GSTP HIGHLIGHTS IN 2016

During the year 2016, the GSTP has continued its goal of providing a flexible response to the needs of ESA Programmes, Member States and European industry through the accomplishment of a large number of new technology developments, representing 95 new activities (worth around 90 M€) and 62 closed activities (worth around 47 M€).

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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 MEuros 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 conceptual space technologies and space missions, between laboratories and the open market. Some good examples are:

- **CO2 family of micropropulsion flown in ASCII and validated for the kicksat**
- **GPS POD instrument baseline in the Sentinels**
- **Earth Observation.**
- Clean Space: ESA’s cross-cutting initiative that supports EGS-CC: an European initiative where the Large MEMS rate sensor flying in Cryosat 2.
- **The Mission Operation Centre (MOC) for CHEOPS.**
- **Improve European technological non-redundancy.**
- **Facilitate spin-in from outside the space sector.**
- **Foster innovation by creating new products.**

**Electric Propulsion alternatives: such as micro-thruster**

**Design to Produce: which allows to perform robust design analysis and digital engineering of systems focusing not only on structure optimization, but also improving digital manufacturing focusing not only on structure optimization, but also improving structural efficiency by predicting critical areas of interest such as: “**The 1N “green” thruster in PRISMA.**”

**Strengthen the competitiveness of European Space Transportation.**

**Enable missions of ESA and national agencies which are also an integral part of the GSTP like the IPV System, the gas monitor Anita, the Melissa project and other health monitoring systems.**

**Always looking ahead, the GSTP is now helping to prepare the future of space in diverse areas of interest such as: “**The Orion European Service Module test article.**”

- **Advanced Manufacturing: a key enabling technology**
- **Spin-off from traditional industries that accompanies the full lifecycle of a space mission.**
- **Adaptability and Potency:**
- **Digital Engineering and Manufacturing**
- **Verification and Methodology Implementation:**
- **Clean Space: udało to bridge the gap between conceptual space technologies and space missions, between laboratories and the open market. Some good examples are:**
- **Latin American and caribbean.**
- **The hybrid low cost magnetometer in ADM-Aeolus.**
- **Always looking ahead, the GSTP is now helping to prepare the future of space in diverse areas of interest such as:**
- **The Orion European Service Module test article.**
- **Advanced Manufacturing: a key enabling technology for space applications that allows to obtain fit-for-purpose hardware in a shorter period time and by using less material:**
- **Design to Produce which allows to perform robust design analysis and digital engineering focusing not only on structure optimization, but also improving structural efficiency by predicting critical areas of interest such as:**
- **The Orion European Service Module test article.**
Closed GSTP periods

Active GSTP periods

Advanced Manufacturing
Innovations in new 3D printing technologies also make it possible to perform on-site engineering, reducing lead time and assembly costs in-situ.

Digital Engineering
Increased collaboration between the so-called ‘open space’ and tooling plus digital tools such as additive manufacturing, simulation and digital twin technologies to ensure the successful development of the low-cost and mass-produced payload.

GOMX-4
ESA’s biggest nanosatellite yet, built for testing new miniaturized technologies and paving the way for future missions. One of the key elements of GOMX-4 is the 3D printed CoolCube that will be used for on-site manufacturing and facility maintenance. Launch planned in 2018.

QARMAN
The next generation of hypersonic propulsion engine for Earth orbiters and long-range interplanetary missions. Development and testing of the SABRE engine will take place in 2017 at the Spirit of Innovation test facility in Southern California. Launch planned in 2018.

GOMX-3
ESA’s inaugural In-Orbit Demonstration CubeSat with the primary goal of testing new tribology, structural integrity and composite materials. Launch planned in 2017.

Energetic Particle Technology

Focusing on attitude control, RF transmission and high-speed data downlink. Mission to demonstrate new capabilities of nanosatellites and their usefulness for Earth observation. Launch planned in 2018.

IBDM
Friction Stir Welding

Reliability and facilitating the downlink of Earth Observation data. New 3D printing service located at the same site. Launch planned in 2018.

Space Based Automatic Identification System receiver

Re-use and upgrade of Space Antennas

When it comes to designing technology that changes the way we access space and conduct operations, antenna solutions for spacecraft, spaceports and ground facilities need to be revolutionary. Launch scheduled in 2018.

SABRE
Hybrid Low Cost Magnetometer

Baseline for Sun-facing surfaces on Solar Orbiter. Launch planned in 2019.

Clean Space

Alternative: Energetic Particle Technology

The idea is to employ ultra-high photometry to conduct a detailed exoplanet search with extremely low background noise. The mission is planned for 2020.

CHEOPS
European Ground Systems Common Core

Equipment for future mission to demonstrate new capabilities of nanosatellites and their usefulness for Earth observation. Launch planned in 2018.

Multi-frequency Space Receiver (First with Galileo signal).

Based on the performance of the GIOVE Test Receiver, this mission will bring worldwide sea traffic tracking within reach. Launch planned in 2018.

VEGA TVC

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.

IBDM International Berthing and Docking

European androgynous low impact docking mechanism, capable of docking and berthing large and small spacecraft. Development and testing of the IBDM is ongoing. Launch planned in 2018.

IBDM

Control


EGS-CC

Common Procedure Language

Basis for the current ESSC standard for procedure languages. Proven and selected for several ESA and non-ESA missions. Used in Rapid Eye (launched in 2008) and Proba V (launched in 2013). Launch planned in 2019.

ECLANS

Precise Orbit Determination, Sentinels

Basis for sun sensors and star trackers like the one baseline in Earth-monitoring Sentinel family and the BepiColombo mission.

GIOVE Test Receiver

Spacecraft controller already flight proven and selected for several ESA and non-ESA missions. Launch planned in 2018.

Shaking FLEA


Sloshsat

Later Cryogenic Monopropellant based upon ADN.

CryoSat 2

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.

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The Automatic Dependent Surveillance Broadcast system (ADS-B) is a technology where an aircraft broadcasts its flight information periodically using a dedicated transponder at L-band frequencies, with a power of up to several hundred watts, which is then received by corresponding ground stations and forwarded to air traffic control. This system will enable precise, efficient and safe surveillance of aircrafts in the near future as the signal includes flight related information such as speed, position, flight number and direction. With respect to the classical surveillance technologies, such as primary and secondary surveillance radars, the ADS-B will significantly reduce infrastructure costs and will allow more precise aircraft position data with higher update rates.

From 2020, the utilisation of ADS-B transponders will be mandatory in most airspaces of the world for commercial traffic. However, with 71% of the world covered by oceans, the reach of the presently used terrestrial surveillance installation is limited and current terrestrial coverage has surveillance gaps at low altitudes and in mountainous areas. Moreover, the installation of a terrestrial surveillance infrastructure based on radars or ADS-B is cost efficient for remote areas such as the poles and continental areas such as Africa. Thus, a complete surveillance of remote areas (so called Non-radar airspaces, NRA) by terrestrial surveillance infrastructure is beyond the current technical and budgetary means.

To overcome this situation, a possible step is to bring the ADS-B receiver stations into space and establish global real-time surveillance of air traffic. Such a system will detect ADS-B signals transmitted by aircrafts on regular basis and make this data available to air traffic control stations. In the demo demonstrator mission is already flying on board the ESA Proba-V satellite in order to demonstrate the overall feasibility of global coverage and near real-time capability, requiring additional effort to reach these objectives.

One of the main advantages of the ADS-B is the usage of existing equipment already installed in today’s aircrafts. Consequently, there are no additional costs for retrofitting equipment to the aircraft or developing, certifying and installing something new. This cost ADS-B system would receive what is already broadcasted, requiring no change on the aircraft’s infrastructure. In addition, another key component of such a surveillance system is the ADS-B receiver payload that could be integrated into dedicated or multi-purpose satellite constellations.

The objective of this activity consisted in the design, development and manufacturing of an ADS-B receiver and antenna for a small satellite mission, which was denoted as SABIP (Space-Based ADS-B Payload Development for Air Traffic Surveillance). SABIP’s project outcome is a qualified, versatile, multi-channel, software defined radio platform which implements a multi-channel ADS-B receiver.

The SABIP is a prototype of a possible constellation payload to demonstrate operational scenarios of air traffic control based on in-orbit ADS-B receiving stations. This is an important step towards a future commercial ADS-B system in space based implementation.
**CRYOGENIC VALVE SEALING**

In the current European launcher, cryogenic valves sealing the propellant lines are pneumatically driven. For future launches, the possibility to actuate the valves electromechanically has been assessed as a major improvement prospect in terms of functional performance, handling masses, masses and costs (by replacing heavy pneumatic piping with simple wires). The drawbacks with electric actuation, compared to the conventional one, are the difficulty to reach high actuation power with reasonable voltage and conventional one, lies with the difficulty to reach pneumatic piping with simple wires). The easiness, mass and costs (e.g. by replacing heavy

The comparison of different material confirmed that metallic seals are advantageous for the development of high pressure valves working under cryogenic conditions. By choosing an appropriate design and using hybrid sealing the closing forces can be reduced significantly (by 40% compared to PEEK). In addition, other criteria and excellent performance will be kept even under extreme conditions like cryogenic temperature, high pressure and/or oxygen atmosphere.

Finally, the activities also aimed for preparing the next European launcher – Ariane 6 – in a competitive world-wide environment. A further advantage is that by eliminating helium or nitrogen pneumatic actuation systems the engine's overall mass and complexity will be reduced to a high extent.

**DEVELOPMENT AND CHARACTERISATION OF ADVANCED METAL COMPOSITE MATERIALS**

Metal matrix composites (MMCs) are hybrid materials composed by a metal matrix and a reinforcing element. The main advantages of MMCs are high strength-to-weight ratio, high thermal and/or mechanical properties, e.g. strength, stiffness, toughness etc. with lightweight design, while maintaining low density. As a result, MMCs are very attractive for advanced applications such as boom structures in the aerospace industry. The comparison of the conventional titanium alloys is shown in Fig. 1 where demand for high pressure systems is still very high and could be detrimental to the possibility of an electrical actuation.

Therefore, the objective of this activity was to investigate the potential of new materials and design for sealing device compatible with a cryogenic environment, with moderate sealing force and good compatibility with oxygen at high pressure. The proposed activity identified possible materials and design concepts. Tests have been performed in a relevant environment to gain experimental data in order to judge on further applications.

As a result, recommended application range was identified for modern actuation systems. The possibility of integrating these actuators, both for pneumatic and electrically, for high actuation power with reasonable voltage and competitive world-wide environment. A further advantage is by eliminating the use of cryogenic temperature, high pressure and/or oxygen atmosphere.

Finally, the activities also aimed at preparing the next European launcher – Ariane 6 – in a competitive world-wide environment. A further advantage is by eliminating helium or nitrogen pneumatically actuation systems the engine's overall mass and complexity will be reduced to a large extent.

**CHARACTERISATION OF ADVANCED PARTICULATE METAL MATRIX COMPOSITES**

The objective of this activity was then to develop and characterise advanced particulate metal matrix composites (MMCs). Upon achieving a satisfactory development of particulate Ti-TiC composites, a sub-scale demonstrator was designed. This was achieved by working on the advantages of the particulate MMCs developed within the project and then morphing them from a sub-scale concept into a demonstrator, which was then validated under typical space environment. The demonstrator was built and technologically validated the overall hybrid TiC approach.

Finally, the technology acquired from this activity has the potential to be transferred to all applications that need hybrid MMCs, as well as for aircraft engine components. The hybrid MMCs developed within the project and then morphing of them into a demonstrator was validated under typical space environment. The demonstrator was built and technologically validated the overall hybrid TiC approach.

As an example of an initiative that is looking to evaluate the performance of new materials and design for sealing device compatible with a cryogenic environment, with moderate sealing force and good compatibility with oxygen at high pressure. The proposed activity identified possible materials and design concepts. Tests have been performed in a relevant environment to gain experimental data in order to judge on further applications.

**LOW COST 5-BAND FLEXIBLE TRANSCEIVER FOR MINISATELLITES**

Minisatellites based on small satellite platforms are constrained to use low cost, low mass and low power (LCO) flexible antennas and transponders. However, transponders currently available are either targeting large Earth Observation missions or the low end of the market. In addition, they possess no coherent modulation of signals. The 5-Band power is often quite low and there is limited flexibility in the antenna beamwidth and gain.

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In 2016, 62 GSTP activities were completed achieving the technology development objectives originally targeted.

FIBRE BRAGG GRATING EXPERIMENT SHEFEX

Aerodynamic performance and heat-loading characteristics are important factors in the proper design of a hypersonic re-entry vehicle. During atmospheres entry transition, the exposed materials are submitted to an extreme load for a few minutes, leading to sharp increase of temperatures, thus making it necessary to use thermal protection systems (TPS) to shield the hypersonic vehicle.

Currently non-optical sensors are used to monitor TPS temperatures during re-entry, which are based on thermocouples and thermistors. The main disadvantages of these sensors are their sensitivity on thermocouples and thermistors. The main drawbacks of these sensors are their sensitivity to electromagnetic interference effects during re-entry. Slow response times and some cases of drift/cracking along the TPS components subjected to high temperature during re-entry transition, the design and operation of any future aerospace vehicle. During atmospheric re-entry transition, the temperature of the exposed materials are submitted to an extreme load during a few minutes, leading to sharp increase of temperatures, thus making it necessary to use thermal protection systems (TPS) to shield the hypersonic vehicle.

The objective of this activity was then to provide a multichannel fibre optic sensing system, which will enable a large number of distributed measurements of temperature and strain on the re-entry vehicle using a monovision position/centralized interrogation unit, whose packaging concept and monitoring approach would be very well suited for a reusable launch vehicle. This is where optical fibre sensors offer some unique advantages in the mapping of TPS systems due to their electromagnetic immunity (EMI), reduction in weight due to the use of low mass optical fibre, and by offering multiplexing of sensors on a single fibre optic cable and has been shown to be able to measure reliably in re-entry temperatures up to 2000°C.

In 2016, 62 GSTP activities were completed achieving the technology development objectives originally targeted.

EXPERIMENT SHEFEX

The Fibre Bragg Grating (FBG) are fibre optic sensors written in standard telecom fibres, with a fundamental blue shift in angle, that were selected as the most optimal solution for various flight tests, since it allows multiplexing of sensors along a single fibre optic cable and has been shown to be able to measure reliably in re-entry temperatures up to 2000°C.

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The客观内容是关于在2016年完成的62个GSTP活动，这些活动在最初的目标下完成了技术开发。
Due to the complexity and unpredictability of the challenges encountered in space, it is very important to minimize the mission risks as much as possible. The GSTP enables missions, helping novel technology to reach the right maturity level.

**PROPELLANT MANAGEMENT**

Successful commercial and scientific space activities depend on the capability of the spacecraft to operate in terms of the mission objectives. One of the key technologies identified in the management of the conventional and cryogenic propellants send on spacecraft, and, more specifically, the tank with its ancillary structures such as the storage, acquisition and transfer of the propellant to and from the pressurized and thermal control. The development of such systems needs a deep understanding of the behavior of the propellant, an understanding of the environment that needs to be taken into account, as well as the environmental conditions met during the mission. In particular, sloshing is the dominant environmental conditions met during the spacecraft in microgravity conditions, with an understanding of the behavior of the propellant and the pressure and structural interactions, which allows the storage, acquisition and, more specifically, the tank with its ancillary structures such as the storage, acquisition and transfer of the propellant to and from the pressurized and thermal control.

The result of this activity was a software package that can simulate the propellant behavior in thermal stratification, crystallization and non- crystalline states, which is able to cover the various phenomena such as changes in density, pressure and temperature. The result of this activity was a software package that can simulate the propellant behavior in thermal stratification, crystallization and non-crystalline states, which is able to cover the various phenomena such as changes in density, pressure and temperature.

**DEVICES**

The software technology is sufficiently mature and a number of key systems have been developed: the propellant management (software), cryogenic PIV (particle Image Velocimetry) for cryogenic propellant management (software), cryogenic CFD (computational fluid dynamics) development and validation (software). The software packages are able to cover the various phenomena such as changes in density, pressure and temperature.

**TIME SAVING WITH FRICTION STIR WELDING (FSW)**

Titanium propellant tanks are one of the most costly items in the spacecraft propulsion system, with a cost of $100,000 per tonne of propellant. Therefore, the objectives of this activity were the prediction of sloshing in tanks for all phases of the mission, including launch, in-flight, and post-maneuvers and gravitational accelerations. Prediction of sloshing in tanks for all phases of the mission, including launch, in-flight, with a cost of $100,000 per tonne of propellant.

The result of this activity was a software package that can simulate the propellant behavior in thermal stratification, crystallization and non-crystalline states, which is able to cover the various phenomena such as changes in density, pressure and temperature.

This is further amplified by the thermo-kinetic study of the cryogenic propellant fluid.
RELIABLE LARGE-AREA FILTERS — RELAX

Instrumentation for space missions and many other applications require windows and filters that are capable of tolerating large amounts of unwanted radiation. It is essential that the filters have very good transmittance in the wavelengths of interest, combined with sufficient filtering of unwanted radiation in the same range, including high temperatures with low energy (soft X-rays). This is a challenging design due to the fact that such radiation is absorbed readily by thin material layers. To mitigate this, the window or filter must be simultaneously extremely thin, radiation tolerant, mechanically strong and dimensionally tight; for space applications, it should also tolerate high temperatures and withstand vibrations and impacts. This set of requirements makes the development very challenging.

Furthermore, while state of the art X-ray transmission performance has already been demonstrated for the ultra-thin filters, the technology is still immature with significant potential for growth. Modifications to the filter structure will improve the total performance in X-ray transmission and the reliability necessary for space instrumentation. Some of the problems that need to be addressed include the necessity for durable filters in large areas as large as possible (target around 38 mm in diameter) and the appearance of pinholes during the etching process that decrease the production yield of the filter. In addition, for window applications, a good understanding of the coating technology between the filter and filter frame is essential. Reliable joining methods make it possible to attach the delicate filter structure onto a robust frame, allowing robust handling of the device. In simple cases an approach based on a suitable adhesive is acceptable but more challenging applications demand more sophisticated solutions. For example, an optical joining with high accuracy (up to 10^-5 m deviation for the misalignment) during the etching process that decreases the production yield of the filter.

In addition, for window applications, a good understanding of the coating technology between the filter and filter frame is essential. Reliable joining methods make it possible to attach the delicate filter structure onto a strong frame, allowing robust handling of the device. In simple cases an approach based on a suitable adhesive is acceptable but more challenging applications demand more sophisticated solutions. For example, an optical joining with high accuracy (up to 10^-5 m deviation for the misalignment) during the etching process that decreases the production yield of the filter.

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The main objectives of this activity are to further improve the stability and production of ultra-thin filters by improving measurement accuracy and to improve performance in X-ray transmission, demonstrate window joining methods for large area applications (using vacuum/metal joints), improve the large area filter TRL and demonstrate a high-quality manufacturing process.

Further advantage is represented by the outstanding output frequency accuracy and very low frequency drift, given the reduced distance between the clock and the microwave cavity. This activity is dedicated to the design, manufacture and testing of a Mercury Ion Frequency Standard (MIFS) that is fully integrated and is a high performance, compact design, composed by the physical package and related electronics, for the final application.

During 2016, 95 new technology activities were initiated under the frame of the GSTP addressing new needs and emerging applications.
Flexible and deployable heat shielding is an important strategy for protecting a capsule from atmospheric re-entry. The objective is that the capsule will be both compact before the atmospheric re-entry, with a properly designed ballistic coefficient, thus it is not usually a design parameter that contradict the achievement of a low ballistic coefficient. However, the volume constraints imposed by space applications including payload retrieval from LEO can be satisfied with a deployable and flexible heat shield, and allow lower, short-diameter missions in order to satisfy the ballistic coefficient constraint of the satellite (e.g. MIRENE, IRENE). A prototype demonstrator (MINI IRENE) has already been demonstrated in vacuum, and at different temperatures, proving confidence in the feasibility of gecko adhesives in space conditions. The technology is in its early development stages and its benefits include the low total impulse requirements for those applications, review and optimisation of their performance, and the large range of materials and surface conditions, which cannot be addressed with the existing micro-colloid thruster technology. The objectives of this activity are to improve the specific impulse, thrust density and reliability of the existing micro-colloid thruster technology. The focus of this activity has to date been limited to future mini and micro-thruster development programs. Development of electrospray colloid electric propulsion (EP) has been underway since 1999. Active research in this field has been pursued in order to operate at specific impulse of the order of 1000s s with a scalable high thrust density capability. To reach a better understanding of how gecko-inspired adhesives can be verified not only in vacuum conditions, but also in the manufacture and experimental performance of a thruster for space applications requiring specific impulse and thrust density, a thruster is being tested in a vacuum chamber. The GSTP aims at the development of new propulsion technologies that can provide affordable, reusable and reliable space transportation. The objectives of this activity are to concentrate on the qualification thrust head (THT) design, material selection and manufacturing process development, substantiate in the manufacturing and experimental performance of a first generation (THT) demonstrator model. After initial performance verification the reliability of the THT components will be demonstrated via endurance testing. The activity will conclude with an initial system design and analysis with the participation of Germany, the UK and Italy.
CARBON NANOTUBE TECHNOLOGY AND MATERIAL ENGINEERING FOR VARIOUS SPACE APPLICATIONS (NACO)

Full paper available online

Carbon nanotube (CNT) embedded in composite materials such as Carbon Fibre Reinforced Polymer (CFRP) polymers or ceramics can improve specific performance characteristics such as electrical conductivity, resistance to mechanical and thermal loads, fatigue and crack propagation, structural damping, passive intermodulation reduction or thermally-induced phase noise. Some of these improvements were demonstrated in the GSTP projects NACO-1 and NACO-2 performed between 2007 and 2013. In the course of those previous activities, several potential applications and associated products were also identified, where the introduction of CNT into composite materials can potentially lead to attractive performance improvements. Some future applications would include mirror facing, beamforming, beam steering, antenna feed horns.

In the current activity, two space applications have been identified using CNT technologies, for which demonstrations were then developed, manufactured and characterized using the know-how acquired by the consortium in the previous studies.

The first demonstrator consists of a 58-cm-long feed horn made of CFRP material, which was built as a backup of CST on the external surface of the antenna. The demonstrator was used to measure, and the ability to match the outer surface and its accuracy. The objective of the activity is to establish a verification methodology for the use of AM parts for space applications, meaning that it will define the necessary requirements and test methods. Some future applications would include mirror facing, beamforming, beam steering, antenna feed horns.

In other words, the capability to detect defaults using conventional Non-Destructive Inspection (NDI) techniques should be investigated on processed items and when feasible, repeated on the same items after the AM parts have been inspected. The methodology shall be generic in order to be applicable to the largest amount of AM parts as possible and will only focus on powder bed fusion processes for metals.

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Market Oriented Closed and Initiated Activities

Development of In-Situ Characterization with Original Ceramic Engineered Materials

With the purpose of designing new materials that play a critical role in increasing the performance of launchers, spacecrafts and technology development in other space industries such as telecommunications. Thus, a better understanding of the behavior and performance under ceramic conditions is increasingly required for current and future research, development and application activities. However, for new materials and processes, this type of data is missing or obsolete. Moreover, the lack of data does not cover new areas always selected for next generation missions. This means the need for adapted simulation tools.

Today’s developments focus on the need to replace metallic parts with lightweight designs. As a possible solution, industries must be able to replace metallic parts with material solutions based on laminated materials made of fiber reinforced polymer (unidirectional or woven) and environmental constraints that force them to explore and implement strategies for developing lightweight designs. As a possible solution, industries must be able to replace metallic parts with material solutions based on laminated materials made of fiber reinforced polymer (unidirectional or woven) and environmental constraints that force them to explore and implement strategies for developing lightweight designs. The main benefits of this software are its ability to analyse complex laminated structures and composite materials (coupling inter- and intra-laminar analysis, specific progressive damage models for composites (coupling inter- and intra-laminar analysis, progressive damage models for composites). The software (LMS Samtech Samcef) has many features to adapt to different requirements of composite materials, predicting the non-linear progressive damage propagation inside plies and at their interface, identify its failure modes, predict damage propagation, determine tight safety margins, reduce costs and sensitivity analysis modules along with a comprehensive finite element library.

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Qualification of a Micro Pulsed Plasma Thruster for Cubesat Application

In recent years, the trend in small satellite missions has continued with an increase in micro/nano-satellites and Cubesat missions being flown on small launchers, leading to a more ambitious space development scenario. The microsatellites (including nano-paneled technology) are part of this scenario as they are very competitive from a cost or performance viewpoint and have a strong market potential. Currently, the MicroPulsed Thruster for Cubesat Applications (PPTCUP) is under development. This PPTCUP-M is a pulse thruster with very low impulse (1 mN-s) and low total impulse (10 mN-s for 100 pulses when powered at 5 W). It is therefore capable of achieving a high performance-to-mass ratio and includes a low risk for damage performance, the recurring price of the PPTCUP-M systems and the significant reduction in mass and volume (40x 15x 15) make it for more attractive and competitive with the developing Cubesat market that a complex spacecraft can be built for approximately 100k€.

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The PPTCUP-M development compares favourably with available Cubesat cold-gas systems in terms of mass (100 g vs 150 g), power (5 W vs 23 W), thruster lifetime (10,000 vs 800 s) and total impulse (10 mN-s vs 10 mN-s) at 5 W. It is therefore capable of achieving a high performance-to-mass ratio and includes a low risk for damage performance, the recurring price of the PPTCUP-M systems and the significant reduction in mass and volume (40x 15x 15) make it for more attractive and competitive with the developing Cubesat market that a complex spacecraft can be built for approximately 100k€.

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Performances have met or exceeded expectation, leading to flight qualification of the PPTCUP-M. This has been demonstrated. The PPTCUP-M is a pulse thruster with low impulse (1 mN-s) and low total impulse (10 mN-s for 100 pulses when powered at 5 W). It is therefore capable of achieving a high performance-to-mass ratio and includes a low risk for damage performance, the recurring price of the PPTCUP-M systems and the significant reduction in mass and volume (40x 15x 15) make it for more attractive and competitive with the developing Cubesat market that a complex spacecraft can be built for approximately 100k€.

The objective of this activity was to develop a simulation software that allowed to:

• study the behaviour of structures made of composite materials,
• facilitate the detailed analysis of a critical area in composites (coupling inter- and intra-laminar analysis),
• increase structural efficiency and reliability by predicting the size and shape of progressive damage inside plies,
• perform structural optimization in order to maximize the weight of the developed product,
• simulate the manufacturing process and predict the final properties of the parts and the residual stresses and distortions.

The software (JMS Sembach Systems) has many features to adapt to different requirements for damage models, failure mechanics, powerful optimization algorithms and accurate analysis routines along with a high degree of automation and exportation. Its main capabilities are its ability to analyse complex laminated structures and progress damage propagation at their interfaces, predict damage propagation and failure, perform damage probabilistic analysis and determine failure safety margins. The software has a high degree of automation and exportation.
Angular position sensors are utilized in numerous space applications to provide accurate monitoring of the main operation of rotating elements. For this function in space applications to provide accurate monitoring and control of rotating elements, for longer life time, better accuracy, and to be used in harsher environments, space missions will be more and more challenging, and will require advanced angular sensors meant to withstand radiation, thermal cycling, single event effect testing (SEE) and burn-in among others. Finally, the test board design was updated to extend the temperature range.

The main purpose of the CAPS is to replace the traditional potentiometers used within space mechanisms since this new sensor has a similar behaviour is not fully mastered yet. Next future space missions will be more and more challenging, and will require advanced angular sensors meant for longer time, better accuracy, and to be used under heavier environments.

This activity had the objective to perform a test campaign of the contactless angular position sensor (CAPS) prior to the component examination to verify the uniformity of the sensor more specifically, the aim was to upgrade the design with the results of the previous project phase. The findings of high thermal stress, long and hard production process for the substrate cause the wafer manufacturing step to be the most critical part of the process. To ensure that the new sensors have both led to noise problems during testing and will require advanced angular sensors meant for longer time, better accuracy, and to be used under heavier environments.

The final product was a contactless magnetic rotary encoder (SAR) for accurate angular measurement over a full turn of $\pi$. It is a system-on-chip, combining integrated Hall elements, analog front end and digital signal processing in a single device.

On the other hand, the potentiometers, either traditional potentiometers or contactless angular sensors, have both led to noise problems during testing and will require advanced angular sensors meant for longer time, better accuracy, and to be used under heavier environments.

In order to do that and to avoid the earlier mentioned deficits, two processes have been updated. First, the edge now has a more rounded profile, making it more robust towards impact and the process itself is inherently less prone towards chipping. Secondly, these microscopic cracks on the etched surface are avoided by using silicon solar cells more than compensated. Still, wafer strength and improve surface finishing. In order to do that and to avoid the earlier mentioned deficits, two processes have been updated. First, the edge now has a more rounded profile, making it more robust towards impact and the process itself is inherently less prone towards chipping. Secondly, these microscopic cracks on the etched surface are avoided by using silicon solar cells more than compensated. Still, wafer strength and improve surface finishing.

The goal to design and fabricate core chip up- and down-converter MMIC on-wafer testing. MMIC on-wafer testing.

**DESIGN & BUILD IN GHz RADAR FRONT END MODULES**

Recent developments in monolithic millimeter wave integrated circuit (MMIC) technologies have enabled commercial scalable RF (radio frequency) systems, such as radars and transmitters, at high millimetre wave frequencies up to 50 GHz, and above. While conventional radars operate at microwave frequencies (below 30 GHz), radar systems at high millimetre wave frequencies have certain benefits that make them attractive for many users. This is due to the fact that shorter wavelengths allow for more precise positioning of the target, smaller equipment and smaller antennas. By the new enabling MMIC technologies, a business opportunity was identified in the global radar market to develop a very high resolution imaging system at 50 GHz. The objective of the activity was to develop novel on-wafer and transmitter modules that cascade the final RF front-end functions of a 50 GHz radar system. The RF function in the module comprises of up- and down-converter, low-noise amplifier, power amplifier, switch and a local oscillator module. Some of these functions are implemented by using commercial MMIC technology.
As an extension to the microwave region, Furthermore, with the advent of modern high-speed digital electronics and microprocessors, the microwave region has been increasingly investigated, finding its use within areas ranging from telecom, space science, military, security to process industry and radar applications.

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HORUS: innovation in attitude control

In order to control their pointing directions, satellites need at least one attitude control system (ACS). In particular, a star tracker allows us to know the attitude of the satellite and to initiate or strengthen corrective actions. Star trackers are an essential device for space missions and currently, thanks to ESA’s leading role in the field, they are used by all important players (small and large) in order to take full advantage of their technology. Star trackers are an essential device for space missions and currently, thanks to ESA’s leading role in the field, they are used by all important players (small and large) in order to take full advantage of their technology. They are widely used in the Earth observation sector, where they are a must-have technology for polar orbiter missions. Star trackers are also used in the geostationary Earth orbit (GEO) domain, due to their ability to perform better and enabling missions with stringent pointing accuracy requirements.

Ongoing AO activity: HORUS

AO activities aim to strengthen worldwide competitiveness in the near term in existing markets, establish strategic capabilities which will result in stronger competitiveness in the medium term, develop products in response to gaps in the supply chain, and to initiate or strengthen technology transfer.

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SABRE - Synergistic Air Breathing Rocket Engine - is a core of a new project, being considered under the development for the last two decades, that promises to become the next generation hypersonic propulsion due to its capability to deliver the fuel efficiency of a jet engine with the power and high-speed ability of a rocket, efficiently changing the way we travel and how we access space and conduct orbital research.

Over the last decade, SESA has been an active partner of SABRE under the TFP/CP Programme, taking up technical management roles in developing the project. After the successful conclusion of that phase and a series of demonstrations, prototype conceptual models in the form of an engine were produced, which was evidence of the potential of space propulsion with the power of air breathing systems.

The ultimate goal is to deliver a truly versatile propulsion system that can operate from a standing start to Mach 5+, capable of carrying a small satellite into orbit, without the need for a separate booster. This system will make it possible to deliver the fuel efficiency of a jet engine with the power and high-speed ability of a rocket, effectively changing the way we travel and how we access space and conduct orbital research.

Today’s propulsion systems have high operational costs due to the recurring use of a new expandable flight segment for each flight. Coupled with the significant development costs, this leads to a situation where fully commercial operations are prohibitively expensive. Thus, system reuse is seen as the best solution and is the motivation behind the concept of the SABRE system. It must be able to accommodate the simultaneous engagement of multiple engines, the ability to return to earth, and the capability to be used for a wide range of missions.

The SABRE heat exchanger technology has the potential to revolutionise what can be achieved with thermal management across a range of industries, from aerospace to motorsport, industrial processes, and the energy industry. In addition to the SABRE development programme, the heat exchanger technology has the potential to deliver the fuel efficiency of a jet engine with the power and high-speed ability of a rocket, effectively changing the way we travel and how we access space and conduct orbital research.

High altitude propulsion test facility

A vacuum test cell sized for larger engines (at least 1.5 kN but projected up to 6 kN). The facility will be located in Westcott Venture Park (J-site) in the UK, where the full engineering drawings and plans will be finalised, whereas the second phase will consist in realizing those plans and building the facility which will consist of the following:

- A vacuum cell sized for at least 1.5 kN but projected up to 6 kN.
- A steam source either a gas or oil-fired boiler.

Testing of the fully integrated engine core in the new facility by 2020.

SKYLON SYSTEMS

The technology has matured to a point where there are a number of key milestones over the next few years that can be achieved:

- High temperature test of the pre cooler in 2018.
- Demonstration of critical enabling technologies in 2019.
- Development of the core engine and by-pass systems in 2020.
- Vacuum cell and test facility commissioning in 2021.
- Vacuum cell testing in 2022.
- Testing of the fully integrated engine core in the new facility by 2025.

Future milestones and applications

The technology has matured to a point where there are a number of key milestones over the next few years that can be achieved:

- Intake development: this involves the design and build of an intake capable of functioning to Mach 5.5 and beyond.
- By-pass burner and nozzle development: this involves the design and build of a by-pass burner and nozzle capable of Mach 25.
- System Engineering: this involves the design and build of a system capable of achieving air-breathing flight from Mach 0 to Mach 5+.
- Performance counter-flow heat exchanger: this involves the design and build of a heat exchanger capable of achieving a heat transfer rate of 1,000 MW.
- Future missions and applications: the technology can be applied to a wide range of applications, from space transportation to industrial processes, and the energy industry.

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GROUP EFFORT

A consortium of twenty economic operators is developing the EGS-CC across 10 countries as a set of software components. The development is taking place, largely, in parallel with its integration into the environments of the Large System Integrators and Agencies. Most of these organisations are funding their own significant internal projects to this end and are integrating intermediate releases of the EGS-CC into their respective ground segment infrastructures.

FEATURES AND GOALS:

• Support of all mission types and phases and of all systems.
• Open, component based and service oriented architecture.
• Generic and extensible functionality.
• High performance and scalability.
• Layered implementation.
• Long term maintainability.
• Inter-operability through standardized interfaces.
• Clear separation between generic M&C functions (kernel) and specific features of the controlled system (adaptation layer).
• Clear separation between infrastructure (EGS-CC proper) and specific applications (EGS-CC based applications).

COMMON INFRASTRUCTURE

The EGS-CC is solving several problems currently affecting space activities in Europe:

1. It provides a common infrastructure which eliminates the burden of transferring information between different organizations.
2. It offers a platform for collaboration and exchange of information.
3. It provides a route for modernisation of current infrastructure.

LOWER COST MAINTENANCE

The EGS-CC is designed, also at the documentation level, with a clear distinction between the needs of EGS-CC maintenance and the needs of development of applications based on EGS-CC. There are clear rules regarding which components are user-modifiable or not and which dependencies across components can be optional.

ADAPTABILITY

The EGS-CC also introduces a major change in the M&C (monitoring and control) paradigm for these kinds of systems. The EGS-CC establishes a clear separation between the fundamental M&C functions and the adaptation, communication and transport mechanisms between the M&C system and the controlled system, e.g. spacecraft or ground stations. This takes place at the functional level and the architecture level, which makes EGS-CC adaptable and flexible in order to cope with the different environments and modular architecture that offers specific and well-defined mechanisms to adapt the infrastructure to new applications without the need to modify EGS-CC source code or binaries.

COMMON INFRASTRUCTURE

The EGS-CC is 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. The EGS-CC provides a common basis for industry in general and for the full lifecycle of a space system. It supports activities from development to integration and testing of all instrumental/ subsystems as well as for complete space systems and their later operation.

FUTURE

The EGS-CC products will be licensed as open source software within the ESA member territories, making the source code and full documentation available to European industry and agencies and will be maintained and further developed as a collaborative effort. It will be impossible to have better value from one of the ESA member countries.

 lowers the costs for developing M&C systems based on the EGS-CC.

The EGS-CC is specifically designed to support the development of applications based on the EGS-CC. This opens a new market for development of EGS-CC applications offered on a commercial basis.
QARMAN

QARMAN is a triple unit CubeSat which is being built for the framework of the QB50 project. In fact, it has as main goal to prove the feasibility of a CubeSat as a re-entry platform as well as being an innovative system for the mission scenario. Moreover, QARMAN has the specific objective of demonstrating the feasibility of a passive de-orbiting system and performing measurements along with minimizing the transmitted telemetry data (needed every 30 minutes), which is a key point of the principle of operation.

MISSION PROFILE

There are 5 planned phases for the mission scenario of the QARMAN Cubesat:

- **Phase 1:** The mission begins with the launch via one of the participating launchers, followed by deployment and stabilization. In this phase, the antennas are deployed and all systems are checked.
- **Phase 2:** The satellite is put into a safe housing and a safe condition is established. The satellite is ready for a new mission after premission check is performed.
- **Phase 3:** This phase is dedicated to the acquisition of the QARMAN thermal profile. After the deployment, the satellite is transferred to its final orbit to allow the retrieval of the thermal profile data.
- **Phase 4:** This phase is dedicated to the acquisition of the re-entry profile. In this phase, the satellite will be exposed to extreme velocities, exceeding temperatures of around 10,000 K at Mach 20.
- **Phase 5:** The satellite will slowly de-orbit, its velocity will be reduced, and the satellite will begin its path towards re-entry. This phase is the most critical part of the mission as the satellite will experience a black out during re-entry.

DESIGN THERMAL PROTECTION SYSTEM (TPS)

The thermal protection will be achieved with a layer of Aerogel, a lightweight and low-conductance material, which will protect the electronic components from overheating. A ceramic material is used to cover the entire SU and connects it to the rest of the satellite.

Side and Back TPS

A ceramic layer of SiC constitutes the side panels of QARMAN. This protective shield will cover all the lateral sides of the satellite, protecting it from the extreme temperatures. However, the Front Thermal Protection System is placed between the side TPS walls and the electronics structure.

The idea is to collect all the components needed to complete the re-entry phase on one single PCB board, surrounded by a dedicated TPS. The idea is to collect all the components needed to complete the re-entry phase on one single PCB board, surrounded by a dedicated TPS.

TECHNOLOGICAL BREAKTHROUGHS

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IPC 297 - Paris – 27th and 28th of January 2016
ESA/IPC(2016)34 Approval of Sweden’s participation in Elements 2 and 3 of GSTP-6
ESA/IPC(2016)35 Approval of Hungary’s accession to the programme and its participation in Element 3 of GSTP-6
ESA/IPC(2016)61 Update of GSTP-6 Element 1 Work Plan/Procurement Plan
ESA/IPC(2016)62 GSTP-6 Element 2 “Competitiveness” Procurement Proposals
ESA/IPC(2016)63, add.1 Update of GSTP-6 Element 3 Work Plan/Procurement Plan
ESA/IPC(2016)64 Establishing an Element 4 of GSTP-6 approach for cooperative human space transportation projects

IPC 298 - Paris – 14th and 15th of March 2016
ESA/IPC(2016)61, add.2 Update of GSTP-6 Element 1 Work Plan/Procurement Plan
ESA/IPC(2016)62, add.1 Update of GSTP-6 Element 2 “Competitiveness” Procurement Proposals
ESA/IPC(2016)77 Specific Area Initial Work Plan For Asteroid Impact Mission GSTP-6 Element 1 Work Plan/Procurement Plan

IPC 299 - Paris – 10th and 11th of May 2016
ESA/IPC(2016)5 Update of the GSTP-5 Element-1 Work Plan/Procurement Plan
ESA/IPC(2016)61, add.3 Update of GSTP-6 Element 1 Work Plan/Procurement Plan
ESA/IPC(2016)62, add.2 Update of GSTP-6 Element 2 “Competitiveness” Procurement Proposals
ESA/IPC(2016)63, add.1 Update of GSTP-6 Element 3 Work Plan/Procurement Plan

IPC 300 - Paris – 22nd and 23rd of June 2016
ESA/IPC(2016)61, add.1 Update of the GSTP-5 Element-1 Work Plan/Procurement Plan
ESA/IPC(2016)61, add.2 Update of GSTP-6 Element 1 Work Plan/Procurement Plan
ESA/IPC(2016)62, add.4 Update of GSTP-6 Element 2 “Competitiveness” Procurement Proposals
ESA/IPC(2016)63, add.2 Update of GSTP-6 Element 3 Work Plan/Procurement Plan
ESA/IPC(2016)89 Cost Plans of On-going GSTP (GSTP) in Preparation of Draft Budgets for 2017

IPC 301 - Paris – 27th and 28th of September 2016
ESA/IPC(2016)1, add.16 e.Deorbit Consolidation Phase Procurement Proposal – Information Note
ESA/IPC(2016)61, add.5 Update of GSTP-6 Element 1 Work Plan/Procurement Plan
ESA/IPC(2016)62, add.4 Update of GSTP-6 Element 2 “Competitiveness” Procurement Proposals
ESA/IPC(2016)63, add.1 Update of GSTP-6 Element 3 Work Plan/Procurement Plan

IPC 302 - Paris – 24th and 25th of October 2016
ESA/IPC(2016)22 GSTP - Period 4 - Status Report – Information Note

IPC 304 - Paris – 23rd and 24th of November 2016
ESA/IPC(2016)61, add.3 Update of GSTP-6 Element 1 Work Plan/Procurement Plan
ESA/IPC(2016)62, add.4 Update of GSTP-6 Element 2 “Competitiveness” Procurement Proposals
ESA/IPC(2016)63, add.2 Update of GSTP-6 Element 3 Work Plan/Procurement Plan

ESA/IPC(2016)60 GSTP: Request for a transfer of contributions by Germany
ESA/IPC(2016)62 GSTP: Approval of Austria’s access to the programme
ESA/IPC(2016)65 GSTP: Request for a transfer of contributions by Norway
ESA/IPC(2016)651 GSTP - Period 6 element 2 - Status Report – Information Note

ESA/IPC(2016)61, add.4 e.Deorbit Programme Proposal – Information Note (funded by GSTP)
ESA/IPC(2016)62, add.5 GSTP: Approval of Estonia’s accession to the programme
ESA/IPC(2016)63, add.1 GSTP: Approval of Norway’s accession to the programme

ESA/IPC(2016)60 GSTP: Request for a transfer of contributions by Germany
ESA/IPC(2016)62 GSTP: Approval of Austria’s access to the programme
ESA/IPC(2016)65 GSTP: Request for a transfer of contributions by Norway
ESA/IPC(2016)651 GSTP - Period 6 element 2 - Status Report – Information Note

ESA/IPC(2016)61, add.4 e.Deorbit Consolidation Phase Procurement Proposal – Information Note
ESA/IPC(2016)65, add.3 Update of GSTP-6 Element 1 Work Plan/Procurement Plan
ESA/IPC(2016)65, add.4 Update of GSTP-6 Element 2 “Competitiveness” Procurement Proposals
ESA/IPC(2016)65, add.6 GSTP-6 Element 3 Work Plan/Procurement Plan

ESA/IPC(2016)45 Proposal to place a Parallel Contract with the title: “Development & Test of Space Additive Manufactured Space Hardware”

ESA/IPC(2016)61, add.4 e.Deorbit Programme Proposal – Information Note (funded by GSTP)
ESA/IPC(2016)62, add.5 GSTP: Approval of Estonia’s accession to the programme
ESA/IPC(2016)63, add.1 GSTP: Approval of Norway’s accession to the programme

ESA/IPC(2016)60 GSTP: Request for a transfer of contributions by Germany
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ESA/IPC(2016)65 GSTP: Request for a transfer of contributions by Norway
ESA/IPC(2016)651 GSTP - Period 6 element 2 - Status Report – Information Note

ESA/IPC(2016)61, add.4 e.Deorbit Consolidation Phase Procurement Proposal – Information Note
ESA/IPC(2016)65, add.3 Update of GSTP-6 Element 1 Work Plan/Procurement Plan
ESA/IPC(2016)65, add.4 Update of GSTP-6 Element 2 “Competitiveness” Procurement Proposals
ESA/IPC(2016)65, add.6 GSTP-6 Element 3 Work Plan/Procurement Plan

ESA/IPC(2016)60 GSTP: Request for a transfer of contributions by Germany
ESA/IPC(2016)62 GSTP: Approval of Austria’s access to the programme
ESA/IPC(2016)65 GSTP: Request for a transfer of contributions by Norway
ESA/IPC(2016)651 GSTP - Period 6 element 2 - Status Report – Information Note

G627-075ED TM/TC Mixed Signal ASIC
G627-072EP Qualification of Low Cost Solar Cells at Bare and SCA Level
G627-066MM Point of Care Diagnostics & Monitoring Platform - Key Enabling Technologies
G627-065EC Fast Loop Image Processing for Line-of-sight Accurate Pointing
G627-063EP Pegasus II - PErformance GuAranteed SUbStrates
G627-062MM GOTCHA ``Goac TRL-Increase Convenience-Enhancements, Hardening and Application
G627-058MM Rubidium POP (Pulsed Optical Clock)
G626-077ET QA707 Real Time Simulator
G626-074ET Digital Beam-Forming For RAIL
G626-070ET GNSS Hill Simulation
G621-079ET Land Analytics EO Platform
G621-064ED Image Compression Module
G620-059ET QA703 Architecture and Reuse

Annex 4: Complete List of GSTP Activities Closed in 2016

3.8.5.1.1909 Composite Space Structure Modelling and Analysis Software
3.8.5.1.1908 Optical Reference Center for Space Deployment (ORC)
3.8.5.1.1907 Qualification of a Micro MRT (MEP) for CubeLab Application
3.8.5.1.1906 HARM Handle Antenna Array
3.8.5.1.1905 Vernalis Low Density High Resolution Resolved Spectral Array
3.8.5.1.1904 Orbitology Based Search (OBSO)
3.8.5.1.1903 NanoSatellite Design & Development - Phase I
3.8.5.1.1902 Heliolux
3.8.5.1.1901 Space Rail Assembly Technology Development for ORCA/GOAL
3.8.5.1.1900 Development of Methane Recovery Activity
3.8.5.1.1899 Melissa Satellite Characterisation Phase 2
3.8.5.1.1898 Production Methods for Proprietary Management Devices
3.8.5.1.1897 Advanced Imaging of Encapsulation Environment Software
3.8.5.1.1896 Cryptography Value Adding
3.8.5.1.1895 Development and Characterisation of Advanced Metal Matrix Composite
3.8.5.1.1894 Drapability of Composite Capsule Structures
3.8.5.1.1893 Establishment of a Simulation Model Reference Library
3.8.5.1.1892 Small - Mandate of Space Project Competition Fund Process
3.8.5.1.1891 Automated Startup of Thermal Processing Facilities (APSF)
3.8.5.1.1890 P Vegas - CSI in Orbit for High Resolution Reentry
3.8.5.1.1889 Reaction Wheel Industrialization
3.8.5.1.1888 Data-Driven Carbon Nanotubes for Super Supercapacitors
3.8.5.1.1887 AGC in a Navigational Framework (MUP)
3.8.5.1.1886 STERN Design & Development of a Reliable Microuse for Future ITS/RDA (ORCA Project Activity)
3.8.5.1.1885 Identification of Structural Interface Changes Characterizing Moisture Level
3.8.5.1.1884 Multi-Modal Large Probe (MLP) in Orbit Development
3.8.5.1.1883 Development of a Technique for Recovering irreversibly Released Dust Particles from Satellites
3.8.5.1.1882 GHPC / GHPC 2 Mobile Wedge MEXX Switch (SHE) (MEDA activity)
3.8.5.1.1881 Low Cost Light Based High Power Transponder for Autonomous Spacecraft
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
Switzerland
United Kingdom
Canada

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