PROJECT FINAL REPORT

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1 Executive Summary

When talking about communications, terrestrial technologies are far more advanced than those applied in space. Motivated by the global mobile communications market, permanently seeking new products and development areas, these technologies experience an unparalleled evolution. Therefore, spin-in of terrestrial technologies should be seriously pursued to provide the technology push that can lead space markets beyond the current state of the art. The space market is globally small and very conservative, making it extremely difficult for new companies to enter the market and be competitive, making their growth and establishment an extremely slow process. Part of the solution is to have inexpensive standardized platforms, which could be developed in a short timeframe, and more adequate tool to put them in orbit. For this reason, small satellites have been receiving much attention lately as an alternative to large spacecraft and expensive missions. Smaller platforms are interesting in many ways: they are simpler to design and develop, have shorter timeframes, are less expensive, embody less associated risks and enable brand new types of multi-satellite collaborative missions. Particularly popular in this category is the CubeSat concept, which started as an academic tool for hands-on experience but now is being looked at as a new concept for technology validation.

Taking these trends and concerns into account, the GAMALINK project proposed to research and develop an integrated communications solution targeting small satellite platforms and compatible with the CubeSat standard. GAMALINK combines expertise on satellite navigation, ad hoc networking, attitude determination, ranging, antenna design and beamforming into a common technological platform, suitable for LEO small satellite missions. The underlying hardware is based on Software-Defined Radio (SDR) and on the top of this radio platform several features were implemented: mobile ad hoc networking, an enabler for creating Inter-Satellite Links (ISLs), radio-based attitude determination, GPS waveform reading and signal decoding and ranging between different satellites (Figure 1).

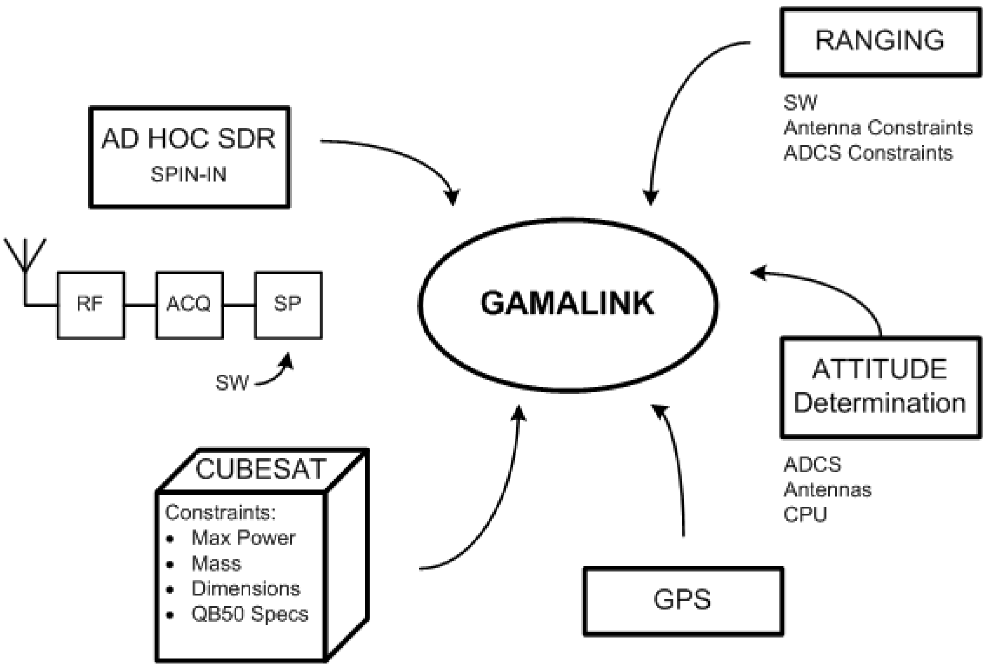


Figure 1 – GAMALINK concept.

The first year of the GAMALINK project was spent around two main technical areas: system design and the SDR hardware platform. The first included a careful analysis of the CubeSat platform constraints and the baseline QB50 mission requirements. From these studies, a set of system and subsystem requirements was derived for the GAMALINK project. Afterwards, this set of requirements was the input to the system architecture design. This task was of the biggest challenges in this first year and included several iterations of the design before reaching a final solution. The full SDR hardware platform was divided in four main blocks: antennas, RF frontend, signal acquisition and digital signal processing. A lot of effort was put to design these components in detail, starting from the architecture decisions.

The second year of the GAMALINK project was dedicated to the final design and prototyping of the hardware modules, the conclusion of the software applications development started in the first year, their implementation on the SDR platform, the integration and testing of GAMALINK and, on a less technical angle, the definition of an exploitation strategy. In terms of integration and testing, two prototypes have been integrated, including all hardware modules and the required mechanical interfaces. The testing activities were carried out at two levels: module level, by each team developing the module, and at GAMALINK level. At this system level, functional and performance tests have been performed, as well as environmental tests (e.g. structural, thermal-vacuum).

Particular care was taken to ensure proper dissemination activities and outreach for the GAMALINK project. A public website was built, highlighting the project goals, the Consortium and the major achievements during the project execution. A press release and a project brochure were also prepared to strengthen the outreach strategy of GAMALINK. A dissemination plan and a calendar of possible events were prepared and most partners attended conferences of interest and presented articles based on the GAMALINK enabling technologies. The dissemination highlight has been the GAMALINK public workshop, in Ankara, where the Consortium presented the results from more than a year of work through the project. In terms of exploitation, a thorough assessment of the GAMALINK potential markets was made, including also non-Space markets, and an exploitation strategy has been defined.

2 Project Context and Objectives

The terrestrial communications market is going through a massive evolution at financial, technological and paradigmatic levels. This has been mainly driven by the mobile communication devices, which changed the way of life of almost every person around the world. The communication pattern has changed dramatically over the last decade, since the massiveness of mobile devices. Nowadays, the paradigm of mobile phones has changed into an almost ubiquitous access to everything, where internet access, video conference and GPS are the key enablers to a new lifestyle. These trends have been permanently pushing communication technology beyond limits, demanding better and more complex features in smaller and less power consuming devices. On the other hand, space technology has always been characterized by innovation, backed up by defence research and funding and driven by the stringent requirements of the harsh space environment. However, funding has been gradually decreased and space is a conservative market, which has reduced the entry of innovative and state of the art devices. Particularly in the communications field, technology has been progressing faster in terrestrial applications than in space. Some of these technologies are key elements of devices that we use every day, but have never been tested in space.

One promising example is Software-Defined Radio (SDR), an increasingly popular technology that allows building modular and adaptive communication devices, by performing as much processing as possible by software. This technology is being used for instance in the smartphone industry to perform all the embedded communications, including GSM, WiFi, Bluetooth and even GPS, but it can even be used in fields like spectroscopy. It can greatly reduce mass and volume, since hardware can be shared, but SDR's strongest asset is its flexibility. With appropriate antennas, a radio device can change its operating frequency by reprogramming software and without any changes in hardware. When thinking about satellites for example, flexibility is a big advantage as changing hardware is normally not an option and sending a new satellite is extremely expensive. Software-Defined Radio has excellent conditions to revolutionize the space market and start a new era in space communications. There has also been a growing interest in the concept of ad hoc networks as we are moving into the mobility age. These networks are especially interesting since they don't require an infrastructure, dedicated management or monitoring. Their autonomy makes them fit not only to rather static applications, but also to extremely dynamic environments, where nodes are constantly entering and leaving the network. In space, these protocols are especially interesting for inter-satellite communications in swarm missions, where a large group of small satellites needs to cooperate to complete a mission, or in setting up Wireless Sensor Networks (WSNs) for scientific missions or planetary exploration.

Bringing these terrestrial technologies to space has tremendous validation challenges, especially if we think of SMEs, which don't have the resources to afford the stringent and expensive technology validation missions. In fact, new mission concepts now deserve growing interest and attention from the global space community, in an attempt to lower the costs and make the space sector more competitive and accessible to all. Within these new approaches is the use of small satellites to perform technology validation in space and in particular CubeSats. Such small platforms bear many advantages when compared to the traditional missions. They have lower development and launch costs, less strict requirements and shorter mission duration. The main constraint of CubeSat missions is however the space available on-board. Since these platforms are extremely small, most devices have strong dimension constraints and most of the times the payload is actually a bus subsystem as well, i.e. the technology to be validated is actually used as a primary subsystem. Since communications are a key subsystem for any mission, the **GAMALINK** project developed a CubeSat compatible communications platform which will at the same time support the mission and validate several technologies in space. In fact, **GAMALINK** went even further and used the same communications platform to implement other functionalities like GPS position decoding, attitude determination and ranging techniques based on RF signals. Ultimately, **GAMALINK** can merge COMM and AOCS subsystems in just one device, which can greatly reduce the mass, dimension and even power budgets, an extremely interesting feature to such small platforms.

In the end, **GAMALINK** adapted a multifunctional SDR-based hardware platform for space applications, from an existing terrestrial design. It started by clearly identifying the system requirements and constraints and by defining a complete and detailed system architecture. The hardware research then focused on the design and development of the different modules: antenna design, RF electronics, acquisition and signal processing, considering also beam forming techniques to save transmission power and keeping in mind flexibility as the main design driver. The software research developed space-oriented solutions for GPS signal decoding, ad hoc networking, radio-based attitude determination and ranging between satellites, based on regular communication signals between them. These software protocols were then implemented on top of the SDR platform. The entire system was then integrated, tested and evaluated against its functional and performance requirements. Two functional prototypes were developed, first to test the hardware and later with a fully-functional integrated prototype of **GAMALINK**, featuring all the different protocols developed within the project.

In short, the proposed project objectives were:

- Develop an SDR platform prototype to support space communications.
    - Develop an adequate antenna design to cover the required frequency range.
    - Include beam forming capabilities to save communications power.
    - Adapt and build the SDR platform electronics for space applications.
- Implement different innovative functionalities on top of the SDR platform.
    - GPS waveform decoding.
    - Ad hoc networking.
    - Randio-based attitude determination.
    - Ranging algorithms.
- Integrate and test two **GAMALINK** prototypes for CubeSat applications.

3 Main S&T results/foregrounds

3.1 System design

The project started by analysing a set of constraints and requirements coming from the QB50 baseline mission and the CubeSat standard. This platform was selected due to its popularity and also because it has the most stringent requirements among small satellite platforms. Therefore, the starting point of the project was to identify and study the constraints imposed by the CubeSat standard (size, mass, materials, available power...), the space environment (temperature, cosmic radiation and charged particles at different altitudes), and the baseline QB50 mission requirements (scientific, operational and launch).

Based on the identified constraints, together with a survey of the existing solutions in the market, system level and environmental requirements were derived, such as maximum altitude, radiation levels, lifetime, size and mass, power consumption, temperature, shock and vibration. Rigorous studies of the different launch vehicle characteristics and an exhaustive analysis of environmental requirements for launch were made for setting the requirements. From this point, subsystem requirements were also defined to guide the development of the GAMALINK hardware modules (antennas, RF frontend, acquisition and signal processing) and the software applications (software GPS receiver, ad hoc networking algorithms, radio-based attitude determination and ranging). Finally, test requirements were derived to guide the preparation of the test environment and the validation plan.

Afterwards, the GAMALINK constraints and requirements were translated into a system-level architectural design that is able to integrate the different functionalities described above. Work started by summarizing the system-level requirements and their impact on the architecture and then moved to identifying the GAMALINK components: hardware modules and software applications. The system architecture was then iteratively and progressively derived based on the various Consortium meetings and discussions. This included the number of transmission and reception RF chains, the methodology used to implement beamforming, the modulation and coding schemes, the bandwidth of the acquisition module, the clock architecture, the software algorithms access management, efficient ways of implementing radio-based attitude determination and ranging techniques and the RF signal structure and architecture.

Other system-level subjects relevant for the global system definition and for the lower-level component design and development we also addressed. These included configuration considerations, describing the GAMALINK platform from a physical perspective (Figure 2) and identifying the constraints for mounting it in a CubeSat platform (e.g. distance between antennas or assembly procedures), detailed internal and external mechanical, electrical and data interface definition, the GAMALINK main operating modes, including transition schemes, and a preliminary definition of the system mass, power, data and link budgets.

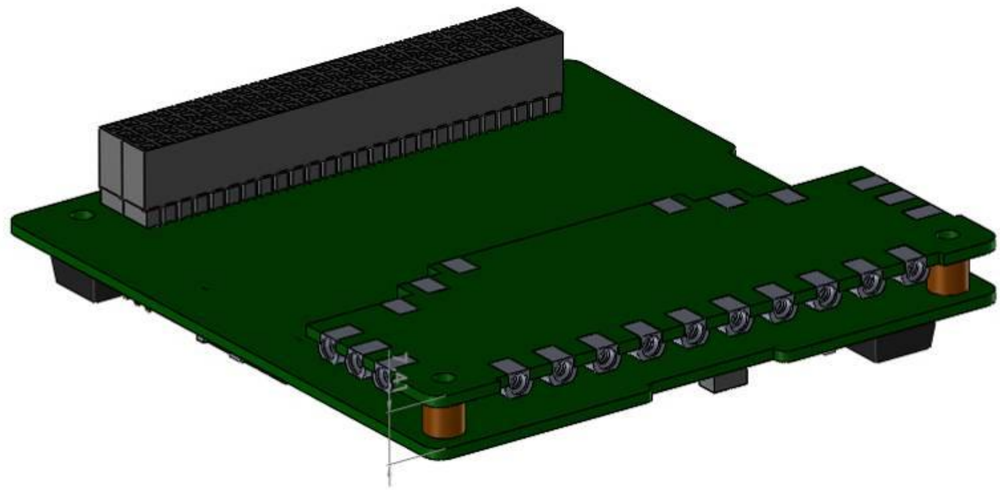


Figure 2 – GAMALINK preliminary configuration.

3.2 Hardware development

The hardware development included four different functional blocks of GAMALINK: antennas, RF frontend, acquisition and signal processing.

The antenna design and development focused on miniaturisation and smart antenna processes to achieve beamforming. Since CubeSats are small platforms, common antenna designs and materials are not appropriate to satisfy the dimension requirements. Four different antennas have been designed based on the studies done, not only in miniaturisation techniques but also on the best materials used. Based on the tests carried out on these prototypes, S-Band and GPS antenna designs were completed. Simulated and measured results are summarised in Table 1 below:

	S-Band Antenna		GPS Antenna	
	Simulation	***Measured***	***Simulation***	***Measured***
Center Frequency	2.433GHz	2.422GHz	1.572GHz	1.575GHz
Bandwidth (S11<-10dB)	55MHz (2.26%)	55MHz (2.27%)	19MHz (1.2%)	19MHz (1.2%)
Boresight Gain	4.45dBic	5.28dBic	5.06dBic	4.13dBic
Radiation Efficiency at Center Frequency	90%	80.8%	78.9%	64.7%
HPBW at center frequency	131.6^{0}	82^{0}	90.5^{0}	98^{0}
Max. Dimensions (LxWxH)	24mm x 24mm x 3.175mm		28mm x 28mm x 3.175mm	
Substrate Material	Rogers TMM6		Rogers TMM10	
Polarization	Circular- RHCP			
Feeding	Pin fed-single port			

Table 1 – Comparison of specific values obtained by simulation and experiments for final design of GAMALINK antennas.

Regarding the RF frontend, the performed activities in this task were:

- RF Design and simulation stage: The design and simulation of the RF front-end from/to I/Q signals up to/from the S-band signals and GPS receiver was completed.
- RF Development: Several prototypes of the RF frontend and the antenna switching board were designed, manufactured and assembled (Figure 3).
- RF Integration: Key parameters as the interfaces with acquisition block have been defined, including the type, nature and level of the signals exchanged between RF board and digital board.

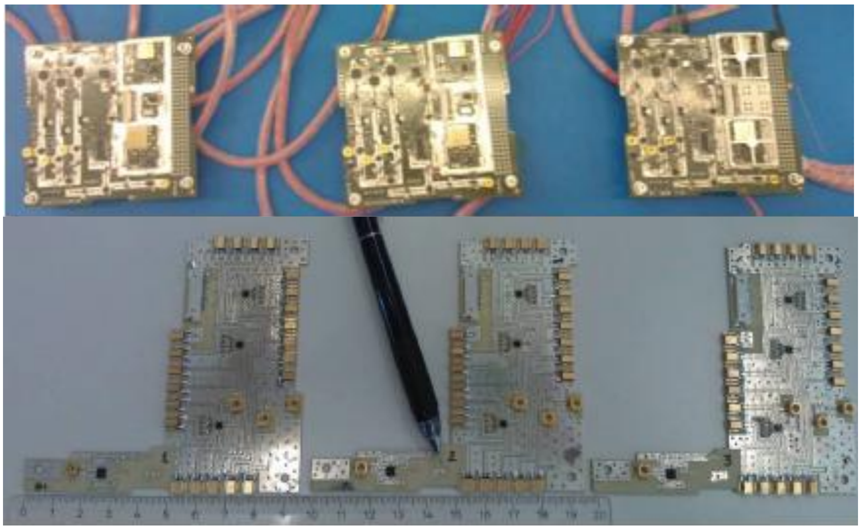


Figure 3 – RF frontend (top) and antenna switching (bottom) PCB prototypes.

The acquisition module was mainly devoted to the A/D or D/A conversion stages design. It was designed and developed taking into account the system architecture and the interface with the RF module. The choice of the components (especially ADC and DAC) and the detailed electronic design of this module have been the core activities. Basic prototypes were developed to test the module.

Finally, the signal processing module is responsible for the computing and interfacing tasks of GAMALINK and is the core of the SDR platform. The achievements include the creation/decoding of the transmitted/received signals, running the different software application modules, controlling the transitions between GAMALINK operation modes and managing the external data interface protocols. The major challenges of this module were the selection of the components, since they had to have low power consumption and some space compatibility (in radiation-hardened versions), and the definition of the core processing architecture, which should be efficient in providing enough computational power to cope with the GAMALINK requirements.

3.3 Software development

This work package was devoted to the design, development and implementation of the software applications, which added functionality to the underlying SDR-based communications platform. These applications included the software GPS receiver, the ad hoc networking algorithms, a radio-based attitude determination technique and ranging protocols.

The software GPS waveform design included an initial overview of the GPS signal structure and theory, the development and simulation of the GPS algorithms and finally the analysis of the results obtained. The results have shown a position precision of about 4.5 m and a speed accuracy of about 4 cm/s. The experiments have also shown that the navigation data is successfully decoded and can be used to feed the PVT estimation module. The results showed that no significant degradation occurred in position, velocity or time estimation.

The work performed for the ad hoc networking was focused on the selection of techniques and algorithms to implement the waveform. It started with a brief analysis of the requirements and decisions at architecture level and then with an overview of the current state of the art in Mobile wireless Ad hoc NETworks (MANETs), together with some considerations that are relevant for Space applications. Afterwards, a summary of the extensive studies performed in routing protocols and metrics, resource management, load balancing and Quality of Service (QoS) were analysed, with some considerations on the GAMALINK application. The algorithms have been successfully implemented and tested in the SDR platform.

Attitude determination radio signals were implemented as part of the protocol and transmitted together with beamforming control signals, at the end of data communication packets. The activities under this task have also included establishing switching layer requirements considering the attitude determination specifications and measurements. Attitude determination method with the transmission of signals through different antennas has been identified with the operation of other subsystems and related minimum speed for switching layer devices. The antennas switches were implemented in the switching board and are accessible from the RF main board to be controlled by digital board according to the algorithms developed for GAMALINK. Compatibility of RF devices control parameters and functionalities has been assessed.

The activities for ranging started with an analysis of different ranging techniques. Based on this analysis, it has been decided to use two-way ranging as a ranging technique between the nodes. Moreover, the factors influencing the resolution of the ranging estimates were studied and methods to compensate these effects were proposed. A simulation environment was developed for ranging taking into considerations the effect of the signal design and link budget parameters. Additionally, a calibration loop algorithm was designed to estimate the time elapsed by sending and receiving the ranging signals.

In the end, all modules were successfully implemented in the SDR platform, with significant capacity margins. This was extremely important to assess the possibility of future implementations on the platform.

3.4 Integration and Testing

The integration and testing involved the manufacturing of two GAMALINK prototypes. The first prototype integration accomplished essentially three tasks:

- Integration of the first SDR platform prototype (digital part) and of several RF blocks.
- The manufacturing of a housing 2U CubeSat structure and side panels. In this sense, the 3D CAD drawings of the side panel, antenna switching board and the SDR Platform PCBs were also developed to build a 3D model of the integrated unit.
- Optimization of cable lengths and RF connectors to minimize total weight.

This first integration provided valuable insight for the potential problems that could appear on the second integration stage. The second prototype already expected the integration of the antennas with the side panels, and the integration of all hardware modules inside the structure. Activities included:

- The design of the mechanical structure holding the antennas and mounting of the antenna prototypes with the Side Panel PCBs manufactured. The antenna RF cables have also been manufactured and integrated.

- A procedure was written for the integration showing the integration steps keeping in mind the accessibility of screws and harnessing.
- The GAMALINK mechanical prototypes were assembled and integrated, together with the electronics.

The testing and evaluation task lasted the entire second year of the project and performed the various types of testing foreseen in GAMALINK:

- Module level functional and performance tests, carried out individually for each hardware and software module, to ensure that the different components of GAMALINK were working properly before integration.
- Integrated level functional and performance tests, checking the functionality remained after integration and also carrying out system-level tests.
- Environmental tests:
    - EMC tests using an anechoic chamber, to validate the full RF chain EMI.
    - Vibration Testing was performed simulating mechanical loads which are induced on the GAMALINK during launch.
    - Thermal Vacuum Tests was performed testing the simulated conditions in orbit.

4 Potential impact, dissemination and exploitation

The main GAMALINK outcome was a multipurpose communications platform prototype to be used by CubeSats and other small satellites. The innovative feature of this platform is the capability of integrating several communications and attitude and position determination functionalities on one single hardware module. It is well known that one of the major CubeSat challenges is integration and the ability to fit all required subsystems in such a small platform. GAMALINK could be used in future CubeSat missions, acting as a communications subsystem, but also as an attitude and control subsystem, for the same mass and volume. Power consumption would also be reduced. This has a major impact in small satellite missions, since reducing the bus mass, volume and power overhead leaves more resources for the mission itself. Technology validation for instance could be performed to bigger and more power consuming payloads. Ultimately, with integrated features like ranging and ad hoc networking, GAMALINK will enable the design of novel mission concepts, like formation flying, inspiring and motivating advanced research on other CubeSat technological areas.

Having a satellite communication system based on SDR also holds many direct advantages. In case of a communications failure for instance, the chance of being able to solve the problem by uploading new software is high, especially since there will be less hardware involved. This has a major impact on the way current satellites are designed and operated. A failure in communications can compromise an entire million-dollar mission, which SDR can avoid up to some extent. Therefore, the use of this technology in space has a relevant economic impact in the entire space sector. Another big advantage is flexibility, as already mentioned, which has an impact in several aspects. With SDR, it is possible to have one device transmitting in different frequencies. This has a huge impact on mass and volume, which is particularly critical for small satellites (especially CubeSats). Such technology can also improve Ground coverage, which has a strong impact in operations, allowing for recovering more easily lost spacecrafts or ultimately enabling more data to be downloaded.

The fact that there were three SMEs participating shows the interest that these companies give to the space market. Actually, SMEs altogether account for the largest employment share of Europe and can be excellent assets for the space sector. Bringing these technology development nodes to space will create a different dynamic environment in the space market, accelerating technology maturing and reducing considerably the time it takes to validate components and achieve the so-called space-qualified technology. It will create new space business areas and ultimately enlarge the global space market, increasing the number of technological solutions available and therefore competitiveness. One good example is the CubeSat technology, which started being developed at the universities and gave birth to a series of new spin-off SMEs, which are now the major providers of CubeSat subsystem solutions to universities and companies all over the world. Ultimately, these factors will lead to a major revolution on the way missions are designed and conducted, greatly reducing their costs and development times, accelerating the achievement of great milestones in space exploration.

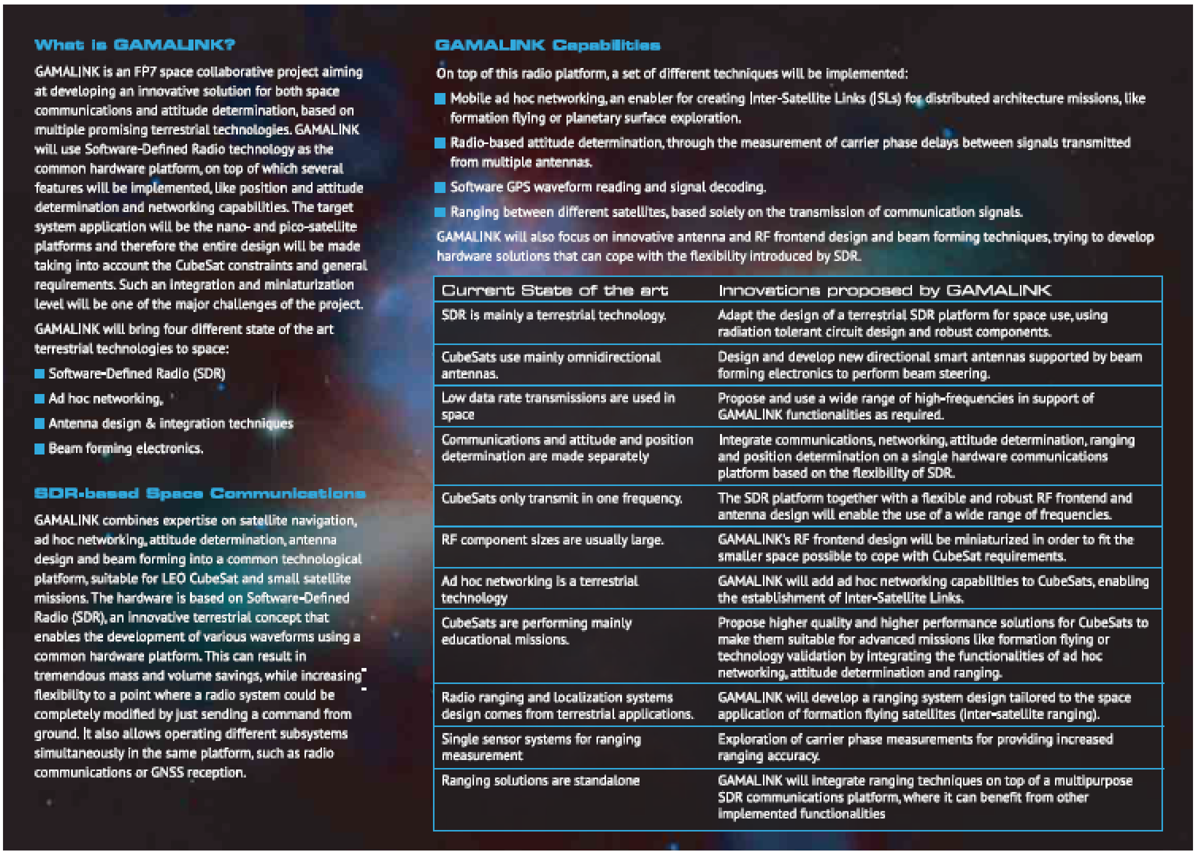
The GAMALINK dissemination activities were based on promoting two essential topics: the relevance of bringing advanced terrestrial technology to Space (particularly in the field of communications) and the massive new mission scenarios that can be supported by GAMALINK and that will be the genesis of a new era in space exploration. These outreach actions were targeted to the most relevant communities in order to effectively spread the message of the major impact that the new capabilities of GAMALINK could have on the traditional space missions. The goal of the Consortium was also to generate discussion around a brand new generation of multi-satellite cooperative scenarios and their great advantages for space science and technological endeavours.

The first dissemination activities focused on the preparation and publishing of a press release. A project website was then created and maintained at http://www.gamalink.eu (Figure 4). A project brochure was also designing for handing out project information at events and conferences (Figure 5 and Figure 6). In the second year of project, a public project workshop was organized on the 4th and the 5th of June, 2014, at TUBITAK UZAY facilities in Ankara and it was open to the public. The 2-days workshop was focused on the results obtained within the first 1.5 years. Table 2 includes the dissemination calendar updated with information on the attendance of project partners and outputs.

The exploitation activities lasted the entire second year of the GAMALINK project, to prepare the GAMALINK results for future exploitation, beyond the project conclusion. The final goal behind the activities carried out was to define a clear path to market, from the results obtained during the project. The key effort was to identify the potential markets for GAMALINK. An extensive survey was done, not only analysing the existing solutions and competitors already in the market, but also in looking forward into new emerging mission concepts that will be enabled by or take benefit from GAMALINK. This market analysis went further into non-space market areas, where the technology could also be commercialised. On the other side, an exploitation strategy for each partner was devised, distinguishing between the industry (in this case including the SMEs) and the academia and taking into account the exploitation interests of each partner. IP management issues were also addressed.

Figure 4 – Website home page.

Figure 5 – Brochure front page.



What is GAMALINK?

GAMALINK is an FP7 space collaborative project aiming at developing an innovative solution for both space communications and attitude determination, based on multiple promising terrestrial technologies. GAMALINK will use Software-Defined Radio technology as the common hardware platform, on top of which several features will be implemented, like position and attitude determination and networking capabilities. The target system application will be the nano- and pico-satellite platforms and therefore the entire design will be made taking into account the CubeSat constraints and general requirements. Such an integration and miniaturization level will be one of the major challenges of the project.

GAMALINK will bring four different state of the art terrestrial technologies to space:

- Software-Defined Radio (SDR)
- Ad hoc networking,
- Antenna design & integration techniques
- Beam forming electronics.

SDR-based Space Communications

GAMALINK combines expertise on satellite navigation, ad hoc networking, attitude determination, antenna design and beam forming into a common technological platform, suitable for LEO CubeSat and small satellite missions. The hardware is based on Software-Defined Radio (SDR), an innovative terrestrial concept that enables the development of various waveforms using a common hardware platform. This 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. It also allows operating different subsystems simultaneously in the same platform, such as radio communications or GNSS reception.

GAMALINK Capabilities

On top of this radio platform, a set of different techniques will be implemented:

- Mobile ad hoc networking, an enabler for creating Inter-Satellite Links (ISLs) for distributed architecture missions, like formation flying or planetary surface exploration.
- Radio-based attitude determination, through the measurement of carrier phase delays between signals transmitted from multiple antennas.
- Software GPS waveform reading and signal decoding.
- Ranging between different satellites, based solely on the transmission of communication signals.

GAMALINK will also focus on innovative antenna and RF frontend design and beam forming techniques, trying to develop hardware solutions that can cope with the flexibility introduced by SDR.

Current State of the art	Innovations proposed by GAMALINK
SDR is mainly a terrestrial technology.	Adapt the design of a terrestrial SDR platform for space use, using radiation tolerant circuit design and robust components.
CubeSats use mainly omnidirectional antennas.	Design and develop new directional smart antennas supported by beam forming electronics to perform beam steering.
Low data rate transmissions are used in space	Propose and use a wide range of high-frequencies in support of GAMALINK functionalities as required.
Communications and attitude and position determination are made separately	Integrate communications, networking, attitude determination, ranging and position determination on a single hardware communications platform based on the flexibility of SDR.
CubeSats only transmit in one frequency.	The SDR platform together with a flexible and robust RF frontend and antenna design will enable the use of a wide range of frequencies.
RF component sizes are usually large.	GAMALINK's RF frontend design will be miniaturized in order to fit the smaller space possible to cope with CubeSat requirements.
Ad hoc networking is a terrestrial technology	GAMALINK will add ad hoc networking capabilities to CubeSats, enabling the establishment of Inter-Satellite Links.
CubeSats are performing mainly educational missions.	Propose higher quality and higher performance solutions for CubeSats to make them suitable for advanced missions like formation flying or technology validation by integrating the functionalities of ad hoc networking, attitude determination and ranging.
Radio ranging and localization systems design comes from terrestrial applications.	GAMALINK will develop a ranging system design tailored to the space application of formation flying satellites (inter-satellite ranging).
Single sensor systems for ranging measurement	Exploration of carrier phase measurements for providing increased ranging accuracy.
Ranging solutions are standalone	GAMALINK will integrate ranging techniques on top of a multipurpose SDR communications platform, where it can benefit from other implemented functionalities

Figure 6 – Brochure back page.

No	Activity	Participants	Location	Date	Explanations
1	AIAA (The American Institute of Aeronautics and Astronautics) Space Conference &Exposition		San Diego, California	10 - 12 September 2013	
2	64th International Astronautical Congress (IAC)	TEKEVER	Beijing, China	23-27 September 2013	
3	IEEE Global Communications Conference, Exhibitions and Industrial Forum		Atlanta, GA, USA	9-13 December 2013	
4	2-days project workshop (*) organized by TUBI	All partners	Ankara, Turkey	4-5 June 2014	
5	ICSSC 2014 : International Conference on Satellite and Space Communications		France, Paris	28-29 August, 2014	
6	6th European Cubesat Symposium	TUBI	Estavayer-le-Lac, Switzerland	14 - 16 October 2014	Two presentations in 6th European Cubesat Symposium, 14 – 16 October 2014 Estavayer-le-Lac, Switzerland : 1- Antenna Subsystem of GAMALINK Platform 2- A Simple Miniaturized Printed Antenna Adaptation for CubeSats and Small Satellites Abstracts and presentations are available on https://www.cubesatsymposium.eu/index.php/programme
7	65th International Astronautical Congress (IAC)	TEKEVER	Toronto, Canada	29 September – 3 October 2014	
8	European Microwave week	TTI	Rome, Italy	5 October 2014	A flyer of GAMALINK was distributed and presented during the workshop of GaN Technology for Space Applications organized by TTI, together with "open" discussion with 42 attendees (including ESA delegates). http://www.eumweek.com/docs/2014_conf_programme_MAIN.pdf
9	16th International Symposium of ANtenna Technology and applied ElectroMagnetics		VICTORIA, CANADA	13-16 July 2014	
10	NASA/ESA Conference on Adaptive Hardware and Systems			14-18 July 2014	
11	18th International ITG Workshop on Smart Antennas	FhG IIS	Erlangen, Germany	12-13 March 2014	GAMALINK poster was presented during the poster session to more than 70 participants http://www.wsa2014.com/

Table 2 – GAMALINK dissemination calendar.

5 Website and contacts

More information about the project is available at http://www.gamalink.eu. The main contacts for GAMALINK results on each partner are provided below:

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