Highlights of Spanish Astrophysics VIII, Proceedings of the XI Scientific Meeting of the Spanish Astronomical Society held on September 8–12, 2014, in Teruel, Spain. A. J. Cenarro, F. Figueras, C. Hernández-Monteagudo, J. Trujillo Bueno, and L. Valdivielso (eds.)

The PLATO 2.0 mission. Spanish contribution

J. Miguel Mas-Hesse[1], Roser Urquí O'Callaghan[1], J. Carlos Suárez[2,3], Juan Cabrera[4], Hans Deeg[5,6] and Ana Balado[7]

[1] Centro de Astrobiología (CSIC–INTA), 28691 Villanueva de la Cañada, Spain
[2] Instituto de Astrofísica de Andalucía (CSIC), 18008 Granada, Spain
[3] Universidad de Granada, 18071, Granada, Spain
[4] Deutsches Zentrum für Luft- und Raumfahrt (DLR), 12489 Berlin, Germany
[5] Instituto de Astrofísica de Canarias (IAC), 38205 La Laguna, Spain
[6] Universidad de La Laguna, Dept. de Astrofísica, 38206 La Laguna, Spain
[7] Instituto Nacional de Técnica Aeroespacial (INTA), 28850 Torrejón de Ardoz, Spain

Abstract

The PLATO 2.0 space mission (PLAnetary Transits and Oscillation of stars) was selected by the ESA Science Programme in February 2014, as the M3 mission to be launched in 2024. PLATO 2.0 will detect terrestrial exoplanets in the habitable zone of bright solar-type stars and characterise their bulk properties. The exoplanets will be detected by the weak eclipses they produce when transiting in front of their parent star, while the long uninterrupted observations will allow also to analyze the oscillations of these stars, yielding their internal structure and evolutionary state. The stellar sample targeted by PLATO is bright enough ($V < 11.5$) to be able to confirm the planets candidates using radial velocity spectroscopy from ground, providing so a complete characterization of the exoplanetary systems. Spain will contribute to the PLATO 2.0 instrument by providing the Focal Plane Assemblies of its 34 telescopes, as well as the Main Electronics Units which will perform onboard and in real time the photometric extraction of the stellar lightcurves.

1 Introduction

The PLATO mission was proposed in 2007 as a medium class candidate for a launch in 2017–2018, in response to the first call for missions of the Cosmic Vision 2015-2025 programme.The proposal was submitted by Dr. Claude Catala (Observatoire de Paris) on behalf of a large consortium of scientists from laboratories all across Europe, including CAB (CSIC–INTA). PLATO was selected in 2007 as one of the candidate missions, undergoing an assessment study in 2008–2009, and, after a second selection, a definition study in 2010–2011. Following the non-selection of PLATO in October 2011 for the M1/M2 launch opportunities, PLATO 2.0 was proposed in 2012 for the M3 launch opportunity, with Prof. Heike Rauer (DLR) as new PLATO Mission Consortium lead. In February 2014, the ESA Science Programme Committee finally selected PLATO 2.0 for a launch in 2024.The present PLATO 2.0 concept is shown in Fig. 1.

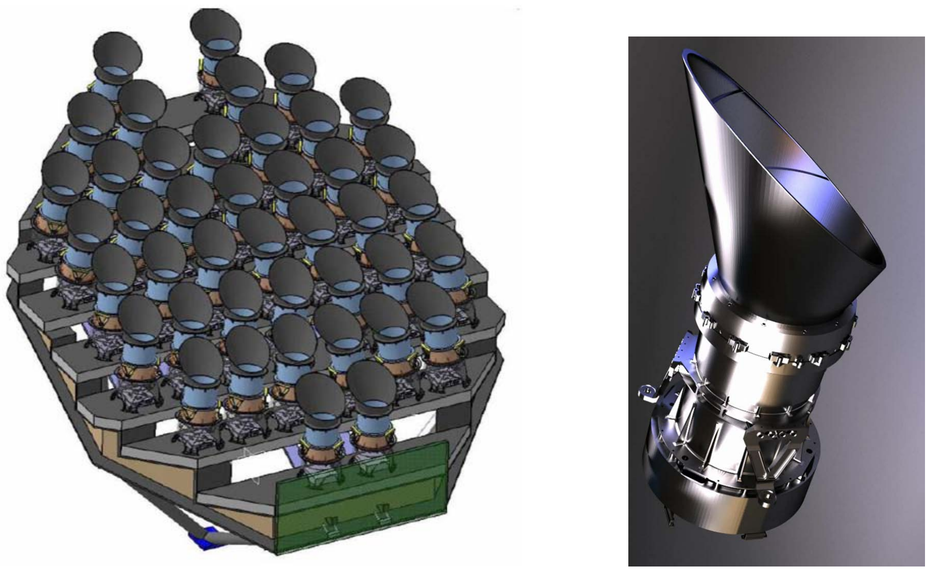

Figure 1: One of the PLATO 2.0 configurations under study (left). Detail of the individual telescopes (right).

The PLATO 2.0 space mission (PLAnetary Transits and Oscillation of stars) will detect terrestrial exoplanets in the habitable zone of bright solar-type stars ($m_v \leq 11$) and characterise their bulk properties. PLATO will provide the key information (planet radii, mean densities, age, stellar irradiation, and architecture of planetary systems) needed to determine the habitability of these unexpectedly diverse new worlds. PLATO is being designed to address the following fundamental science questions:

- How do planetary systems form and evolve?
- What makes a planet habitable?
- Is the Earth unique or has life also developed elsewhere?
- How common are worlds like ours and are they suitable for the development of life?

Nowadays, there are more than 1000 exoplanets known [6], extremely diverse in their masses, sizes, composition, and orbital properties, specially when compared to our Solar System. But for most of these planets only one of their fundamental parameters, mass or radius, is constrained by observations. This is a consequence of the success of radial velocity surveys, which typically detect non-transiting planets, whose radius cannot be measured. In a similar way, small planets detected by space-borne transit surveys, like Kepler, orbit faint stars and current radial velocity instrumentation cannot determine their masses. PLATO 2.0 builds on the expertise of current and past surveys, targetting transiting planets orbiting bright stars (with radial velocities measurable with available instrumentation), so that their bulk properties can be accurately measured, with uncertainties down to 2% in the radius, 10% in the mass, and 10% in the age. Asteroseismology of planet-hosting stars will be a fundamental tool for this purpose [2]. In particular, it will allow the determination of the age of planetary systems and thus their evolutionary state, a parameter which so far has not been explored for a large sample of planets. Each characterized system will be then a snapshot of the result of the processes of planetary formation and evolution, and by obtaining an assembly of well characterized planetary systems, we will increase significantly our understanding of these processes.

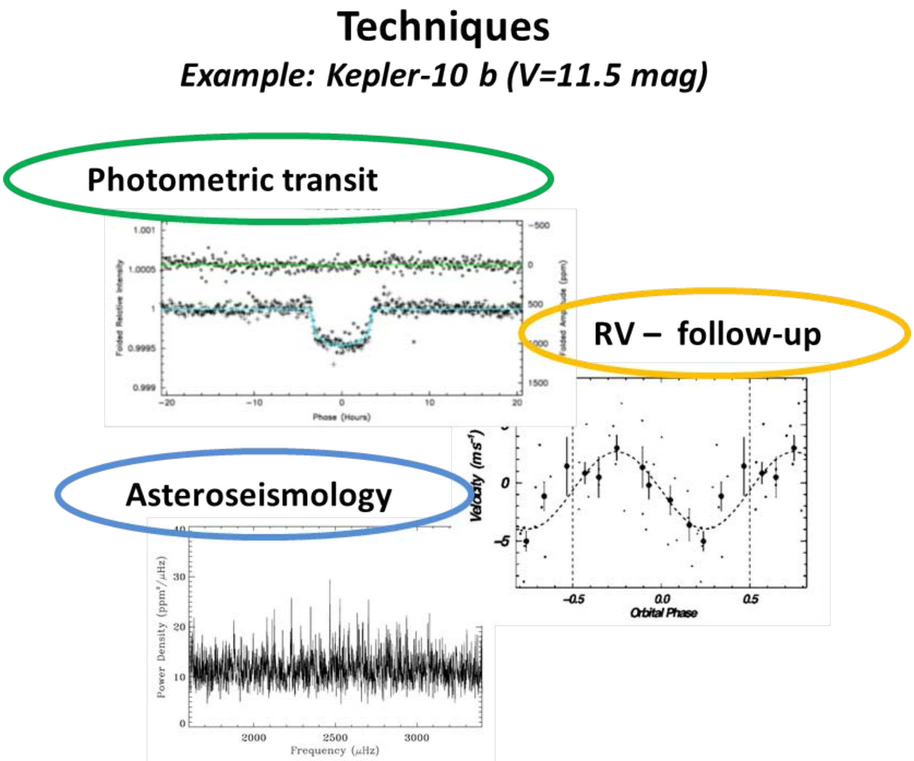

Figure 2: Photometric transit, oscillations frequency spectrum and radial velocity curve of Kepler 10-b, an $m_v = 11.5$ star, illustrating the 3 techniques to be used by PLATO 2.0.

The PLATO catalogue will consist of thousands of characterised planets. In the nominal observing strategy, 20 000 bright ($m_v \leq 11$) stars will be observed for intervals between 2 and 3 years and 80 000 more will be observed for intervals between 2 and 5 months, for wich accurately known ages and masses will be obtained, yielding several hundreds of planetary systems, including small planets in the habitable zone of their host star. Additionally, up to 1 000 000 light curves ($m_v \leq 13$) will be observed with different level of precisions, allowing statistical studies of planetary occurence and stellar properties in different regions of the Galaxy, in synergy with Gaia results. PLATO 2.0 will thus provide a huge long-lasting legacy for generations of astronomers to come that will not be limited to the realm of exoplanet and stellar science, but extend into many other fields in astronomy. The PLATO 2.0 mission and its scientific objectives are described in detail in [4] and [5]. See also the contribution by [7] in these proceedings.

2 The PLATO 2.0 mission

The strategy of the mission is to perform very high accuracy optical photometry (< 80 ppm in 1 hour down to $m_v = 13$ mag) of a very large sample of stars (> 245.000), during extended and continuous periods of time (up to 3 years). The exoplanets will be detected by the weak eclipses they produce when transiting in front of their parent star, while the long uninterrupted observations will make it also possible to analyze the oscillations of these stars, a tool that will allow to study in detail their internal structure and age.The observations will be complemented with radial velocity measurement from ground. Fig. 2 illustrates the 3 techniques to be used with an example taken from the Kepler sample of exoplanets, one of the few ones bright enough for radial velocity determination.

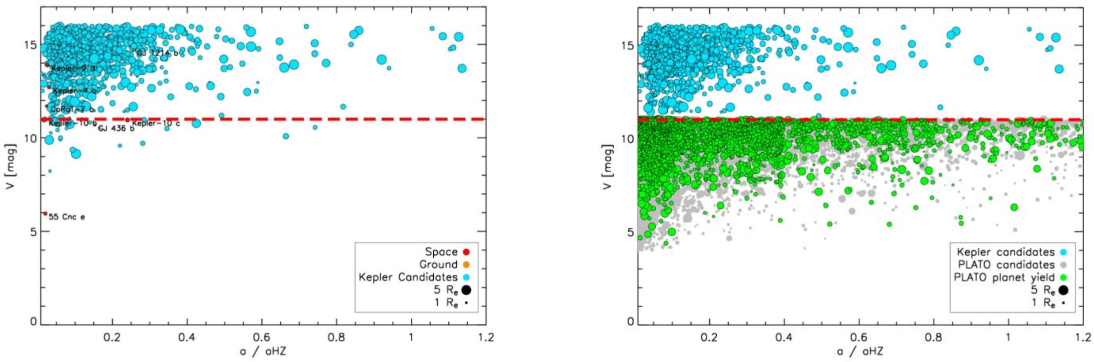

Figure 3: Kepler planet candidates from [1] (left). PLATO detection yield (right). Grey: detected transits, green: expected planets with measured radii and masses. Expected PLATO detections around stars fainter than 11 mag are not shown for clarity.

To achieve these goals, the PLATO 2.0 instrument consists of 32 "normal" telescopes with CCD based focal planes, operating in white light and providing a very wide field of view (FoV). They will be read out with a cadence of 25 s and will monitor stars with $m_v > 8$. Two additional "fast" telescopes with high read-out cadence (2.5 s) will be used for stars with $m_v \sim 4 - 8$. This concept will provide a large photometric dynamic range of $4 \leq m_v \leq 16$ ($4 \leq m_v \leq 11$ for the prime targets) and an extremely wide field of view (each telescope has an 1100 deg^2 FoV and a pupil diameter of 120 mm). The focal plane array will be formed by 4 CCDs, each with 4510×4510 pixels of 18×18 μm^2 size, working in full frame mode for the "normal" telescopes and in frame transfer mode for the "fast" ones. The current telescope concept resulting from the M1/M2 studies is shown in Fig. 1 (right).

The present baseline observing plan consists of a combination of two long-term target fields which will be monitored continuously during 2–3 years each, with a step-and-stare phase where some additional fields will be observed for up to 5 months per field within the 6 years of total mission lifetime. With this strategy the mission will be able to cover a significant fraction of the sky (up to 50%) during the nominal observing time.

With these performances PLATO will detect thousands of exoplanets of different sizes and orbits. The key objective of PLATO will be, nevertheless, Sun – Earth analogs (i.e., planets of similar size to the Earth, at a similar orbit around a dwarf star similar to our Sun). PLATO should be able to detect several tenths of these systems, depending on their occurence, which is not well constrained today [3]. The stellar sample targeted by PLATO is bright enough to be able to confirm the planets candidates using radial velocity spectroscopy from ground, a technique which is out of question for most of the Kepler candidates due to the faintness of their parent stars (see Fig. 3). Moreover, PLATO will be able to analyze in detail the properties of their parent stars by doing asteroseismology, especially their age, and will therefore characterize for the first time completely these systems and their evolutionary state. PLATO should not be considered as another planet hunter, but a mission aimed to the fine characterization of all kind of planetary systems, down to the size of terrestrial planets in the habitable zone.

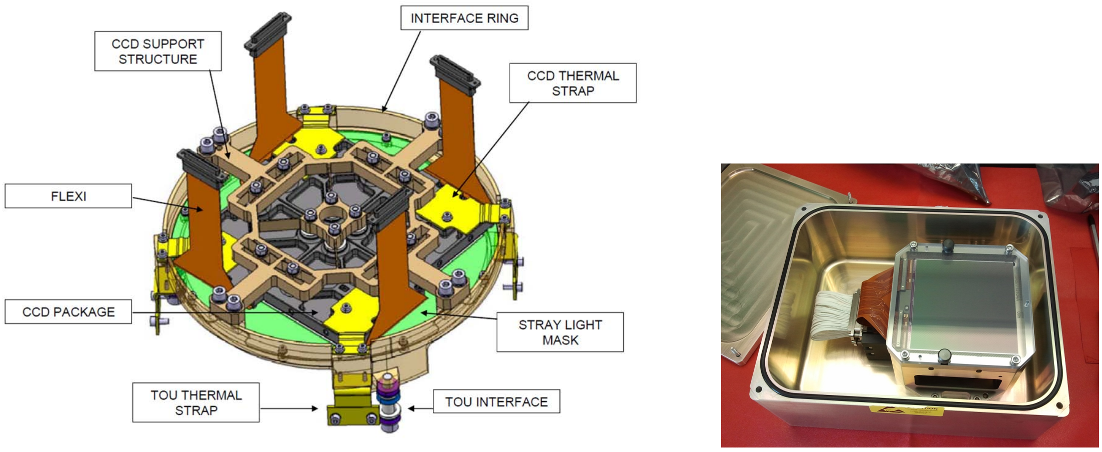

Figure 4: CAD design of the Focal Plane Assembly, with the identification of its principal elements (left). First prototype of the CCDs to be used in PLATO, manufactured by e2v (right).

3 Spanish contribution to the payload

The Spanish contribution to the PLATO 2.0 instrument is currently led by J.M. Mas Hesse (CAB-INTA), and Juan Carlos Suárez (IAA-UGr).The elements under Spanish responsibility are the structure of the focal plane assemblies (FPA) for each of the 34 telescopes, and the Main Electronics Units (MEU) hosting the Data Processing Units for the 32 "normal" telescopes. In addition to these hardware contributions, other Spanish teams will contribute to the development of the PLATO Data Centre (PDC), and to the organization of the required ground-based observational effort under the coordination by the PLATO Science Preparation Group (PSPM).

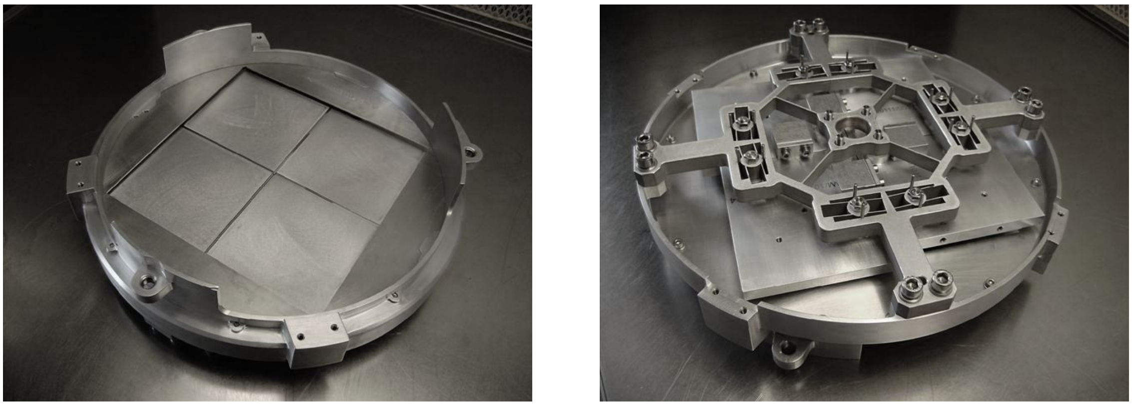

Figure 5: First prototype of the Focal Plane Assembly, manufactured by LIDAX in Aluminum and with dummies replacing the CCDs (top and bottom views).

3.1 Focal Plane Assembly (FPA)

The Focal Plane Assemblies support the 4 large size CCDs of each PLATO telescope. The main drivers for their design are essentially the thermomechanical stability required by the detector, and the very tight mass constraints, two questions which are clearly confronted. The stability is required to achieve the very high photometric accuracy needed to detect Earth analogues. Even relatively small thermomechanical deviations would induce changes in the shape and/or location of the stellar images, which would be enough to produce photometric alterations larger than expected from small exoplanets transits. The supporting structure will be built in AlBeMet to match the properties of the telescope structure. The interface with the CCDs packages, made in SiC, required the design of special flexures to guarantee a proper match at different temperatures. The heat produced by the CCDs readout is chanelled through a specially designed thermal strap to the telescope structure, which acts a as heat sink (the baffles will be used as radiators). The CCDs will be connected by special flexi wires to the front end electronics, located below the telescopes and mounted on the optical bench. Our responsibility includes the design, fabrication and qualification of the FPA structures for the 34 different telescopes, including the supporting mechanical structure, the thermal control subsystem, the purging hardware, the radiation and light shielding and the simulation of the impact that these elements could have on the performances of the instrument. We show in Fig. 4 the present status of the FPA design at the end of the M1/M2 Definition Phase, together with the first e2v CCD prototype. In Fig. 5 we show the first mechanical model of the FPA, manufactured in Aluminum with the goal of checking the feasibility of the design and the integration procedure. This work was done in collaboration with the Spanish LIDAX company.

3.2 Main Electronics Units (MEU)

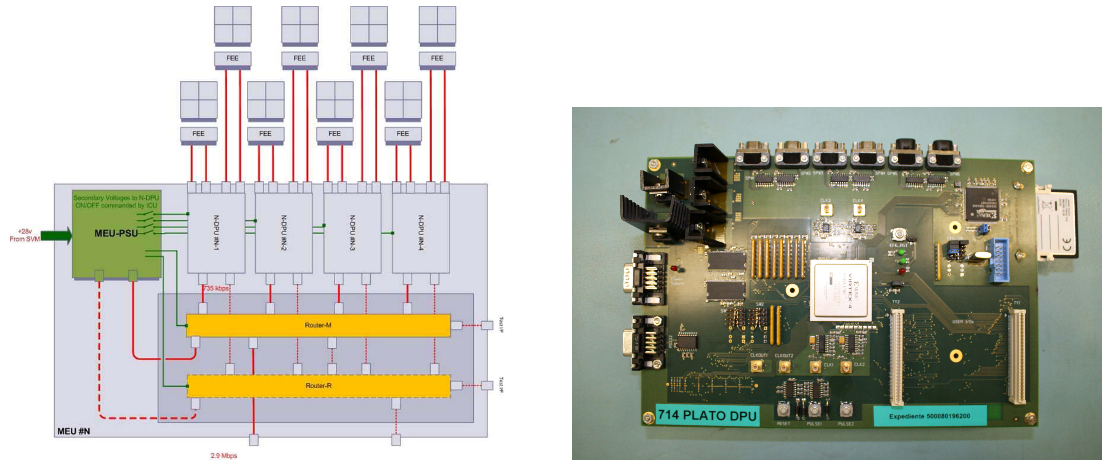

Figure 6: Global architecture of each Main Electronics Unit–MEU (left). Interface breadboard card built by Thales Alenia Space for the M1/M2 Definition Phase (right).

The Main Electronics Units (MEU) contain each 4 data processing boards. Each board is being designed to process the data provided by 2 telescopes focal planes. The present design includes 4 MEUs, which would perform the digital data processing of the 32 "normal" telescopes. Each MEU includes also a power supply unit (PSU) to feed the DPU cards and the SpaceWire interfaces. This concept is shown in Fig. 6. The main challenge in the design of the MEUs is the huge amount of data that have to be processed onboard, in order to extract automatically the photometric lightcurve of tens of thousands of stars every few seconds. To achieve a cadence of 1 image every 25 seconds, the CCDs readout will be shifted so that one of each will be read every 6.25 seconds, generating each time more than 20 millions of pixel. In this time (6.25 s) the onboard software running on the MEU DPUs has to process the data for all stars within the field of view of each CCD, around 30.000, and prepare their lightcurves to be transmitted to the central onboard computer. The photometric extraction will include cosmic ray rejection, bias subtraction and weighted masks photometry. An additional design driver is again the mass constraints, as well as the reduced power budget available. We show in Fig. 7 the overall architecture of each of the Data Processing Units card, as defined during the M1/M2 studies by the Spanish company Thales Alenia Space. A breadboard was manufactured to test the SpaceWire data interface between the Front End Electronics of each telescope and the DPU cards (Fig. 6 right). The tests performed on this prototype demonstrated that the required rates of 100 Mbps per channel could be achieved with enough margin, and that data could be transferred at even higher rates, up to 200 kbps as it is being currently considered for the next design iteration.

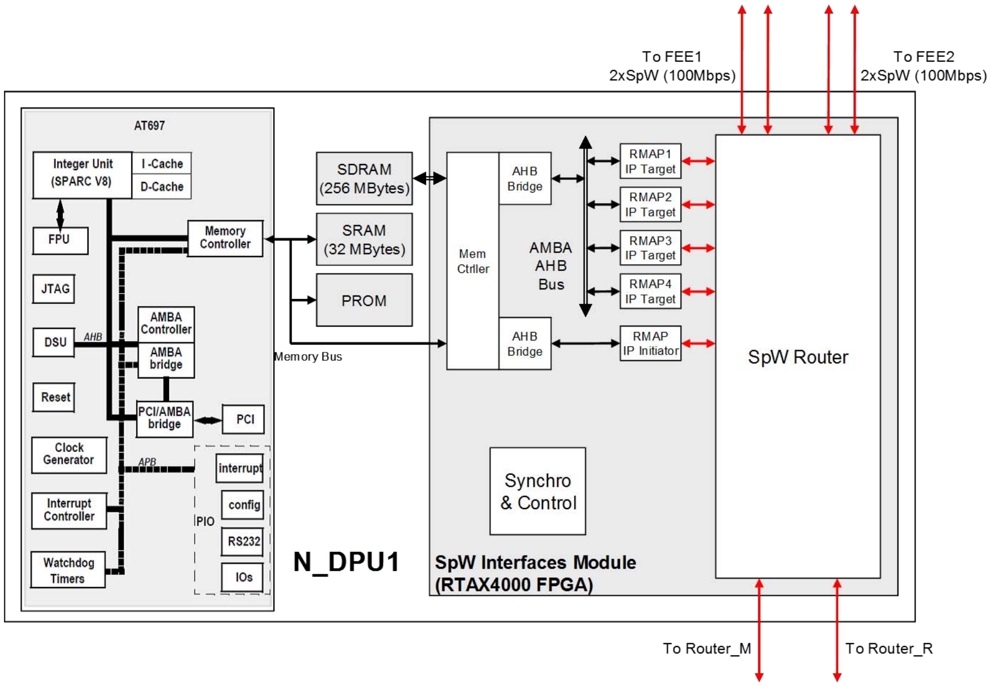

Figure 7: Conceptual design of the individual DPU cards performed by Thales Alenia Espacio for the M1/M2 definition study.

4 Present status and future prospects

After the selection as M3 mission in February 2014 the PLATO consortium was reconfigured. Activities started formally at the kick-off meeting held in July in Berlin, and at the time of writing this paper we are fully inmersed in the phase B1 studies. The timeline of the PLATO mission will be as follows:

- 2007: proposal and selection of PLATO as M1/M2 candidate
- June 2008 – June 2009: Our team contributed to the successful assessment study of the payload performed by the PLATO Consortium. In parallel ESA performed 2 industrial assessment studies of the whole mission
- January 2010 – July 2011: Definition Phase. We contributed to the definition studies of the payload, improving the design resulting from the assessment study
- October 2011: Evaluation and non selection by ESA. Invitation to enter M3 selection competition
- January 2012: submission of the proposal to enter the M3 selection
- December 2012: submission of the revised management plan

- February 2014: selection of PLATO as M3 mission
- Oct–Nov 2015: System Requirements Review
- Feb–Mar 2016: Mission adoption and IPC approval
- Oct 2016: Industrial prime contractor kick-off
- 2017: System PDR
- 2017–2021: Implementation phase. Our team will build, test, qualify and provide the focal planes for the PLATO telescopes and the MEUs
- Mid-2020: System CDR
- Q4 2021: delivery of all cameras
- Q1 2024: PLATO launch and start of the science operations
- 2031: End of the nominal in-orbit science operations

Around 2027–2028 the first long staring phase (3 years) should have been completed, yielding already a huge amount of high–precision lightcurves and exoplanets candidates. At the end of the next decade truly Earth analogues should have been identified and characterized, opening a new and exciting age in which the objective will be to look for tracers of biological activity.

Acknowledgments

The PLATO 2.0 mission is being developed by ESA and the Payload Mission Consortium, formed by scientists and engineers all over Europe. This work has been funded at CAB–INTA by Spanish MINECO research grants AYA2008-03467/ESP, AYA2011-24780 and AYA2012-39362-C02-01. JCS acknowledges funding support from MINECO/FEDER grant AYA2012-39346-C02-01, from SpaceInn grant FP7–SPACE–2011–1: 312844, as well as from the Spanish MINECO Ramón y Cajal programme. HD has been funded by MINECO grant AYA2012-39346-C02-02.

References

[1] Borucki, W. J., Koch, D. G., Basri, G., et al. 2011, ApJ, 736, 19

[2] Huber, D., et al. 2013, ApJ, 767, 127

[3] Petigura, E., et al. 2013, PNAS, 110, 19273

[4] Rauer, H., et al. "PLATO: Assessment Study Report", December 2013, ESA/SRE(2013)5

[5] Rauer, H., Catala, C., Aerts, C., et al. 2014, Experimental Astronomy, 41

[6] Schneider, J. et al. 2011, A&A, 532, 79

[7] Suárez, J.C., this volume