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PROJECT FINAL REPORT

Grant Agreement number: 313002

Project acronym: SPARTACUS

Project title: Satellite Based Asset Tracking for Supporting Emergency Management in Crisis Operations

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1. Final publishable summary report

1.1 *Executive Summary*

The SPARTACUS project "Satellite Based Asset Tracking for Supporting Emergency Management in Crisis Operations" refers to the EU Framework 7 collaborative research project with Grant Agreement number 313002. It addresses the theme SEC-2012.4.2-1: "Positioning and timing tools to guarantee security assets trace & tracking together with worker safety in a secure environment".

The project addressed the importance to support the management of emergency services and aid, following a natural or man-made disaster, as one of the key enabling element in order to increase the resilience of society. GALILEO together with EGNOS will provide more robust positioning capability, enhancing the adoption of satellite technologies in services where signal continuity and integrity are required. This will have an impact on various sectors and applications, including emergency and disaster management, Search and Rescue Service (SAR) tasks and location-based services (LBS) supporting responders in mission critical operations.

In this scenario, SPARTACUS project designed, realized and tested in simulated and real world scenarios a wide span of solutions that can be deployed in operative missions for enhancing Location Awareness in emergency management, replacing the use of the traditional terrestrial networks, which are supposed to fail or been denied during disasters with satellite-based navigation and communication technologies, that can be deployed in operative missions.

SPARTACUS aims to impact in two main sectors: the transport sector (rail system monitoring and logistics operations), and the security sector (emergency response). For the transport sector, SPARTACUS answered the need to look for precise and robust tracking solutions in order to trace freight train across the whole railway network (across national or network boundaries) and to improve the system reliability and safety of vehicles transporting dangerous goods. For the emergency response sector, SPARTACUS developed tools and methods that have the potential to be taken up by practitioners in Crisis Management by promoting the consistency in the response of disasters (networking), and the support to coordination of operational organizations in the field.

In order to achieve these objectives, SPARTACUS relies on a consortium of leading experts across diverse fields, capable of realising the results technically and supporting their validation in a real operational environment, composed by technology providers and developers, service providers, system integrator, and relevant end users. By its Consortium, SPARTACUS innovations include hardware adaptations, algorithms for precision improvement, dead reckoning functionalities, location awareness, and ad-hoc independent communication networks.

The project activities culminated with the demonstration of the innovations of SPARTACUS integrated system carried out during the whole last project year through a validation campaign that comprised both laboratory test and real operational in-field exercises. As last, a specific emergency scenario (i.e. train accident) has been designed to demonstrate the SPARTACUS support capabilities during the operational management of a crisis, involving operators for transport assets and first responders. The final validated system is able:

1. to provide and enhanced positioning features in indoor and outdoor environment by modular devices and smartphone applications;

2. to be independent on the condition of in-situ communication infrastructure since it relies on ad-hoc and deployable communication networks enabling access to a set of mobile / web applications.
3. To display in an integrated common picture a large set of real time data from the field (tracking devices and smartphone apps), enabling a reliable support for coordination and management to decision makers.

1.2 *Summary Description of Project Context and Objectives*

1.2.1 SPARTACUS Project Context

Nowadays the available Global Navigation Satellite Systems (GNSS) (e.g. GPS, Glonass, Beidou) are a consolidated technology for applications where precise location is needed, demonstrating their reliability in the positioning and tracking of moving objects. Looking closer, as part of the European GNSS (EGNSS) program, the European Geostationary Navigation Overlay Service (EGNOS) is nowadays a reality and has been more and more used in aviation applications[2], whilst the European satellite system GALILEO is going to complete the launching phase and is now ready to be fully operative since the first satellites in orbit started to broadcast navigation signals[3]. GALILEO together with EGNOS will provide more robust positioning capability enhancing the adoption of satellite technologies in services where signal continuity and signal integrity are required, such as those related to Public Regulated Service (PRS) and Safety of Life (SOL) applications (available from EGNOS since 2011). This will have an impact on various sectors and applications, including emergency and disaster management, Search and Rescue Service (SAR) tasks (linked to the GALILEO SAR service) and location based services (LBS) supporting responders in mission critical operations. Finally, the availability of GALILEO full services, expected by 2018 for both PRS and SAR[4] opens the door for a two year (2016-2018) demonstration phase where new solutions can be introduced and tested.

In this scenario, the SPARTACUS project started in November 2013 with the ambition of studying, designing, developing and testing in real case applications a complete set of modular solutions for enhancing Location Awareness in emergency management and crisis operations, replacing the use of the traditional terrestrial networks, which are supposed to fail or been denied during disasters with satellite-based navigation and communication technologies, that can be deployed in operative missions.

The SPARTACUS project "Satellite Based Asset Tracking for Supporting Emergency Management in Crisis Operations" refers to the EU Framework 7 collaborative research project with Grant Agreement number 313002. It addresses the theme SEC-2012.4.2-1: "Positioning and timing tools to guarantee security assets trace & tracking together with worker safety in a secure environment".

In order to achieve this overall objective, SPARTACUS lays its foundation on satellite-based technology that ensure precise positioning and timing capabilities to secure tracking, tracing and functionalities, customized for the following areas of application:

- Tracking, tracing and localizing critical transport assets (railway containers) in case of major failure of existing networks (communications and power)

[2] http://egnos-portal.gsa.europa.eu/aviation-sector
[3] http://www.esa.int/Our_Activities/Navigation/More_Galileo_satellites_broadcasting_navigation_signals
[4] http://www.spaceinfoday.eu/system/h2020-space-infoday/files/D2-GNSS-Overview.pdf?1447770603

- Tracking the flow of relief support goods from the sending side to the receiving/end place
- Supporting coordination of first responders in disaster management operations, ensuring their safety

By working on technological solutions at both HW and SW level and by empowering the use in operational scenarios of decision support tools and mechanisms, SPARTACUS will result in a set of modular, scalable and configurable solutions, that are application-oriented, technologically advanced and user accepted.

From a technical standpoint the SPARTACUS system comprises, smart tracking units, which are customization (e.g. creation of a pedestrian profile) of Commercial Off The Shelf (COTS) devices, smart-devices running applications which specialise in localisation, coordination in the field and dead reckoning (FLARE), the exchange of geo-tagged media (ASIGN) and tracking and managing of transport assets (TIMISS and CTAT). The SPARTACUS Communication Units provide the link between on-site and remote site elements using terrestrial cellular networks, namely 3G, 4G or Wi-Fi or a satellite backhauling link. Tracking data, together with relevant information and critical content are visualized my means of a mapping portal provided with Decision Support logics and capabilities embebbed into a Geographical Information System (GIS) configuration. These continuously track and trace time, position and ID of all units together with other local data and data available from open services and third party platform are key features that SPARTACUS integrate and can offer to the users. By linking with each other through a common communication architecture, the system can monitor and manage assets, aid delivery and first responders at the scene.

1.2.2 Project objectives

SPARTACUS had the aim to create an integrated system relying on spatial and terrestrial technologies, to strengthen the coordination and situational awareness at an operational level in emergency and disaster scenarios. To accomplish it, the project focused on different clustered objectives, reported in the following:

- Identification of critical assets, user's requirements, needs, gaps and procedures in crisis management operations
- Development of positioning and timing capabilities and realization of satellite based solutions
- Guarantee no lacks of communications among the solution elements, in emergency scenarios
- Ensuring system reliability and integrity for security applications
- Ensuring system flexibility and adaptability
- Ensuring that system support emergency management in crisis operations

1.3 *Description of the Main S&T Results/Foregrounds*

The section contains a summary of the main SPARTACUS results and generated foregrounds.

1.3.1 SPARTACUS results

SPARTACUS Tracking units achieved various innovative features presenting an all-in-one GNSS + INS solution for multiple application areas (i.e. rail, road logistics, emergency services, etc.). They are cost-effective (especially in the case of personnel tracking) respect to the State of Art with similar technology characteristics, with advanced detection of GNSS outliers and cutting edge pedestrian navigation algorithms implemented in the firmware. The tracking units are able to monitor position continuously (any-time and any-where) thanks to GNSS and INS cooperation for localization and they are autonomous (battery integrated) and so infrastructure independent. Moreover, work on prototypes optimization was performed in order to minimize power consumption, weight and cost. For first responders' application, the possibility to link via Bluetooth the tracking device with smartphone application furtherly enlarge the capability to track, trace and navigate ensuring good accuracy also in indoor environment.

SPARTACUS communication units were specifically designed to enable communication over different and multiple users, being fully independent from external infrastructure, and last but not least being compliant to different operational conditions (i.e. rail environment, portability by backpack from field users, transportability by vehicles). The designed communication units rely on multiple technologies in a single access point, provide high data-rate (4G), enabling hundreds of users through Wi-Fi and terrestrial networks. Multiple features and services were designed and tested to allow wide communication capabilities such as: group-calls, push-to-talk, pre-emptive calls and interoperability. Work was performed to optimize weight, size and usability, resulting in a user-fitted solution, supported by specific protocols and algorithms to monitor status of connections and automatic channel selection features.

SPARTACUS apps and web portals: The mapping capabilities of SPARTACUS system are given from relevant information (i.e. positioning, point of interests, messaging, etc.) gathered by smartphone applications deployed and used in the field and from desktop tools (web-portals) made available to coordination centers. These elements were designed to visualize in-field information in georeferenced maps, and so supporting decision-makers with a more comprehensive scenario made by contextual information. Through the project testing phase, the capabilities validated comprises: sending-receiving GNSS tagged video and audio clips, collection with offline supports, high-performance tracking functionalities/algorithms (outdoor and indoor transitions, step detection, collaborative positioning) and activity recognition. Through the Spartacus Mapping Portal, a comprehensive mapping tool was designed and validated able to support adding layers coming from all the Spartacus web-portals (ASIGN, flare, TIIMISS, CTAT).

1.3.2 Recommendations from users and SPARTACUS heritage

A series of best practices and recommendations resulted from the demonstration and validation of SPARTACUS results are reported hereafter:

- An extensive campaign under field conditions is necessary with the engagement of real and various users (as happened in SPARTACUS project – i.e. Urban Search and Rescue, Technical Assistance and Support Team, Assessment & Coordination Experts, Operations Center, Fire & Rescue Services);
- Field trials enhanced the understanding of relevant application scenarios, and end-user feedback contributed to continuous improvement of technologies that should be performed throughout the project life-cycle;
- It is noted the effectiveness of the integration of technical project personnel into the first responders team, especially during the in-field exercise, facilitating the exchange of relevant information from users and update on new tools and technology advancements for the users;
- Technical setup and configuration need to reflect the Standard Operations Procedures (SOPs), in such a way to firmly evaluate the impact on operations and potential benefit;
- Comprehensive Training is required;
- Operational environment set by real end-users independently by research project are necessary and fruitful to enhance user acceptance on the value and effectiveness of the technology;
- Synergies between Field Exercises and Technology Demonstrations in research project are necessary and need to be fostered and strengthened from European Commission entities and policy makers. Exercises like EU-ModEX are the most suitable environment to test and validate results for projects of the size of SPARTACUS guaranteeing: mission realistic scenarios, economically efficiency, excellent option for maximizing project impact (dissemination, exploitation, standardization).

1.4 *Project Impact including dissemination and exploitation activities*

In what follows the project impact is presented with a focus on both Dissemination and Exploitation. SPARTACUS aims to impact in two main sectors: the transport sector, mainly rail system monitoring, logistics operations and fleet management, and the security sector with particular emphasis to emergency response, management/coordination and first responders' safety.

Transport application

In the transport application area, infrastructure managers and companies dealing with vehicles (operators and owners) in railway environment – such as combined transport (or intermodal) operators represent the customers, although they are also users.

In details, rail infrastructure managers might be interested in SPARTACUS solution since it offers an alternative to the further infrastructure investments in legacy and signalling system (such as wayside systems). SPARTACUS allows the transfer of investments on vehicles domain that can independently send positioning/timing information to infrastructure managers in order to recover potential information on the use of infrastructure and enabling possibilities to refine charges/toll services on the operators (so decrease of investment cost and increase of revenue possibilities). Concerning intermodal operators, the monitoring of proprietary fleet of wagons is one of the main requests for such stakeholder. They can exploit SPARTACUS tracking technology as enabling element for assets monitoring and management, allowing them to intervene precisely and in advance on wagons before potential accidents or failures occur. In the same sector but for different scopes, the logistics companies represent customers since they can benefit from SPARTACUS tracking solutions to trace and monitor own fleet vehicles and goods delivered for their own customers. For logistics purposes, NGOs can also benefit from the SPARTACUS solutions, but dedicated motivations are needed in this case. At a preliminary level, the purchase of equipment is related to financial capabilities of the organization, which largely depend on donors' offers.

It's worth to notice that currently there is not present a reference standard for logistics operations among humanitarian organizations because of the fragmentation of the technology means for shipments' monitoring and goods' delivery. As example, the International Federation of Red Cross and Red Crescent Societies (IFRC) or the international organization Médecins Sans Frontiers use the business suite ODOO (new version of Open ERP).

Transport domain: rail system monitoring and logistics operations	
Users	Railway and logistics stakeholders: ▪ Rail-traction service providers ▪ Containers owners/operators ▪ Combined transport operators or wagons-keepers ▪ Rail Infrastructure managers ▪ Public bodies and authorities
Customers	▪ Rail infrastructure managers ▪ Combined transport operators ▪ Logistics companies ▪ NGOs

Emergency response application

For the domain of emergency response the users involved are the operational units[5]. In detail:

- actors that role is to take action in the disaster field such as fire-fighters, first responders, emergency services, police and civil protection units;
- actors involved in disaster management and coordination which role is in the framework of decision-making (i.e. OSOCC[6]).

Differently to the transport sector, the customers in the emergency management field are different from the users. In this case, a classification among public and private entities represents an effective way for customer identification.

For the public side, SPARTACUS customers are: European Civil Protection (EUCP), United Nations Disaster Assessment and Coordination (UNDAC), National authorities (e.g. Ministries), etc. For the private side, potential customers are companies offering disaster management services and/or technologies in support of civil protection, which often are ruled by national regulations in turn.

Emergency domain: disaster response operations		
Users	Operational units, field and action bodies involved in response phase: ▪ Actors that take action in disaster field: first responders, fire-fighters, police, civil protection units ▪ Actor involved in disaster management and coordination: decision-makers (i.e. OSOCC)	
Customers	Public sector: ▪ European Union Civil Protection (EUCP) ▪ United Nations Disaster Assessment and Coordination (UNDAC) ▪ Governmental organizations (local/regional/national civil protection) ▪ Fire-fighters service	Private sector: ▪ Companies offering disaster management services and/or technologies in support of civil protection

1.4.1 Dissemination

The focus of project dissemination activities was to enlarge opportunities within the aforementioned two target domains, exploiting the network capabilities of the Consortium.

In order to raise awareness on the project, contribute to decrease any potential non-technological barrier to the market uptake and last but not least, share the research advancements and project innovations also general public and scientific community have been fully considered as target audience of dissemination activities. The main target audience reached by project dissemination activities are summed in the following table.

Target audience	**Examples of target domains**
General Public	• Citizen association • Magazines • The Media and the web
Emergency operations	• Emergency response • Emergency management/coordination • Safety of first responders

[5] Such definition is in accordance to the CoU user mapping

[6] http://www.unocha.org/what-we-do/coordination-tools/osocc-rdc/overview

Transport asset	• Fleet management • Rail system monitoring • Logistic operations
Scientific community	• Research in tracking and navigation technologies • Research in communication technologies • Research in monitoring applications • Research in space and security

In the following for each year, key events and general considerations of the dissemination performance are presented.

1.4.1.1 First year

The first step in project dissemination was to raise awareness to the wide public and one of the main target domain related to the project (emergency response). This was done in the early stage of the project since the 1st year mainly focused on setting up of the project context and initial design phase. Some of the most strategically relevant events are reported highlighting the target audience and interactions to increase SPARTACUS visibility:

- SPARTACUS and REWARD project: On 23rd and 24th October 2014 at Mostra d'oltremare (Naples), the REWARD final workshop was successfully held with around 50 participants including EC projects' coordinators and partners, research centers and institutions dealing with nuclear radiation detection, industries and several representatives from Security Forces. The occasion was useful to get interest from a highly targeted audience such as Civil Protection of Regione Campania, the Italian Fire Brigades, the Spanish Guardia Civil, a representative from the International Atomic Energy Agency, a researcher from the Serbian VINCA Institute of Nuclear Sciences and the Emergency Operation Center Manager from the U.S. Navy;
- SPARTACUS and TIIMISS Workshop Sarajevo: On June 19th and 20th 2014, at the Federal Office of Civil Protection of Bosnia and Herzegovina, the TIIMISS Spartacus workshop was held. The conference was attended by people from various municipalities and cantons of Bosnia and Herzegovina. The workshop proved to be an eye-opening experience for the individual parts that make up the civil defense of the country.

1.4.1.2 Second year

In the dissemination actions performed during the second project year, particular attention has been paid to strength the link of SPARTACUS project from one side with other relevant research projects to other side with the stakeholders of target domains. In the following, some of the most relevant events attended in compliance to this strategy:

- SPARTACUS and DRIVER projects: in the same framework of the Community of Users (CoU), SPARTACUS has been actively involved in the 2nd CoU meeting held in Brussels on 4-5th May 2015. SPARTACUS has been identified as project related to Crisis Management developing promising tools and methods that have the potential to be taken up by practitioners, for such reason the project has been presented at the meeting, in a dedicated session specifically addressed in how fruitful interactions with DRIVER project can be performed.

- SPARTACUS and SUSTRAIL projects: by taking advantage of SPARTACUS network in the field of rail system, a presentation of the project has been performed within the final meeting of FP7 project SUSTRAIL, involved in bringing innovation in freight vehicles – track system design for higher delivered tonnage with improved availability at reduced cost. A market-oriented SPARTACUS presentation showed the benefit of the solution developed for the rail field emphasizing how the innovations matched with the relevant needs claimed by stakeholders.

1.4.1.3 Third year

For what concerns the 3rd and final year, the strongest dissemination activities have been addressed towards scientific community and stakeholders in emergency management domain by means of workshops, tests in the field and trainings. In absolute terms, stronger efforts in dissemination was done compared to other project years. In the following, some of the key events considered of high impact to the project outcomes:

- SPARTACUS as case study for the Community of Users: On 22nd June 2016, at BAO Congress Centre, Brussels (Belgium), the SPARTACUS project was presented at the 4th Community of Users meeting on Natural Hazards Crisis Management. In that occasion SPARTACUS project was presented as case study with the aim to highlight the importance to test research project results in an environment fully set by real users independently by the research project objectives, and so strengthening the quality level of validation. The example reported to the Community of Users was the DG-ECHO Module Exercise (held from 8th to 11th June 2016) when SPARTACUS solutions were used by emergency teams (e.g. Urban Search and Rescue - USAR) during their operations.
- SPARTACUS and CIMTEC 2016: On 9th June 2016, at Centro Congressi Hotel Quattrotorri - Room SPOLETO B, Perugia (Italy), SPARTACUS partners have presented the innovations and results of the project during a special session “Security Devices” of CIMTEC 2016, 5th International Conference on Smart and Multifunctional Materials Structures & Systems, dedicated to space technologies in the security field. In that occasion, the attending public got knowledge of the SPARTACUS system and in particular the robustness of tracking and communication capabilities over different environmental and potentially harsh conditions (e.g. no terrestrial communication, indoor environment, no GNSS signal coverage, etc.).
- SPARTACUS and Public Safety Communication Europe (PSCE): From 23rd to 24th November 2016, a conference focused on security and public safety was held in Athens, Greece. The conference was organized by PSCE (Public Safety Communications Europe), a forum that provides a common platform for researchers, industry and users to meet and network, learn about technologies used for public safety and influence policy makers at European levels. The presentation raised high interest among users since the solutions fit safety and security needs in two different field: transport and emergency operations.
- SPARTACUS and INSARAG: From 7th to 9th September 2016, SPARTACUS partners (DMAT, JUH, ANSUR, TGS) have participated to the annual International Search and Rescue Advisory Group (INSARAG) Team Leaders Meeting in Tokyo,

Japan under liaison of Johanniter-Unfall-Hilfe (JUH). More than 157 participants from over 57 countries and organizations working on urban search and rescue (USAR) were present. A dedicated session about new developed technology for USAR Responders was placed, where SPARTACUS solutions raised interest about its capabilities especially in communication and information management. From feedback gathered, professionals were very interested to learn if and how SPARTACUS system can be implemented and used by INSARAG, enlarging the geographical dimension of SPARTACUS beyond the EU to a UN perspective.

1.4.2 Exploitation

The expected results of the project are modular and scalable GALILEO-ready SPARTACUS kit/solutions that can be configured to deliver specific services user-oriented. The following table summarizes the SPARTACUS expected exploitable results.

N°	*Title*	*Description*
1	Tracking Units for First Responders	Small-size and light satellite-based devices adapted for first responders localization and tracking featuring satellite antenna embedded, low power consumption, integration with an inertial navigation system, implementation of dead reckoning functionalities and enabled SBAS (EGNOS) and GBAS corrections for better accuracy.
2	Web and Smartphone application for First Responders (ASIGN)	Smartphone application and Web service for collecting in-situ field information and tracking of first responder for emergency field assessments. This is done by: develop in-situ image & video solutions for professional users, including configurable assessment templates, geo-positioning, smartphone and PC versions with sensor attachment options; develop solutions for server access to remote field in-situ video over satellite and radio; develop support for geo-tagged audio / voice / image input and presentation; develop geo-tagged assessment templates.
3	Web and Smartphone application for First Responders (FLARE)	Smartphone and web application providing accurate positioning information to the users in the field, allowing navigation and guidance functionalities to first responders also in case of GNSS signal outage. It uses the tracking unit and smartphone internal GNSS module as positioning data sources. It enables alerting functionalities to first responders' clusters (collaborative view).
4	Communication network for emergency response and transport application	The communication networks are built by units (SComU) intended to provide a centralized communication point that supports many different ways of communication over a wireless and cellular networks (Wi-Fi, 3G, 4G) with a backhauling functionality over satellite technologies like BGAN or DVB-RCS, but also over terrestrial cellular networks (GSM/3G/4G) if they are available. Services are mainly voice calls, SMS, Internet access and TETRA-like features. The SComU serves a GUI to allow its operation and to display system information such as: the current link selected the battery remaining time or the possibility to switch on and off devices remotely.
5	Upper level Algorithms (ULA)	Advanced optimization at software level used for multiple asset tracking in rail application to improve precision of non-calibrated units.
6	Tracking and Collecting Units for transport case	Satellite-based devices adapted for localization and tracking of goods addressed on freight rail sector and goods distribution by road vehicles. The solutions present modularity (wagon, containers and locomotive solutions or trailer/truck solutions to be freely combined), satellite antenna embedded, small-size and weight, low power consumption, integrated with an inertial navigation system, dead reckoning functionalities, SBAS (EGNOS) and

		GBAS corrections. The collecting units (SColUs) gather and store the positioning information from multiple tracking units by wireless, refine each of their position and perform the tracing and timing functions to avoid losses of information in case of the communication unavailability
7	Web and Smartphone application for Dangerous goods Transportation (TIIMISS)	Set of smartphone/desktop solutions to provide fleet management, distribution and logistics functionalities. The set is composed by: • R-TIIMISS for Relief Good Distribution (RGD) process; • D-TIIMISS for Driver Assistance; • W-TIIMISS for Mobile Warehouse Management in RGD process.
8	Fully integrated system ready for trainings on site and for exploitation	The fully integrated SPARTACUS system designed, realised, tested and validated in simulated and real world scenarios, offering tracking/positioning solutions for critical asset tracking and crisis management.

1.5 *Project Public Website*

The project website is fully described in the Deliverable document 8.1 "Project Website". It is divided in two main parts: the public area and the private area. The first area is accessible to everyone interested in SPARTACUS, while the second one is exclusively accessible by project partners and the EC. To accomplish this intent private accounts have been created to allow partners easily and individually accessing the private area. The project website is available at: http://www.spartacus-project.eu

The public area consists of following main pages:

- Home
- Project Details (containing Motivations, Methodology, Objectives, Project Structure)
- Technology
- Partners
- News & Events
- Public Documents (containing Brochures, Media, Papers and Presentations, Posters, Reports)
- Demo
- Contacts

The private area accessible by "Sign In" is substantially identical to the public area except the addition of the following part:

- Project Documents

It is worth to highlight that the dedicated page "Demo" was set up to allow interested users to interact with the SPARTACUS applications and SMaP in trial version. The demo is accessible by the official project website link: www.spartacus-project.eu/Demo jointly with an informative video that gives an introduction of the applications and their use during the real exercise. The user can try by hand the SPARTACUS applications by clicking the link "Enjoy the interactive demo" which have been specifically set for trial purposes.