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Abstract:
SWIPE proposes a new approach to perform planetary exploration, using distributed sensors capable of gathering scientific data and establishing a network among them to share and process data. Ultimately, such a Wireless Sensor Network (WSN) will enable scientists to continuously monitor certain areas, extracting more information than a single sensor. The research focuses on a resource-efficient node hardware design, including all required subsystems, on the design of a network capable of supporting space-WSNs and on the study and implementation of data processing and fusion techniques to reduce the amount of generated data and improve the information that can be extracted from it.

This exploitation plan reflects the work done in the exploitation task, consisting essentially of a summary of the currently existing opportunities, identified partner interests, components to consider for the IP management and a brief list of targeted dissemination actions for the SWIPE stakeholders. Included in this report are also defined IP measures and management considerations.

[1] Nature of deliverable: **R** = Report; **P** = Prototype; **D** = Demonstrator; **O** = Other
[2] Dissemination level: **PU** = Public; **PP** = Restricted to other programme participants (including the Commission Services); **RE** = Restricted to a group specified by the consortium (including the Commission Services); **CO** = Confidential, only for members of the consortium (including the Commission Services).

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Executive Summary

SWIPE proposes a new approach to perform planetary exploration, using distributed sensors capable of gathering scientific data and establishing a network among them to share and process data. Ultimately, such a Wireless Sensor Network (WSN) will enable scientists to continuously monitor certain areas, extracting more information than a single sensor. The research focuses on a resource-efficient node hardware design, including all required subsystems, on the design of a network capable of supporting space-WSNs and on the study and implementation of data processing and fusion techniques to reduce the amount of generated data and improve the information that can be extracted from it.

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List of Acronyms

Acronym	Meaning
AHS	Adaptive Hardware and Systems
BIPR	Background Intellectual Property Rights
ECSS	European Cooperation on Space Standardization
ESA	European Space Agency
IAC	International Astronautical Congress
IEEE	Institute of Electrical and Electronics Engineers
IP	Intellectual Property
ITAR	International Traffic in Arms Regulations
LSI	Large System Integrator
MANET	Mobile wireless Ad hoc NETwork
MED	Mediterranean Conference on Control and Automation
MIL	US Military Standards
NASA	National Aeronautics and Space Administration
OBC	On-Board Computer
PCB	Printed Circuit Board
RTD	Research and Technology Development
SDR	Software-Defined Radio
SME	Small and Medium Enterprise
SWIPE	Space WIreless sensor networks for Planetary Exploration
TRL	Technology Readiness Level
WSN	Wireless Sensor Network

Table 1 – List of acronyms.

1 Introduction

Research projects are carried out to perform studies or fundamental experiments about a given topic, generating results and outcomes that may allow pushing the boundaries in the current state of the art of that specific topic. A common challenge of these projects is to define a strategy to give good use to these results, in order to improve and maximise their potential benefit, either economically, scientifically or socially. As a research project, SWIPE results face the same challenges and therefore the Consortium had dedicated a task to prepare and define an appropriate strategy for the exploitation of the project outcome.

SWIPE proposes a new approach to perform planetary exploration, using distributed sensors capable of gathering scientific data and establishing a network among them to share and process data. Ultimately, such a Wireless Sensor Network (WSN) will enable scientists to continuously monitor certain areas, extracting more information than a single sensor. The research focuses on a resource-efficient node hardware design, including all required subsystems, on the design of a network capable of supporting space-WSNs and on the study and implementation of data processing and fusion techniques to reduce the amount of generated data and improve the information that can be extracted from it.

At the end of the project there were results generated from each of these lines of research and also from the integration of all elements in the validation of the SWIPE concept. It was possible to make use of the integrated results as well as of those individually coming from each of the research topics. In fact, being a collaborative research project involving several partners, SWIPE faced additional challenges on the use of the project data, related to intellectual property management and with the different visions for exploring the different results from the project.

All these aspects are addressed in this report SWIPE exploitation plan, in order to perform a detailed analysis of the available directions that can be taken to explore the project results and to devise a consistent roadmap to reach them. This exploitation plan reflects the work done in the exploitation task, consisting essentially of the currently existing opportunities, identified partner interests, components to consider for the IP management and a list of dissemination actions for the SWIPE stakeholders.
The next section will focus on an initial revision of the individual exploitation goals coming from each partner, already highlighted at the proposal stage [RD1]. This was used as a starting point to define strategies for the project outcome, since it has to be driven by the Consortium expectations. A list of dissemination actions taken this far and oriented towards the SWIPE stakeholders is also included and finally, some considerations on IP protection and management will be provided.

2 Individual exploitation goals

The starting point for defining a strategy for the exploitation of the SWIPE results is to understand what the main results of the project are and which expectations of the different partners in the Consortium have to be considered. This was done briefly just before the project started [RD1] and was slightly updated at the beginning of this task. The revised table is shown in Table 2.

Partner	Knowledge / Result	Use & further research	Exploitation / Benefit
TEK	Modifications and adaptation of TEK's SDR platform to space environment	Application of the SDR concept and platform in satellite payloads and communication systems	Become a supplier of space LSI supply chain in support to prime contractors; development of new and/or more competitive products.
	Adaptation of routing protocols for mobile ad-hoc-satellite networks to environments different from Earth	Continued research in ad-hoc networks and application to other environments and application in TEK products	Increased expertise in the field; Involvement in other applied research initiatives
	Advanced MANET radio based on SDR for space use	Promotion of the concept as a payload for CubeSats and small satellite platforms and as enabler for formation flying and robotic exploration missions.	Become a supplier of space LSI supply chain in support to prime contractors; development of new and/or more competitive products.
ARQ	Dust Deposition Sensor	Application of Dust Deposition Sensor developments to future scientific missions	Become a supplier of space LSI supply chain in support to space missions prime contractors, development of new more competitive products
	25N Pin-Puller	Complement the Arquimea´s family of actuators for space application including a release actuator for low mass and low volume payload deployment	Become a supplier of space LSI supply chain in support to space missions prime contractors, development of new more competitive products
	Rad-hard SWIPE ASIC	Increase Arquimea´s know-how in the development of mixed signal rad-hard technologies, particularly in the area of radiation sensors, but more generally in the development of a rad-hard library of components for the European Space industry.	Become a supplier of space LSI supply chain in support to space missions prime contractors, development of new more competitive products
	Thermal Switch	Application of Thermal Switch developments to future scientific missions	Become a supplier of space LSI supply chain in support to space missions prime contractors, development of new more competitive products

Partner	Knowledge / Result	Use & further research	Exploitation / Benefit
AST	Inclusion of WSN in space exploration mission concepts and design of long range communication data-links for support of WSN	Development and proposal of new mission concepts and mission solutions based on WSN for the European Space Agency, CNES or other interested parties	Increase the number of missions involving AST as the prime contractor and system integrator in innovative scientific and exploration space project.
ULEIC	Data fusion algorithms for a cluster-based WSN to process efficiently local scientific data, local housekeeping data and network level data.	Continued research on the application of data fusion results to improve network configuration and performance. Application of results in future missions.	Increasing ULEIC knowledge in the field and developing innovative approaches for future environment monitoring WSNs. Increased expertise in the field facilitating involvement in other applied research initiatives. Use of results as a basis for future Master and PhD theses and /or to inform students through internal seminars.
	Sensor scheduling algorithm for the WSN and a distributed sensor data error estimation mechanisms.	Continued research on data sensing and processing, focusing in particular on the inclusion of sensor constraints and distributed filtering.	
	Data aggregation algorithms removing redundant information in the WSN at regular node, cluster head and relay link levels.	Continued research on data aggregation algorithms for energy efficiency, data accuracy and improved latency.	
UoR-CRAT	Hybrid Network Algorithms	Continued research on resource management in hybrid MANET/satellite networks, covering advanced routing and data exchange. Potential application in future exploitation missions	Increasing UoR-CRAT knowledge in the field and developing innovative approaches.
	Multisensor Data Processing	Continued research on data sensing and processing, focusing in particular on sensor constraints (e.g. limited battery).	
	All relevant RTD activities	Didactic and teaching purposes	Use of results (i) as basis of Master degree and PhD thesis, (ii) to update the programs of courses, (iii) to organize seminars at the University of Rome and in companies.

Table 2 – Consortium expectations on the exploitation of the SWIPE results.

It is possible to see that the exploitation expectations are different depending on the type of institution each partner represents. Universities and research institutes focus on continuing research lines to generate high-quality academic theses and on building up knowledge that can translate to published articles. The SMEs want to mature their innovative technology to reach the supplier chains of the LSIs and major space players. The LSI wishes to probe new approaches and position themselves in the front line to be selected for new missions involving space exploration.

This heterogeneity poses a challenge in defining a common exploitation strategy for the SWIPE results, but on the other hand it fits properly in the Space market value chain, where research institutes and universities break ground in new technological approaches, SMEs incorporate that in their product lines, and LSIs integrate the available products into space missions. In fact, covering the entire value chain was a concern when setting up the SWIPE Consortium to better understand the market needs at each stage and come up with a consistent proposal for exploiting the SWIPE project results.

3 Baseline exploitation approach

Space technology follows a standardised development and maturing process based on Technology Readiness Levels (TRL), as shown in Figure 1. The process starts with fundamental research and concept validation using prototypes in relevant environments, which are the stages covered in SWIPE. After the concept validation, the technology needs to undergo a space qualification campaign, involving environmental and robustness testing in space-equivalent conditions. Finally, the technology is considered to be flight-proven once it is validated successfully in space and from there on it gains space heritage.

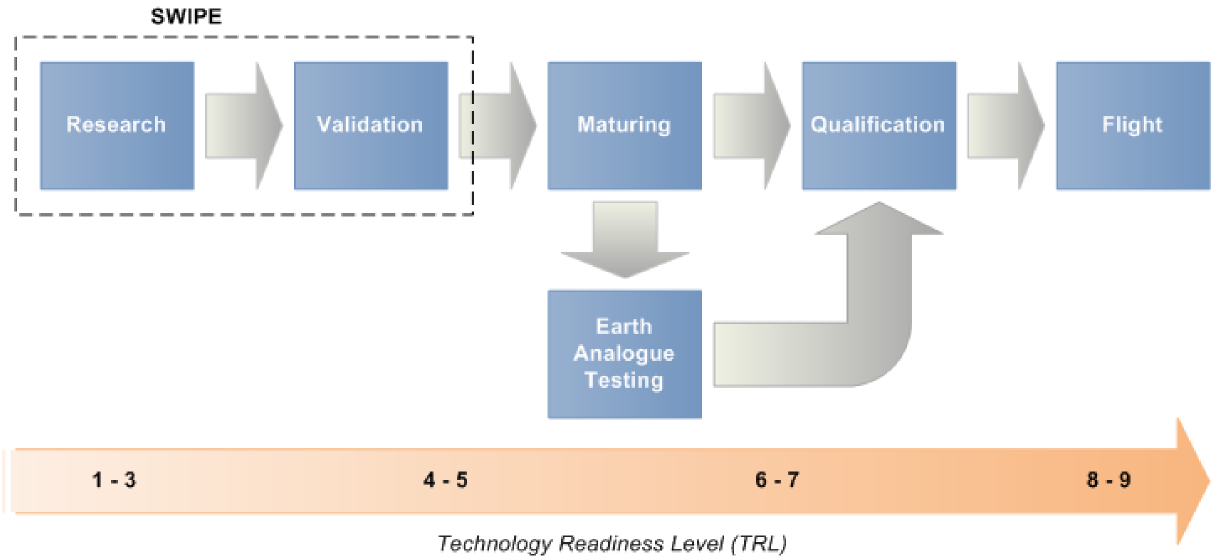

Figure 1 – Typical space technology evolution and development phases.

Undergoing this process is a required condition to bring new technology to the space market. It is a conservative, expensive and slow approach, being challenged nowadays by new mission types, especially those based on small satellites, which propose cheaper and faster access to Space. However, given the fact that the SWIPE concept requires a rather complex mission, the approach in Figure 1 is being considered as a baseline for the SWIPE exploitation strategy. However, during the exploitation task, other approaches were considered, including the latest trends in affordable space missions and eventually new models, and their applicability to SWIPE.

As mentioned above, by the end of the SWIPE project the two first steps shown in Figure 1 were already covered. The Consortium will have to mature the technologies, testing them in Earth analogue scenarios and pursue qualification of the design and look for flight opportunities to achieve a flight-proven readiness level (TRL9). Once achieved, the technology is qualified and a SWIPE mission could be devised and included in the space exploration roadmaps of the major Space Agencies around the world. As mentioned, the process is strenuous and long, requiring large investments and a long-term vision to be successful. The next subsections briefly describe these exploitation steps that the Consortium needs to take in order to make a SWIPE mission a reality using this traditional approach.

3.1 Maturing the technologies and concept of SWIPE [Short term]

Although the planning was meticulous and many of the problems foreseen, by the end of the project many other obstacles arise that weren't predicted. At the end of SWIPE the consortium learned a great deal, gathering information that is very useful to maturing the technologies of SWIPE. It is a natural step to take what was developed and improve it with the knowledge gained from the test campaigns, and that step can be taken in the direction of the interests of each part of the consortium.

3.2 Earth analogue testing [Short to Medium term]

Having learnt from the tests in Svalbard, before including the SWIPE in a space mission, the concept shall be put to tests in Earth analogue scenarios so that the problems can be found and solved before the enormous investment in a space mission is to be done. Earth analogue test beds are ideal scenarios to test the concept in representative conditions, allowing for the tweaking of the constituent parts of the SWIPE network.

This phase can be done in parallel to the qualification phase in order to take the design in the direction of space, making it more and more reliable on Earth analogues, and closer to space qualification.

3.3 Space-qualified implementation [Medium to Long term]

The SWIPE project philosophy focused on the validation of the concept and the applicability of the involved technologies for space exploration. It was assumed from the beginning that SWIPE would not attempt to develop space-qualified nodes within the project scope, using radiation-hardened components for instance. This decision was taken based on two main factors: components are extremely expensive and representativeness of the results could still be achieved using equivalent and commercially available parts. This would also avoid any required long lead items subjected to ITAR restrictions, for instance.

Nevertheless, as a compromise, SWIPE made a clear distinction between hardware and software design and their implementation. The design was made taking into account space-qualification concerns (e.g. choosing components that have direct radiation-hardened counterparts, considering redundancy on some critical modules, etc.), but the manufacturing of the node prototypes was done using commercially available devices and without putting into place any space-qualified processes during manufacturing (e.g. manufacturing of mechanical parts, PCBs, etc.).

Particularly regarding NASA and ESA standards, it is relevant to stress that the main goal of the project was to prove the feasibility of applying some technologies that have been proven worthy in terrestrial application for planetary exploration missions. It is also important to note that the aim of the project was neither to fully design a complete space planetary mission nor to finish the project with space-qualified hardware. For this reason, ECSS standards on space engineering, in particular verification and qualification have not been considered due to the research and concept feasibility nature of the project.

The consortium is aware that there are several challenges to address concerning a truly space qualified solution based on SWIPE. The approach is to consider these only after the feasibility of the concept and technologies is investigated through SWIPE. Therefore, a brief revision of the design would have to be made and qualification models would have to be built using space-qualified components and processes. This would be strongly based on the designs already accomplished during the project, requiring therefore low effort, though a considerable budget to procure the parts.

3.4 Qualification testing [Medium to Long term]

The second step would be the qualification of the models in space-equivalent conditions. This would require an initial familiarisation stage with the applicable standards (e.g. ECSS from ESA or MIL from NASA) and an extensive and detailed list of both facilities and tests required to achieve space-qualification. Undergoing these mechanical and environmental tests is also extremely expensive due to the restricted number of facilities available for carrying them out and is subjected to their availability. This could introduce massive delays in the roadmap.

3.5 In-flight validation [Long term]

Access to Space is currently extremely expensive and restricted and therefore being a primary client in a launch requires a huge investment. For this reason and since the orbit is not critical for in-flight demonstration, search would focus on secondary payload opportunities. This search can be carried out in parallel with the qualification testing or at least once the test calendar is defined, which would reduce any possible delays or the chance to miss an opportunity. However, since flying is subjected to an available slot, a long time could be required until the in-flight validation is done.

3.6 Potential missions and exploration programmes [Long term]

The final step, after reaching the highest maturity level for the SWIPE technology, is to create and secure a SWIPE mission opportunity, either in an existing exploration roadmap or in future strategies defined by the major worldwide Space Agencies. The Global Exploration Roadmap [RD2], involving all major Agencies, has selected the Moon and an asteroid as intermediate waypoints in exploration to reach the ultimate goal: manned mission to Mars. [RD2] already identifies some planned missions to the Moon until 2025. One of the goals of the exploitation task is to understand if it would be feasible to incorporate SWIPE in an existing mission, though the studies already done in the project [RD3] suggest that SWIPE requires a mission on its own. In any case, three non-exclusive options will be considered and further analysed during this task:

1. Incorporate SWIPE in an on-going mission already being planned, as a payload. This would be the most efficient option, but would require compatibility with the main mission goals and requirements.
2. Propose a SWIPE-dedicated mission in a currently existing space exploration programme (i.e. ESA Aurora).
3. Pave the Ground for the future space exploration roadmaps, beyond 2025, interacting with the relevant groups and stakeholders in order to ensure that the SWIPE mission is considered.

Particularly, the ESA Aurora Programme is mentioned here because it is seen as the major European space exploration programme. It must be noted that currently the only space exploration programmes are institutional ones promoted, defined and managed by Space Agencies (there are no private initiatives in this domain). The Aurora roadmap foresees several preparatory missions to culminate with a manned mission to Mars. These preparatory missions target other planetary bodies (including the Moon). The SWIPE concept has potential for both manned and unmanned missions and it seems therefore natural to consider a SWIPE-based mission under Aurora. However, this Programme has evolved in the recent years and therefore it is important to better assess if SWIPE could still fit within it.

4 The SWIPE Wireless Sensor Network

"In order to prepare for manned missions to other planets, it is necessary to monitor permanently the surface environment and have a clear notion of its conditions. Hundreds or thousands of small wireless sensors (also called smart dust) would be dropped from a satellite orbiting the planet onto the surface to assure a uniform and sufficient coverage. These autonomous sensors would then create their own ad hoc network while some of them, equipped with satellite communication capabilities, would establish a link between the WSN and the satellite. Data gathered from the sensors would be processed and sent to the satellite and later to Earth.". This is the SWIPE concept, the wireless sensor network will be the main result to be exploited, but, as it was specifically developed with a moon mission in mind, and since no moon missions are planned to take place in the near future, the consortium might have to resort to breaking down the Network components.

The SWIPE project produced two types of nodes, developed with specific functions in mind. Those nodes are the Full Nodes and the lighter, Network Nodes. The first consists of the most complete node, with all sensors integrated in each pyramidal structure and the later being only constituted by the communications systems including other systems that are needed to manage power generation, storage and distribution. A Full Node consists of: a pyramidal structure, the OBC, the EPS, batteries, solar panels, the communications systems and its network algorithms, and the payloads: Irradiance Sensor, Dust Deposition Sensor, Temperature Sensor and Radiation Sensor.

The nodes have the specific goal of being used on the moon but, since there are no missions where they could be used in a near future, an effort to mature and adapt the concept and push it into the roadmaps of space exploration must be done. Simultaneously one could find missions where the SWIPE could be adapted into, e.g. changing its shape, where instead of a tetrahedral shape it would be a sphere that could be thrown ballistically and/or roll to be used in Earth scenarios.
Although the prospect of using the complete node can look discouraging due to the new space exploration conjuncture where no new celestial bodies are on the roadmaps as new exploration goals, the SWIPE nodes could, in principle, hitchhike along another mission due to its shape and low weight. This lift could take them anywhere with minor adaptations to the base design which would be a great opportunity to validate the concept in a real scenario.

If the whole node cannot be used in a mission because of the lack of plans to explore or other major reasons that impede the use of the complete SWIPE solution in real life then the companies can resort to use its individual technologies, here developed, in different applications.

Hereafter is a breakdown of the individual systems that can be separately used by the consortium:

4.1 Irradiance Sensor

The irradiance sensor or the multispectral illumination sensors (VIS, IR and UV) measure the lunar illumination environment. Three multispectral sensors are situated with a separation of 180º for a total field of view of 360º.

This mission aims to find a shelter from radiations for future human exploration missions but bear in mind that one of the most significant resources to human activity is the solar irradiance. Indeed, the solar energy is a fundamental resource to our mission and also to future human mission or human outpost. Besides, the illumination will be the main driver to human activity and human mission timeline due to the visibility necessity to carry out experiments on the Moon. The observation needs to be done on the visible wavelengths to assess an accurate illumination pattern and duration that is necessary to future manned missions. The near infrared and ultra-violet also need to be monitored. Illumination environment of the mission site can also be used to observe some dust levitation glow during the terminator events. In addition, prolonged ultraviolet exposure may induce some damaging interactions with regolith. The wavelengths of interest are 300nm for ultraviolet (UV), 415-650nm (visible spectrum), 950nm (Near Infrared, NIR), 8000nm (Mid Infrared, MIR) and 20 000nm (High Infrared, HIR, thermal behaviour).

Finding the sweet spot for these types of radiation is a common denominator in space exploration. This sensor could justify sending the SWIPE network of nodes to study other space bodies where the human race expects to settle one day, to monitor the radiations conditions for long periods of time.

4.2 Dust Deposition Sensor

Dust Deposition Sensor (DDS). The DDS sensor measures the dust deposited over a horizontal surface during a certain exposition time to estimate dust deposition rate in function of solar incidence and soil temperature.
Dusty environment conditions over upper layers of rocky space bodies (like the Moon, Mars, Phobos, comets, etc.) are a potential problem for planned robotic and manned missions. A particular concern is the dust over the Moon surface (fine and sharp dust levitating particles that are especially harmful for astronauts´ health).
The dust deposition sensor designed is aimed to characterize the rate of dust deposition over the Moon surface by natural means in function of time (avoiding man-made disturbances as during the Apollo missions). This data will be very valuable in order to better understand the dynamics and hazards of dust over the Moon surface, for the moment only barely theorized (dust deposition rate is unknown). From the know-how obtained in previous experiences, an ultra-low mass, volume and power consumption DDS has been designed and manufactured based on optical scattering. The working principle is as follows: Infra-Red (IR) pulses of light are emitted directly towards a high IR transmittance optical window. This window, horizontally exposed to the Moon surface, will accumulate the dust on it by natural deposition means. An IR detector is situated geometrically out of the path followed by IR ray-pulses. The dust particles on the optical window will scatter the IR rays and change their paths to hit the detector, thus obtaining a measure at the IR detector as a function of the quantity of dust.

The Dust Deposition Sensor developed under the SWIPE project demonstrated a great performance. The evolution from the prototype generated under this project to a final Flight Model is found very straightforward as the design contemplated procedures, materials and components that can be directly substituted by space qualified procedures, materials and components.
This potentially permits to Arquimea to offer for future scientific missions a Dust Deposition Sensor of low mass, low volume and low power consumption.

As above mentioned, there are other space bodies that present dusty environmental conditions which broadens the possible missions where SWIPE could be used. This sensor, attached to the SWIPE node provides a valuable tool to access the environment without disturbing it in an autonomous way, but it still can work independently thus adaptable to new platforms.

4.3 Temperature Sensor

The surface thermal sensors are situated at the end of the node walls. Once the walls are deployed, thermal sensors will be in contact with the lunar ground for thermal measurements.

Another important parameter that needs to be monitored is the thermal variation during the synodic period. The Moon has a very harsh environment because of the great temperature variation of the regolith. As a consequence some temperature probes need to monitor precisely the thermal evolution that will be correlated to the illumination information [8]. Three temperature sensors are included in the payload. These sensors measure the temperature by conducting means. The temperature sensor is attached to a high thermal conductivity and low thermal inertia material (aluminium) that will be used as a probe to measure the upper surface temperature of the Moon (figure 16). The thermal probes would be situated at the end of the deployed petals. Once the petals are deployed, the probes will be in contact with the lunar ground for thermal measurements. This concept has the following advantages:

• The force used to deploy the solar panels will be used to introduce the probes some centimetres deep into the soil of the Moon. The immediately upper part of the Moon soil is made of non-compacted dust. This deployment technique will allow obtaining a good thermal contact with the upper surface of the moon soil, avoiding this dust layer.

• The probes will be the only part of the deployed solar panels in contact with the Moon surface. This is very important to avoid massive dust ejection. The sharp shape of the probes and its reduced area will significantly reduce the dust ejected during the solar panels deployment (it is important to note that the Moon surface can be considered to have vacuum conditions, so the absence of gas flow during the petals' deployment will not imply dust ejection).

4.4 Thermal Switch

Under the SWIPE project a custom passive thermal switch has been developed. This development is of great interest as it demonstrates the concept of a passive thermal switch using Shape Memory Alloys. From the concept demonstrated in this project it could be possible to initiate a R&D project to evolve the prototype to a qualified product. This potentially could be used by Arquimea to become a supplier of passive thermal switches for thermal regulation in support to space mission's prime contractors and the development of new more competitive products.

4.5 Radiation Sensor

The radiation sensor is a mixed signal Application Specific Integrated Circuit (ASIC) and is designed to provide Total Ionizing Dose (TID) and Single Effect Upsets (SEU) radiation monitoring over the moon surface. The ASIC has been designed using rad-hard techniques using non ITAR technology.

Radiation over the Moon surface is an environmental parameter of major importance for a future stable human presence on the Moon surface. A radiation sensor based on a mixed signal ASIC has been designed and manufactured in order to reduce at a minimum the mass of this sensor and optimize the power consumption.
The technology selected for the design and manufacturing of this ASIC is a European commercial high voltage technology with proven radiation heritage. The ASIC has been made tolerant to radiation using different radiation hardening techniques: Enclose Layout Transistors (ELTs), systematic guard rings to avoid latch-up between nMos and pMos transistors or Triple Modular Redundancy (TMR) among others. The ASIC also includes the auxiliary front-end electronics; a multiplexing and switching system to measure all the integrated sensors and a configurable charge amplifier to provide a normalized output signal.

The sensor is capable of measuring two different radiation parameters: TID and SEUs. In order to provide a wide TID dynamic range without limiting the resolution of the sensor, two different TID transducers have been used: (i) an external RADFET with responsivity in the range of 0.2 mV/rad (zero-bias mode) for low doses (<50 krads) and (ii) leakage current monitoring of integrated MOSFETs with different layout characteristics for high dose (>50 krads).
The SEUs sensor designed is based on digital Shift Registers (SRs). Four digital SRs (128b) with different susceptibility to SEUs have been designed. Each SR will be loaded by the FPGA with a known value and the FPGA will shift the register. After a configurable time, the FPGA will read the value of each SR and compare it with the initial value loaded. The number of changed bits will represent the number of SEUs detected. Because each SR is susceptible at different Linear Energy Transfer (LET) levels it will be possible to estimate a statistical occurrence of SEUs at different LET levels. The 4 LET levels established by design for the sensor are 0.90, 9.75, 30 and 60 Mev·cm2/mg.

Arquimea´s rad-hard microelectronics products are aimed to enhance the technical capabilities and overall competitiveness of European space industry satellite vendors on the worldwide market. The development of a rad-hard microelectronics technology will permit to open new competition opportunities for European manufacturers by reducing the dependency on export restricted technologies that are of strategic importance to future European space efforts. They should enable the European industry to get non-restricted access to high performance technologies that will allow increasing its competitiveness and expertise in the space domain.

In this context, the ASIC developed under the SWIPE project will help Arquimea to increase its know-how in the development of mixed signal rad-hard technologies, particularly in the area of radiation sensors, but more generally in the development of a rad-hard library of components for the European Space industry. At this respect, after the finalization of SWIPE project, Arquimea will continue with the SWIPE ASIC characterization potentially including this device in future radiation tests campaigns.

4.6 Communications Subsystem

The communication hardware was developed and integrated by Tekever based on the resulting hardware and software platform that was the end result of GAMALINK another FP7 project.
The hardware communications platform of GAMALINK is based on Software-Defined Radio (SDR), an innovative terrestrial concept that enables the development of various waveforms using a common hardware platform. Its characteristics can result in tremendous mass and volume savings, while increasing flexibility to a point where a radio system could be completely modified by just sending a command from ground. Moreover, it allows the operation of different subsystems simultaneously in the same hardware such as radio communications. On top of this radio platform, mobile ad hoc networking algorithms, an enabler for creating WSNs, are implemented. Their self-discovery, self-organization and auto-configuration capabilities guarantee the autonomy required for future space missions using flexible distributed architectures, like planetary surface exploration. Ultimately, a mobile ad hoc space network can enable lower communication costs and latencies between satellites, space vehicles and astronauts or satellites and ground stations. Additional techniques that can be implemented on the SDR platform are radio-based attitude determination, through the measurement of carrier phase delays between signals transmitted from multiple antennas, signal decoding and ranging between different platforms, based solely on the transmission of communication signals.

The data processing and network algorithms are the heart of the SWIPE concept, the sensors could be changed, the shape might have been different but the base of the SWIPE is its data processing and network algorithm. These two algorithms enable the sensor network to work as one distributed sensor, manage its data, power and network configuration automatically so that it can work without human intervention for prolonged periods of time.

4.7 Electrical Power Subsystem

The Electrical Power Subsystem (EPS) of SWIPE is responsible for generating, regulating, controlling and distributing the node's electrical power. The main drivers of the EPS design are the payloads power demand and the power supply which are the solar panels on the petals of the pyramid structure.

All the energy provided to the node is generated by solar cells placed on the faces of SWIPE nodes. The energy collected from those cells is, then, regulated and controlled to be stored in a four cell battery. Distribution then allocates the energy stored for each subsystem and/or payload.

This subsystem also controls the state of each one of the other subsystems. Controlled by the OBC, the EPS switches the other subsystems, on and off, whenever required.

What was he describe and further developed by the SWIPE consortium fits perfectly the needs of the rising trend that are cube satellites. Cube satellites are small, light and cheap platforms that have multiple subsystems that are powered by the sun through their solar panels. The EPS can effectively be adapted to fit in a satellite like these, and manage all energy circuitry from its production via the solar cells to its distribution to the payloads on board. The nano satellite market is one with immense growth and generates interest from many relevant parts.

4.8 On Board Computer

The OBC block does the command and control of the whole node and shares communications with the rest of the elements.

The On-Board Computer (OBC) subsystem has a bus architecture where all the subsystems rely on the information released to the BUS for data exchange. Each subsystem releases and retrieves a set of commands or data to/from the bus.

It takes care of the logic decisions of the node. It also commands the different payloads, the subsystem's states and the node's modes.

The development and adaptation of the OBC to the nano satellite market is also an objective in the horizon of the consortium. The capability of controlling, managing and fusing data, and commanding different payloads allied to the low power consumption makes it ideal to that market. The fact that it was developed with the space environment in mind will ease its qualification process, which translates in a lower cost and less time to develop the space qualified model.

4.9 Release mechanism

Focusing on the mechanical devices, ARQUIMEA specializes in linear actuators triggered by an SMA material. The linear displacement initiated by the SMA can be used in several products targeting different applications:

Pin pullers and pin pushers are used as locking/unlocking mechanisms; these types of actuators are utilized in most of the space systems, including:

- solar panels,
- communication antennae,

- instrument cover doors,
- radiators,
- heat shields,
- isolation systems.

They are usually commercialized as recurrent or off-the-shelf products, though tailored designs are also possible for specific applications.
In the frame of the SWIPE project, the 25 N release actuator (Pin Puller) developed would be used to complement the Arquimea´s family of actuators for space application including a release actuator for low mass and low volume payload deployment. From the prototype developed under SWIPE project it could be possible to evolve to a qualified product in future qualification campaigns.

It is estimated that an average of 35 pyro/SMA units per satellite are needed. Therefore, just considering the expected number of satellites set in Space per year by the European market, the number of release actuator devices based on SMA has a potential annual market as stated below:

- ESA MARKET (Includes Launchers, EO, Science & Exploration):
  Around 250 units per year

- DEFENSE AND INTELLIGENCE
  Around 350 units per year

- TELECOMM. MARKET (EU)
  Around 200 units per year TBC

TOTAL: Around Units/year → 20% SMA Market Share. That leads to an average of 250-300 Units per year and specifically around 50 units of Pin Pullers similar to those used in the SWIPE project.

5 Dissemination activities

5.1 Publications

Dissemination activities in 2013 and 2014 consisted mainly in:

- Year 2013:
  - Presentation of a scientific paper to the 21st Mediterranean Conference on Control and Automation (MED'13).
    Topic presented: a distributed routing algorithm applicable to wireless ad-hoc networks.
    Audience and impact: The paper was presented in front of an auditorium of about 50 people, mainly experts in control of communication networks. The presentation was organised as a 15 minute talk with additional 5 minutes for questions and answers.
  - Presentation of a scientific paper to the 64th International Astronautical Congress IAC'13, Beijing, China, 2013.
    Topic presented: overall SWIPE concept and first results about the mission design. *Audience and impact*: The paper was presented in front of an auditorium of about 50 people.
- Year 2014:
  - Presentation of three scientific papers to the 2014 NASA/ESA Conference on Adaptive Hardware and Systems, held on July 14 - 17, 2014 at the University of Leicester, Leicester, UK.
    Topics presented: The papers dealt with, respectively: (i) the SWIPE overall node and network architecture, (i) Data Fusion schemes, and (iii) Routing algorithm for WSNs.
    Audience and impact: Audience composed by experts from Academia and Industries mainly interested in adaptive hardware/system/software for space applications. In particular, one of the three contributions (the paper on routing in WSN) was presented during the poster session of the conference, while the other two papers were presented during the plenary session of the conference. Presentations were organised as a presentation of 20 minutes, with additional 5 minutes for questions. The poster was presented during a poster session of 1 hour and 50 minutes. The papers and the poster were discussed in front of an auditorium of about 50 experts.
  - Presentation of a paper to the IEEE SENSORS 2014 conference held on the 3rd of November, in Valencia, Spain.
    Topic presented: The paper gave details on the Radiation sensor and the Dust Deposition Sensor designed in SWIPE.
    Impact: About 50 experts attended the presentation of the paper.
- Year 2015:
  - Two papers were presented at the 2015 International Astronautical Congress (IAC-2015), held during 12th-16th October, 2015, in Jerusalem, Israel
  - A paper was published in the International Journal of Communication Systems, Special Issue - Energy Efficient Networking, Wiley Online Library, Online ISSN: 1099-1131. The paper was written by UoR-CRAT.
  - A paper was presented at the 6th Emerging Security Technologies International Conference (EST-2015), held during 3rd – 5th September, 2015, in Braunschweig, Germany.

- A paper, written by ULEIC, was published by the AIAA Journal of Aerospace Information Systems, previously known as the AIAA Journal of Aerospace Computing, Information and Communication. doi: 10.2514/1.I010373
- The SWIPE consortium disseminated some results of the project through a paper presentation within the 2015 Mediterranean Conference on Control and Automation (MED 2015), held on 16th-19th June, 2015, in Torremolinos, Spain.

5.2 Targeted dissemination actions

In the first two periods of the project, two targeted dissemination actions were prepared, aiming at potential space stakeholders: a project and concept presentation at the International Astronautical Congress (IAC) in 2013 and a dedicated SWIPE session in the Adaptive Hardware Systems (AHS) Conference in 2014. These events are briefly described in the following subsections. More target actions are expected during the upcoming final year of the project.

5.2.1 IAC 2013

The first targeted dissemination action in SWIPE was a published paper [RD4] and conceptual presentation, with some initial progress in terms of mission design and node configuration, at the largest global space conference, the International Astronautical Congress, held in Beijing in 2013. The IAC is held once a year and gathers all Space Agencies and the major players in the Space market together.

The presentation was given in a specific moon exploration session, with the presence of several specialists in Moon science and planetary exploration, and got a large amount of feedback from the audience, during the question and answer period and afterwards, in individual discussions carried out offline. This dissemination action took advantage of the session limited focus to raise awareness about the project, targeting specifically the experts working on the field.

5.2.2 AHS 2014

A second targeted action was carried out after the first project review, once the requirements and architecture were defined and during the design tasks. The Consortium organised a dedicated SWIPE session in the NASA/ESA Adaptive Hardware Systems Conference, held in Leicester in 2014, where three papers have been published and presented [RD5] [RD6] [RD7]. The focus was on the WSN and data processing algorithms and their adaptive inherent nature in SWIPE.

The conference was organised by the two largest and most important Space Agencies in the world, gathering experts from different fields of adaptive systems. A dedicated session on wireless sensor networks for planetary exploration allowed a targeted communication of the SWIPE progress and achievements to date, reaching once again the planetary exploration experts in a much focused way.

5.2.3 IAC 2015

The last target was the known IAC conference. The papers deal with, respectively, (i) the implementation of the SWIPE routing protocol and (ii) the implementation of the SWIPE node as a fully autonomous platform, both in terms of operation and power harvesting. The audience of the event was composed by experts from Academia and Industries mainly interested in adaptive hardware/system/software for space applications. The sessions were organised as oral presentations of 20 minutes each, including the time for questions. The papers were discussed in front of an auditorium of about 50 experts.

5.2.4 SENSORNETS 2016

SWIPE will be promoted with an exhibition booth at the 5th International Conference on Sensor Networks (SENSORNETS 2016, website: http://www.sensornets.org), which will be held in Rome from the 19th to the 21st of February, 2016. The SWIPE project will be presented in the so-called "European Project Space" (EPS), which provides an opportunity for researchers involved in European research projects to present the objectives and outcomes of the projects and future plans on follow-up opportunities.

5.3 Other dissemination tools

The project website is being continually updated, providing users with the latest news on the SWIPE activities. A Facebook page[3], accessible from the website, has been set-up in order to increase visibility of the project and reach a wider audience. Furthermore, news about the project is regularly published on the website. It is also possible for interested users to subscribe to receive news updates.

Moreover, a brochure is available for download on the website, with key information on the project (a final brochure will be made available by the end of the project, with main focus on project results and the field tests). The partners are seeking also for opportunities to publish SWIPE news to wider-audience media, such as newspapers.

5.4 Future paper submission opportunities

The following table shows the next dissemination opportunities related to the submission of papers to international conferences or journals in the topics of SWIPE. The list of next paper submission opportunities is also constantly updated in the "Events" page of the SWIPE website.

Conference/ Journal	Date(s) (if conference)	Location (if conference)	Link	Submission deadline
IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC 2016)	4th September – 7nd September, 2016	Valencia, Spain	http://www.ieee-pimrc.org/	18th March 2016
5th International Conference on Wireless Sensor Networks (WSN 2016)	11th-14th September, 2016	Gdansk, Poland	https://fedcsis.org/2016/wsn	18th April 2016
18th International Conference on System Theory, Control and Computing (ICSTCC 2016)	5th-6th December, 2016	Sydney, Australia	https://www.waset.org/conference/2016/12/sydney/ICSTCC	5th June 2016

[3] https://www.facebook.com/pages/SWIPE-EU-Project/1382396062041672

IEEE 2016 International Conference on Multisensor Fusion and Integration for Intelligent Systems (MFI 2016)	19th-21th September, 2016	Baden-Baden, Germany	http://mfi2016.org/	21th May, 2016
67th International Astronautical Congress 2016 (IAC 2016)	26th-30th September, 2016	Guadalajara, Mexico	http://www.iafastro.org/	29th February 2016

Table 3 – List of next relevant opportunities for paper submission.

5.5 Events participation opportunities

The following table shows the list of next events which the consortium can attend, either with specific presentations focused on the SWIPE project/results or because the topics or the audience are relevant for SWIPE (the relevance is highlighted in the fifth column of the table).

Event name	Date(s)	Location	Link	Relevance to SWIPE
24th Mediterranean Conference on Control and Automation (MED 2016)	21th-24th June, 2016	Athens, Greece	http://med2016.org	Topics of interest for SWIPE: • Computing and communication • Distributed systems. • Fault tolerant control • Wireless sensor networks
25th European Conference on Networks and Communications (EUCNC 2016)	27th June – 30th June, 2016	Athens, Greece	http://www.eucnc.eu/	Topics of interest for SWIPE: • Ad hoc, multi-hop and sensor networks. • Satellite based services and architectures • Routing protocols and cognitive radio. Good opportunity for networking with several stakeholders at Italian and European level.
Ad Hoc Now 2016	4th July – 6th July, 2016	Lille, France	https://project.inria.fr/AdHocNow2016/call-for-papers/	Topics of interest for SWIPE: • Ad hoc network applications, algorithms and architectures
35th Chinese Control Conference (CCC 2016)	27th-29th July, 2016	Chengdu, China	http://ccc2016.swjtu.edu.cn	Topics of interest for SWIPE: • Advances in control of systems and applications.
55th IEEE Conference on Decision and Control (CDC 2016)	12nd-14th December, 2016	Las Vegas, USA	http://cdc2016.ieeecss.org/	Topics of interest for SWIPE: • Data scheduling and filtering. • Network control. CDC 2015 will give us the opportunity of making a link with researchers and practitioners in the field of automatic control applied to space applications.

Table 4 – List of next relevant international events.

Moreover, the SWIPE consortium also plans to present results about the following topics:

- New actuators based on SMA alloys.
- ASIC Mixed signal technology hardening for space applications.
- Low mass/volume/power meteorological station for planetary exploration.
- New advances in low mass/volume thermal switch based on SMA technology.

Such results will be presented in the context of events organized by the International Lunar Exploration Working Group (ILEWG) (website http://sci.esa.int/ilewg), the International Academy of Astronautics (website https://iaaweb.org/content/view/277/416/) and the IEEE Robotics and Automation Society (website http://www.ieee-ras.org/).

6 Intellectual property management

This section begins by presenting the rules applied by the consortium during the project for managing the Intellectual Property generated by the research carried out. The rules used were defined and established in the SWIPE consortium agreement and were drafted based on Articles II.26. to II.29 of the Grant Agreement. The consortium then made additions to these articles, specifically concerning foreground, its ownership, transfer, dissemination and access rights.

Generally speaking the rules defined by the consortium were established taking the following as general guidelines:

- Ownership of Background knowledge is not affected by participation. If relevant to the project, it will be made available to the consortium members who require it to perform the research in this project, free of charge.
- Side-ground knowledge (acquired in parallel to the contract) is to be negotiated between partners on a case-by-case if access for the project is needed.
- Foreground knowledge is owned by the partner generating such result.
- Each partner shall make its foreground knowledge available, on a royalty-free basis unless otherwise agreed, to other contractors to the extent that such information is necessary for the production of their own foreground knowledge.
- Knowledge generated by joint work of several partners where respective shares of the work cannot be ascertained, shall be jointly owned. The parties concerned shall agree to the allocation and terms of exercising ownership (otherwise a default regime for joint ownership is foreseen).
- Pre-existing know-how and foreground knowledge will be made available to other project partners for exploitation purposes at favourable conditions, with respect to the normal commercial conditions applied by the granting partner.
- Research partners will be granted a fair compensation in the form of royalties by the partners exploiting the foreground knowledge in which the research partners have contributed.
- Research partners will be entitled to freely reuse internally their foreground knowledge, and to freely disseminate such in any academic paper. Such papers must include as co-authors all the partners who contributed to such work.
- Research partners will be entitled to create spin-offs for the commercialization of their foreground knowledge, in which case same conditions apply as to any other partner of the SWIPE project.

6.1 Background knowledge

The rules of engagement regarding the background knowledge are described in the consortium agreement. Please refer to that document for further information.

6.2 Foreground knowledge

One of the key aspects regarding the results obtained is how to protect and manage the intellectual property of those results beyond the project execution. This will be addressed as part of the exploitation plan and will involve all partners who are generating foreground intellectual property in the SWIPE project.

These aspects have started to be addressed inside the Consortium for the project execution, assigning ownership of foreground knowledge produced during the project to the partner that produces it and protecting any background intellectual property which could be required to properly fulfil the SWIPE task objectives. This will be valid beyond the project conclusion, but it is also necessary to define measures to properly protect the results from the outside environment.

Clearly, when foreground is generated by a single beneficiary, then there is no question concerning the ownership of such foreground. When foreground IP is generated by joint work by more than one partner, ownership is determined according to the parts of said foreground that were developed by each partner. If it's impossible to distinguish between the parts developed by the partners (i.e. the work is so intermingled that it is impossible to determine who developed what) a joint ownership agreement must be established. Where no joint ownership agreement has yet been concluded the consortium determined that:

- each of the joint owners shall be entitled to Use their jointly owned Foreground on a royalty-free basis, and without requiring the prior consent of the other joint owner(s), and
- each of the joint owners shall be entitled to grant non-exclusive licenses to third parties, without any right to sub-license, subject to the following conditions:
    - at least 45 (forty-five) days prior notice must be given to the other joint owner(s); and
    - fair and reasonable compensation must be provided to the other joint owner(s).

An initial step is to identify the different blocks, modules or parts in which the SWIPE results can be independently divided. A possible baseline solution then to protect each of them is to file patents for each of the innovative elements identified. The individual elements that will be generated by SWIPE are therefore:

- Node communications module.
- Node system control module (OBC).
- Node power generation, storage and distribution module.
- Node payload modules
- Node housing mechanical design.
- Node petal deployment system.
- Node wireless sensor network algorithms.
- Node data processing and fusion algorithms.

Transfer of ownership of a party's own foreground follows the procedures established in Article II 27 of the Grant Agreement. A list of specific third parties to which partners might be interested in transferring foreground IP was established at the beginning of the project and all other Parties waived their right to object to a transfer to such listed third parties. Nevertheless, it was established that the transferring Party must notify the other Parties of such transfer and must ensure that the rights of the other Parties will not be affected by such transfer. Addition of third parties after the consortium agreement's signature requires the approval of the Project Management Committee.

Currently only the communications systems are under Industrial Design protection, all other systems have no IP protection. The planned action are to protect the whole node under a patent and upgrading the protection of the communications systems to a patent as well.
The following table summarizes the current and planned protection action for the constituents of the SWIPE nodes.

	Patent		Industrial Design		No IP protection	
	Current	Planned	Current	Planned	Current	Planned
Whole Node		X			X	
Irradiance Sensor				X	X	
Dust Deposition Sensor				X	X	
Temperature Sensor				X	X	
Thermal Switch				X	X	
Radiation Sensor				X	X	
Communications Subsystem		X	X			
Power Subsystem					X	X
Networking Algorithms					X	X

Table 5 – Current and planned protection actions

7 Access Rights

Access rights to IP were established based on the following:

	Access rights to background	Access rights to foreground	Timing (to request access rights)
For implementing the project	Yes, if a participant needs them for carrying out its own work under the project		Until the end of the project
	Royalty-free, unless otherwise agreed before acceding to the grant agreement	Royalty-free	
For use purposes (exploitation + further research)	Yes, if a participant needs them for using its own foreground knowledge		Until 1st year (unless otherwise agreed) after the end of the project or termination of the participant concerned
	Either royalty-free or on fair and reasonable conditions to be agreed		

Table 6 – Rules for knowledge sharing.

The background covered by the project and to which partners were ready to grant access rights was identified in the consortium agreement. Withdrawal of background from this list was only permitted by decision of the Project Management Committee. All Background not listed in the CA was explicitly excluded from Access Rights. Provisions were also made to allow a partner to list specific Background as excluded in the CA.

Any Access Rights granted expressly excluded any rights to sublicense unless expressly stated otherwise. Access Rights were made free of any administrative transfer costs. Access Rights when granted, were granted on a non-exclusive basis, if not otherwise agreed in writing by all. Foreground and Background were to be used only for the purposes for which Access Rights to it had been granted.

Requests for Access Rights must be made in writing. The granting of Access Rights may be made conditional on the acceptance of specific conditions aimed at ensuring that these rights will be used only for the intended purpose and that appropriate confidentiality obligations are in place. The requesting Party must show that the Access Rights are needed.

When foreground and background was needed for the performance of a partner's own work in the project access rights must be granted on a royalty-free basis.

Access Rights to Foreground if Needed for Use of a Party's own Foreground including for third-party research shall be granted on fair and reasonable conditions. Access rights for internal research activities shall be granted on a royalty-free basis. Request for Access Rights may be made up to 24 months after the end of the Project.
Access Rights to Background if Needed for Use of a Party's own Foreground shall be granted on fair and reasonable conditions.

Access rights for Affiliated Entities were established and managed under the conditions of the GA Article II.34.3.

Granting of Access Rights not covered by the GA or the CA were made to be at the absolute discretion of the owning Party and subject to such terms and conditions as may be agreed between the owning and receiving Parties.

Parties' Access Rights to Software do not include any right to receive Source Code or Object Code ported to a certain hardware platform or any right to receive Source Code, Object Code or respective Software Documentation in any particular form or detail, but only as available from the Party granting the Access Rights.
Access Rights to Software which is Foreground were made to comprise:

- Access to the Object Code; and,
- Where normal use of such an Object Code requires an Application Programming Interface (hereafter API), Access to the Object Code and such an API; and,
- If a Party can show that the execution of its tasks under the Project or the Use of its own Foreground is technically or legally impossible without Access to the Source Code, Access to the Source Code to the extent necessary.

Background shall only be provided in Object Code unless otherwise agreed between the Parties concerned.

Where a Party has Access Rights to Object Code and/or API which is Foreground for Use, such Access shall, in addition to the access for use, comprise the right

- To make an unlimited number of copies of Object Code and API; and,
- To distribute, make available, market, sell and offer for sale such Object Code and API alone or part of or in connection with products or services of the Party having the Access Rights;

Provided however, that any product, process or service has been developed by the Party having the Access Rights in accordance with its rights to use Object Code and API for its own Foreground.

When access rights to object code are shown to be necessary for the use of a partner's own foreground, then it was determined that that partners has the right to grant in the normal course of the relevant trade to end-user customers buying/using the product/services, a sublicense to the extent as necessary for the normal use of the relevant product or service to use the Object Code alone or as part of or in connection with or integrated into products and services of the Party having the Access Rights and, as far as technically essential:

- To maintain such product/service;
- To create for its own end-use interacting interoperable software in accordance with the Council Directive of 14 May 1991 on the legal protection of computer programmes (91/250/EEC).

Access Rights to Source Code, as far as needed for the Use of the Party's own Foreground, comprise a worldwide right to use, to make copies, to modify, to develop, to adapt Source Code for research, to create/market a product/process and to create/provide a service.

Several innovations have been carried out during the SWIPE Project. The main novelties have been described in the deliverables and therefore the details on the content of the innovation could be found in those documents. Theses optimisations are considered as foreground of the partners responsible for its development and the IPR rules defined between the SWIPE partners are applicable to these innovations.

Protection of IP is the responsibility of the owner of such IP and follows the rules established in Article II.28 of the Grant Agreement.

References

[RD1] SWIPE Consortium, SWIPE Description of Work, European Commission Seventh Framework Programme – Space Theme, Grant No 312826, February 2013.

[RD2] International Space Exploration Coordination Group, The Global Exploration Roadmap, August 2013.

[RD3] SWIPE Consortium, Deployment Strategies Tailoring to SWIPE Scenarios, European Commission Seventh Framework Programme – Space Theme, Reference: 312826-SWIPE-D2.3-DeploymentStrategies, Issue 1.0, December 2013.

[RD4] P. Rodrigues, A. Oliveira, R. Mendes, F. Alvarez, M. Crosnier T. Vladimirova, F. Delli Priscoli, G. Oddi, A. Pietrabissa, "*Wireless Sensor Networks for Moon Exploration*", 64th International Astronautical Congress, Beijing, China, September 2013.

[RD5] G. Oddi, A. Pietrabissa, F.Liberati, "*Energy-balancing in multi-hop Wireless Sensor Networks (WSNs): an approach based on reinforcement learning*", 9th NASA/ESA Conference on Adaptive Hardware and Systems (AHS) Conference, Leicester, United Kingdom, July 2014.

[RD6] P. Rodrigues, A. Oliveira, F. Alvarez, R.Cabás, M. Crosnier, T. Vladimirova, X. Zhai, H. Jing, G. Oddi, A. Pietrabissa, F. Liberati, " *Space Wireless Sensor Networks (WSNs) for planetary exploration: node and network architectures*", 9th NASA/ESA Conference on Adaptive Hardware and Systems (AHS) Conference, Leicester, United Kingdom, July 2014.

[RD7] X. Zhai, H. Jing, T. Vladimirova, "*Multi-Sensor Data Fusion in Wireless Sensor Networks for Planetary Exploration*", 9th NASA/ESA Conference on Adaptive Hardware and Systems (AHS) Conference, Leicester, United Kingdom, July 2014.

[RD8] SWIPE Consortium, D7.1 – SWIPE Dissemination Report 1, European Commission Seventh Framework Programme – Space Theme, Grant No 312826, April 2014.