China-Europe Co-Operation Agreements for Navigation: SART and LRR Developments

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Abstract. The European Commission and the European Space Agency through the Galileo Joint Undertaking (GJU), have launched in China a number of developments related to Navigation Applications and Infrastructurs. The programmatic framework is part of a broad agreement between the GJU and the Chinese Ministry of Science and Technology through which China is providing an important contribution to the Galileo development. The type of activities included in the co-operation agreement cover system studies and navigation applications services plus the development of both ground and onboard equipment for Galileo. Eleven contracts have already been kicked off, others are subject of ongoing tender actions which will raise the first, overall contribution of China to Galileo to an amount of about 65 M€. The space related developments are currently involving the development of the Galileo Search and Rescue Transponder (SART) and the satellite Laser Retro Reflector (LRR). An overview of the ongoing activities is provided in this article with a more detailed reporting on the SART and LRR developments.

1 China-Europe Co-Operation Framework

The European Commission and ESA have signed in 2003 a co-operation agreement with the Chinese Ministry of Science and Technology defining the contribution of China to the overall development plan of Galileo. The technical annex defining the contents of this co-operation foresees the development of on-board/ground equipment, plus activities related to system studies to promote the use of Galileo in China. The contribution of China to the Galileo development is channelled through the Galileo Joint Undertaking which is the institutional body constituted by the European Commission and the European Space Agency to steer the activities related to the validation and full deployment phase of Galileo.

2 Galileo Activities in China: Overview

Between the year 2005 and 2006 the Galileo Joint Undertaking has kicked off eleven different projects. A detailed description of the SART and LLR project is provided in the following paragraphs, while a summary description of the other activities is given here below.

China Galileo Test Range. The overall objective of this activity is the development, deployment and operation of a ground based infrastructure of Galileo pseudolites, to be used:

- As a tool to perform analysis and research on the Galileo 'Signal In Space' (SIS)
- Act as a 'Test Environment' for Galileo receiver and applications.
- Form the basis of a series of demonstration and promotion activities for Galileo services and applications.
- Act as a local augmentation system to deliver high performance positioning and navigation services.

Location Based Services Standardisation. This is activity is dedicated to the definition of the work to be carried out for the standardisation of Galileo as a system for mobile phones, location applications.

Ionosphere Studies. The primary objective of this activity is the investigation of on effective ionospheric correction for single frequency Galileo receivers on a regional basis and the study of ionospheric scintillations.

Fishery Applications. The project is addressing the implementation of a system based on GNSS to support applications in the fishery domain in the Chinese region. The activity includes an overall analysis of the technical and commercial aspects related to the system implementation, and will also consider the design and development of a system demonstrator proving the effectiveness of the system concept from a technical, operational and commercial perspective.

Medium Earth Orbit Local User Terminal. The Search and Rescue transponders on the Galileo Satellites will relay the distress signals transmitted by Cospas-Sarsat emergency beacons towards dedicated ground stations MEO Local User Terminals (MEOLUTs). These MEOLUTs will be in charge of recovering the message and locating the emergency beacon, as well as providing the relevant SAR distress data to the associated Cospas-Sarsat Mission Control Centre (MCC). The objective of this activity is the development of a MEOSAR Local Users Terminal Prototype (MEOLUT Prototype).

Search and Rescue End to End Validation. The primary objective of this activity is the end-to-end verification of the SAR/Galileo system requirements and the validation the forward link service by demonstrating the system and evaluating its technical performances.

Up-link Station development. For the control of the Galileo system the ground segment is organized in control centres, located in Europe, and remote stations, located worldwide and includes the following types of stations:

- Tracking, Telemetry & Command (TTC) stations.
- Mission Up-Link Stations (ULS).
- Galileo Sensor Stations (GSS).

The ULS stations are composed of one or more full-motion antennas (approx. 3-m diameter) for transmitting a spread spectrum signal in C-band (5000–5010 MHz), without operational downlink implementation, for uploading mission related information. This activity is addressing the design of the ULS station front end.

Satellite Laser Ranging Services. Satellite Ranging Services are essential for a precise determination of the Galileo satellites orbits. Through this activity the European Space Agency is procuring SLR services in China to for the GIOVEA and GIOVEB mission (the two Galileo experimental satellites) and will develop a dedicated station for the need of the IOV phase.

3 The SART and LRR Developments

3.1 The Search and Rescue Transponder on Galileo Satellites

The Galileo constellation is designed to provide, together with a global navigation service, also support to the COSPAS-SARSAT system for the provision of Search and Rescue, MEO services. The Galileo Satellites are, for these purposes, embarking a Search and Rescue Transponder interfaced with the Navigation Payload. The aim of the Galileo support SAR services is to relay distress signals from Cospas-Sarsat-defined beacons to specialised ground facilities and to relay messages from ground to beacons equipped with a Galileo receiver, using the constellation of Galileo satellites.

The SAR/Galileo service can be subdivided in two other sub-services, the Forward Link Service (relaying distress signals from beacons to ground stations) and the Return Link Service (relaying messages from ground to beacons equipped with a Galileo receiver) Fig. 1 shows a common scenario where both SAR/Galileo sub-services are used. The roles of the different components are:

- Galileo Space Segment: to relay distress signals transmitted by type-approved beacons to ground stations, transponding signals from 406.05 MHz to 1544.1 MHz; to disseminate Return Link Messages received from ground within the L1 navigation signal. The Galileo Space Segment is part of a single MEOSAR constellation and is interoperable with other MEOSAR systems such as DASS/GPS and SAR/Glonass.
- Intergovernmental SAR Satellite System (ISSS): to process beacon signals in order to recover the transmitted message and determine the beacon location; to distribute

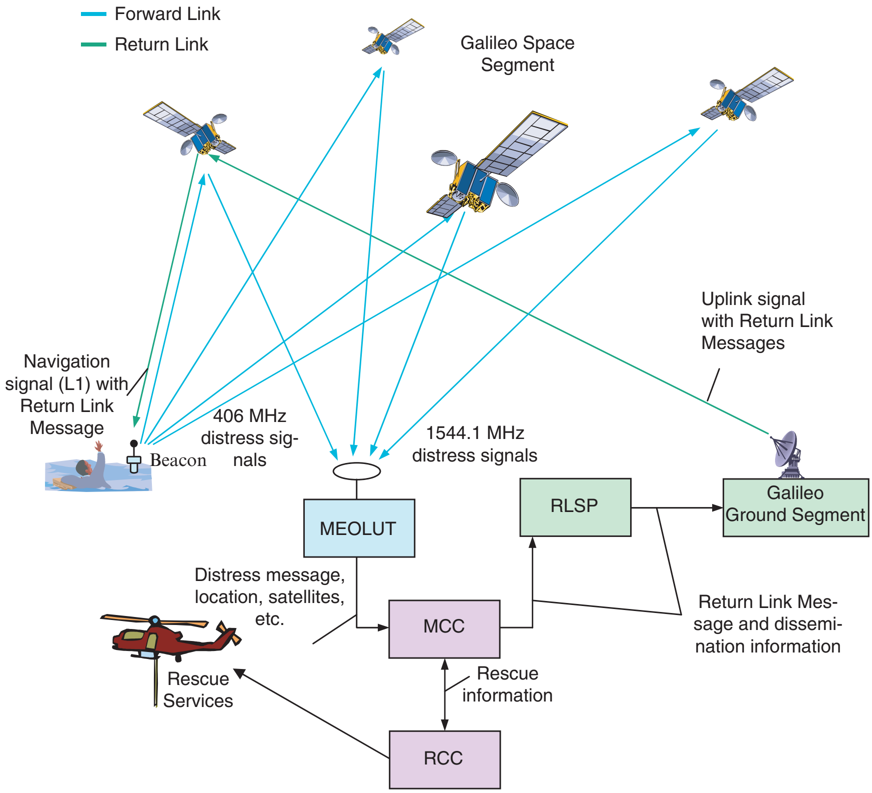

Fig. 1. Search and rescue service system architecture.

messages across the network to the Return Link Service Provider (RLSP) and appropriate Rescue Coordination Centres (RCCs). The ISSS consists of: Medium-altitude Earth Orbit Local User Terminals (MEOLUTs), Mission Control Centres (MCCs) and Nodal MCCs.

- Rescue Coordination Centres (RCCs): to launch and coordinate rescue operations.
- Return Link Service Provider (RLSP): to coordinate the requests of Return Link Messages and interface with the Galileo Ground Segment. It might be implemented as an extension/integral part of the ISSS, or as an independent centre.
- Galileo Ground Segment: to uplink the Return Link Messages to the appropriate satellites for dissemination.

3.1.1 SART Architecture and Design Driving Requirements. The SAR transponder layout and architecture are presented in Figs. 2 and 3. The transponder includes a receive chain, a down conversion section and an up conversion and amplification chain.

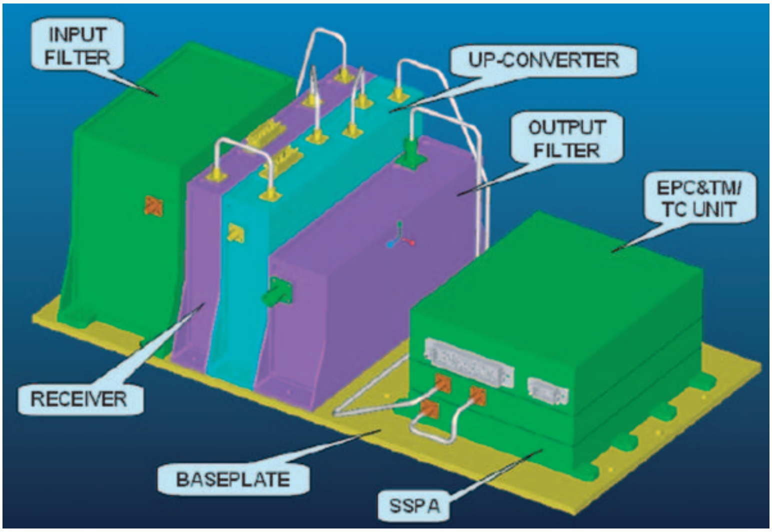

Fig. 2. SAR transponder layout.

The major design driver requirements are:

Group Delay Stability. This parameter is important as it affects directly the Time Difference of Arrival (TDOA) techniques at a MEOLUT and therefore the precise location of the distress beacon. This is a function of the BW of the input filter design.

Receiver Noise Figure. This parameter is important as it is affecting the overall G/T requirement at system level.

Frequency translation accuracy. It is an important parameter for the use of the Frequency Difference of Arrival as a distress beacon location technique. This is ensured in the SAR transponder by the use of the highly stable reference frequency from the Clock Monitoring and Control unit.

Linearity and output Power. A high linearity requirement is needed on the SART to ensure minimum occupied spectrum of the relayed beacon signals, and minimum inter-modulation or cross-products generated by the beacon signals, to avoid creating any false in-band signals. This requirement is impacting directly the design of the output power amplifier and is critical for the overall transponder power consumption. The Transponder corresponding output Power for the linearity requirement shall be equal to 5 Watt and this makes critical the design of the SSPA.

Mass and Power. Critical parameters due to the limited margins existing today at satellite level. The SART overall mass shall not exceed 8.8 kg. The overall power consumption shall be less than 45 W.

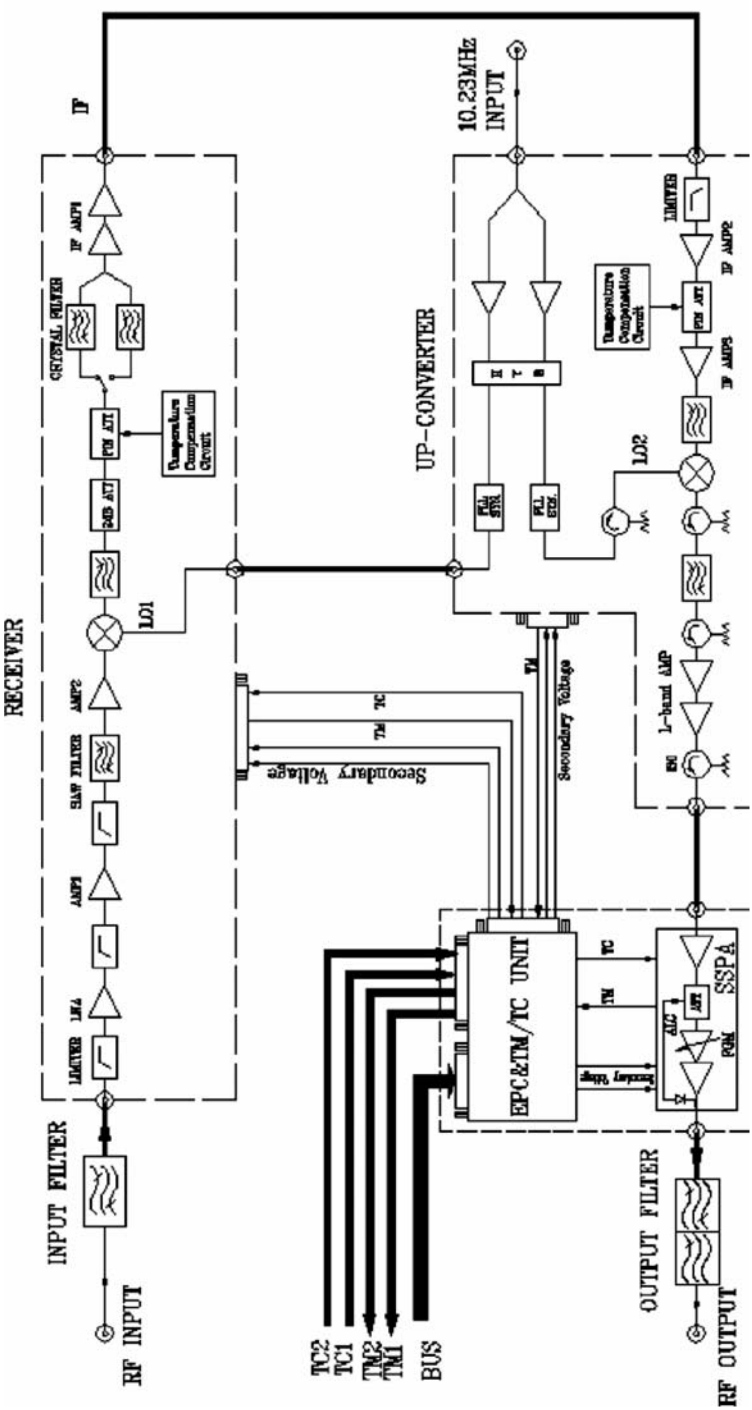

Fig. 3. SART transponder architecture.

3.1.2 Industrial consortium in China and Program Status. The SART prime contractor is China Galileo Industry with main subcontractor CAST (China Academy of Space Technology and in particular the XIRST division).

XISRT is one of the subsidiaries of CAST, located in Xi'an(China) and it is leader in payload developments in China,. Xirst has been engaged in many space related activities, including:

- Communications payloads;
- Navigation Payloads;
- Space-born communicating antenna;
- Microwave remote sensing systems;
- Space-born TT&C system and ground TT&C facilities;
- Space electronic systems and applications.

Since its foundation in 1965, it has developed a series of onboard satellite subsystems and ground applications systems for communication satellites, manned space mission and Ground TT&C stations.

The SART contract was kicked off in November 2005. It has a time span of two years and will be concluded with the delivery of 1 EQM and 4 flight models of the SART.

3.2 The Laser Retro Reflector

The Galileo Satellite will be equipped with a Laser Retro Reflector (LRR), a passive unit used for precise orbit determination. The LRR has the peculiarity to reflect Laser Pulses back to their originating source (i.e. laser ranging ground station).

The LRR consists of an Aluminium base-plate, equipped with an array of Corner Cube Reflectors (CCRs), made of fused silica and fixed in individual aluminium housings. These CCRs have the property to reflect the incoming laser pulses exactly into the direction of the laser source, independent of their incidence angle. Increased incidence angles, however, reduce the intensity of the reflected laser light. So for practical purposes the incidence angle is limited to about 15° which fully satisfies the Galileo needs.

The required LRR size (470 mm × 430 mm), respectively number of CCRs (84) is determined by the satellite orbit altitude and by the required incidence angle to receive valuable signals in the ground stations. The LRR is mounted on the +Z panel of the Galileo Satellites (Nadir orientted), lateral to the Navigation antenna, the Search and Rescue antenna is also present on this panel.

3.2.1 Major Requirements. The main requirements for the LRR are reported here below. Of particular importance for the achievement of the overall performance is the effective reflective area of the LRR that shall be grater than 660 cm^2 for a Field of View of ± 15degree. The total mass shall also be less than 5 kg as limited margins are available at satellite level for the accommodation of payload and platform equipment. The design of the LRR shall also be radiation-proof ensuring a lifetime of the equipment greater than 12 years.

LRR Main Technical Requirements

Performance	Specification
Range finding	Provide capability for range finding between laser ground station and the Galileo satellite.
Laser wavelength	532 nm
Field of View angle	Elevation: ±15°(wrt + ZLRR axis) Azimuth: 360°(about +ZLRR axis)
Ranging accuracy	To be considered to match the overall accuracy of 2 cm.
Physical Characteristics	Symmetrical, planar array, whose normal to the entrance surface coincides with the nadir axis of the Satellite.
Corner cube material	Fused silica with coated or nocoated
Total effective area	> 660 cm^2, at any point of the Earth
The mass of the LRR	< 5 kg
Lifetime	In-orbit: > 12 years

A picture of the structure of the LRR is shown in Fig. 4

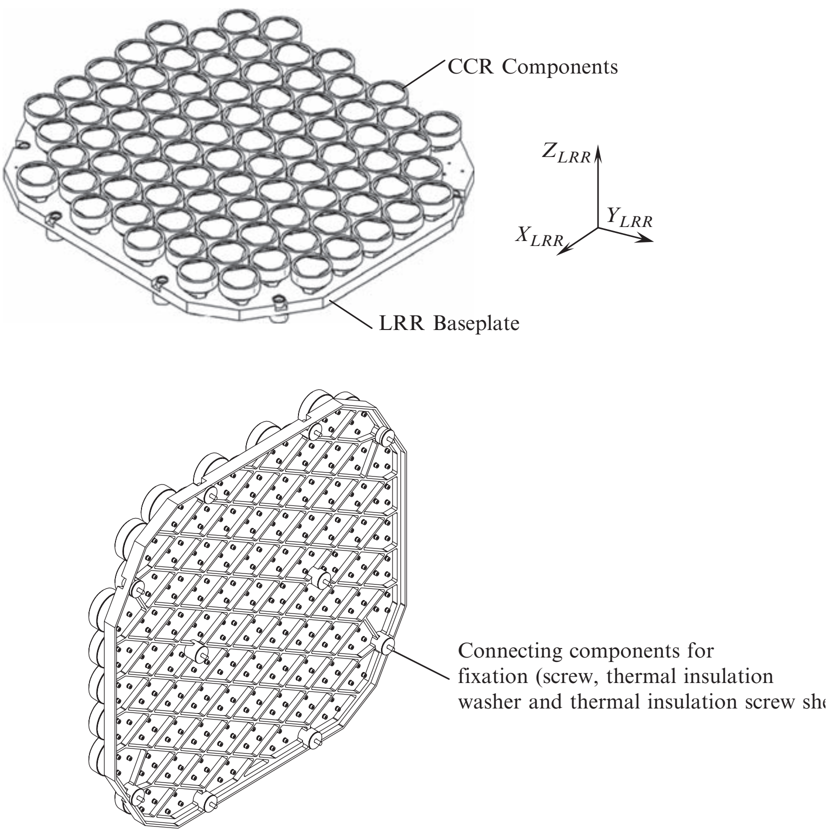

Fig. 4. Physical structure of the LRR Unit.

3.2.2 Industrial Consortium in China and Program Status. The LRR prime contractor is China Galileo Industry with main subcontractor NCRIEO. NCRIEO is a state-owned Class I institute that belongs to China Electronic Technology Group Corporation (CETC).

NCRIEO was established in 1956. As the earliest national electronic component and material institute, it undertook much important national technological projects and obtained 127 researching achievement.

NCRIEO started the R&D in infrared related technology from 1958, laser related technology from 1964. It is the only integrated institute that forms a complete set with laser and infrared material, components, devices and application system. In recent 30 years, the institute undertook and accomplished over 500 national research tasks.

The LRR contract was kicked off in November 2005. It has a time span of two years and will be concluded with the delivery of 1 QM and 4 Flight Models and 1 Flight Spare of the LRR at the beginning of 2007.

4 Conclusions

This article has provided an overview of the activities performed in China in the context of a broad co-operation agreement between the European commission, the European Space Agency and the Chinese Ministry of Science and Technology. A detailed description of the development of two on board equipment: the SART and the LRR has been given. The involvement of China in activities related to the development of Galileo and its world-wide applications is quite important and covers ground developments as well as onboard HW development.

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