GALILEO Research and development activities

First call

Activity A

User receiver preliminary development

STATEMENT OF WORK

GJU/03/094/issue2/OM/ms

Issue 2
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1. **INTRODUCTION**

1.1. **Background**

The user segment and in particular the user receiver is at the heart of business opportunities. Tools and systems adapted to user requirements shall be developed to enable the optimal integration of Galileo services (timing, positioning and navigation) into everyone's life.

Receivers, and more generally, user terminals (defined as receivers with additional functionalities like communication, local element interface, inertial device, maps…) must be commercially available in time for the Galileo exploitation phase to ease and catalyse the market penetration of Galileo services. Therefore the user segment of Galileo must be developed in parallel with the core system.

The main aims for the receiver development are:

- To foster the European industry in the area of GNSS receivers and terminals. Galileo is a unique opportunity to encourage the development of GNSS receivers in Europe. Taking into account the strong position of Europe in the manufacture of telecommunication device, the development of a strong European capability in the manufacture of positioning device (GNSS receiver) is important to afford the emergence of the combined telecommunication-positioning technologies, applications and services that represent a huge market.
- To make available as soon as possible prototype of Galileo receiver to ease the market penetration of the different Galileo services.
- Create an appropriate research and development environment to ease the creation of patents (Intellectual Property Rights) on the Galileo receiver. The revenue coming from software and chipset royalties, themselves based on patent IPR revenues has been identified as a possible revenue source for the Galileo Operating Company.

1.2. **Development objectives**

The objectives of this activity are:

- to detail and consolidate the receiver and user terminal development plan in order to have a robust and consolidated picture of all the necessary developments.
- to create a development tool called “Software Receiver” that will serve as a basis for all the future receiver and user terminal prototyping activities. It will support the receiver manufacturer to develop in an innovative way the appropriate knowledge and expertise in various domains in order to build competitive, efficient and quality prototype of user receivers in the near future.
- development of “core technologies” necessary to develop Galileo and combined GPS/Galileo receiver (in view of optimal miniaturisation process)
- development of the prototypes (front-end, antenna..) as building blocks of the Galileo receiver prototype.
• to develop a validation tool for testing the receiver prototypes before the availability of the Galileo signal in space.

Three tasks shall be performed in this first call:

1. **Support to the receiver and terminals development strategy.** In order to have a clear picture of the development of the user segment, the first task consists in the consolidation of a Development Plan for the receivers and user terminals considering the Galileo development and the potential combination with other GNSS and non-GNSS systems at user level.

2. **Receiver core technology.** The second task is devoted to the development of the receiver core technologies. This research-oriented activity is an important step in the development of the Galileo User Segment. It supports the receiver manufacturer to develop the appropriate knowledge and expertise, in order to build a competitive, technologically innovative, and high-quality prototype of user receivers in the near future. It will also offer the possibilities to investigate more deeply some specific aspects, potentially protected by new IPR.

3. **Prototype of user receiver.** The third task considers the development of a first prototype of a Galileo receiver, based on the current knowledge on GPS and SBAS receiver technology and existing studies on the Galileo receiver. It provides at an early stage a Galileo/GPS/SBAS combined receiver (even with limited capabilities and performances), demonstrating its feasibility. Basic validation tools will also be developed in this activity.

All the development within this first call shall consider an integrated GPS/Galileo/SBAS GNSS receiver.

### 1.3. Input documents

The following inputs are provided to this task. Some documents will be delivered by the customers at the Call for Tender time, others at the Kick-off of the project.

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2. ACTIVITIES DESCRIPTION

2.1. Task 1: Support of the receiver and user terminals development strategy

a) Consolidation of the development plan
The contractor shall develop and consolidate the development plan considering the followings elements:

1. The different phases (development and validation phase, deployment phase, operational phase) and milestones (utilisation of the GSTB V2 satellite, IOV...) of the Galileo program.
2. The GPS evolution and modernisation (e.g. introduction of L2, L5).
3. All the phases of the development of the receivers and user terminals (definition, prototyping, testing, commercialisation).
4. The different types of receivers considering the four following Galileo services: Open Service, Safety of Life Service, Commercial Service, S&R.
5. The different types of receiver considering the constraints and requirements of the existing and future GNSS application domain (chipset for mobile phone and for car navigation system, receiver for rail, aviation, maritime, geodesy, S&R, indoor, LBS...).
6. The evolution of other navigation systems (e.g. inertial sensors) and communication technologies (e.g. UMTS, UWB...) that can be combined with Galileo within the user terminal.
7. The existing market analysis of the GNSS application and services.

Other external elements that can influence the development of the receivers and user terminals shall be identified by the contractor and agreed with the customer.

The contractor shall issue several version of the development plan at
- KO+2m (version 1)
- KO+9m (version 2)
- KO+16m (version 3)

At each issue of the development plan the contractor shall provide:
- An executive summary
- A Gantt chart representation of the development plan
- The development plan
- A justification document including all the analysis made to support the consolidation of the development plan

The main document shall at least include:
GALILEO JOINT UNDERTAKING

- The main actions and milestones
- The key external factors (GPS modernisation, UMTS, other technologies development)
- The key internal factors (development of the local elements, GSTB v2, Galileo full operation capability…)

The justification document shall at least include:
- assumptions taken for the development plan
- remaining open points
- specific studies to assess the choices
- sources of information

b) Receiver development analysis
In addition to the development plan and associated document, the contractor shall perform the necessary analysis to extract the following information and provide it under the form of dedicated analysis documents.

1. Identification of the core technologies that need further developments to bring competitive combined (Galileo/GPS/SBAS) user receivers and terminals on the market (identification of priorities).
2. Schedule for an optimised development and testing of receiver/terminal breadboard and prototyping
3. Possible industrialisation and commercialisation strategies for the introduction of combined user receivers/terminals in various application domains (schedule, market penetration)
4. Identification of the standardisation or certification needs for the receiver
5. Identification of the criteria for the receiver to address the future GNSS market needs (e.g. miniaturization, low power consumption, provision of integrity, certification…)
6. Identification of the development process of the user receiver and terminals for specific applications and services

These analysis documents shall be submitted two months after the second and third issue of the development plan:
- KO+11m (version 1)
- KO+18m (version 2)

Outputs
The following document shall be delivered as a minimum resulting from this activity:
- Development plan and associated justification document (version 1, 2 and 3)
- Analysis document (version 1 and 2)

In addition a progress report shall be submitted every 6 months. A final report shall be submitted at the end of the project.

Schedule
The overall schedule for this activity is 18 months.
The main milestones are:
- Kick-off meeting in Brussels
- Initial update of development plan (KO+2m)
- Second update of the development plan (KO+9m)
- Final updated of the development plan (KO+16m)
- Final meeting (KO+18m)

2.2. Task 2: Core technology development

The Galileo system has some similarities with existing GNSS but presents also clear particularities that have a direct impact for the GNSS receiver.

The development of a Galileo receiver shall be partially based on the existing technologies developed for the GPS, Glonass and SBAS receivers. However, the Galileo system will provide new features that imply specific developments. In the same way, the creation of a combined Galileo/GPS receiver is also an important technological challenge that will deserve specific developments.

Investigation in various core technologies shall be made, for example: L5 signal (antenna, RF...), BOC modulation, utilisation of the pilot tone, E6 signal, encrypted data processing, new architecture (multi-correlator, multi-channel receiver...), SV selection strategies, interference mitigation, multi-carrier phase ambiguity resolution (MCAR), high-sensitivity receiver, assisted techniques, provision of integrity, provision of authentication, Galileo data demodulation including investigation on the forward error coding (FEC).

Moreover, the different possible environments must be taken into account (indoor, urban, high dynamic, interference, multipath...). Investigation on the impact of these environmental conditions shall be made, such as interference mitigation device (e.g. pulse blanking, data wiping).

2.2.1. Subtask 1: Software Receiver development

In order to allow the development of the core technologies in the most efficient and optimal way, the contractor shall develop a Software Receiver (possibly conceived as for Radio receiver future development).

It shall allow performing most of the analysis of the core technology proposed above.

The software receiver shall be conceived as a tool to make specific development and further investigation in all the specific functions of a GNSS receiver.

The functions of the Software receiver shall include, at least:

- Signal simulation
- Front-end modelling
- Correlation and filtering
- Signal and Data processing
- PVT computation
During its specification, this software receiver shall be conceived as an “open tool” with a modular design that can be used without restrictions (IPR, COTS licenses) by third parties in order to perform their own investigation by replacing some implemented algorithm by their own algorithms (e.g. a skeleton software structure with more modules for the different functions).

The software tool architecture shall allow the future development and integration of additional functions related to e.g. local element, inertial sensors, telecommunication interface…

The development of the receiver shall be organised in different phases:

- **Specification phase**
  The contractor shall propose a document including all the specification for the Software receiver (architecture, functionalities…).

- **Design phase**
  After the receiver specification, the contractor shall start the detailed design of the software receiver. This phase shall be concluded with a milestone called Critical Design Review. A document describing the detailed design of all the elements of the Software receiver shall be proposed.

- **Implementation phase**
  Having designed the software receiver, the contractor shall start the implementation (coding) of the various elements. In particular, the Graphical User Interface shall be presented and discussed with the customer.

- **Integration and validation phase**
  Having implemented all the elements of the receiver, the contractor shall integrate them and make the necessary internal test to validate it.

- **Testing phase**
  In this phase the contractor shall successfully test the software receiver in conformity with the test plan and initial requirements.

During the specification phase, the contractor shall define:

- The interface between the different modules of the Software Receiver (input, output, exchange format)
- A consolidated implementation and development plan for the Software Receiver
- The integration and validation plan
- The test plan

An intermediate version of the Software Receiver shall be submitted to the customer for comments. The availability date (indicatively at the mid term of the project) of this preliminary version will be proposed by the contractor according to the optimal overall software life cycle.

For each release of the Software Receiver, a user manual shall be provided. In addition the specific documentation describing the assumption and choices made during all the phase of development of the receiver shall be produced.

The recommendations for the evolution of the Software Receiver shall also be specified within the task.
The following constraints shall be applied to the development of software:
- The contractor shall follow the standard engineering rules for implementation of software.
- The software receiver will be based on a modular architecture allowing to replace modules without re-building the tool;
- The software receiver shall run on a standard personal computer to allow the maximum use from people not involved on its development;

**Dissemination activities**
Appropriate dissemination activities shall be undertaken in order to describe the Software Receiver under development and propose it as a reference tool for the future core technology development for the Galileo receiver and terminals.

Among other activities, the contractor shall:
- Produce a leaflet explaining the main development objectives of the Software Receiver
- Produce a leaflet explaining the achieved result at the end of the project
- Participate at different conference (around 2 per year) to present the Software Receiver.

**Outputs**
- Software Receiver Specification document
- Interface description document
- Implementation and development plan
- Validation plan
- Test plan
- Design data package
- Verification results
- A software receiver including all the basic functions of the receiver (source code, building procedures and all the necessary tools to run the software)
- Recommendation document for the improvement of the software receiver
- Leaflets for the dissemination activities

In addition a progress report shall be submitted every 6 months. A final report shall be submitted at the end of the project.

**Schedule**
This activity shall start at KO and last 24 months.
The following main milestone are foreseen:
1. Kick off (KO)
2. Completion of specification phase
3. Completion of design phase
4. Completion of implementation phase
5. Completion of integration and validation phase
6. Completion of testing phase
7. Final meeting (KO +24m)

The experts from Task 1 shall be associated to the main review.
2.2.2. **Subtask 2: Software receiver utilisation**

Using the preliminary version of the Software receiver, the contractor shall start the investigation on some of the core technologies as listed in the introduction of this Task. These core technologies will be agreed with the customer at the beginning of this activity.

The contractor shall investigate different algorithms for some core technologies and present a comparison report.

**Output**
- Description of the core technologies that will be implemented and tested containing the state of the art in the domain and the major issues.
- Results of the experiments performed using the developed Software receiver and recommendations for further activities;
- Synthesis report

In addition a progress report shall be submitted every 6 months. A final report shall be submitted at the end of the project.

**Schedule**
This activity shall start not later than KO+12m and last until KO+24m.
The main milestones are:
1. Start (KO+12m)
2. Core technologies selection
3. Implementation review
4. Testing and analysis review (KO+24m)
2.3. **Task 3: Receiver prototype development**

In parallel to the activities around the software receiver development and the core technologies proposed in task 2, the Galileo program needs to have prototype of combined receiver (Galileo/GPS/SBAS) at an early stage.

The tasks shall include the four following subtasks:

1. The specification, design and development of the tool for the validation of the prototype development (simplified single satellite simulator).
2. The specification, design and development of a GNSS antenna for a Galileo multi-frequency receiver (L1, E5a, E5b)
3. The specification, design and development of the HW Front End for a Galileo multi-frequency receiver (L1, E5a, E5b)
4. The FPGA specification and design of the other elements of the prototype receiver (correlation and filtering, signal and data processing, PVT algorithm, component choice)

The development of these elements of the prototype receiver shall be based on the state of the art development in the GNSS technologies and on existing studies on the Galileo specific technologies.

It shall be capable to perform all the basic functions of a Galileo/GPS/SBAS receiver.

The work shall be organised considering the following phases:
- Specification
- Design
- Development (not applicable for subtask 4)
- Integration and validation (not applicable for subtask 4)
- Testing (not applicable for subtask 4)

During the specification phase, the contractor shall produce the following documents:
- Development plan of the simulator
- Validation plan of the simulator
- Test plan for the simulator
- All the interface control documents

**Schedule**

All the subtasks should start at the latest at KO+6m and finish at KO+24m.

2.3.1. **Subtask 1: Mono-channel simulator of Galileo satellite**

The contractor shall specify, design, develop, validate and successfully test a simulator that shall produce (before front-end) a Galileo like signal coming from a single satellite.

The simulator shall allow the validation of all the functions of the receiver prototype from the RF input to the signal and data processing (but without the PVT functions).
The input and output capabilities of the simulator shall be described with a dedicated document.

**Outputs**
- Specification of the simulator
- Design of the simulator and associated studies
- Development plan of the simulator
- Validation plan of the simulator
- Test plan for the simulator
- Document describing the result of the validation
- Document describing the result of the tests
- Interface description document
- Simulator user manual
- Mono-channel simulator

In addition a progress report shall be submitted every 6 months. A final report shall be submitted at the end of the project.

### 2.3.2. Subtask 2: L1-E5a/E5b antenna design

The contractor shall specify, design, develop, validate and successfully test an antenna prototype to be able to receive the real signal for future validation of the receiver prototype with real signal from the RF input to the PVT solution. The antenna shall be able to detect Galileo signal in the L1, E5a and E5b frequency bands.

At the end of the project the contractor shall make recommendation for future development of GNSS multi-frequency antenna.

**Outputs**
- Specification of the antenna
- Design of the antenna and associated studies
- Development plan of the antenna
- Validation plan of the antenna
- Test plan for the antenna
- Document describing the result of the validation
- Document describing the result of the tests
- Interface description document
- Prototype antenna
- Recommendation for the design of the multi-frequency antenna

In addition a progress report shall be submitted every 6 months. A final report shall be submitted at the end of the project.

### 2.3.3. Subtask 3: Front-end prototype design
The contractor shall specify, design, develop, validate and successfully test a Front-end prototype to be able to receive the signal and down-convert it in an intermediate frequency. RF and IF filtering functions shall be implemented.

**Outputs**
- Specification of the front-end prototype
- Design of the front-end prototype and associated studies
- Development plan of the front-end prototype
- Validation plan of the front-end prototype
- Test plan for the front-end prototype
- Document describing the result of the validation
- Document describing the result of the tests
- Interface description document
- The front-end prototype

In addition a progress report shall be submitted every 6 months. A final report shall be submitted at the end of the project.

2.3.4. *Subtask 4: Receiver prototype specification and design*

This subtask includes all the activities to specify and design additional functionalities of the prototype receiver.

The receiver functions shall be specified and designed for a future implementation in FPGA.
- correlation and filtering
- signal and data processing
- PVT computation

During the specification phase, the selection of the hardware components (processor, interface…) shall be made.

The contractor shall issue the entire specific documentation data package required for the specification phase.

At the end of the subtask, the contractor shall draft recommendation for the future development.

**Outputs**
- Specification document of the prototype receiver
- Design document of the prototype receiver

In addition a progress report shall be submitted every 6 months. A final report shall be submitted at the end of the project.