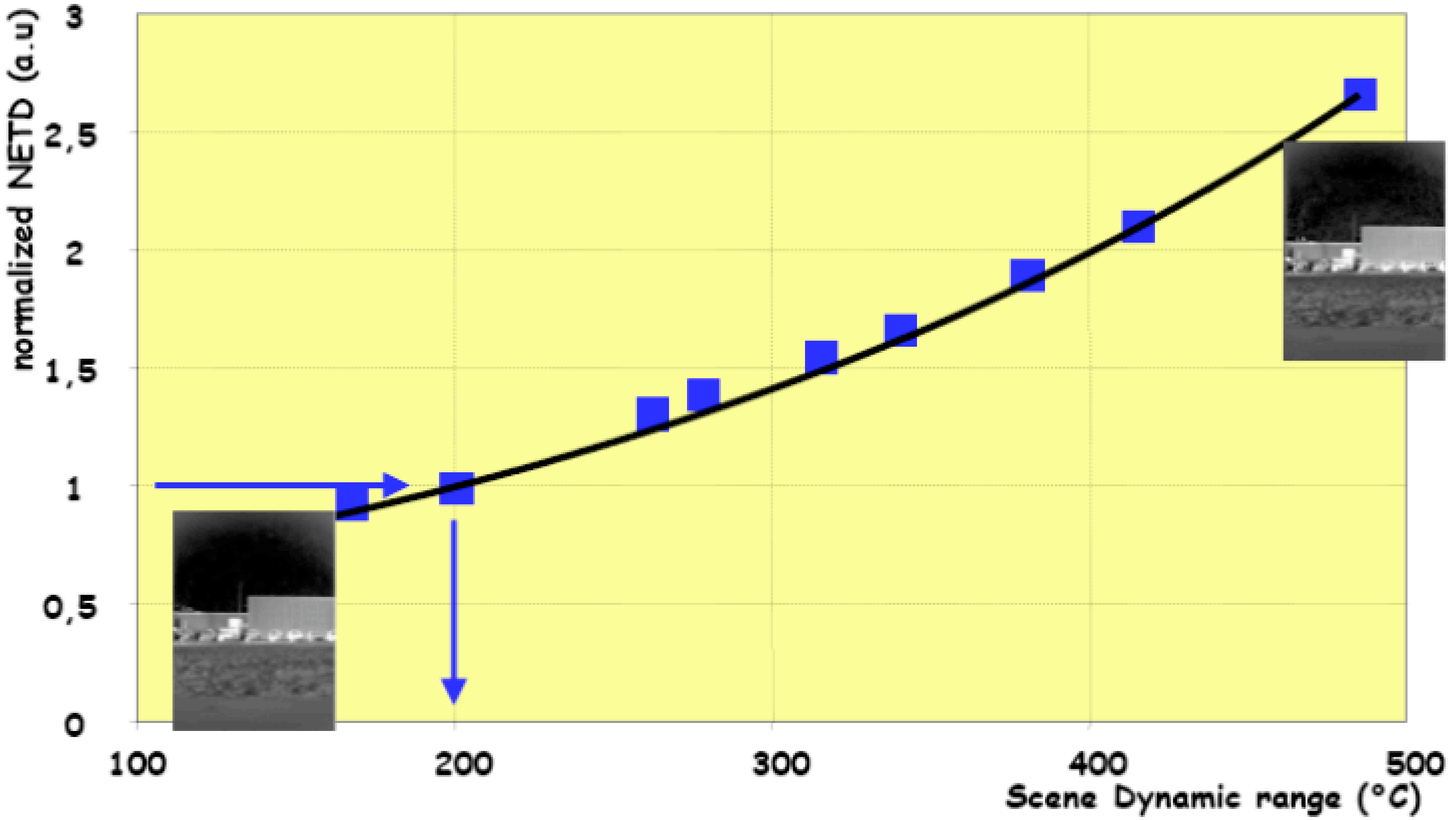


Blind bolometer role:

di<<i

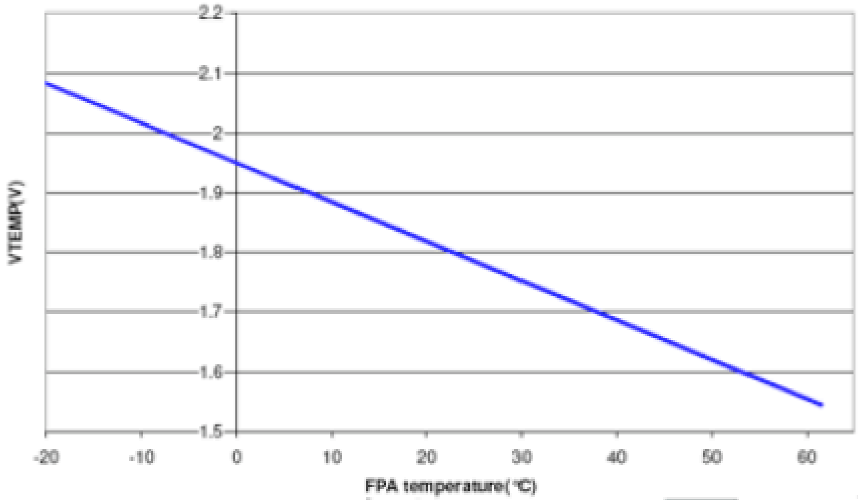
only di is amplified by CTIA

Dynamic range vs NETD trade off

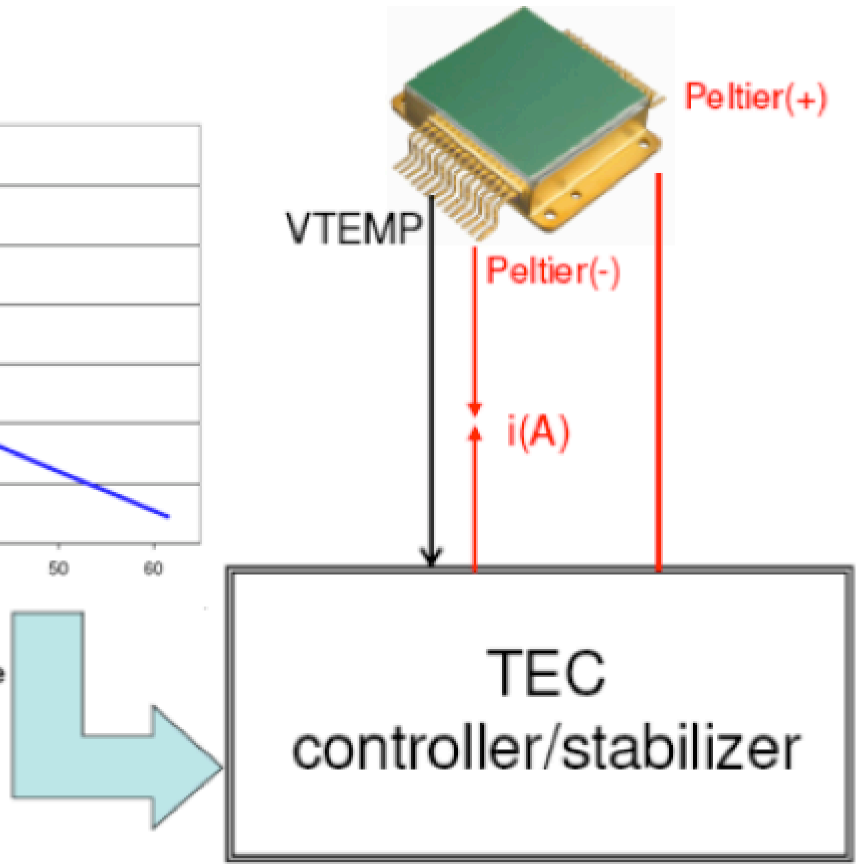


NETD & Dynamic range depend on the operating point

The integrated Thermo Electrical Cooler



Set point temperature voltage
1.752 V for a 30°C working temperature



Focal Plane Array regulation accuracy and stability < 10mK

Tasks first defined to be done at the IAC

To develop the control electronics, **power supply** and a **detector test experiment** to perform a series of tests to answer the following questions:

- What is the effect of the operating temperature on the performances, and what is the acceptable range?
- Which thermal stability is required to reach a given absolute radiometric accuracy?
- What is the dynamic range of the detector?
- What is its sensitivity?
- What is the spatial homogeneity of the detector response?
- How long is the readout time and how fast can the detector be operated?

To do PDR design and to built a breadboard model of the electronic control unit, to demonstrate that the design works and also to serve as a test bench to other parts of the instrument, e.g., the optics.

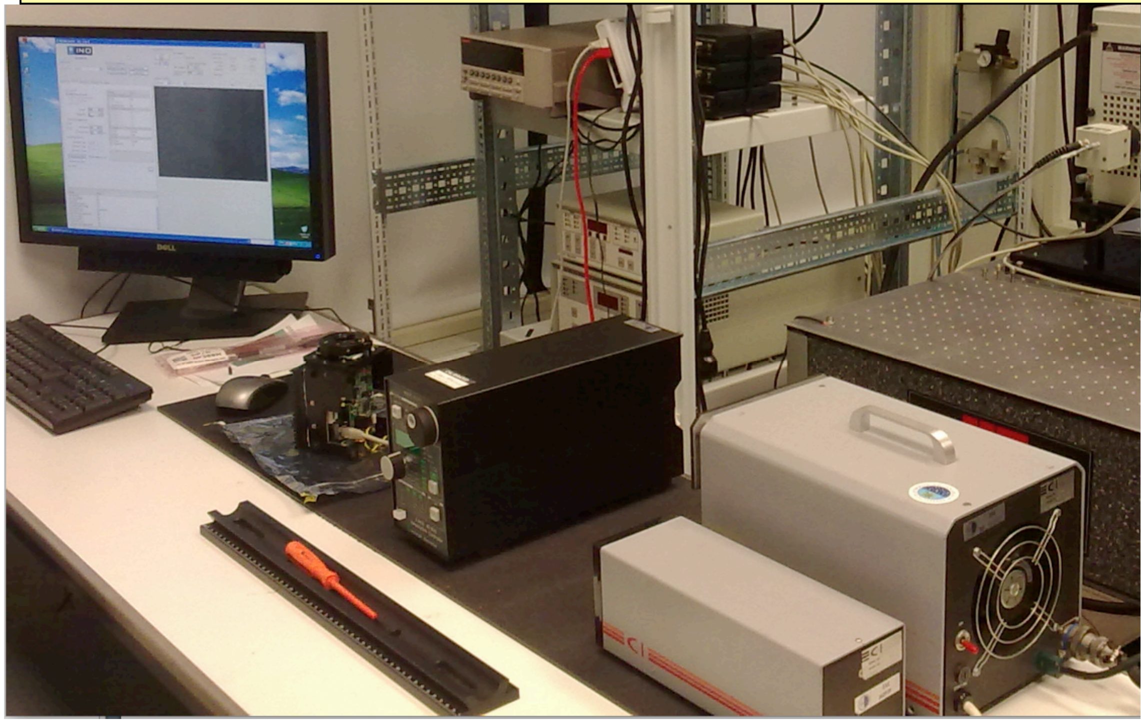
IC JEM-EUSO requirements

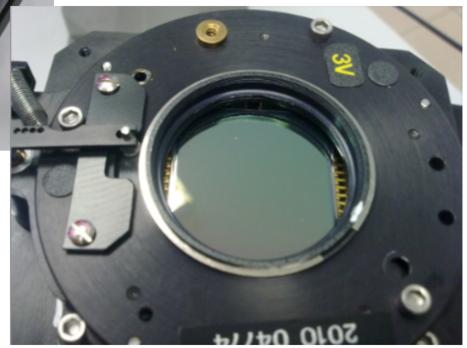
Parameter	Target value	Comments
Measurement range	200 K - 320 K	Annual variation of cloud temperature plus 20 K margin
Wavelength	10-12 μm	Two atmospheric windows available: 10.3-11.3 μm and 11.5-12.5 μm
FoV	60^o	Same as main instrument
Spatial resolution	0.25^o@FOV center 0.22^o@FOV edge	Threshold values.
Absolute temperature accuracy	3 K	500 m in cloud top altitude
Mass	≤ 7 kg	Inc 30% margin.
Dimensions	$200 \times 280 \times 320$ mm.	$300 \times 300 \times 500$ mm. Max
Power	≤ 11 W	Inc 30% margin.

Table 1: Requirements for the IR camera.

The detector test experiment

Mounted in LISA, the IAC test-bench for detector calibration and characterization





- We use a **camera built by INO** that use the ULIS array.
- An optics from INO has just arrived
- A **new Black Body** is coming (-40 to 100, cost 30.000 €!!!!)
- Test will be performed this summer (with the help of a summer student)
- Will be used to test JEM-EUSO IC optics
- Will be used to test ATMS optomechanic breadboard

Some tests planned

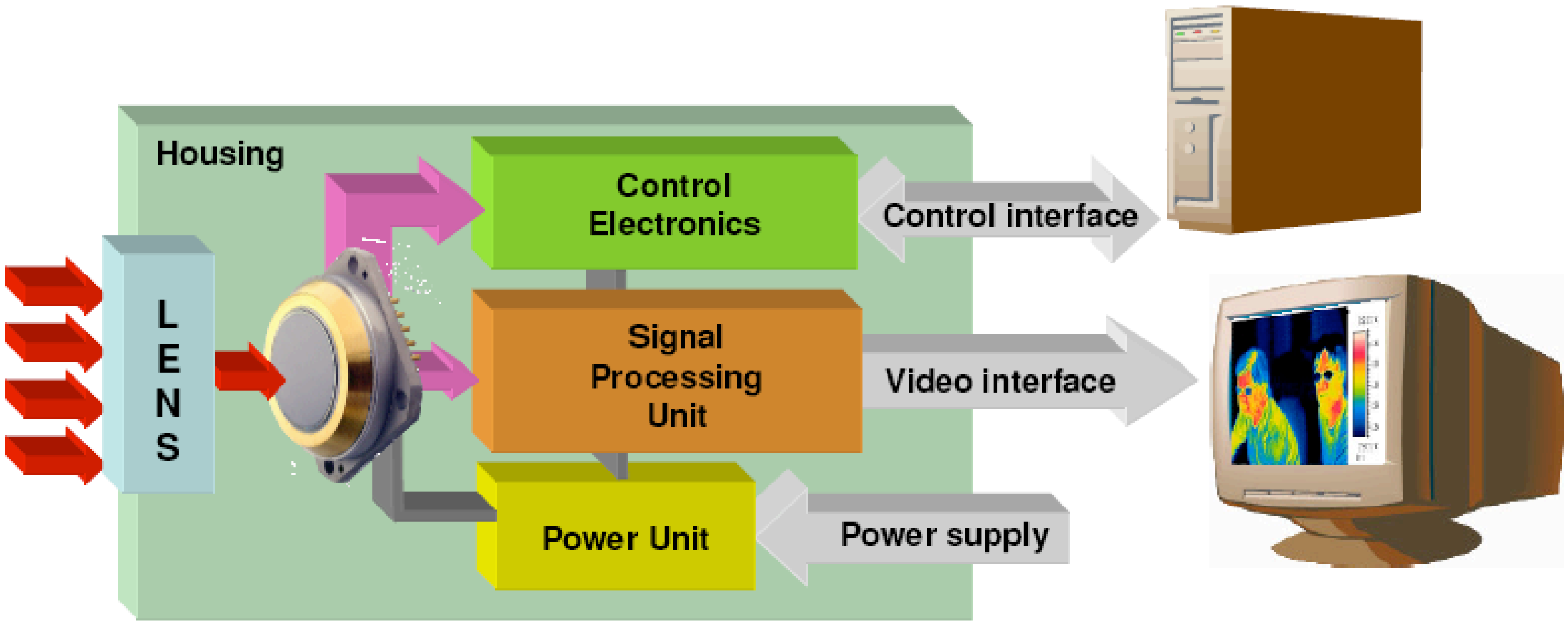
- **Sensitivity/accuracy as a function of operating temperature.** The detector is in principle optimized for an operating temperature of typically 300K. The trade-off between operating temperature, electronic capability and sensitivity has to be tested for different operating temperature in the range 200-320K (TBD). Need a black-body.
- **Sensitivity/accuracy of the detector to its environment.** This has to be tested, for different environment temperature between 200-320 K (TBD). Need a climate chamber.
- **Sensitivity/accuracy of the detector to the observed scene.** On an asteroid the expected temperature range is 200 - 400 K
- **Sensitivity/accuracy as a function of integrating time.**

The IAC Climate Chamber

Environment controlled tests will be done in the IAC Climate Chamber

- ➢ The Climate Chamber is able to control both Temperature and Humidity.
- ➢Temperature control range goes from -20ºC to +50ºC (+/- 0.5ºC).
- ➢ Humidity control range goes from 5% to 95% (+/- 1-2%).

The electronics needed for the detector

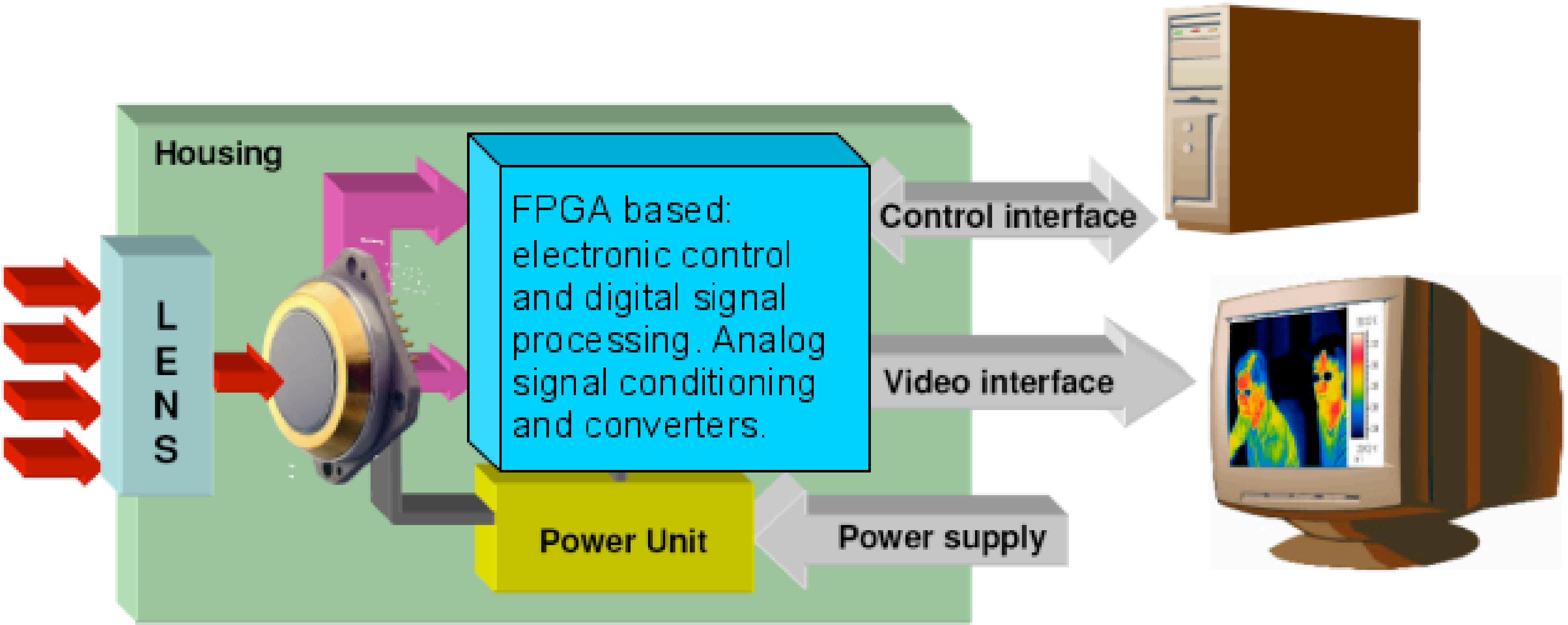


Should consist of:

- An amplifier to adapt the dynamical range to the Analog Digital Converter (ADC)
- An ADC
- A sequencer to manage these electronics
- The control command and output interface

The electronics developed for the detector

The electronic is developed and built at the IAC by Ing. G. Herrera

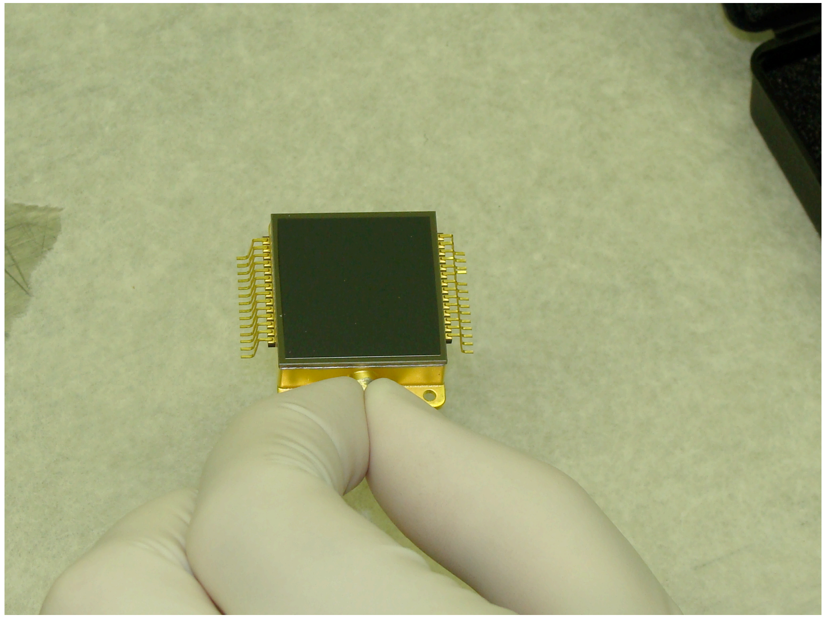


➢Based on Field Programmable Gate Arrays (FPGAs) that allow to implement application specific programs
➢Control will be able to reach the maximum frame rate of the Microbolometer FPA trying to push the system to the top of its limits

Status of the ECU design & breadboard model

- **Preliminary design of the laboratory is DONE.**
- **The detector and most of the electronic parts have already been purchased and are in the laboratory.**
- **Study of the INO design will help to finish the design.**
- **The breadboard model por JEM-EUSO is expected to be built summer 2012** (We asked for funding to the “Plan Nacional”)
- **PDR for the space design of the ECU for JEM-EUSO should be ready November 2012.**

Development of the ECU breadboard



➢**Preliminary design of the breadboard ECU** is **DONE.**
➢The **detector** and most of the **electronic parts** have already been **purchased** and are in the laboratory**.**
➢**The breadboard model por JEM-EUSO** is expected to be **built summer 2012**
➢**PDR for the space design** of the ECU for JEM-EUSO should be **ready November 2012.**


Any question?

Comparison with other detectors

⅃IR

	Bolometer	Ferroelectric	Thermopile
Physics	Carrier density mobility	Dielectric polarization	Seebeck effect
Object	Temperature	Temperature change	Temperature gradient
Signal	Resistance ΔR	Polarisation ΔQ	Voltage ΔV
Chopper	Unnecessary	Necessary	Unnecessary
Comment	silicon like technology	high temp. annealing	Difficult to design small pixel-pitch