# THE ROLE OF SPATIAL INFORMATICS IN CULTURAL HERITAGE SURVEY

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**Abstract**:

*Archaeologists may be committed to studying the past, but their use of technology is quite up-to-date so that digital heritage, e-heritage, digital archaeology, virtual archaeology and open archaeology are fast-moving fields. In the digital age the field of Cultural Heritage is now a very data and information abundant sector because of the exponential growth of data volume, complexity and quality driven by the exponential surveying, analysis techniques and computing technology. Hence, coherent and standardized architectural framework -'GeoCHEAF- has been designed and proposed to the Cultural Heritage domain. Since currently numerous Cultural Heritage recording, documentation, conservation, restoration, reconstruction, renewal, rehabilitation, digital preservation projects and etcetera are in progress. The "Geo-enable Cultural Heritage Enterprise Architecture Framework (GeoCHEAF)" is the result of rigorous analysis of the Cultural Heritage domain operations, data/information/knowledge/content/application/service sharing requirements, and consideration of the ways in which modern information and communication technologies can support the Cultural Heritage projects workflows. Recent developments in spatial informatics technologies used in the field of Cultural Heritage, such as capturing and positioning techniques, mobile mapping, mobile computing, etc. will be analyzed and cutting-edge data acquisition design for archaeologist will be built in the context of this study. Other relevant architectures and components of "GeoCHEAF" are beyond of the scope of this paper.*

## 1. INTRODUCTION

The "**Geo-enable Cultural Heritage Enterprise Architecture Framework (GeoCHEAF)**", a spatially-enabled open enterprise architecture framework for the Cultural Heritage (CH) domain, has been specially developed to demonstrate how a CH organization works within a geo-enable enterprise architecture in order to make CH projects of the organization more effective in almost every sense. It explores and captures business and technical requirements of the CH domain (*challenges*) and elaborates design principles for the requirements (*objectives*). These principles have been intended to undertake management and research at all levels, to deliver enterprise solutions and to provide decision-making activities in a CH enterprise. [1]

The field of Cultural Heritage is now a very data and information abundant sector because of the exponential growth of data volume, complexity and quality driven by the exponential surveying, analysis techniques and computing technology. Moreover, many of today's CH organizations rely on digital Information and Communication Technology (ICT) to gather, organize, interpret, and disseminate data, information and knowledge relating to their various projects. The aim of this study is to promote the role of spatial informatics technologies in cultural heritage survey through "GeoCHEAF". The crucial point of the "GeoCHEAF"'s design is to pinpoint web-based spatiotemporal GIS at the center of the geoenterprise architecture framework for defining spatiotemporal characteristics of CH resources and integrate it with ICTs in a coherent conceptual model along with an executable architecture for optimized use to uncover the secrets of the past and better investigate sites of great historical and cultural importance. In this way,

"GeoCHEAF" increases the operational capacity and enhances productivity and overall effectiveness of a CH enterprise to build more understandable, easier to configure, and lower cost systems for any business process in the CH domain (e.g. CH resource management, documentation, assessment, interpretation, digital heritage preservation, excavation, conservation, restoration, renovation projects and etcetera).

"GeoCHEAF" develops geo-enabled strategies which allow for a universal method of mapping the spatial dimensions of CH resources since CH resources need to be perceived in space and time; their essence cannot be grasped through a one dimensional representation of their physical characteristics.

## 2. DATA ACQUISITION AND CAPTURE

The field of CH is now a very data and information abundant sector because of the exponential growth of data volume, complexity and quality driven by the exponential surveying, analysis techniques and computing technology. Several technologies, particularly the huge explosion in air- and space-borne remote sensing systems and the increase in spatial resolution of aerial and satellite imagery, offer the potential to improve monitoring, assessment, preservation and management of CH resources. New aerial and satellite imaging camera and sensor technologies for data capture, and surveying techniques, some of which are given in figure 1, are effective means for economically creating new topographic maps, updating existing ones, and recording image-based CH information. Geometrically- and radiometrically-corrected satellite images with field surveys, ground-truthing and photo interpretation, can be used to search for new CH sites by combining with other geoinformation sources, such as historical maps, GIS files, PostGIS files, DTM/DEM/DSM, and utilizing image draping capabilities, geospatial modeling, spectral analysis, land use/cover change analysis and object-based image analysis techniques. Instead of using expensive geoimagery technology, the aerial images of the excavation site and its sections can be also captured by using calibrated fixed lens digital camera/LIDAR/IR sensor suspended beneath a helium balloon, zeppelin, kite, model helicopter system when the project budget cannot afford the fly planes to collect LIDAR data or stereo aerial photographs from aircraft. Then, the orthophotos can be generated with free and open source image modeling and processing tools, such as *OSSIM, e-foto, insight3D, ImageJ, Visualization Toolkit*, using digital photogrammetry techniques on the metric images of the CH resources recorded using low-cost systems.

Having located supposed locations of CH sites/resources on the orthorectified imagery, these supposed locations then are located on the ground with satellite-based positioning technology using Global Navigation Satellite System (GNSS) receivers by establishing control points of a earth-centered, earth-fixed coordinate system (ECEF) (e.g. *ITRF, WGS84, ETRS*) of a 4D geodetic infrastructure joined to a cadastral infrastructure based on a Spatial Data Infrastructure (SDI) at national (NSDI), regional (e.g. *INSPIRE*) and/or global level (GSDI) [2]. Geodetic Coordinate Systems, which specify spatial and temporal location of CH objects and display the distribution of CH objects as a whole, store georeferencing information and define coordinate transformations from one spatial reference frame to another. Multi-GNSS technology, which is a combination of GNSS systems (see figure 1) to improve accuracy, provides users with a highly accurate positioning service.

The supposed locations on the ground can be determined which are most promising using geophysical techniques (e.g. *ground-penetrating radar(GPR), geomagnetism, geoelectric, electromagnetism*) and GNSS systems are used to map all the discoveries. Static and Kinematic (e.g. *DGPS, RTK, KOF*) GNSS measurements based on a multi-constellation and multi-frequency GNSS with support of Continuous Operating Reference Stations (CORS), Satellite-Based Augmentation Systems (SBAS) and Ground-Based Augmentation Systems (GBAS) improve the accuracy of positions from few centimeters to millimeters depending on the measurement and processing techniques chosen. (see figure 1)

Whenever dealing with height systems, for instance height information provided by GNSS (*ellipsioidal system*) or leveling (*orthometric system*), the geoid undulation model is needed to connect ellipsoidal and orthometric heights. The models of gravity field of the earth globally (e.g. *EIGEN, EGM96, EGM07*), and its temporal and local/global variations in time can be determined with high precision and resolution by means of gravity field satellite missions. Geodetic Altimetry contributes to determination of gravity anomalies over the ocean, determines mean sea-level variations, and maps ocean surface topography. Bathymetric mapping of near-shore coastal environments using hydrographic survey for underwater or maritime archaeology provides measurements of depth water depending on geographical coordinates, just as topographic maps represent the altitude of Earth's surface in different geographic points. (see figure 1)

The most promising locations can be excavated using Terrestrial Positioning System (TPS, *more frequently called as total station*) for positioning artifacts, and laser leveling and alignment for determination of the height information of the artifact (*both above surface or below surface*). Furthermore, the close-range image measurement techniques can be used for high precision and detailed measurement of the artifacts, such as close range photogrammetry to focus on details, terrestrial 3D laser scanning to produce a 3D-model of a facade. Additionally, hybrid approaches for creating a 3D digital model to perform evaluation, assessment and analysis of CH resources, can also be used, for instance, 3D Laser-based photogrammetry that combines terrestrial photogrammetry and laser scanning for 3D modeling of close-range objects. The combination of digital photo modeling and laser scanning can enhance the point cloud data allowing for the recognition of better definition in the texture and geometry of scanned objects. (see figure 1 and figure 2)
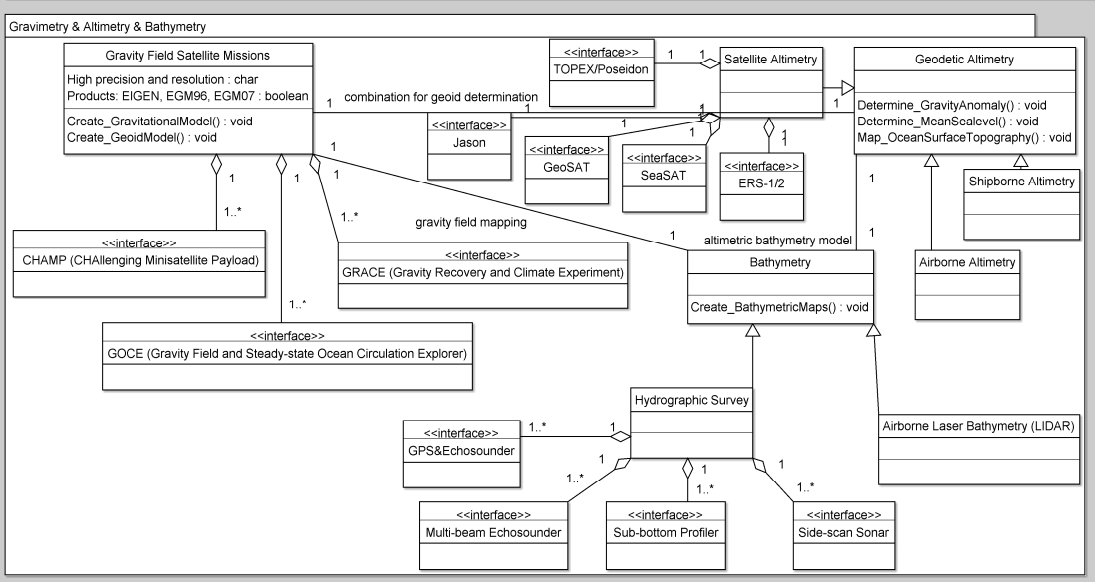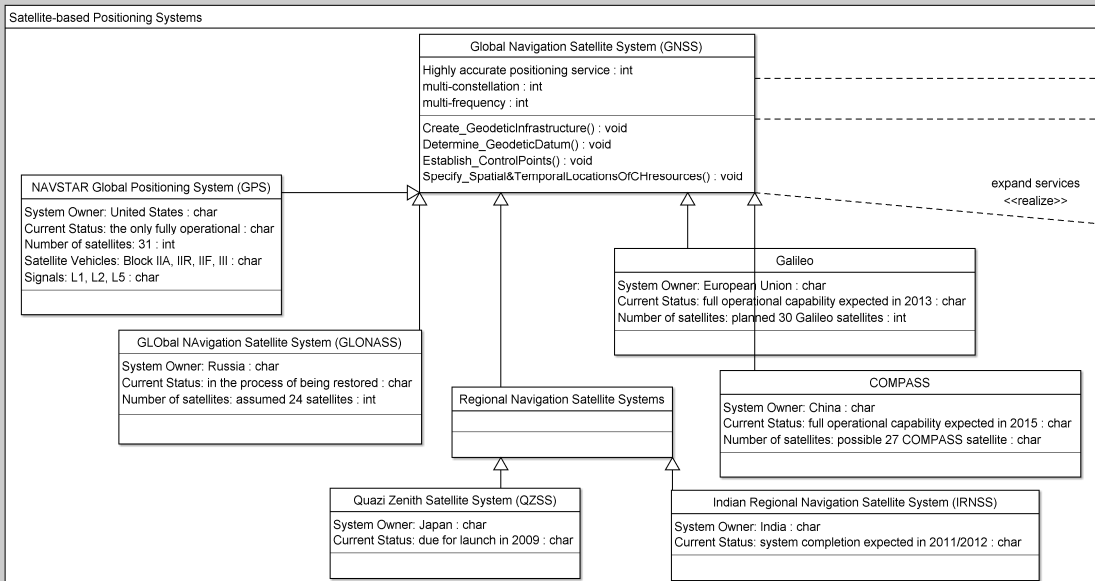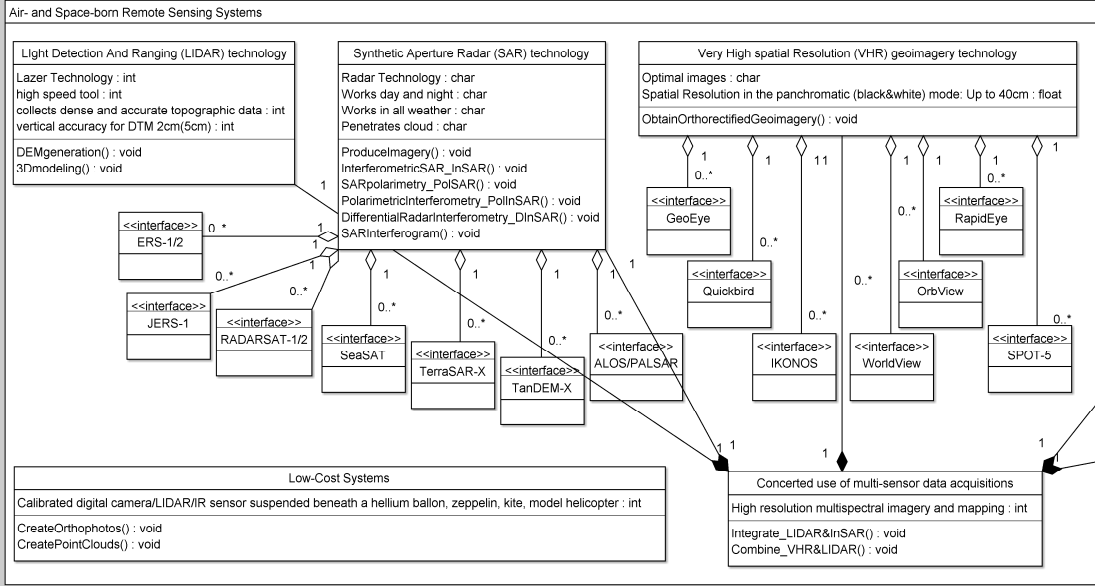
Recent developments in mobile technologies (e.g. *mobile computing, mobile surveying, mobile mapping and high-speed digital data transfer*) have enabled GIS information to be taken into the field as digital maps on compact, powerful portable computers, providing field access to enterprise geospatial information. The land-survey & data-collection process in the design of "GeoCHEAF", in other words gathering historical attributes related to spatial information using GNSS- and WiFi-enabled handheld mobile device with internal high definition camera (e.g. *smartphones, iphone, tabletPCs, rugged laptops*), which allows data acquisition with feature codes and built in COGO routines that is fully compatible with CAD- and GIS-based land survey software solutions, enables the CH specialist in the field to wirelessly send job files back and forth between the site and office using cellular technology into the enterprise's GIS database. As wireless bandwidth increases, more collected data will be sent straight to the office from the field, while at the same time more will be passing straight from office to field: job orders, digital models, maps and geoimagery products. This navigation environment based on mobile GIS approach, which operates on a server and provides mobile location-aware services, in particular Location-Based Services (LBS) and Ubiquitous GI services (u-GIS), enables the CH specialists on site with information relating to their current geospatial position for field-based data capture, editing and transferring data directly to the geodatabase. This enables CH organizations to add real-time or near real-time information to their enterprise geodatabase and applications, and extend enterprise's GIS capabilities, such as speeding up analysis, display, and decision making by using up-to-date, more accurate spatial data. (see figure 1)

## 3. GEOPROCESSING AND SEAMLESS GEOCOMPUTING

Incorporating all relevant data/information about the site, such as the results of chemical and material analyses, is immediately being made available for further processing by controlling spatial data quality, correcting errors, performing calculations, integrating spatial data with the non-spatial data and etcetera. Thereafter, the digital base maps of the site are produced, essential topologies are created, and multi-dimensional (2D, 3D, and 4D) spatial data models of CH sites are built. Complex queries and spatial analysis are performed using these models and topologies, and finally, thematic maps are produced by means of versatile GIS technology to capture the pattern. Consequently archaeological hypotheses can be tested with the help of the proliferation of spatial informatics, such as 3D imaging, image- and range-based 3D modeling, cloud computing, geostatistics and thematic processing. [3]

The quality, resolution, size, and complexity of geospatial data is increasing exponentially. Thus, CH enterprises are needed for more efficient data management solution, in other word it is time for a transition from '*Spatial Information Management*' to '***Managing Information Spatially***'.

Massive and complex data is collected once with the highest resolution, used many times for different purposes, and accessed when required by the dynamic web content generation systems and served with different resolutions due to the users' requirements utilizing automated generalization techniques, on-the-fly generalization capabilities, Multiple Resolution/Representation Databases (MRDB) and multi-agent systems. This approach proposed avoids duplication and inconsistencies in data/information, provides changeable views of same information and reduces data management costs.
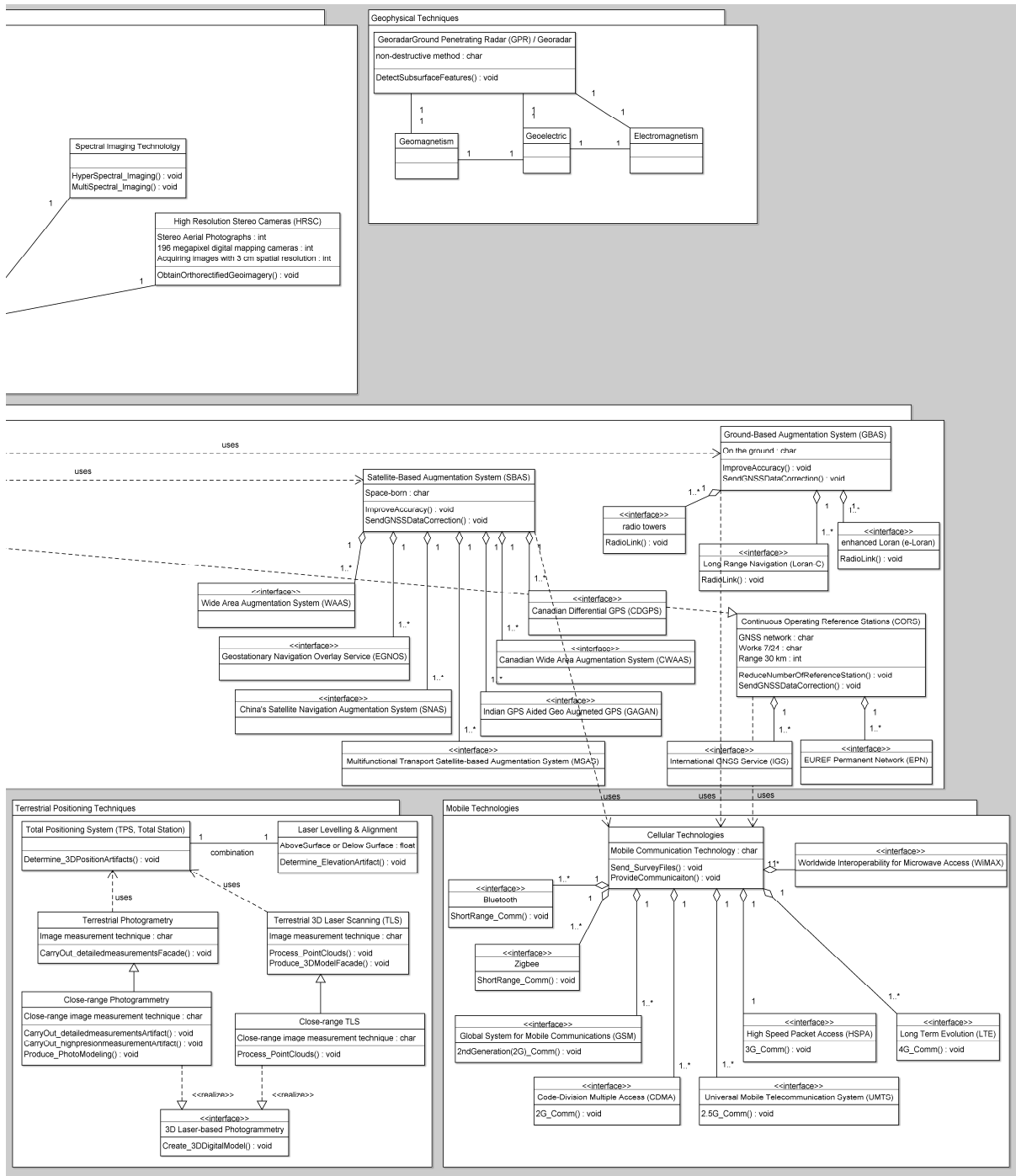
## Air- and Space-born Remote Sensing Systems

**LIght Detection And Ranging (LIDAR) technology**

Lazer Technology : int
high speed tool : int
collects dense and accurate topographic data : int
vertical accuracy for DTM 2cm(5cm) : int

DEMgeneration() : void
3Dmodeling() : void

**Synthetic Aperture Radar (SAR) technology**

Radar Technology : char
Works day and night : char
Works in all weather : char
Penetrates cloud : char

ProduceImagery() : void
InterferometricSAR_InSAR() : void
SARpolarimetry_PolSAR() : void
PolarimetricInterferometry_PolInSAR() : void
DifferentialRadarInterferometry_DInSAR() : void
SARInterferogram() : void

**Very High spatial Resolution (VHR) geoimagery technology**

Optimal images : char
Spatial Resolution in the panchromatic (black&white) mode: Up to 40cm : float

ObtainOrthorectifiedGeoimagery() : void

**<<interface>>**
**ERS-1/2**

**<<interface>>**
**GeoEye**

**<<interface>>**
**RapidEye**

**<<interface>>**
**JERS-1**

**<<interface>>**
**RADARSAT-1/2**

**<<interface>>**
**SeaSAT**

**<<interface>>**
**TerraSAR-X**

**<<interface>>**
**TanDEM-X**

**<<interface>>**
**ALOS/PALSAR**

**<<interface>>**
**Quickbird**

**<<interface>>**
**OrbView**

**<<interface>>**
**IKONOS**

**<<interface>>**
**WorldView**

**<<interface>>**
**SPOT-5**

**Low-Cost Systems**

Calibrated digital camera/LIDAR/IR sensor suspended beneath a hellium ballon, zeppelin, kite, model helicopter : int

CreateOrthophotos() : void
CreatePointClouds() : void

**Concerted use of multi-sensor data acquisitions**

High resolution multispectral imagery and mapping : int

Integrate_LIDAR&InSAR() : void
Combine_VHR&LIDAR() : void

## Satellite-based Positioning Systems

**Global Navigation Satellite System (GNSS)**

Highly accurate positioning service : int
multi-constellation : int
multi-frequency : int

Create_GeodeticInfrastructure() : void
Determine_GeodeticDatum() : void
Establish_ControlPoints() : void
Specify_Spatial&TemporalLocationsOfCHresources() : void

expand services
<<realize>>

**NAVSTAR Global Positioning System (GPS)**

System Owner: United States : char
Current Status: the only fully operational : char
Number of satellites: 31 : int
Satellite Vehicles: Block IIA, IIR, IIF, III : char
Signals: L1, L2, L5 : char

**Galileo**

System Owner: European Union : char
Current Status: full operational capability expected in 2013 : char
Number of satellites: planned 30 Galileo satellites : int

**GLObal NAvigation Satellite System (GLONASS)**

System Owner: Russia : char
Current Status: in the process of being restored : char
Number of satellites: assumed 24 satellites : int

**Regional Navigation Satellite Systems**

**COMPASS**

System Owner: China : char
Current Status: full operational capability expected in 2015 : char
Number of satellites: possible 27 COMPASS satellite : char

**Quazi Zenith Satellite System (QZSS)**

System Owner: Japan : char
Current Status: due for launch in 2009 : char

**Indian Regional Navigation Satellite System (IRNSS)**

System Owner: India : char
Current Status: system completion expected in 2011/2012 : char

## Gravimetry & Altimetry & Bathymetry

**Gravity Field Satellite Missions**

High precision and resolution : char
Products: EIGEN, EGM96, EGM07 : boolean

Create_GravitationalModel() : void
Create_GeoidModel() : void

combination for geoid determination

**<<interface>>**
**TOPEX/Poseidon**

**Satellite Altimetry**

**Geodetic Altimetry**

Determine_GravityAnomaly() : void
Determine_MeanSealevel() : void
Map_OceanSurfaceTopography() : void

**<<interface>>**
**Jason**

**<<interface>>**
**GeoSAT**

**<<interface>>**
**SeaSAT**

**<<interface>>**
**ERS-1/2**

**Shipborne Altimetry**

**<<interface>>**
**CHAMP (CHAllenging Minisatellite Payload)**

**<<interface>>**
**GRACE (Gravity Recovery and Climate Experiment)**

gravity field mapping

altimetric bathymetry model

**Bathymetry**

Create_BathymetricMaps() : void

**Airborne Altimetry**

**<<interface>>**
**GOCE (Gravity Field and Steady-state Ocean Circulation Explorer)**

**Hydrographic Survey**

**Airborne Laser Bathymetry (LIDAR)**

**<<interface>>**
**GPS&Echosounder**

**<<interface>>**
**Multi-beam Echosounder**

**<<interface>>**
**Sub-bottom Profiler**

**<<interface>>**
**Side-scan Sonar**

**Figure 1:** UML class diagram of robust combination strategy for spatial data/information fusion.

**Figure 2:** A laser-scanning snaphot from the fortress of 'Seddülbahir'

## 3. CONCLUSION

"GeoCHEAF" has been designed to provide e-heritage solutions in order to let users in the systems within the enterprise, such as archaeologist, art historians and museum curators, simply integrate the enterprise's base map with their own thematic geo-referenced information along with associated non-spatial information through the web-based spatiotemporal GIS architecture with 2D/3D/4D/nD hybrid web mapping component of "GeoCHEAF". It enables its users to plot the locations of artifacts and structures discovered across a region and more accurately analyze variations and patterns, and to reproduce archaeological landscapes and monuments in 3D, which enables CH specialists to develop a better understanding of CH resources' purpose and relationship to their environment. Further information regarding the "GeoCHEAF" and its business and other technical architectures is available in Güney's dissertation and the web page of "GeoCHEAF" *http://www.geo.itu.edu.tr/GeoCHEAF*. [1]

## 4. REFERENCES

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