During the year 2017, the GSTP has continued its goal of providing a flexible response to the needs of ESA Programmes, Member States and European Industry. Selected accomplishments are illustrated in this GSTP Annual Report 2017. Overall, in 2017, the GSTP supported a remarkable number of new technology developments, representing 107 new activities (worth around 70 M€) and 67 closed activities (worth around 43 M€).
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GENERAL SUPPORT
TECHNOLOGY PROGRAMME

Inspection of the Aeolus telescope.
In the frame of the General Support Technology Programme (GSTP), European space industry develops leading edge space technologies that enable missions to discover the Universe, understand our environment, navigate, educate and save lives. Roughly 90 M€uros are invested annually in technologies building know-how and capabilities in industry, and helping to secure Europe’s competitiveness in the global market by creating jobs and keeping Europe at the forefront of technological innovation.

During more than two decades, the GSTP has successfully helped to bridge the gap between concept proven technologies and space missions, between laboratories and the open market. Some good examples are:

- LEON family of microprocessors flown in AlphaSat and selected for the Sentinels
- GPS POD instrument baseline in the Sentinels and Earth Care missions
- MEMS rate sensor flying in Cryosat 2
- The 1N “green” thruster in PRISMA
- APS development that led to the lightweight star tracker in BepiColombo
- The hybrid low cost magnetometer in ADM-Aeolus
- The Mission Operation Centre (MOC) for CHEOPS

It is also worth mentioning the Thrust Vector Control system flown in our small European Launcher VEGA or the human spaceflight related activities that are an integral part of the GSTP such as the IPV system, the Anita gas monitor and other health monitoring devices for astronauts.

In the GSTP, technology concepts are transformed into engineering models and then converted into a broad spectrum of mature products – everything from individual components, to subsystems, up to complete satellites. The GSTP also offers flight opportunities to demonstrate technology or new concepts via PROBA (Project for OnBoard Autonomy) and other flight opportunities. Examples include the first technology demonstration CubeSat GOMX-3, CubeSat GOMX-4 intended to test and prepare the way for future satellite constellations, PROBA-V designed for global environmental and agricultural monitoring, the SMOS Instrument MIRAS or the technologies demonstrated on-board the ISS (e.g. the Automated Identification System (AIS)) and the QARMAN CubeSat - the very first of its kind, intended to demonstrate the feasibility of a CubeSat as a re-entry platform and an economical solution for research in telemetry.

Always looking ahead, the GSTP is now helping to prepare the future of space in diverse areas of interest such as:

- Advanced Manufacturing: a key enabling technology for space applications, which allows fit-for-purpose hardware to be obtained over shorter time periods and by using less material;
- Design to Produce: Design to Produce: this allows digital engineering systems to focus on and improve structural optimisation and efficiency by predicting progressive damage to structures and highlighting critical areas;
- Clean Space: ESA’s cross-cutting initiative, which aims to contribute to the reduction of the environmental impact of space activities;
- Electric Propulsion alternatives: such as micro-colloid thruster technology or IFM nano thruster;
- EGS-CC: a European initiative where the Large System Integrators and space agencies are, for the first time, collaborating in the development of common infrastructure for ground systems that accompany the full lifecycle of a space system.

These are only some of the new challenges being addressed by GSTP that will enable the European missions of the future.

### Participating States

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### GSTP Objectives

- Enable missions of ESA and national programmes by developing technology
- Foster innovation by creating new products
- Strengthen the competitiveness of European industry
- Improve European technological non-dependence and the availability of European sources for critical technologies
- Facilitate spin-in from outside the space sector

### The GSTP Service Domains

- Earth Observation
- Science
- Human Spaceflight
- Space Transportation
- Navigation
- Generic Technologies
- Space Situational Awareness
- Robotics Exploration

The GSTP ensures that the right technology with the right maturity is available at the right time.
GTP EVOLUTION (1993-2020)
Closed GTP periods

**PROBA 1**

**ERC32**
A radiation-tolerant SPARC V7 processor developed for space applications.

**Advanced Crew Terminal**
Columbus on ISS.

**Digital Signal Processor (DSP 21020)**
Flown in ROSETTA (2004-2016) and baseline in METOP.

**Sloshsat FLEVO**
Facility for liquid experimentation and verification in orbit. Launched in 2005.

**LEON PROCESSOR**
32-bit microprocessor – Selected for Alphasat, Proba-V, the Earth-monitoring Sentinel family and the BepiColombo mission.

**Launcher Payload Separation System**
Considered for sensitive and heavy payloads on launchers (Ariane 4 and 5).

**Autocorrelation Spectrometer Chip-Set**
SMART mission launched in 2003.

**PROBA 2**
Technology demonstration mission launched in 2009, including 17 new technological developments and 4 scientific experiments.

**Active Pixel Sensor**
Based on the Proba-V baseline and start trackers like the one baseline in BepiColombo.

**High Performance Green Propulsion**
Liquid monopropellant based upon ADN.

**Common Procedure Language**
Based on the current ESSC standard for procedure languages.

**TMA Telescope**
Used in Rapid Eye (launched in 2008) and Proba V (launched in 2013).

**MELISSA**
Regenerative life support systems.

**SMOS - MIRAS**
The Soil Moisture and Ocean Salinity mission launched in 2009 makes global observations of soil moisture over land and sea surface salinity over the oceans.

**EXPERT**
European Experimental Re-entry testbed.

**GTP-1**
50.5 M€

**GTP-2**
119.8 M€

**GTP-3**
242.5 M€

**GTP-4**
319.6 M€

**GTP-5**
602 M€
**Active GSTP periods**

**Proba V**
Technology demonstration mission launched in 2013 to supply needed imagery for applications such as climate impact assessments, water resource management, agricultural monitoring and food security estimates.

**AIS on ISS**
Space based Automatic Identification System receiver brings worldwide sea traffic tracking within reach.

**Hybrid Low Cost Magnetometer**
Baseline for ADM-AEOLUS. Launched in 2018.

**Lightweight APS-based Star Tracker**
Selected for BepiColombo.

**Nodding Mechanism on ISS**
Positioned in the Station’s Cupola to support a camera taking high-definition pictures.

**Nanomaterials**
Non-conventional matrix/carbon nanotube skelton reinforce composites.

**EPT - Energetic Particle Telescope**
Flying in Proba V, records the charge, energy and angle of incoming charged particles along a broad range of energies across a wide 50° field-of-view.

**IBDM International Berthing and Docking Mechanism**
European androgynous low impact docking mechanism, capable of docking and berthing large and small spacecraft.

**EGS-CC**

**Proba 3**
First precision formation flying mission, Two spacecraft separated by 150 m will be used as a solar coronagraph to study the Sun’s faint corona. Launch planned in 2020.

**Advanced Manufacturing**
Including not only 3D printing but also materials processing, surface engineering, shaping, joining and assembly related activities, etc.

**Digital Engineering**
Structure optimisation structural efficiency and progressive damage prediction of fit-for-purpose hardware using software tools.

**Clean Space**
ESA’s cross-cutting initiative that aims to contribute to the reduction of the environmental impact of space activities.

**GOMX-3**
ESA’s inaugural in-orbit demonstration CubeSat with the mission to demonstrate new capabilities of nanosatellites focusing on attitude control, RF transmission and high-speed data downlink.

**GOMX-4**
ESA’s biggest nanosatellite yet, built for testing new miniaturised technologies and paving the way for future operation nanosatellite constellations. Launched in 2018.

**Friction Stir Welding**
Welding technique with less residual stress and distortion that at the same time reduces cost and overall production time.

**QARMAN**
Built for the purpose of studying the atmospheric re-entry process and the associated aerothermodynamic phenomena.

**Re-use and upgrade of Space Antenna:**
Re-erection of the 15-metre-high Perth Antenna at Santa Maria in Azores, Portugal, with the purpose of providing tracking services and facilitating the downlink of Earth Observation data.

**2009**
**2010**
**2011**
**2012**
**2013**
**2014**
**2015**
**2016**
**2017**
**2018**
**2019**
**2020**

*Since 2012 GSTP became a Permanent Programme*
SUMMARY OF ACHIEVEMENTS & CHALLENGES
Future Moon missions have a demand for dedicated ground terminals, hence the Goonhilly-6 antenna located in Cornwall (UK), with its 32-metre-wide diameter dish, has been identified by ESA as a suitable candidate for European support to upcoming Moon missions. In particular, the Exploration Mission 1 (EM-1) managed by NASA, was chosen as a potential target mission that an upgraded Goonhilly-6 antenna can offer the required Tracking, Telemetry and Telecommand (TT&C) services.

This activity assessed what was required for EM-1 related to the ground station and what upgrades would be needed for the existing antenna system in order for it to cope with the mission. Furthermore, the activity defined a preliminary optical layout, identified potential contractors and provided a cost estimate for the overall antenna system upgrade.

The antenna has a Cassegrainian configuration and employs a Beam Waveguide (BWG) feed system. The antenna mount is of an elevation-over-azimuth type with a wheel-on track azimuth drive configuration. As outcome of the activity, both BWG feed system and antenna drive will be upgraded and after the upgrade, the Goonhilly-6 antenna will provide a useful level of performance for EM-1 at S-band and potentially at the other frequencies of interest for subsequent missions (e.g. X-band). Similarly, the antenna drive and servo systems will also require an upgrade in order to provide the necessary performance for spacecraft tracking. In addition, the activity also concluded that the employment of cryogenic LNAs (Low Noise Amplifiers) will not be mandatory and that the use of HPAs (High-Pressure Air-cooled systems) may be enough to achieve the required transmit power.

Finally, this antenna and facilities are viable solutions for the support of Moon and Deep Space missions, namely ESA’s 35-m deep space antenna network. As follow up of this activity, a 9.5 M€ project, funded by the Cornwall & Isles of Scilly Local Enterprise Partnership (CIOLEP) is currently under preparation. Within this project, the Goonhilly-6 antenna will be upgraded under ESA’s technical oversight to provide high bit rate data links for missions that travel far from Earth – typically exceeding 2 million km distance.
2ND GENERATION APS STAR TRACKER – OPTICAL HEAD

With the participation of Denmark

Between 2002 and 2010, ESA successfully developed the first generation of APS (Active Pixel Sensor) based star trackers, which have come to dominate the market and have changed the way AOCS (Attitude and Orbital Control Systems) sub-systems are designed. In turn, the detectors, on which these first generation star trackers were built, were actually designed in the early 2000s. and, due to technological developments in the meantime, their performances can now be significantly improved by embedding additional logic on the same chip.

Thus, this activity was aimed at manufacturing and testing a second generation of an advanced, low cost and easily accommodated miniature star tracker optical head and baffle, and exploiting the capabilities of the new generation of APS detectors. The development was focused on the use of the LCMS detector (Liquid Chromatography Mass Spectrometry) for initial prototyping and of the Faint Star detector (currently in development under an ESA contract) for the final engineering model.

In further detail, the Optical Head has been developed for both the LCMS and the Faint Star APS detectors, with identical optical and mechanical design for the two versions and with a single stage baffle to allow for faster and cheaper manufacturing. The development reduced cost, mass and power consumption, while maintaining competitive accuracy. The Optical Head can be directly connected to the S/C on-board computer, hosting the Star Tracker software, without the need for a dedicated electronic unit.

In fact, a big achievement is that, still during the first phase of the activity, a total of 13 units of the LCMS-based version of the Optical Head were sold for the FormoSat-7 and Carbonite-2 missions.

As a result of this activity a new generation of highly miniaturised APS based Optical Head is now available in the European market. A follow-up GSTP activity is currently on-going to develop the electronic unit and the software that, together with the Optical Head, will complete the full second generation star tracker product. Completion of this follow-up activity is expected within 2018.
TECHNOLOGIES AND KEY COMPONENTS FOR COMPACT HYPERSONTRAL INSTRUMENTS (CHIEM)
with the participation of Belgium

Hyperspectral instruments detect the reflected radiation of a scene (on Earth) over a defined range of the electromagnetic spectrum. Instrument parameters, such as the spectral coverage, the number of bands and band widths determine possible targets of observation. The spectral data can then provide information on, water quality, land cover, land use and climate change.

Currently, the challenges of hyperspectral instrument developments are achieving compactness, cost efficiency, design simplicity and revisit rate. Hence, the CHIEM activity addresses the combination of high spectral resolution imaging with smaller and cheaper satellite platforms using a Linear Variable Filter (LVF) directly deposited on a 2D sensor array.

The goal of the CHIEM activity was to modify an existing large format CMOS (Complementary Metal Oxide Semiconductor) sensor design to allow the deposition of Fabry-Pérot filters at wafer level and to improve the LVF to match the detector format. The filter deposition technique was applied on both, FSI (Front side illuminated) and BSI (Back side illuminated) sensors. At the same time, sensor performance could be maintained or even increased. The overall system should then be able to operate at 600 km altitude and perform hyperspectral imaging for Earth observation with a swath of at least 100 km, and a GSD (Ground Sample Distance) of 25 m. Moreover, the instrument should be sufficiently compact to be compatible with a 12U CubeSat form factor.

The system is completed by read-out electronics (ROE) that are capable of high speed operation and allow post processing techniques to improve SNR (signal to noise ratio), along with the design and testing of a compact high quality optical system. The sensors with hyperspectral filters, together with the ROE and the optical design, form a powerful system that allows hyperspectral imaging from a small space platform.

To sum up, through CHIEM, cost-efficient high spectral resolution imaging is enabled for future missions from a small space platform and, when operating in constellation mode, hyperspectral Earth observations at a high revisit rate can be realised. Finally, planned work includes the development of a compact hyperspectral imager proto-flight model, which is compatible with the 12U CubeSat platform and is scheduled for an in-orbit demonstration in 2020.

In 2017, 67 GSTP activities were completed achieving the technology development objectives originally targeted.
CUBESAT TECHNOLOGY PRE-DEVELOPMENT QB-50 COMMUNICATIONS & AOCS TECHNOLOGIES

with the participation of the Netherlands

CubeSats, a class of nano-satellites between 1-10 kg, have become increasingly capable and popular as they can serve several mission applications due to a relatively low cost and short development time. This is as a result of their miniaturisation, flexibility in integration and modularity. However, current performance of the CubeSats still has some limitations and constraints caused by available technology. This activity was initiated by ESA to further develop core technologies for CubeSats to enable improvement in their performance for future missions so that they can support more demanding payloads.

The main purpose of this activity was to design and develop a CubeSat high data rate S-Band Transmitter and a miniaturised star tracker for CubeSat attitude control, and validate these technologies in relevant environments, against the targeted requirements and identified market needs, to achieve TRL4 and TRL5 respectively. In addition, a large amount of knowledge on developing high accurate star sensors and CCSDS compliant RF systems was gathered, which will lead to further improvements in performance of these subsystems in the future.

In more detail, the CubeSat high data rate S-band transmitter prototype supports at least 1 Mbit/s (user) data rate, is compatible with existing ESA ground stations and is also compliant with CCSDS applicable documents. This will contribute to the transmission of much larger amounts of data to the ground for more demanding CubeSat missions. The flight model of S-Band Transmitter has already been delivered for a CubeSat mission expected to launch in 2018.

On the other hand, the miniaturised Star Tracker prototype for CubeSats attitude control has an accuracy of 0.01° (3σ) and a Sun exclusion angle of 55°, which has contributed to improve CubeSat attitude determination with at least an order of magnitude without imposing huge constraints or impacts on the CubeSat Spacecraft bus. A flight model of the Star Tracker has been delivered for the Gomx-48 mission for in-orbit-demonstration purpose and was launched in February 2018.

In the near future, the development of the S-band transmitter into a more competitive product is being planned, along with a receiver section, so that both can be integrated into a full-duplex S-band transceiver (combined with a diplexer). Considering the targeted objectives of more demanding CubeSat future missions, the star tracker’s functional performance and lifetime are being planned to be improved as well.

Due to the complexity and unpredictability of the challenges encountered in space, it is very important to minimise the mission risks as much as possible. The GSTP enables missions helping novel technology to reach the right maturity level.
RADCUBE AND RADMAG STUDY PHASE (A/B1)

The research on space weather and its effects will be more and more important in the near future, as a continuous increase in human presence is in progress in the near-Earth region and the technology dependency of the human civilisation has become higher than ever, mainly in the fields of energy and telecommunication systems. To study space weather, as a first step, it is necessary to develop and establish an advanced monitoring system to provide scientific data about the high energy particle environment and the status of the magnetosphere to obtain a reliable forecast database.

The overall objective of the RADCUBE CubeSat Mission is to demonstrate – through successful mission operation – the future use of the RADCUBE 3U CubeSat system in strategically important fields such as space weather research (and forecast services) and general radiation damage monitoring, for commercial use. This will be achieved by demonstrating the capabilities of an appropriate 3U CubeSat platform and providing the RadMag space radiation measurement system. This is based on silicon detector technology, with magnetic field sensing capabilities, where a sensitive magnetometer is deployed on a boom.

For this activity, the conceptual approach of the RADCUBE mission definition and the preliminary mission/system requirements have been formulated, including major components and their preliminary specifications. The detailed feasibility study of the RadMag instrument has been performed and showed that such a complex instrument can fit within the constraints of a 3U CubeSat mission. The preliminary design concept was elaborated the instrument to assess the expected performance of the scientific measurements. Finally, the project passed the System Requirements Review and ESA provided the authorisation to proceed with the implementation phase.

In addition, the RADCUBE Study Phase has shown that the RADCUBE CubeSat could potentially be used as a space weather service provider platform. The developer team introduced the concept called CROSS (Cosmic Ray Observatory Satellite System), which proposes a fleet of RADCUBE CubeSats to provide near-real time data about the space weather conditions and support the possibility of an European reliable space weather forecast system and database within ESA SSA SWE programme.

The next step is the RADCUBE mission implementation phase to demonstrate in-orbit its space weather service capabilities. In the frame of the implementation phase, the detailed design will be expanded and an EQM/FM based model philosophy will be followed in order to reach lower development risk.
MINIATURISATION OF A MAGNETOMETER BASED ON MEMS TECHNOLOGY

with the participation of Portugal

The micro-electromechanical systems (MEMS) market is nowadays very broad and competitive, ranging from printer heads and position sensors to some more exotic gas and humidity sensors. MEMS allows miniaturised and application specific systems to be embedded into a larger architecture, drastically reducing the mass and noise associated a large structure.

It was the primary objective of this activity to design, develop and manufacture a MEMS magnetometer sensor for space applications based on the Lorentz force principle. The activity was intended to couple a commercial, off the shelf, compatible Application-Specific Integrated Circuit (ASIC), with MEMS so that characterisation and early performance assessment could be executed.

In more detail, the characterisation was narrowed down to discrete circuitry limitations as no commercial ASIC able to couple with the MEMS, could be identified. The MEMS design shows potential to fully comply with the established requirements, except for noise requires an improvement on the next iteration of the sensor. Proof of concept was, nonetheless, demonstrated from this activity. Additionally, a more detailed understanding of the needs for a compatible ASIC and package for this MEMS was achieved.

The MEMS Magnetometer has potential applications in all LEO and MEO missions and, with the advent of New Space and the growing demand for LEO constellation small satellites, the need for a miniaturised space qualified (radiation tolerant) magnetometer has never been so present. Additionally, since the MEMS magnetometer has been designed with high reliability in mind, non-space applications where this is of concern are also potential candidates for the usage of this technology. However, for more specific scientific environments that also have high radiations and/or temperatures and that require magnetic fields measurements (e.g. particle colliders), the utilisation of this system still needs to be evaluated.

The full development of the MEMS Magnetometer will require several important steps before a technologically mature sensor is achieved. As a first step, a side by side ASIC development and MEMS design improvement are required. The ASIC development shall at first focus on the development of a suitable product to interface with the developed MEMS, and at a second stage a fully radiation-hardened compatible ASIC. The MEMS design improvement shall focus on the reduction of the noise levels and iteration over some minor reliability mechanical concerns. Afterwards, further reliability assessment shall be performed, followed by the development of a reliable packaging solution for the MEMS+ASIC, such that it would constitute the basis of the MEMS based Magnetometer sensor. Finally, a space qualification (and possibly IOD) is required for the sensor to reach an appropriate TRL to be considered for space missions.
IMAGE RECOGNITION AND PROCESSING FOR NAVIGATION (IRPN)  
with the participation of Germany

A major goal of ESA’s Clean Space initiative is the study and development of key technologies needed for Active Debris Removal (ADR). For a mission to function in this scenario it will need to use complex autonomous Guidance, Navigation and Control (GNC) systems on the chaser spacecraft to allow the closed loop control operations to grab the target debris and then de-orbit the entire compound target-chaser. In such operations, the most sensitive phases will be close approach, mating and capture, and then the de-orbit.

In fact, the environment in an ADR mission is similar to that of a rendezvous mission, but with the added difficulty of having an uncooperative target. In addition, there are several constraints that have to be taken into account, namely dynamic lighting conditions (eclipses every hour to every couple of hours varying illumination angles), and a regular loss of contact with Earth, which results in extremely small variations of the angles for illumination and communication. In addition, image processing for precise navigation was not meeting the necessary requirements in an ADR scenario to conduct a safe approach between a target and chaser objects without a suit of sensors.

The solution explored in this activity involved the usage of cameras in the visual and infrared ranges of the spectrum as well as LIDAR sensors. These sensors will produce pictures that have to be quickly analysed on-board and in real-time using target matching algorithms by the image processing function. In particular, the infrared cameras and 3D imaging LIDARs are key elements in ADR scenarios as they acquire a 3D point-cloud of the target object with high accuracy, including features such as size, relative position, behaviour (movement and speed) and shape, and thereby enable 3D image processing algorithms for pose estimation of the target object or hazard detection and avoidance in the case of planetary landing.

Thus, this activity aimed at the design, development and verification of the necessary capabilities for image processing and computation of a navigation solution for position, pose and angular motion estimation on an ADR scenario with uncooperative targets. A complete set of sequences of synthetic images had to be generated to represent different illumination conditions in the approach trajectory of the chaser spacecraft to the target one, providing confidence on the robustness of the navigation solution. Moreover, all Image Recognition and Processing (IRP) algorithms and the overall Image Recognition and Processing for Navigation (IRPN) system have been evaluated extensively in different test environments: model-in-the-loop (MIL) and processor-in-the-loop (PIL) with synthetic (rendered) images and in the laboratory environment, within the hardware-in-the-loop (HIL) facility producing very realistic images.

The activity has increased the TRL level of the technologies under development using visual and infrared cameras along with LIDAR, with many lessons-learnt for the on-ground testing that can be applied in future projects. In particular, the advantages of using passive thermal infrared sensors in relative navigation became clear when operations could continue in situations where this would not be possible with visual sensors alone, having been demonstrated in orbits with significant eclipse periods.

A continuation of the project implemented a number of meaningful Image Processing (IP) functions in flight representative processors (LEON-4 and FPGA) or real time applications and missions, including the definition of a scalable architecture of such configuration along with a comprehensive assessment of the needs for the overall migration of the complete system to such a platform.
The increase in electrical power available on board modern spacecraft is paving the way to the use of very high power electric propulsion systems (EPS) for a variety of deep space exploration missions to cis-lunar space, asteroids and planets of the inner solar system, as well as private commercial space missions. More specifically, the Hall-effect thruster technology offers a favourable combination of performance, reliability, and lifetime for such applications.

When it comes to space exploration and transportation missions that could benefit from the development of high-power EPS, they typically pose challenging constraints in terms of expected performance, i.e. operational lifetime above 20 000 hours (more than twice that of existing space-qualified thrusters), compliance with severe environmental requirements, and operation flexibility. The challenges posed by the development of very high power EPS are thus related to the design of systems able to comply with such requirements.

Starting from the first 20-kW class Hall-effect thruster prototype developed previously (the so-called HT20k, that was operated at the nominal power level of 20 kW until stationary thermal conditions and performed a short endurance test of a few hundred hours), the goal of this activity is to develop a 20kW-class Hall Thruster with extended capabilities (the HT20k XC) to be offered to the space transportation and exploration market. The HT20k XC is expected to be optimised to operate at high-voltage, high-specific-impulse conditions.

At the moment, the System Requirement Review for this activity has been successfully achieved. In preparation of the Design Review of the thruster unit, aimed at complying with the agreed requirements, the so-called magnetic shielding approach has been implemented in the new design to overcome the lifetime limitation associated with the channel erosion. Moreover, the implementation of technological solutions aiming at improving thruster performance and reliability is planned. Namely, the choice of materials to optimise thermal behaviour, the harness and connection selection for electric design improvement, covers and surface treatments to limit plasma-induced erosion of poles, and a revised configuration and design of electrodes aimed at ensuring long-term reliability of the system.

In addition, on the basis of forecasted market trends, market niches that could benefit from a long-life, high-power Hall thruster in the next 5 to 10 years and beyond are space transportation (either in Earth Orbit and within the Solar System), exploration mission to NEOs and Solar System planets and future large GEO SatCom.

Finally, beside this GSTP activity, other development activities of the 20 kW-class Hall effect Thruster are also funded in the framework of the EU’s H2020 CHEOPS programme and a dedicated, pre-qualification ESA Expert programme. Synergies are envisaged between these programs aiming at achieving prequalification by 2020 and flight qualification in the next 5 to 10 years.
RE-ERECION OF THE 15 METRE PERTH ANTENNA AT SANTA MARIA, AZORES, PORTUGAL - PHASE 2

with the participation of Portugal

The ESA ground station antenna of Perth (PER-1) was first installed in Carnavon, Western Australia, in 1975 and later relocated near Perth. Originally it supported space research missions and from 2007, it supported launchers, mainly Ariane 5. However, due to the large expansion of the city of Perth, sharing the frequency spectrum with the local telecommunication operators was no longer possible. Furthermore, with the launchers’ tracking support being shifted to a small terminal in nearby New Norcia, PER-1 was finally decommissioned from the ESA tracking station network, ESTRACK, in 2016, and instead acquired by Portugal for future repurposing.

The objective of the activity is the relocation of PER-1 to the island of Santa Maria, Azores, Portugal. The main goals consist of ensuring the same performance as before relocation and optionally, to have the new antenna provide launcher support, dual-band uplink/downlink for the ESA PROBA-3 mission and be used for commercial applications at S- and X-band. Although the objectives may seem relatively simple, relocating a 30-year-old antenna presents numerous challenges, namely the fact the installed equipment is outdated and the moulds for fabricating its panels no longer exist.

A detailed re-test of the performance of PER-1 was undertaken in 2017 before it was dismantled and shipped to the Azores. Currently, the re-design of the antenna front end, necessary to cope with the replacement of outdated equipment and to prepare the antenna for potential users (like PROBA-3), is under review. In addition, a re-conditioning of all metallic parts has been started while the infrastructure works (e.g. roads, facilities, antenna tower) are being provided by the regional government of the Azores. It is foreseen that the re-erection of the antenna and integration of the new equipment will start in November 2018 and to validate it by August 2019.

The future steps are the validation of the antenna performance at S- and X-band by 2019, the validation of the back-end interfaces later in 2019, a qualification campaign with existing satellites by 2020 and, potentially, the validation of the dual carrier uplink & dual carrier downlink concept requested by PROBA-3.
DEEP SPACE LOW COST 4M MONOLITHIC OPTICAL ANTENNA FOR DAY/NIGHT OPERATIONS

with the participation of Belgium

Optical communication for deep space applications is under technical standardisation in the Consultative Committee for Space Data Systems (CCSDS). Designs for deep space on-board terminals are being developed based on experience for near Earth optical communication systems (e.g. Optel-D terminal). At the moment, a major step is the preparation of technologies necessary for ESTRACK’s future deep-space optical communication capability, for which one of the main challenges is the necessity of a large effective aperture within a very tight budget envelope.

Future deep-space missions will generate increasing quantities of data from hundreds of millions of kilometres away, requiring an increased data transmission capacity. Optical communication has the potential to increase data rate without increasing the mass and power consumption of the onboard communication module. Thus, affordable optical antennas with large aperture on ground are a key element for deep-space optical communication.

Therefore, the objective of this activity is to develop a cost-effective solution for a deep space optical communication ground station for day & night operation. In order to achieve that, the scope of the activity entails the following work:

- Critical review of system requirements and requirements consolidation.
- System Analysis and preliminary design of a cost-effective optical antenna in a critical trade-off aiming to achieve the performance and cost target.
- Elaboration of an advanced design of the chosen version of the optical antenna including all its relevant sub-systems and interfaces
- Reliable and realistic parametric evaluation of all cost elements.

The project has successfully passed the system requirements review and is currently in the preliminary design phase. A major design decision is the choice of primary mirror technology, both in terms of manufacturing technology (shaping and polishing glass ceramics vs. alternate techniques, such as cold slumping, diamond turning) and geometry (monolithic vs. segmented). Trade-offs are currently taking place.

In addition, a good grasp of the challenges associated with the design of a large aperture optical ground station have been established, namely the cost envelope due to technical issues such as the very difficult thermal and stray-light management in daytime, the dome design, atmospheric turbulence mitigation and spectral filtering. Also, very innovative concepts for solar stray-light baffling are being investigated, including shading by manoeuvrable balloons, deployable and rotating sunshades, open all-reflective designs, etc. Finally, assuming that the activity concludes that optical communication for deep space is economically viable, the boarding of critical components is envisaged in the next step.

In this activity, the objective is the development of large scale fabrication of the HBV components. Their performance will be studied over time and in different environments, such as elevated temperatures, to ensure they meet needs and standards for the successful use in a variety of future missions. In more detail, the fabrication of Schottky and HBV circuits will be developed with high yield for 3 inch wafers and preliminary reliability testing will be performed to ascertain circuit lifetimes by number of tests, such as operation at elevated temperatures, DC and RF biasing. The testing will be compared to thermal 3-D and electrical modelling to understand the distribution of internal temperatures and electric fields.

The project is currently in the phase of determining the details of the reliability test to be performed and the design of the DC and RF test structures is under way. The next milestone will be the fabrication of a 3 inch wafer with Schottky mixers and HBV multipliers with acceptable yield, including the implementation and execution of stress tests to find the thermal and electrical limits of the fabricated circuits and diodes. In fact, during the following milestone the devices will be subjected to a fraction of the aforementioned limits for longer periods of time (1000 h), which will help to determine the lifetime of the produced components in different operating environments.

Receiver detecting at Terahertz and submillimetre wave frequencies are a vital part of instrumentation monitoring the Earth’s atmosphere or identifying the molecular make up of distant planets. These receivers depend on the availability and reliability of semiconductor devices such as Schottky- and Heterostructure Barrier Varactor (HBV) diodes. At the moment, the limits of what is possible to sense and resolve with these receivers is being pushed further, thus it is important that the semiconductor devices at disposal meet the evolving requirements and are able to be used in a wide range of applications.

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μSADA - MINIATURISED SOLAR ARRAY DRIVE ASSEMBLY FOR 6U/12U CUBESAT

with the participation of Italy

The trend of CubeSat missions is growing, but currently several constraints do not allow their usage for high performance missions in Earth Observation (EO) or Telecommunication (TLC) markets. One of the limiting factors in question is the on-board available power, since the small geometry of a CubeSat impacts the dimensions of the Solar Array and thus, the generated power. The μSADA addresses this problem by composing the system of two deployable solar wings (44 dm² total area) and a steerable mechanism to align the solar arrays with the Sun. This leads to an increase of the generated power. In fact, the peak power value of fix geometry arrays corresponds to the average power in a steerable one like μSADA.

The objectives of the activity encompass the development and testing of a miniaturised Solar Array Drive Assembly (SADA), suitable for future utilisation on 6U/12U CubeSat platforms, in order to enable deployable and steerable solar arrays generating significantly increased power for RF payloads, high-speed downlink and electric propulsion. After the usual development phases (requirement definition, concept selection, design and optimisation manufacturing and assembly), the resulting Engineering Model will be tested at qualification levels, namely environmental testing (vibration, shock, thermal), functional performance testing, mechanical testing (deployment test, life test, actuation margin) and electrical testing (power generated, power distribution and transmission).

In fact, it is expected that the improvements made in μSADA will contribute to an increased CubeSat mission performance and allow for several high-power units to be used on board such as electric power propulsion, high-data-rate transmitter and active antenna. Furthermore, the Requirement Definition Review has successfully been closed and the Preliminary Design and Trade-Off activities are ongoing. By Q4 of 2018, the unit is expected to be ready for the Verification and Qualification and at the end of Q1 of 2019, the unit will reach TRL 6. Once this is achieved, the μSADA will be ready for its In Orbit Demonstration (IOD) mission aboard a CubeSat, which will validate the technology and allow it to be available for commercialisation.
Resin systems for composite parts form a cornerstone for the manufacture of any modern spacecraft, however, both the manufacturing and procurement processes are often limited by the pot and/or shelf life of the prepreg/resin materials. A longer shelf life could mean reducing the amount of scrappage which occurs from any typical spacecraft composite system manufacturing line. In fact, usually it can be necessary to scrap and reprocure significant quantities of unused prepreg or resin materials simply because the shelf life is shorter than any recurrent manufacturing. Improved shelf life could significantly reduce both the cost of manufacture and the environmental footprint of composite processes. Secondly, the extension of pot life for resin systems could allow for extended manufacturing cycles for both larger and more complex smaller composite parts, in particular employing out-of-autoclave processing.

The use of CFRP out-of-autoclave technologies is being utilised for an increasing number of applications for improved automation, either for large structures or smaller complex geometries. In fact, the production of large structures is time consuming and requires long layup times at room temperature that can take up to a week. In addition, smaller structures can also require significant out-time of the prepreg and mostly need to be stored in low temperature freezers to prevent curing.

The objective of this activity is the development of two types of epoxy resins systems that provide sufficiently long pot life for manufacturing large and complex carbon fiber composites. These resins will be designed to allow cost effective curing at low temperature regime. More specifically, resin type A will be formulated to have low viscosity and be applicable by infusion process. On the other hand, resin type B will have high viscosity and will be designed to be suited for preparation of towpregs and prepreg fabrics. The qualification of the resin type A and B (for towpregs) will be verified by the manufacture of a pressure vessel by filament winding, simulating industrial production of CFRP Booster Cases for Ariane 6 launchers. While resin type B (for prepreg fabric) will be used for the manufacturing of composite parts having complicated shapes, where filament winding is not possible to use.

Nevertheless, either study shall consider both the fiber and resin system as a mated pair, which shall be tailored for compatibility towards each other. Following the initial analysis, a trade-off of the significance of both the pot life and shelf life shall be performed to assess the relative potential benefits of improving either property. Any activity shall preferentially identify chemical modifications to extend both properties. In the end, these newly developed resins should provide, when comparing to commercial types, sufficiently long pot life, low curing temperature, high toughness, and excellent thermo-mechanical properties.

The current activity is planned to reach TRL 5 with breadboard demonstrators of curved composite panels and pressure vessels. It is foreseen to utilise the developed technology for serial production of the CFRP boosters for Ariane 6 launchers predicted to begin in 2020. The technology will be further developed toward its industrialisation and further usage for other space and non-space applications will be evaluated.
During 2017, 107 new technology activities were initiated under the frame of the GSTP addressing new needs and emerging applications.
Depletion of stratospheric ozone was first identified in the mid 1970s and received increasing attention after the discovery of the ozone hole in the mid 1980s. Data from space-borne instruments for stratospheric ozone observations is essential for the confirmation and monitoring of the ozone layer recovery after the Montreal Protocol and for operational forecasting services. While continuous availability of ozone total column data is guaranteed with nadir sounding missions such as the Copernicus Sentinels 5p, 4, and 5, a gap is expected in availability of ozone profile data with high vertical resolution due to the lack of limb sounding instruments from the end of this decade.

Thus, the ALTIUS mission was proposed and approved as an element of ESA’s Earth Watch programme to reduce this gap by developing a limb sounding mission based on an evolution of the PROBA satellite platform and incorporating an innovative spectral imager instrument. The current GSTP activity is an essential part of the preparation of the ALTIUS mission implementation by mitigating remaining instrument technology risks.

In more detail, the “Pre-development of the ALTIUS instrument” activity consolidates the overall instrument design (including the design of the 3 separate spectral channels covering the complete 250 nm - 1800 nm spectral range), building on the results obtained in previous GSTP and PRODEX studies. The manufacturing and testing of breadboards of critical subsystems and technologies will demonstrate essential performances and technology readiness.

This will include the Acousto-Optic Tunable Filters (AOTF), their RF driving electronics, Fabry Perot Interferometer spectral filters, mechanisms and detectors. Finally, the manufacturing and tests of a breadboard of the complete visual channel will confirm the overall instrument performance and compliance with mission requirements.

This activity was started in August 2017 and has successfully passed the Instrument Requirements Review in January 2018, having a planned end date for the end of 2018 and on time for the phase B2/C/D of the ALTIUS mission. Currently, preliminary design reviews of the breadboards for several subsystems are ongoing, namely on the level of the Fabry Perot Interferometer, the RF subsystem and mechanisms. In parallel, the optical and electrical performance of the instrument are being analysed to confirm compliance with the mission requirements. The identification of suitable and recently developed detectors, which are now off-the-shelf, retired a considerable technology risk for the mission.

The ALTIUS instrument pre-development activities are paving the way for the full implementation of the phases B2/C/D of the ALTIUS – Earth Watch mission by reducing/removing the remaining instrument technological risks. The level of detail of the design and analysis activities allows shortening the duration of the phase B2 (and thus of the overall project) to a minimum. This is essential for the reduction of the gap in observation data of the stratospheric ozone concentration profiles with high vertical resolution.

Finally, the detailed instrument design, manufacturing and flight qualification will be performed within the phase B2/C/D contract of the ALTIUS Earth Watch Element, expected to start early 2019. It will aim to achieve flight qualification by the end of 2021.
Vision-based navigation has been identified as a major enabling technology in support of the growing demand for autonomy of exploration missions. In particular, for the case of entry, descent and landing on Mars, vision-based navigation techniques are needed to enable future precision landing missions, such as Mars Sample Return. The complexity and high processing speed requirements of the embedded flight software for safe precision landing calls for the development of an end-to-end development, validation and verification testbench capable of reducing the costs of the validation and verification process while increasing the TRL for the Guidance, Navigation and Control (GNC) systems.

This activity builds on several former ESA-funded activities that individually developed navigation optical units, camera electronics, image processing boards and GNC application software. The objective of this activity is to put together all these pieces in an avionics test bench and perform real-time closed loop simulations by means of optically stimulating the camera with images generated with the ESA tool PANGU (Planet and Asteroid Natural scene Generation Utility). PANGU is a powerful set of tools for modelling the surfaces of planetary bodies and asteroids using real and synthetic data. It has the ability to generate camera, LIDAR and RADAR images from any position and orientation, as seen by the on-board spacecraft sensors.

The main problem of the vision-based navigation is the high computational capability required by the image processing algorithms needed to feed the navigation since in addition to the classical on-board computer running the conventional GNC and mission software, a dedicated Image Processing Board (IPB) with high computational capability is mandatory. Furthermore, in order to optimise even more the computational resources to the vision-based algorithm requirements, the IPB is divided into hardware and software sections. In more detail, the relative navigation algorithms based on the Feature Extraction and tracking Integrated Circuit (FEIC) are coded in the hardware part (Virtex5 FPGA) while the Hazard Map generation and Hazard Detection and Avoidance (HDA) algorithms are implemented in the software section using a dedicated powerful co-processor PowerPC7448. Both sections are connected via Space Wire (SpW) links.

Thus far, the activity has successfully integrated and tested the mentioned architecture on an avionics test bench (ATB) composed of three main elements: 1) the Flight Segment (FS), including the On-board computer (LEON-2) and the IPB (Virtex-5 FPGA and PowerPC7448), 2) the Ground Segment (GS) interfacing with the FS and capable of receiving telemetry and sending telecomands to the FS and 3) the Real-Time World Environment Emulator based on Matlab-Simulink and running in dSpace. Currently, a detailed profiling of all the algorithms is being carried out to optimise the code and ensure real-time performance when including the real camera hardware.

The completion of this activity will provide an avionics validation and verification test bench that will include hardware and software elements common to several exploration future missions. As such, this test bench will be useful not only in the initial development effort, but during the whole life cycle of future planetary lander missions after ExoMars 2020.
RADIATION TESTING OF OPTICAL COATINGS FOR SPACE
with the participation of Italy

The qualification and robustness of optical coatings against the space environment is a challenge for every space mission with optical instrumentation on board. It becomes especially challenging for those missions flying in more demanding radiation environments such as polar and geostationary orbits, especially when flying close to the sun or in the Jovian magnetosphere. In fact, electrons, protons and ions are considered among the principle causes of potential damage to optical coatings. This will be especially important in cases where missions operate in unexplored and hostile environments such as JUICE.

This activity aims to address these types of extreme radiation environments and the induced performance degradation of coatings they lead to. This will be done by examining the fundamental underlying damage mechanisms, gaining a better parametric understanding of the physics, and concluding on the mitigating actions that can be taken to increase the radiation robustness of optical coatings.

In more detail, radiation tests using He+, protons and electrons will be carried out on different coating samples. Optical, morphological and structural properties prior and after irradiation will be investigated using different techniques, such as reflectometry, x-ray diffraction, secondary electron microscopy and atomic force microscopy. The selected materials for the coatings to be tested are those used in nearly all the space instruments such as gold, silver and aluminium. Additionally, dielectric materials such as SiO2, TiO2, ZrO2 will be investigated as well.

In an initial phase, nearly 800 coating samples for this activity spanning more than 10 established coating materials will be tested. Subsequently, a study of a selected robust coating against radiation using the JUICE mission as reference will be designed, manufactured, tested and validated.

The true target mission for this activity is JUICE since the optical elements that will fly around Jupiter will be exposed to severe radiation, which presents a challenge for the stability and robustness of optical components, materials and coatings. Furthermore, the lessons learnt of this activity conclude that mitigating actions can be taken to increase the radiation robustness of optical coatings for upcoming missions such as Plato, Euclid and Lgr-II remote sensing.
GR740 NEXT GENERATION MICROPROCESSOR FLIGHT MODELS (NGMP PHASE 3)

with the participation of Sweden

The ESA Next Generation Microprocessor activities were initiated to develop and commercialise a high performance general purpose microprocessor device to meet the ever increasing demand of computational power needed to enable future missions. In fact, the Next Generation Microprocessor and associated software infrastructure has previously been developed under various TDE activities starting in 2006, having resulted in an investment of four million euros.

In this activity, the GR740 (NGMP) flight models shall be manufactured, tested, validated, space-qualified and made commercially available under fair and equal conditions with agreed ceiling prices for users in ESA member states. Product and technical support shall be guaranteed for at least 10 years starting from certification. In addition, the GR740 is accompanied by several activities in various ESA programmes to develop a comprehensive software ecosystem (compilers, operating systems, multicore programming models), and the first applications (e.g. GNSS navigation receivers fully implemented in software). Follow-up activities, e.g. to develop an On-Board-Computer reference design, are also in preparation.

The developed microprocessor will offer a significant improvement in performance over existing European space-grade microprocessors, combined with high resilience against radiation effects. More specifically, it will offer similar performance as a non-European PowerPC processor board used on several ESA missions (GAIA, PILOT), but at a much lower power consumption. In fact, the GR740 is the first implementation in the ESA microprocessor roadmap that introduces multicore technology.

Shortly after kick-off in December 2017, the manufacturing of the flight silicon has been started, and wafers have been delivered in March 2018, followed by a successful functional and radiation validation. At the moment, assembly into flight packages is to begin Q3/2018, and once completed, the flight qualification testing / screening will start. Prototypes and breadboards with the new flight silicon revision will be shipped in Q4/2018, while qualified flight parts are planned for Q4/2019.
STREEGO — INNOVATIVE SOLUTIONS FOR HIGH RESOLUTION SMALL SATELLITES

Streego is a multispectral Earth Observation optical payload designed for small satellites that serve a wide number of applications, such as agriculture, forestry management, urban development, disaster monitoring and coastal water monitoring. This responds to the ever-increasing demand for low-cost Earth observation services with very short revisit-time and to the growing market of the emerging space agencies with a preference for small satellites. In fact, the EO remote sensing is growing at a rate of about 16% per year and remains the fastest growing systems segment in this coming decade. Thus, the development of Streego is aimed at providing a cost-competitive and yet high-performing instrument for small satellites.

The Streego Payload has a fully reflective telescope based on an obscured TMA (three-mirror anastigmat) designed for providing high contrast images. The focal plane is equipped with the last generation CMOS detector with both panchromatic and multispectral channels. The system acquires, from a typical low Earth orbit, panchromatic and multispectral images with 3m, and 6m resolution, respectively. The multispectral channels cover the following spectral bands: 443, 490, 560, 665, 705, 740, 775, 842, and 865. These bandwidths are the same for Sentinel-2, so that Streego imagery can use existing software applications. Furthermore, its athermal architecture places minimum requirements on the thermal control system of the satellite. The design, based on an aluminium telescope, anticipates the requirement of an easy demisability, i.e. not requiring controlled re-entry.

By the end of the activity, a fully representative Engineering Qualification Model (EQM) of the Streego payload has been developed and performance tested. The EQM passed the representative environmental tests, including protons radiation tests on the detector and its focal plane electronics, and thermal vacuum test and vibrations of the full system. Furthermore, this development provided the European industry with the know-how and technologies to compete in the commercial market of EO for small satellites, particularly in the sector of manufacturing and testing of aspherical and free form mirrors.

When it comes to future steps, the design of Streego still has further intrinsic growth potential to accommodate an IR channel and to add a hyperspectral detector, such as the one developed under the CSTP activity “Technologies and Key Components for Compact Hyperspectral Instruments”. Further work shall also be performed to equip the system with a data compression and processing unit. This unit will reduce the data rate and also perform on-board data processing to extract level 2 data in real time for time critical applications, e.g. early detection of natural disaster.
SPACE 3-AXIS CVG GYRO UNIT ARIETIS-1  
(PHASE 1)

with the participation of Ireland

Gyroscopes have been a key component in Attitude and Orbital Control Systems (AOCS) as they allow a reliable measure of satellite angular rates. Such information is used for making sure the spacecraft is pointing in the desired direction as well as to check that the satellite is kept within safe areas in terms of angular rates and attitude throughout its operations.

Over the past 50 years, many different gyro technologies have been developed and used in space, with Fiber Optical Gyros (FOG), Ring Laser Gyros (RLG) and Hemispherical Resonator Gyros (HRG) being predominantly used from the late ‘90s up to today. Each technology offers a wide range of advantages and disadvantages, while most of the time offering a similar performance. More recently, new applications have emerged in the commercial industry for which accuracy and precision are no longer the driving factors. Instead, reliability, mass, power budgets, and meeting performance at reduced cost and size have become paramount. While European companies with the support of ESA have developed gyros for space applications, there is currently a need for a cost effective medium-to-high performance gyro that can meet a variety of mission requirements.

ARIETIS is a 3-axis Rad-Hard Rate Measurement Unit (RMU) based on Coriolis Vibratory Gyroscope (CVG) technology, which shares common features with HRG. With the support of the European Space Agency, ARIETIS is now being developed to address Earth Observation applications in Low-Earth Orbit (LEO), navigation in Medium-Earth Orbit (MEO), scientific missions and AOCS in Geostationary Orbit (GEO) with lifetime requirements of more than 15 years. ARIETIS will take advantage of the flight proven technology and will incorporate a completely new digital control system which will be able to improve performance of this technology.

The project is divided into multiple phases. In the first preliminary design phase, completed towards the end of 2017, key activities have been: agreeing product specification with end customers, overall gyro architecture from both the hardware and functionality point of view, preliminary design of the electronics (both analogue and digital chain) as well as verification that all key technologies are ready for use in space applications. The project now continues thanks to ESA Science Core Technology (CTP) funding. This phase will deliver a complete ARIETIS gyro design, engineering model by the end of 2018 and qualification of the product within 2019. It is expected that flight models will be available starting from 2020, with a goal of flying ARIETIS within the ESA Plato mission.
GNSS DATA ACQUISITION AND REPLAY SYSTEM (GDARS)

with the participation of Switzerland

GDARS is a sophisticated instrument able to record and playback simultaneously up to four independent GNSS bands, with effective signal bandwidth from 4 to 50 MHz per channel, processing all current and planned GNSS signals. The high bandwidth, together with a high degree of re-configurability, makes it intrinsically suitable for recording and playing back any radio frequency (RF) GNSS signal and any planned future extensions of the same.

In more detail, the GDARS unit contains a complex architecture of optimised functional blocks. The signal received by GNSS antennas is down-converted to baseband, allowing simultaneous processing and digitisation of four broadband GNSS signals, thanks to the 50 MHz bandwidth of each channel. In the GNSS bands, the replay unit allows using the registered signal to synthesise a perfect clone of the signal originally recorded. Its transmission can then be replicated as often as the user needs.

The applications of this instrument can be various: for instance, it allows testing of a GNSS receiver under development by exposing the signal originally recorded. Its transmission can then be replicated as often as the user needs.

The project, which has been extended by a short CCN, has completed the second phase mentioned above, i.e. a fully functional prototype has been built and is currently under test in the lab. In addition, field experiments are planned to ascertain and confirm the correct operation of GDARS under real-world conditions while early demonstration of some key characteristics have already been scheduled.

IMPACT ANALYSIS OF PISTON ALIGNMENT ON KEY COMPRESSOR PERFORMANCE CHARACTERISTICS

with the participation of the Netherlands

Long life time cryocoolers rely on the fact that the back-to-back pistons can operate almost friction free thanks to the radial stiffness of the piston suspension and a careful alignment of the piston in the cylinder. Nonetheless, while the current design and alignment procedure of this compressor fit with the need of most missions or commercial products, in the case of more demanding projects like Meteosat Third Generation, it is necessary to improve its design so that the exported microvibration of the compressor is reduced and the yield of the mechanism increased.

To achieve that, the development focused on improving the initial alignment method of pistons in the compressors to reduce the variations in their on-axis vibration signature and their off-axis vibrations. Thus, the activity aimed to understand in detail the underlying fundamentals of the observed behaviour and to subsequently identify and implement corrective and preventive actions, by following several steps during development, namely:

- A comprehensive root cause analysis of misalignment sources was constructed.
- For each root cause, a corrective action, an analysis or a test was proposed to understand or improve the situation.
- More than 40 analyses and tests have been performed at sub-element and compressor levels including the manufacturing and testing of 2 full-scale Elegant Breadboard models, to reach TRL6. One of those using the innovative alignment method, and other MAIT (Manufacturing, Assembly, Integration and Test) processes proposed in the first part of the activity.
- All the analysis and test results were used to issue design and manufacturing change recommendations which were compiled in a design description document.

The result of this activity exceeded expectations, considering that the design improvements identified have been deemed extremely relevant for Meteosat Third Generation, and are being implemented on the flight model coolers of MTG.
CLASS 3 X-BAND HDR TRANSMITTER DEVELOPMENT

with the participation of France

In the current market of X Band Transmitter (XBT) for micro to mini satellites there are usually two choices: the bulkier variety, mainly fitted for 400-500kg to around 1000kg spacecraft that is meant for coding, modulation and amplification but is also very energy consuming and expensive, and the other less expensive solution that also has lower reliability. In addition, the micro & mini satellite market is now moving to high-end, more reliable and cost-efficient spacecraft, where the desire is to combine enhanced performance of the payload with a reduction of cost and size of the platform. This is done by drastically reducing the energy available on board while assuring improvement of the return of investment of the projects and services by extending the mission life time in orbit. For this, Class 3 X-Band HDR transmitter has become the best trade-off between cost and product assurance.

Thus, the purpose of this activity was to develop a High Data Rate Class-3 XBT with relatively small size and weight, using several ‘Non Space Qualified’ components to help keep a good compromise between the desired features and cost. In order to achieve this, within this activity a demonstrator to validate and assess the architecture and design was first developed followed by the full product development, proving that a technology platform based on COTS (Components Off The Shelf) can really be an effective solution for such applications (LEO) and demonstrates that a very low cost solution can comply with ECSS Class-3 requirements.

In addition, environmental tests were carried out successfully and the product passed all EMC, ESD, mechanical shocks, vibrations and thermal tests, along with all additional qualification tests for the ‘Non Space Qualified Components’ (Lot Acceptance Tests). The only detail to still be fully resolved is the transmitter’s Class II level qualification since its GaN amplifier has not completed the radiation tests.

Finally, it can be said that the main benefit of this solution are an improved capacity and features. The transmitter is able to transmit data up to 380Mb/s with a transmit RF power of 10W with low implementation loss, allowing the product to be used for Earth Observation applications and keeping the total weight under 1.6kg. Next steps will include flight models acceptance in 2018 and integration into a satellite, while the first commercial application will be MERLIN (Methane Remote Sensing Lidar Mission) with a launch date planned for 2021.
VIRSI HYPERSONSPECTRAL IMAGING IN-ORBIT DEMONSTRATION

Recent improvements in the fields of CMOS detectors technology, hyperspectral filtering, optics manufacturing, electronics miniaturisation and microprocessors make it possible to fit a hyperspectral camera on a nanosatellite (1-10 kg) platform, which can enable a wide range of low-cost and rich remote sensing applications, complementary to those from big satellites. However, nanosatellites and CubeSats suffer from limitations due to restricted data downlink availability, which affects the flow of large data volume produced by the optical nano-payloads.

VIRSI-HyperScout is a hyperspectral compact payload operating in the VNIR (Visible and Near-InfraRed). Its design makes it extremely flexible and re-configurable in-orbit, enabling a large variety of land and vegetation applications, for which cost efficiency and timeliness are very important. It overcomes the major CubeSat limitation, i.e. the downlink capability, by processing and downloading L2 data products instead of the raw data. Fitting in one CubeSat Unit, the HyperScout payload was successfully built and launched in 2017 aboard the Gomx-4B 6-U CubeSat, for its In-Flight Demonstration. First images from the payload on various land conditions were received in April 2018 and its overall performance has achieved the observation goals of the activity.

Nonetheless, a number of extra tasks are still being carried out, including the on-ground validation of the algorithms and relative software, a set of in-orbit software commissioning, a planned airborne test campaign with the earlier version of the HyperScout payload (as an output of a previous GSTP activity), and the manufacturing and testing of a more advanced payload version, exploiting the lessons learnt during the activity.

The availability of a low-cost hyperspectral payload capable of fitting into a nanosatellite, such as the HyperScout, brings the possibility of hyperspectral data products to a wider audience of users. Its reliable system with high temporal resolution and very quick revisit time provides user communities with new complementary services that would, otherwise, not be economically viable using traditional large hyperspectral instruments.

To sum up, the running VIRSI-HyperScout activity proves the full functionality of the payload, capturing and analysing a number of ground images limited partially by the platform operations. The next step is to fly the advanced HyperScout payload with a new platform and the flight-proven software, thus verifying all the potentialities of this low-cost hyperspectral nano-payload.

MOSAIC NG GNSS RECEIVER

GNSS is an enabling technology for on-board spacecraft navigation and control, including mission concepts such as formation flying, attitude and orbit control, orbit transfer or station-keeping. Recent technology developments and new approaches for GNSS receivers in space have been hand-in-hand with the continuous demand for GNSS on-board in several missions, each with different objectives and required performances, not only for transfer orbits but also for LEO and GEO.

In this context, the overall objectives of this activity were to develop, test and qualify an Engineering Qualification Model for a new multi-constellation GNSS receiver with a better cost to performance ratio, on the basis of the state-of-the-art, industrialised LION1200/1300. From the beginning, the activity aimed at providing similar hardware and software interfaces to other products in the GNSS receiver family, to minimise non-recurring engineering for spacecraft primes resulting in a change from a high-end performance GNSS receiver to a mid-range one. This approach will allow for a cost-optimised solution to end-customers, provided on a case-by-case basis.

The receiver is based on the state-of-the-art AGGA-4 chip for GNSS signal processing, together with a newly designed RF section, and is capable of different single/multi frequency/constellation configurations at assembly level. In addition, the use of the AGGA-4 chip allows for reuse of already developed on-board receiver software for signal processing, navigation and PVT (Position Velocity Time), TM/TC (telemetry/telecommand) and overall control and commanding.

Thus, the MosaicNG, now commercially renamed LIONNeo, complements the GNSS receiver development high-end family with a mid-range performance receiver covering the mass-market. In fact, all 9 flight models available have already been sold.
Market analysis on Medium Power PCDU for Earth Observation and scientific satellites has shown a European market imbalance between supply and demand leading to an increasing pressure on cost reduction, especially for non-recurring items, and an export market demand for competitive products.

The scope of the activity was to develop a building block solution to be used in both off-the-shelf and non-recurring manufacturing of Power Conditioning and Distribution Units (PCDU), in particular:

- A generic TMTC module
- A Buck Regulator module
- Working on an extension of the design flexibility and environmental compatibility of the modules (bus voltage, interfaces, temperature, orbit, etc.)
- A new generation of MEDIA (Modular Equipment Data Interface Avionics)
- A new ASIC embedding μST (slave terminal)
- Ensuring functions and scheduler features for TMTC communications between modules and with satellite communication bus

After review of the specifications for the PCDU modules from the main primes, this activity was able to come up with a generic specification covering the most important aspects to be taken into account in the design of these modules. A prototype of the PCDU generic modules was then manufactured and functionally tested in temperature (ambient, hot and cold) and ambient pressure. The goal was to have a modular design with higher power and efficiency, and thus the implemented design was chosen to consist of two buck regulator modules connected in parallel, where a redundant TMTC module implements the reliable TM/TC interfaces. This module is foreseen to cover all applications under regulated and non-regulated busses.
MODULAR GENERAL PURPOSE REMOTE TERMINAL UNIT (RTU)

The Remote Terminal Unit (RTU) is usually present on medium to large size spacecrafts and is meant to offload the on-board computer’s analogue and discrete digital data acquisition and actuators control tasks. This unit represents a great example of the implementation of a distributed control system on board a satellite since the RTU is usually a not-intelligent unit and only interfaces with the system through serial communication busses.

The goal of this activity was the development of a modular and upgradeable unit that can be used across different missions. This RTU was conceived to be an assembly of different building blocks/boards with standardised internal mechanical and electrical interfaces, and more precisely, in the frame of this activity a total of eight modules have been developed: a DC/DC power supply module powered by a 28DC power feed, a Controller module, a Housekeeping Input/Output module, a serial digital module, a Mono-Propellant Control module, a Cold Gas Control module, and a Heater Lines Distribution module.

In more detail, the full qualification of the unit has been achieved and a full environmental test campaign has been successfully completed without any major issues. In addition, an on-going ESA mission (Proba-3) is using the Modular RTU design on its two spacecrafts and the deliverable of this activity, an EQM, will be used as EM in the project. As for the main features of the Modular RTU, these are:

a) An architecture designed to maximise the modularity and upgradeability of all the modules.

b) Use of self-contained modules and standardising internal connectors.

c) All the slave modules will have the same standard back plane connector and share a standard internal electrical interface.

d) The testing of each module can be performed independently.

e) Ability to configure the RTU as needed for a specific application, adding, removing or duplicating modules without any impact on the overall design.

f) The unit has been designed by minimising the form-factor size in order to maximise the printed circuit board occupancy.

Due to its easy adaptability to different needs and configurations, potential users span a wide domain of applications such as science missions, future telecom spacecraft, Earth Observation satellites and manned missions. In fact, this modular architecture will allow to reduce the cost and development time of flight models and use of a standardised backplane will allow the inclusion of modules developed by third parties.

Finally, the flight qualification of the Modular RTU will be achieved in the frame of the Proba-3 project while parallel activities for the development of other modules could be started to provide additional functionalities such as an intelligent Controller Module based on a microcontroller.
HIGH GAIN DATA DOWNLINK X-BAND ANTENNA

The helix antenna concept, intended for Earth observation missions’ data downlink in X-band, was originally developed under a previous activity. The helix concept was considered as it provides a substantially more compact and lightweight solution when compared with other commercially available designs. Early designs of the helix antenna had proven to be commercially attractive and were used on the Aeolus satellite and the RapidEye satellite constellation. However, these designs had limited power handling and bandwidth, and were not suitable for larger missions.

Thus, the technical objectives of the current activity were to develop further the helix design towards improving power handling, bandwidth and gain and making it suitable for a wider range of missions. Main changes included the re-dimensioning of the helix’s diameter and length. During the activity the design was then qualified by manufacturing and testing of an EQM. In more detail, the development process involved the following tasks:

- Establishing specifications and a conceptual design, where a short trade-off of concepts was performed to confirm the choice for the helix pattern,
- Improving RF, mechanical/thermal and technological designs,
- Manufacturing and assembling of the EQM,
- Testing the EQM.

The current development has significantly widened the market for the fully qualified product, being now suitable for a wide range of Earth Observation missions and has further strengthened Europe’s competitiveness in this domain. In fact, this new antenna has been the basis for the designs of the MetOp 2nd Generation and Sentinel 6 X-band data downlink antennas, and more recently, the Biomass X-band data downlink antenna. In addition, from the experience gained with this type of antenna, new concepts for other applications, including TT&C antennas in X-band and beacon antennas for propagation experiments in K-band, are being developed.

The GSTP’s function is to bridge the gap between having a technology proven in fundamental terms and making it ready for space and the open market.
An electric propulsion subsystem is a complex combination of various heterogeneous elements, which need to operate together in an efficient way. In most of the cases the thruster and its power supply electronics are done by two different entities. This requires a close teamwork and understanding of the different worlds, such as plasma-physics and high voltage electronics. In this activity, however, the chance arose to combine the thruster and driving electronics in one system since both competences are available in the same company. This provides the chance to facilitate the exchange of information in order to optimise the electronics development (and potentially also the thruster), which would bring many benefits, one of them being a cost efficient PPU.

Thus, the aim of this activity is to optimise the design of the electronics to develop a cost-efficient solution capable of serving various applications, while remaining generically configurable and flexible to minimise potential equipment re-qualification or design changes from one mission to another. For example, this would allow the electronics to be compatible with various Hall-effect thrusters and to adapt to a change in operation mode of the thruster (i.e. for orbit raising, station keeping etc.). This approach would also be scalable so that by connecting two or more of these PPUs together (or parts of it) a higher power level could be achieved.

At this early stage of the activity, the market landscape has been assessed and relevant needs of potential customers collected to define the key product requirements, and with this feedback a unit specification was prepared. At the end of 2017, the intermediate design review took place and the architectural design of the unit was defined, which includes the first assessments of electrical, mechanical and thermal design aspects. Currently, the Preliminary Design Review is being prepared where PPU assemblies, subassemblies, including all the electrical and mechanical designs, shall be defined. This data will then be used for the EM development tasks; and as the first representative model, the EM will test:

- proper implementation of functionalities,
- performances,
- electrical, thermal and mechanical interfaces,
- coupling with PPU test bench (including the major test procedures),
- coupling with a 5 kW hall-effect thruster.
The European and world-wide trend is to mature application-oriented technologies in the domains of Earth observation (EO), satellite navigation and satellite communications (SatCom), which contribute to the integration of space in economy and society. The future missions of EO, with its enhanced ground resolutions and wider swaths, along with SatCom applications with high throughput and reconfigurable spectrum-efficient systems, will generate massive amounts of data that will culminate in an unprecedented necessary improvement of performance on data handling and storage levels. More specifically, this calls for an evolution of the mass memory on satellite platforms in that market segment.

The objective of this activity is to develop a mass memory unit — the so called ExtRa MMU — to demonstrate high speed data storage of up to 64 Tbits and retrieval capabilities of up to 64 Gbps via multiple SpaceFibre chains. This MMU unit has a scalable hardware and software architecture for the purpose of flexibility in applications and is equipped with backplane, flash memory, input/output and processor modules enclosed in a housing to build a platform for validation. In addition, it comes with a file and data management functionality and specific test equipment.

At the moment, the flash memory module has progressed to the production phase and first assembled module will be available in autumn 2018 for bring-up tests. Additionally, the input/output module, based on the flash memory module, is in the design phase, while the backplane has already reached the layout phase and is planned for integration activities also in late autumn 2018. Furthermore, thermal and structural analyses in support of the mechanical design are showing promising results, along with the simultaneously developed board level testers – currently in the layout phase – that will be used during the first integration to set up a mock-up of the system.

To sum up, the ExtRa MMU aims to enable future missions for EO and SatCom systems with their increased data handling and storage performance, allowing them to strive for improved timeliness of observations, resolution and wider swath, while assuring they can fully make use of the enhanced performance of their sensors and instruments in remote sensing missions. The goal is for the ExtRa MMU to have a fully space-qualified unit in the near future for deployment in a prospective EO and SatCom missions in the years to follow. Moreover, it is being planned for the unit to be complemented with data compression functionalities.
ENABLING TECHNOLOGIES FOR FUTURE NANOSATELLITE CONSTELLATIONS

BACKGROUND

The present mission is motivated by enabling miniaturised technologies like an on-board propulsion module, compact RF payloads and optical instruments to acquire data of commercial interest. These capabilities motivate the deployment and operation of constellations of CubeSat nanosatellites for application or services requiring low data latency and orbit control.

Demonstration of innovative development increases the reliability and performance of the missions by providing the experience needed for further commercialisation.

OBJECTIVES

The objective of this mission is to acquire the in-orbit experience of relevant nanosatellite constellation related technologies. In this framework, a 6U nanosatellite called GOMX-4B was designed, developed and launched to fly in tandem with a second satellite, GOMX-4A for data acquisition for the Danish Defense Acquisition and Logistic Organisation. Both satellites accommodate inter-satellite link capabilities and other advanced secondary payloads.

GOMX-4B also includes a propulsion module offering orbit control of inter-satellite distance and new instrumentation including a hyperspectral camera, a star tracker and the space radiation experiment, Chimera.

STATUS OF THE MISSION AND ACHIEVEMENTS

The two satellites in the GOMX-4 mission were successfully launched on 2nd February 2018 in a Long March 2D-Y13 vehicle. Then, both satellites were fully commissioned in orbit for the first two months, showing early results from the payloads as well as optimum performance of the advanced 6U platform.

Thereafter, GOMX-4B performed several propulsive maneuvers to adjust its orbit altitude relative to GOMX-4A and establish the proper separation distance rate for the inter-satellite link demonstration for inter-satellite distances under 700 Km. The results achieved during these operations prove orbit control potential in nanosatellites and an outstanding communication capability that enables service providing constellations.

Currently, GOMX-4B is capturing and optimising hyperspectral images with the HyperScout instrument which is the first time this technology is flying in miniaturised satellites.

Performance of the on-board star tracker shall also be demonstrated as well as long-distance inter-satellite link communications up to 4500 Km using Direct Spread Spectrum Modulation.

BENEFITS

The capacities demonstrated in the GOMX-4 mission open a wide variety of applications for future missions.

Firstly, the modular 6U platform provides a flight-proven bus with high capacities of operating numerous payloads and various experiments for further in-orbit demonstration missions.

Secondly, the payload achievements directly drive commercial exploitation of nanosatellites in constellations and satellites providing hyperspectral imaging services.

FUTURE STEPS

- Development of commercial nanosatellite constellations.
- Participation in further ESA In-Orbit Demonstration programs.
- The same high capacity platform will be used in the technology demonstration mission of autonomous rendezvous operations, known as RACE, also funded by ESA.
Advanced manufacturing as a cross-cutting activity takes the opportunities presented by new manufacturing, materials and processes, to create sustainable competitive advantage for the European space industry in the global market.

This is achieved by restructuring the supply chain to facilitate faster and more agile entry to the market place and by creating performance enablers thanks to new materials, added degrees of freedom in the design phase and novel manufacturing capabilities.

Advanced manufacturing (AM) processes are readily available in the current European industrial landscape. They need to be matured to a space qualification level within the scope of the proposed initiatives, focussing on the verification and qualification of the manufacturers’ capabilities.

Additive manufacturing technologies allow creation of shapes that are not possible with conventional machining. This design freedom is very attractive for space hardware, as equipment performance could be significantly improved with increased shape complexity. The potential of additive manufacturing technologies is impeded by the surface finish obtained on the as-built material. Todays version is not as good as the one obtained by conventional machining and the impact finishing has on the material’s properties and design is not well established. A better understanding of the impact of surface characteristics on material behaviour is needed to expand the use of AM for high performance parts.

The objective of this activity is to propose and evaluate surface finishing techniques for parts made by the AM technologies having the highest geometrical accuracy, i.e. Selective Laser Melting (SLM) and Electron Beam Melting (EBM), to derive guidelines for future applications. The impact of selected surface treatment methods on the following is studied: shape, dimensional accuracy, mechanical properties, the compatibility with primers and paints, anodising treatments, tribological properties, particle release and cleanliness.

Additively manufactured samples from different materials - aluminium Al-Si10-Mg, stainless steel SS316-L (with SLM) and titanium Ti-6Al-4V (with SLM and EBM) - were produced in three surface roughness conditions - as-built, rough and fine - approximately targeting specific engineering and product assurance requirements of space components. Surface roughness was obtained employing a down-selected surface improvement methodology specifically developed for the treatment of metal AM components - laser polishing, centrifugal grinding and centrifugal polishing. Materials were subject to space industry standard mechanical, corrosion resistance, geometrical accuracy, tribological, contamination and paint/coating compatibility tests in order to evaluate the effect of the surface improvement methodology.

Materials generally performed in line with parent material predictions. Specific, minor, detrimental effects were observed in some mechanical properties. Materials tended to exhibit increased resistance to corrosion mechanisms and a significant reduction in the generation of particulate contamination. Long-term exposure tests at a launch site are in progress. No issues or adhesive effects were observed indicating compatibility with commonly-used space treatments, e.g. polyurethane paint, anodising, passivation and titanium anodising, subsequent to exposure to humidity and thermal cycling environments. Thus, the surface improvement methodologies are considered to be suitable for further qualification and a guide has been developed for processing various AM geometries.

The present activity was a rather wide-spread project to screen different material and process combinations on relatively simple geometries. Future studies shall focus on more complex, product-specific geometries. Particular attention will be paid to internal, difficult-to-access geometries including channels within injector heads or thrust chambers for liquid propulsion, inner geometries of RF feed chains or waveguides, lattice structures and any other complex geometry having the potential of improving the performance of a space product.
3D PRINTING OF A MODEL BUILDING BLOCK FOR A LUNAR BASE OUTERN SHELL

with the participation of Germany

Human exploration beyond Low Earth Orbit is the subject of multiple studies and activities, in particular in the context of the approaching end of operation of the International Space Station (ISS). Post-ISS exploration will involve long-term missions for manned crew, to farther destinations than the ones reached so far by humans, such as unexplored regions of the Moon or Mars. Exploration missions, in particular on-ground missions, will allow unprecedented scientific studies and foster the development of new technologies. The activities performed on the exploration sites, in particular on the Lunar surface, will also provide an adequate training ground for human exploration to further destinations such as Mars.

Such activities will require the establishment of long-term or even permanent human settlements on the planetary surface. For the construction and the sustainable operation of these long-term settlements, maximising the use of material resources available at destination appears essential, not only to generate substantial savings in the cost and complexity of the exploration missions, but also to reduce the settlement crews’ dependence on cargo. In particular, the construction of a Lunar habitat outer structure, to protect the crew from the Lunar environment, will strongly benefit from the use of locally available material resources. The most abundant being regolith, i.e. the mixture of dust, soil and broken rock, which constitutes the superficial layer of the Lunar surface. Several studies, including ESA-led activities, have looked into processing Lunar regolith into a construction material. Past studies considered combining the regolith with binding agents brought from Earth, to form a solid material that could be additively manufactured into habitat structures.

The objective of this GSTP activity was to develop a 3D-printing process for sintering lunar soil simulant into a solid construction material, using only concentrated solar energy, without involving any binder. The intended first result was the production of brick-sized model building blocks of a lunar base outer shell.

Several lunar regolith simulants have been characterised (composition, granulometry, sintering behavior) and the most relevant, in terms of representativeness of the sintering process in the actual lunar environment, has been selected for the study. An experimental setup for additive manufacturing of lunar regolith simulant by concentrated solar light has been built. The process has been demonstrated using a solar furnace and a solar simulator. The influence of process parameters (substrate, scanning pattern, and scanning speed) on the structure of the sintered regolith material has been studied. The microstructure and mechanical properties of the obtained consolidated material have been characterised and strategies for improving these properties have been proposed. Three brick-sized demonstrators were produced. Considerations of the effort required and the aspects needed to apply this process in the actual lunar environment were studied.

This activity is the first demonstration of additive manufacturing of three-dimensional objects from lunar soil simulant by means of concentrated solar light, in view of possible applications for on-planet construction of habitat and associated structures (e.g. landing pads, shielding walls). The possibility to produce solid construction material without involving any binder brought from Earth and the direct use of sunlight as an abundant source of energy for sintering make this process particularly attractive for application on the Lunar surface.

Future activities should be targeted towards improving the properties of the consolidated material, as well as addressing identified knowledge gaps, which include the behavior of the process in microgravity and the effect of the lunar environment on the process.
Compliant mechanisms are well known types of mechanisms used in space applications under different configurations and categories, such as flexure joints and pivots, special spring elements or in complex actuation devices. They are typically employed when a friction and backlash free motion is necessary to ensure high position accuracy. The absence of friction and wear allows the device to be lubrication-free, which potentially leads to extended service life and improved cleanliness, since no wear particles are generated. The compliant mechanisms present no backlash, no friction variation or stick-slip phenomena, thus removing significant sources of unpredictable errors.

The current activity aims to further characterise this technology, adding the capability of motion transformation, which is not usually implemented since state-of-the-art compliant mechanisms are mostly flexures and pivot that provide guiding function but not reduction function. Moreover, the use of geometrically complex shapes, enabled by additive manufacturing, could allow more performant kinematic topologies or more efficient local deformation states, like torsion-bending combinations.

Thus, the principal objective of this activity is to develop a novel compliant mechanism for space applications based on additive manufacturing. This mechanism shall be able to perform a motion reduction or transform the type and/or direction of motion of payload elements. Additionally, the secondary objective is to reach TRL 5 via an Elegant-Breadboard Model (EBM) demonstrating the critical functions of the elements in a relevant environment. At the moment, the activity is in the early stages, having only achieved the review requirement so far.

This is a generic technology that can be exploited in several different applications where lubrication-free operations and precise motion are required. Currently, part of the activity also aims to identify where this technology could be effectively employed, once the motion transformation is also included in those type of mechanisms. Once identified, further specific development could be addressed.
HIGH DENSITY PCB ASSEMBLIES
with the participation of Belgium

Printed Circuit Boards (PCBs) provide a platform for the assembly and routing of electronic components. PCBs are comprised of a network of electrical conductors and dielectric insulators manufactured using a complex combination of subtractive and additive processes. Historically, the development of PCBs has been driven by Moore’s law, which specifies that the number of transistors per integrated circuit doubles every two years. This leads to more complex component functionality with large package sizes and high numbers of interconnects. This development is responsible for the significant advances in consumer electronics, as well as in high reliability applications for European space projects.

The miniaturisation of the circuit in the PCB is generally named High Density Interconnect (HDI) technology. It specifically requires various advanced manufacturing processes, materials and test methods.

Examples of electronic equipment for space projects that used HDI are: GAIA Video Processor Unit, GAIA Maxwell processor board, Alphasat processors, Sentinel 2 FMM, Inmarsat 4 DSP, EDRS DPU and MTG DPU. Nevertheless, advancements in PCB technology can lead to new failure mechanisms emerging that need to be screened.

Another consequence of the complex component functionality is the increased signal speed. The circuit on the PCB must provide improved signal integrity by shorter routing among a denser environment of other electronic signals on the PCB.

Commercial PCB and assembly industry have successfully mastered the technologies to accommodate high density routing and high speed signals. The present activity targets full development by qualification of high density PCB assembly technologies. Its main development phases are:

I. Develop test methodology for the assessment of capability of PCB manufacturers and the reliability of the HDI technology.

II. Design, evaluate and qualify HDI PCBs that are capable of providing a platform for assembly and the routing of small pitch Area Array Devices (AAD) for space projects.

III. Verify the assembly of HDI components on HDI PCBs.

This should lead to a completed and successful PCB qualification and assembly verification for HDI technology by February 2021. The activity was successfully kicked off in February 2018 and held a stakeholder workshop in March 2018. In parallel, a similar activity named “high density PCB assemblies – expansion of supply chain” has been issued as ITT, supported by the French Delegation and is expected to kick off in 2018.
JUICE thermal development model and Sun simulator.
ANNEX 1
LIST OF DOCUMENTS TO THE INDUSTRIAL POLICY COMMITTEE

IPC 305 – Paris – 8th and 9th February 2017
ESA/IPC(2017)61 Update of the GSTP-6 Element 1 Work Plan/Procurement Plan
ESA/IPC(2017)61, add.1 Update of the GSTP Element 1 “Develop” Work Plan/Procurement Plan
ESA/IPC(2017)61, add.2 Update of the GSTP Element 1 “Develop” Work Plan/Procurement Plan
ESA/IPC(2017)62 Update of the GSTP-6 Element 2 “Competitiveness” Procurement Proposals
ESA/IPC(2017)33 Closure process for GSTP Period 4 – Information Note

IPC 307 – Paris – 23rd May 2017
ESA/IPC(2017)61, add.3 Update of the GSTP Element 1 “Develop” Work Plan/Procurement Plan
ESA/IPC(2017)61, add.4 Update of the GSTP Element 1 “Develop” Work Plan/Procurement Plan
ESA/IPC(2017)78 Update of the GSTP Element 1 “Develop” Work Plan/Procurement Plan
ESA/IPC(2017)43 TRP 2016/2017 Workplan Activities Considered for Transfer to GSTP – Information Note

IPC 308 – Paris – 27th and 28th June 2017
ESA/IPC(2017)61, add.5 Update of the GSTP Element 1 “Develop” Work Plan/Procurement Plan
ESA/IPC(2017)78, add.1 Update of the GSTP Element 1 “Develop” Work Plan/Procurement Plan
ESA/IPC(2017)62, add.1 Update of the GSTP-6 Element 2 “Make” Procurement Proposals
ESA/IPC(2017)76 Cost plans of on-going GSTP in preparation of draft budgets for 2018

IPC 309 – Noordwijk – 26th and 27th September 2017
ESA/IPC(2017)61, add.6 Update of the GSTP Element 1 “Develop” Work Plan/Procurement Plan
ESA/IPC(2017)63 Update of the GSTP Element 3 “Fly” Work Plan/Procurement Plan
ESA/IPC(2017)101 Report on completion of the GSTP Period 4

IPC 310 – Noordwijk – November 2017
ESA/IPC(2017)61, add.7 Update of the GSTP Element 1 “Develop” Work Plan/Procurement Plan
ESA/IPC(2017)120 GSTP Element 1 “Develop” Work Plan/Procurement Plan – Complete list of approved activities – Information Note
ESA/IPC(2017)119 Report on completion of the GSTP Period 4
ANNEX 2
GSTP BUDGET DISTRIBUTION BY SERVICE DOMAINS (2013 - 2017)

- Earth Observation 16%
- Space Transportation 5%
- Science 3%
- Navigation 6%
- Human Spaceflight and Exploration 4%
- Generic Technologies and Techniques 66%
ANNEX 3
COMPLETE LIST OF GSTP ACTIVITIES INITIATED IN 2017

G511-022GR Automated Service Builder for Semantic Oriented Architectures (ASB)
G517-167MP Air-intake and Ram Jet Development for the SABRE Combined-cycle Engine
G523-006EE Next Generation Radiation Monitor (NGRM)
G611-037SY Development of the EQM of a Compact Spectrometer based on Free Form Gratings
G611-045EO Pre-development of ALTIIUS instrument
G611-048EO Development of a GNSS ADC ASIC
G611-155QT Handheld Contactless Surface Cleaner for Removal of Molecular Contamination
G612-001SR CHEOPS Definition and Implementation Phase – Inclusion of the Provision of Assembly, Integration and Test (AIT) Services
G612-004MS Suspension of Cryogenic Detectors at 50mK
G613-025MM WP2017 – Life Test Campaign of the MELISSA Black Water Treatment Breadboard
G613-030HS Adaptation of a Device for Muscle Health and Physical Condition Research
G614-015MP Launcher Payload Fairing Transparency Preliminary Assessment
G616-010SW Multicore Implementation of the On-Board Software Reference Architecture with IMA Capability
G617-098MP High Power (5kW) HEMPT (High Efficiency Multistage Plasma Thruster)
G617-106TC2 Space Solutions Belgium (National Technology Transfer Initiative + Business Incubation Centres)
G617-1377TB ESA Business Incubation Centres (BIC) Optional Funding – BIC Bavaria
G617-1377TH Space Solutions Belgium (National Technology Transfer Initiative + Business Incubation Centres)
G617-1377TJ ESA Business Incubation Centres (BIC) Optional Funding – BIC Finland
G617-1377TI ESA Business Incubation Centres (BIC) Optional Funding – BIC Estonia
G617-199MS Cage Instability Analysis, Testing and Model Correlation
G617-204QT Autocatalytic Silver for Space Applications
G617-205SW Adaptation of a Generic EGSE Controller Software Solution for EGSS-CC
G617-213SW Functional Verification manager (FaVouR)
G617-217MM Optical Stabilising Reference Cavity – Optical and Optoelectronic Testbed Enhancement Activities
G617-218MP Pre-Qualification of Aluminium Free Solid Propellant
G617-222QT Development of Hermetic Optocouplers for Space Applications
G617-224CD Data Mining System for Safer Spacecraft
G617-224ED ESA IP Core Extension
G617-226GStb Re-Erection of the 15 Metre Perth Antenna at Santa Maria, Azores, Portugal – Phase 2
G617-228MP High Altitude Propulsion Test Facility Preliminary Design Phase
G617-229SW Qualification of a Virtual Machine and ORBC Core Engine Based on MicroPython
G617-230Sla Assessment Studies for Synergy Between Technology Developments in Terrestrial Sectors and the Space Sector – SiC Coatings
G617-230Sb Assessment Studies – FPGA Verification Tool
G617-230Sc Assessment Studies for Synergy Between Technology Developments in Terrestrial Sectors and the Space Sector – Micromirror
G617-231GI Building Blocks for End-to-End Validation and Management of Disturbed Ground Segment Systems Components
G617-233GS Deep Space Low Cost 4m Monolithic Optical Antenna for Day/Night
G617-234MM Radiation Testing of Optical Coatings for Space
G617-236MP 6 DOF Micro-Propulsion System Development for Nanosats
G617-237EE X-ray Flux Monitor for CubeSats (XFM-CS)
G617-238SGa Proba-Next Ground Segment Evolution based on European Ground Systems- Common Core (EGS-CC) – Phase 1
G617-240MS Miniaturised Solar Array Drive Assembly for 6U/12U CubeSat
G617-241Taa Assessment to Prepare and De-risk Technology Developments – GNSS Software Define Space Receiver
G617-241Taaa Assessment to Prepare and De-risk Technology Developments – Highly Integral CFRP Components for Satellites (HICCS)
G617-241TAb Assessment to Prepare and De-risk Technology Developments – Multifunctional Power Unit (MPU)
G617-241TAd Assessment to Prepare and De-risk Technology Developments – Magnetic Bearing System
G617-241Tae Assessment to Prepare and De-risk Technology Developments – Adaptation to High Pressure/ Cryogenic Testing
G617-241TAF Assessment to Prepare and De-risk Technology Developments – Long-life Valve
G617-241Tah Assessment to Prepare and De-risk Technology Developments – ORBITA in-orbit diagnostics
G617-241TAI Assessment to Prepare and De-risk Technology Developments – CORRAL Stage 2a Development
G617-241TAj Assessment to Prepare and De-risk Technology Developments – Differential Ray Tracing Software for Improved Assessment of Stray Light Risks
G617-241Tan Assessment to Prepare and De-risk Technology Developments – Austrian Dry Lubricant Composite for Deployment Applications
G617-241Tao Assessment to Prepare and De-risk Technology Developments – Ceramic Packages for Magneto-resistive Sensors
Assessing the Use of Advanced Manufacturing to Improve and Expand Space Hardware Capabilities

Bio-composite Structure in Space Applications

e.Deorbit Consolidation Phase

Avionics Product Line Building Blocks Additional Work Packages

High Speed and Low Power Die-to-Die Interconnects in a Package

Development of a 5kW Class Power Processing Unit (PPU)

Solar Array Digital Regulation Module for Unregulated and Regulated Buses

Thermoplastic Wind Blades

LPSS-380 Separation System Development

Improved GE Wafer Technology for Multi-junction Solar Cells IV

Extreme Rapid Mass Memory Unit

UK-Romania Satellite Advancement Study

Preliminary Activities for a Mars Balloon Probe

Assessment and Accommodation Studies for Technology Flight Opportunities – SPHERE ISS-Tether-Slosh Experiment on ISS

Experimental Setup for POCKET Protocol on Proba-2

Preliminary Identification of TSTO Semi-Reusable Concepts for Launch of Small Payloads

OPS-SAT Phase B2CDE Launch

RadCube IOD CubeSat Mission Implementation

Austrian CubeSat IOD Mission Phase B

Test of LVF based Algorithms on a Compact Hyperspectral Imager (COSI)

Harness for International Berthing and Docking Mechanism (IBDM)

Separation Mechanism for the International Berthing and Docking Mechanism (IBDM)

High Power Hall Effect Thruster (HET) Subsystem for Space Transportation and Exploration

Secure Tracking Services – S-TrackS
### ANEX 4

**COMPLETE LIST OF GSTP ACTIVITIES CLOSED IN 2017**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AO06-12MP</td>
<td>Advanced Particle Filters</td>
</tr>
<tr>
<td>AO06-29EE</td>
<td>High Gain Data Downlink X-band Antenna</td>
</tr>
<tr>
<td>G517-01EE</td>
<td>Multi Frequency High Resolution GEO-Sounder Demonstrator</td>
</tr>
<tr>
<td>G517-042SY</td>
<td>WP2013 – Implementation of a Linear Variable Filter Based Hyperspectral Focal Plane for Earth Observation Instruments</td>
</tr>
<tr>
<td>G517-044MM</td>
<td>Technologies and Key Components for Compact Hyperspectral Instruments</td>
</tr>
<tr>
<td>G517-052MM</td>
<td>Piezo New Sources Materials, Piezoceramics Motor Qualification (Phase 2)</td>
</tr>
<tr>
<td>G517-065MC1</td>
<td>Automated Layup of Thermoplastic Composites for Space Applications (Phase 2)</td>
</tr>
<tr>
<td>G517-116SW</td>
<td>Mission On-board Planning System</td>
</tr>
<tr>
<td>G517-119QT</td>
<td>Miniaturisation of a Magnetometer based on Micro Technology</td>
</tr>
<tr>
<td>G517-121ST</td>
<td>Second Generation APS Star Tracker Breadboard Step 2: Optical Head</td>
</tr>
<tr>
<td>G517-151SY</td>
<td>Upgrade of Proba-V ADS-B Receiver Firmware with Data Analysis</td>
</tr>
<tr>
<td>G517-154MM</td>
<td>Atomic Layer Deposition of Detector Anti-Reflection Coatings (Part A)</td>
</tr>
<tr>
<td>G517-156GI</td>
<td>System Performance Assessment with Data Mining and Process Mining Technique Evaluated on a ISIS Use Case</td>
</tr>
<tr>
<td>G517-165MS</td>
<td>Reaction Wheels – Technology Consolidation</td>
</tr>
<tr>
<td>G521-001ED</td>
<td>Modular General Purpose RTU Supporting Advanced Low Speed and Medium Speed Serial Buses</td>
</tr>
<tr>
<td>G521-004ED</td>
<td>Control Loop Processor (Phase 1)</td>
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<tr>
<td>G523-006EE</td>
<td>Next Generation Radiation Monitor (NGRM)</td>
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<tr>
<td>G547-009Ya</td>
<td>CubeSat Technology Pre-development, QB-50, Communications and AOCs Technologies</td>
</tr>
<tr>
<td>G613-020MM</td>
<td>EPSILON-1: Embedded Psychological Support Integrated for LONGDuration Missions (Phase 1)</td>
</tr>
<tr>
<td>G613-022GS</td>
<td>Goomhilly-6 Antenna Support to the Orion Exploration Mission 1 Flight</td>
</tr>
<tr>
<td>G617-038ED</td>
<td>Demonstration and Validation of an Inter-processor Link for Future OBSCs</td>
</tr>
<tr>
<td>G617-051EE</td>
<td>Accurate RF Material Characterisation Using Scattering Measurements from Quasi-Optical Bench</td>
</tr>
<tr>
<td>G617-054SW</td>
<td>Precise and Flexible WiFi-Based Requirements Engineering</td>
</tr>
<tr>
<td>G617-062GI</td>
<td>Security as a Service for Ground Data Systems</td>
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<tr>
<td>G617-066GI</td>
<td>Automated Rule-based Cross-validation of Operational Data</td>
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<tr>
<td>G617-083MS</td>
<td>In-orbit Manufacturing of Very Long Booms</td>
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<tr>
<td>G617-111QT</td>
<td>Filament Winding TISIC</td>
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<tr>
<td>G617-134MP</td>
<td>Synergetic Air-Breathing Rocket Engine (SABRE) Development (Phase 3a)</td>
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<tr>
<td>G617-136Ta</td>
<td>National Technology Transfer Initiative Open Call – Czech</td>
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<tr>
<td>G617-141ET</td>
<td>GNSS receiver for LEO/GEO/HEO applications (GAMIR-2)</td>
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<tr>
<td>G617-142ED</td>
<td>16-bit ADC</td>
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<tr>
<td>G617-143QT</td>
<td>Nano-enabled CFRP for Space Applications</td>
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<tr>
<td>G617-148EP</td>
<td>Qualification of Fully European 3G30 Bare Solar Cell with Integral Diode up to Solar Cell Assembly Level</td>
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<tr>
<td>G617-153QT</td>
<td>3D Printing of a Model Building Block for a Lunar Base Outer Shell</td>
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<tr>
<td>G617-183GI</td>
<td>EGS-CC Based MICONYS (Engineering Phase)</td>
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<tr>
<td>G617-195GI</td>
<td>Standard Platform for Monitoring (SPMON2)</td>
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<tr>
<td>G617-214MX</td>
<td>Motion System for Thermal Vacuum Application</td>
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<tr>
<td>G617-241TaC</td>
<td>Assessment to Prepare and De-risk Technology Developments -- NGMP (Pre-phase 3)</td>
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<tr>
<td>G617-241TaJ</td>
<td>Assessment to Prepare and De-risk Technology Developments -- ADEO Dynamic Analyses</td>
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<tr>
<td>G617-272SY</td>
<td>Adaptation of Proba-Next for Very High Resolution</td>
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<tr>
<td>G619-012EP</td>
<td>Radiosotope Heater Unit Prototype Development</td>
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<tr>
<td>G61C-007QTq</td>
<td>Surface Engineering for Parts Made by Additive Manufacturing (Step 1)</td>
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<tr>
<td>G61C-015MS</td>
<td>Architectural Design and Testing of a De-orbiting Subsystem</td>
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<tr>
<td>G61C-026YSa</td>
<td>Phase B1 of an Active Debris Removal Mission</td>
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<tr>
<td>G61C-029EC</td>
<td>Image Recognition and Processing Navigation</td>
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<tr>
<td>G61M-006SY</td>
<td>AIM System Consolidation (Phase 1)</td>
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<tr>
<td>G621-008EP</td>
<td>PCDU Product Line Building Bocks</td>
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<tr>
<td>G621-011MM</td>
<td>Streego Innovative Solutions for High Resolution Small Satellites</td>
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<tr>
<td>G626-021ET</td>
<td>GDARS Data Acquisition and Replay System</td>
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<tr>
<td>G626-048ET</td>
<td>GNSS Recorder for Anti-Spoofing (GRAS)</td>
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<tr>
<td>G626-054ET</td>
<td>Multi-GNSS Simulation and Test Environment (MGSE)</td>
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<tr>
<td>G626-057ET</td>
<td>Advanced GNSS Reference Station Bboard</td>
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<tr>
<td>G627-003ET</td>
<td>MosaicNG Single-Frequency Multi Constellation GNSS Receiver Development</td>
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<tr>
<td>G627-016SY</td>
<td>Next Generation Concurrent Design and Engineering</td>
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<tr>
<td>G627-020ET</td>
<td>Class 3 X-Band HDR Transmitter Development</td>
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<tr>
<td>G627-029MM</td>
<td>Narrow Linewidth Laser Diode at 689nm for Strontium Second Stage Cooling</td>
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<tr>
<td>G627-038EP</td>
<td>Leo PCDU Evolution Engineering Model (EM) in the range &lt;1kW for Earth Observation and Science Satellites</td>
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<tr>
<td>G627-045MT</td>
<td>Impact Analysis of Piston Alignment on Key Compressor Performance Characteristics</td>
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<tr>
<td>G627-055EC</td>
<td>HORUS</td>
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<tr>
<td>G627-063EP</td>
<td>Pegasus II- Performance GuAranteed SubStrates</td>
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<tr>
<td>G627-066MM</td>
<td>Point of Care Diagnostics and Monitoring Platform – Key Enabling Technologies (POCDMP-KET)</td>
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<tr>
<td>G627-078EC</td>
<td>Space 3-axis CVG Gyro Unit Arietis-1 (Phase 1)</td>
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<tr>
<td>G637-001TF</td>
<td>GOMX-48 IOD CubeSat Mission and System Definition Study</td>
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<tr>
<td>G637-001Tfd</td>
<td>RadCube IOD CubeSat Mission and System Definition Study</td>
</tr>
<tr>
<td>G637-001Te</td>
<td>Cosmic Radiation and Magnetic Field (RadMag) Instrument Development</td>
</tr>
<tr>
<td>G637-006MM</td>
<td>VIRSI Hyperspectral Imaging In-orbit Demonstration</td>
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</tbody>
</table>
GSTP Participating States

Austria
Belgium
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Luxembourg
Netherlands
Norway
Poland
Portugal
Romania
Slovenia
Spain
Sweden
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