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1 INTRODUCTION

Global Monitoring for Environment and Security (GMES) is a joint initiative of the European Commission (EC) and the European Space Agency (ESA), designed to establish a European capacity for the provision and use of operational monitoring information for environment and security applications. In 2008 the foundations and the structuring elements of the European Capacity for Global Monitoring of Environment and Security should be in place and operating.

This Capacity is seen to be composed of three modules, which together constitute the functional GMES 'system':

- The production and dissemination of information in support of EU policies for Environment and Security;
- The mechanisms needed to ensure a permanent dialogue between all stakeholders and in particular between providers and users;
- The legal, financial, organisational and institutional frame to ensure the functioning of the system and its evolution.

Many elements of the modules already exist but have been conceived, designed and managed in isolation, thus limiting interoperability and production of relevant information. The coherence, efficiency and sustainability of a shared information system for Europe will be the added value of GMES. Developing compatibility between the existing elements, establishing cooperation between the organisations and filling the gaps where necessary will achieve this.

In the context of ESA's role to provide the definition and the development of the space-related system elements. GMES Sentinel-2 mission provides continuity to services of relying on multi-spectral high-resolution optical observations over global terrestrial surfaces [RD-1]. Sentinel-2 will capitalise on the technology and the vast experience acquired in Europe and the US with systems such as the SPOT and Landsat families over the past decades.

The land surface requirements for low spatial resolution and high revisit optical imaging will be covered by the Sentinel-3 mission. This mission will provide continuity to MERIS-Envisat and VEGETATION-SPOT/AVHRR observations. In addition, within Sentinel-2 a thermal infra-red sensor (referred to as IR Element) will be specified. This system will be dedicated to the requirements of services such as the monitoring of high temperature events. Although part of Sentinel-2, the mission requirements for this instrument are described in a separate document [RD-28].

This document is the Sentinel-2 Mission Requirements Document (MRD), the top-level document describing the mission requirements for the GMES Sentinel-2 mission based on the underlying objectives. The MRD outlines the identified user requirements and transforms these requirements into traceable mission requirements specifying the observational needs and quantitative requirements in terms of geographical coverage, revisit time, spectral, radiometric and geometric performance. The MRD is used for subsequent derivation of the system requirements, specifying in detail the system requirements for all engineering aspects implementing the mission. System requirements are specified in the System Requirements Document (SRD).

2 USER INFORMATION REQUIREMENTS

2.1 Introduction

User requirements and their definition are evolving with time; they are formulated in terms of information needs and have to be translated into observational requirements. Matching user requirements and observational capabilities requires the establishment of an interface between system designers and data providers with the user community. As it is not feasible to satisfy all user requirements an order of priorities will have to be established.

The choice of initial services to establish the foundations of GMES, is based on three main criteria [RD-8]: (1) availability/maturity; (2) reliability/usefulness, and (3) long-term sustainability. These criteria lead to the following choice of priority services for which the Sentinel-2 mission is tailored taking also account of potential new services and service evolutions over time:

- Natural hazards management (e.g. floods, forest fires, volcano eruptions, subsidence and landslides)
- European land use / land cover state and changes (including soil sealing),
- Forest Monitoring,
- Food security - Early warning systems,
- Global change issues,
- Humanitarian Aid.

Service requirements for Sentinel-2 have been identified taking into account the following projects:

- **GMES FTS (Fast Track Services).** The following core services have been considered: LMCS (Land Monitoring Core Service) and ERCS (Emergency Response Core Service) [RD-3; RD-29].
- **GSE (GMES Service Elements)** [RD-2]. The following GSEs are relevant for the Sentinel-2 Mission Requirements: Land; Forest Monitoring; GMFS (Global Monitoring for Food Security); RISK-EOS; RESPOND.
- **Framework Programme-VI Integrated Project Geoland** [RD-4].
- **DUE (Data User Element) Projects** [RD-5]. The following core projects have been taken into account: Globcover, Globwetland and Desertwatch.

2.2 Summary of the User Information Services

The aim of this sub-chapter is to briefly describe the different services that have been identified and considered in the definition of the Sentinel-2 mission requirements. These services are included in the following projects.

2.2.1 GMES FAST TRACK SERVICES

These FTS aim at developing and validating pilot operational services. It is planned that these services will be pre-operational by 2008. Two GMES Fast Track Services (FTS) are relevant for Sentinel-2:

- LMCS (Land Monitoring Core Service) [RD-3].
- ERCS (Emergency Response Core Service) [RD-29].

2.2.1.1 LMCS

LMCS aims at providing reliable, affordable and cost efficient European geo-information services, for supporting the implementation of European and International directives/policies. It is its goal to provide timely, continuous and independent observations about the use of soil and other land resources and the changes of the land environment for responsible and farsighted policy-making at all levels (European to local). Core information services should feed predictive models of climate change, development of resources, impacts of human actions and provide citizens with location-based data for their daily decisions.

Land monitoring is a quite complex task since it covers a wide range of resources and variegated policies: soils, water, agriculture, forests, ecology sites, energy and utilities, build-up areas, recreation, infrastructures and transports. It will address a large variety of user requirements related to European policies and international commitments.

The European Policy drivers for land monitoring have been already identified in detail in the conclusions of the "GMES User Workshop on a Land Monitoring Service for Europe" of October 2005 as:

- Environmental policies, i.e. climate change, nature protection and biodiversity, natural resources, environmental hazards, environmental impact assessment,
- Regional policies, territorial cohesion and European spatial development perspectives,
- Common Transport Policy,
- Enterprise,
- EU development policies,
- Common Agricultural Policy (CAP).

EU agencies and EC offices have mandates for regular information provision related to land, such as:

- EEA: land use data centre (core land cover data, CORINE), land and ecosystem accounting
- ESTAT: application of aerial survey and remote sensing to agricultural statistics (LUCAS for 1999-2007), GISCO database
- EUSC (EU Satellite Centre agency CFSP) : support to EO police/military operations, support to humanitarian missions, event planning, treaty verification

At international level, the EC is a party to many International Environmental Agreements such as the Rio Conventions, requiring data and reporting on land use and land cover changes:

- UN Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol
- UN Convention to Combat Desertification (UNCCD)
- UN Convention on Biological Diversity (UNCBD)
- UNECE Long Range Transboundary Air Pollution Deposition

and is supporting the:

- UN Forum on Forest with the related "FLEGT " policy whereby EU contributes to the transparency of the international timber market,
- UN Millennium Development Goals, where Goal I pledges to improve food and nutrition security.

2.2.1.2 ERCS

The objective of the Emergency Response Core Service (ERCS) is to reinforce the European capacity to respond to Emergency situations associated with meteorological driven-hazards (e.g. storms, fire, floods) geophysical hazards (e.g. earthquakes, tsunamis, volcanic eruptions, landslides), deliberate and accidental man-made disasters and humanitarian disasters.

Its initial scope is to provide rapid mapping services, including preparatory services to collect and map spatial and socio-economic in areas at risk. In the longer term it will expand beyond the crisis phase to include the crisis prevention and early warning phases, post crisis reconstruction and situation assessments. Two families of rapid mapping services will be provided: "Reference Maps" derived from data available pre-crisis, and "Assessment maps" generated during the crisis.

GMES Emergency Response services are world wide; however the following should be considered as priority areas:

- For Natural Disasters: all regions where international assistance may be solicited and primarily Central America, Eastern Africa and South-East Asia
- For Complex emergencies: all regions where international assistance may be solicited primarily Central Africa and Middle East

2.2.2 GSE LAND

GSE Land is based on the main results related to land issues of the projects SAGE, GMES Urban Services (GUS) and CoastWatch from the GSE consolidation phase. It provides a set of priority information services responding to the main information needs of European users on all levels (DGs, national ministries of environment, regional authorities, municipalities, etc.) with respect to mainly European policies (given priority to Water Framework Directive, Soil Thematic Strategy, Integrated Coastal Zone Management, Urban Environment Thematic Strategy, European Spatial Development Perspective). The GSE Land [RD-18] requirements are summarized in Table 2.2.1.

Operational Level	User and Intermediary Organisations	Summary of Main Information Required
European	European Institutions and mediators (EEA, Eurostat); European Commission (DG-REG, DG-ENV, DG-AGRI);	1) Detailed standardised pan-European Land Cover and Land Use information at 1:50,000 scale (updated every 3-5 years): • Legend based on CORINE III level; • Environmental and regional development indicators; 2) Low cost yearly updated standardised pan-European Land Cover Land Use information at 1:50,000 to 100.000 scale: • Legend based on CORINE I level enhanced with additional classes of interest for the European Institutions; • Environmental, agri-environmental and regional development indicators; 3) Urban Atlas: Standardised Pan-European land cover land use information at 1:25,000 scale covering all the urban functional areas in EU-25 with more than 100,000 inhabitants: • Legend based on GUS / Moland level IV with MMU of 0.25 ha for urban classes and level II with MMU 1 ha for natural classes.. • Dedicated regional development indicators; 4) Standardised Pan-European land cover land use information at 1:10,000 to 1:25:000 scale covering all the NATURA 2000 sites: • Legend based on CORINE level IV.

		• Dedicated Environmental Indicators;
National	Ministries of Environment National Environmental Agencies National Mapping Agencies National Statistic Agencies	Standardised National (or sub-national: e.g., Regions, Landers, Provinces) coverage information at 1:25,000 to 1:50,000 scale on: • Land cover and land use; Legend based on CORINE level III with level IV information for specific topics (agriculture, urban areas, coastal zones); • Soil sealing areas; • Soil sealing levels; • Brown field maps; • Water contamination; • Water consumption for agricultural use;
Sub-national	Regional authorities Regional technical bodies and Environmental Agencies	
Local	Local administrations Protected areas managers River and basin authorities	High resolution (1:10,000 to 1:25,000 scale) information for inventorying, assessment and monitoring of protected areas: • Base maps; • Land cover & land use; • Land cover & land use change; • Seasonal change analysis (e.g., water cycle); • Environmental Indicators;
		High resolution (1:10,000 to 1:25,000 scale) information for environmental management of urban areas and spatial planning: • Land cover & land use maps; • Long and medium term land cover & land use change identification; • Fast change analysis: e.g., for illegal buildings identification and development control; • Sealing levels; • Brown fields map; • Urban planning support information; • Environmental Indicators; Basin wide irrigation information for water management in Mediterranean areas: Land cover & land use; • Scale: 1:100,000 to 250,000 • Overall thematic accuracy: >80% • Geometric accuracy: < 200m Minimum mapping unit 25 – 100 ha

Table 2.2.1 User Requirements to GSE Land

The services reflecting these requirements are grouped in four baseline services:

- **Urban Atlas Service** with very high resolution land cover mapping and further downstream services (Urban Atlas Indicators like urban sprawl, environment and regional development indicators and fine-tuning of maps to local needs).

- **Inland Water Quality Service** with high resolution regional land cover and agricultural land use mapping and further downstream modelling related to nutrient loss and pesticides.
- **Impervious Area Service** with land-take maps, trend analysis and social-economical impact.
- **Water Abstraction / Irrigation Service** with the mapping of arable acreages and the downstream modelling of irrigation volumes.

The mapping services are used for monitoring of urban areas in Europe, covering issues related to urban sprawl, urban planning modelling & forecasting, changes in urban land use, environmental monitoring and enforcement of urban planning discipline. The intention is to implement in the user's environment products and services derived from satellite data and other sources in close cooperation with mandated users, from local (cities), regional national and European level. The service relies now to a large extent on classification of land cover using optical imagery of the SPOT-HRV/Landsat-TM type sensors. These are complemented by very high spatial resolution sensors such as Ikonos and SPOT-5 for mapping of small features (small roads/rivers). Integration of these land cover maps with ancillary data and models lead to the specific downstream services.

The water resources services aims at a comprehensive range of products to serve the demands coming from the European Water Framework Directive and the upcoming regulations of the Thematic Strategy on Soil Protection usually referred to as Soil Thematic Strategy. Public and private partners together have established core services addressing basic geo-information needs from the agricultural/environmental community. They mainly address water availability and water stress related issues as well as anthropogenic influence on surface and ground water quality. These services are the basis of customised end-user applications supporting the national and local implementation of the European Water Framework Directive and Soil Thematic Strategy.

2.2.3 GSE FOREST MONITORING

The GSE Forest Monitoring (FM) [RD-15] addresses the policy related demands for securing the ecological functions in the forestry and land use sector. Existing infrastructural systems and data sources were reviewed and utilised in order to develop forest monitoring services such as yearly carbon balance information, forest disturbance data, as well as products for practical forest and land use management. For a national coverage cloud free data is needed within one growing season (preferably within 2 months window in Scandinavia).

A service portfolio of validated products and services was provided by the monitoring service and delivered standardised spatially referenced, quality products, e.g. maps, that are cost effective, readily accessible and transparent to users, thereby promoting key applications and good governance within the forestry sector with sustainability as a paramount consideration.

GSE FM is also connected with a partner project named Kyoto Inventory. The Kyoto Inventory (KYOTO INV) [RD-33] is a component of the ESA Data User Programme (DUP). It defines and develops key inputs required for UNFCCC (United Nations Framework Convention on Climate Change) and Kyoto reporting including area assessments and classifications for forests and country-specific land use.

Figure 2.2.1 summarizes the main products and services included in this GSE.

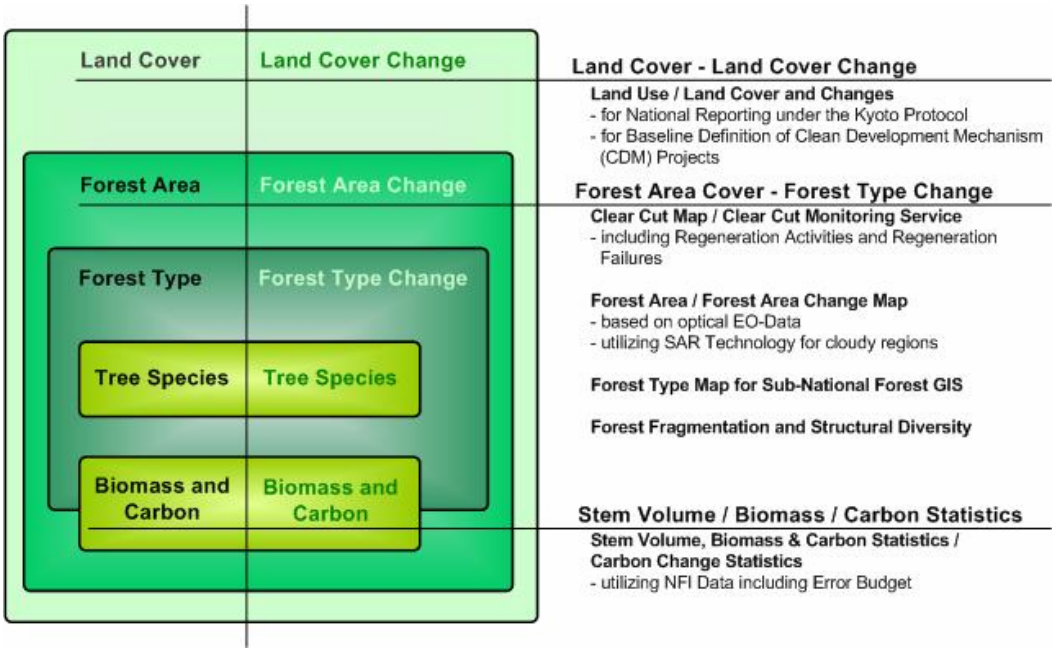

Figure 2.2.1: Overview of the Forest Monitoring related products and services [RD-15].

2.2.4 GSE GMFS

The objective of the GSE GMFS (Global Monitoring for Food Security) [RD-16] is to provide Earth observation based services to support monitoring of food security and related environmental processes. It aims to assist stakeholders, national governments and international organisations to better implement their policies towards sustainable development.
The GMFS services are tailored to meet the information requirements of specific core users and currently include two applications:

- Continental scale monitoring, aiming at continuous monitoring of vegetation state by analysing long-term Earth observation time-series (usually on a 10 days basis).
- National monitoring, mainly aiming at supplying detailed information for major food crops, such as the planting date and the national extent of cultivation. These products are delivered once or twice per growing season.

Additional important parts of the service are the *in-situ* data collection, including field data used for validation purposes and as input for agro-meteorological modelling.

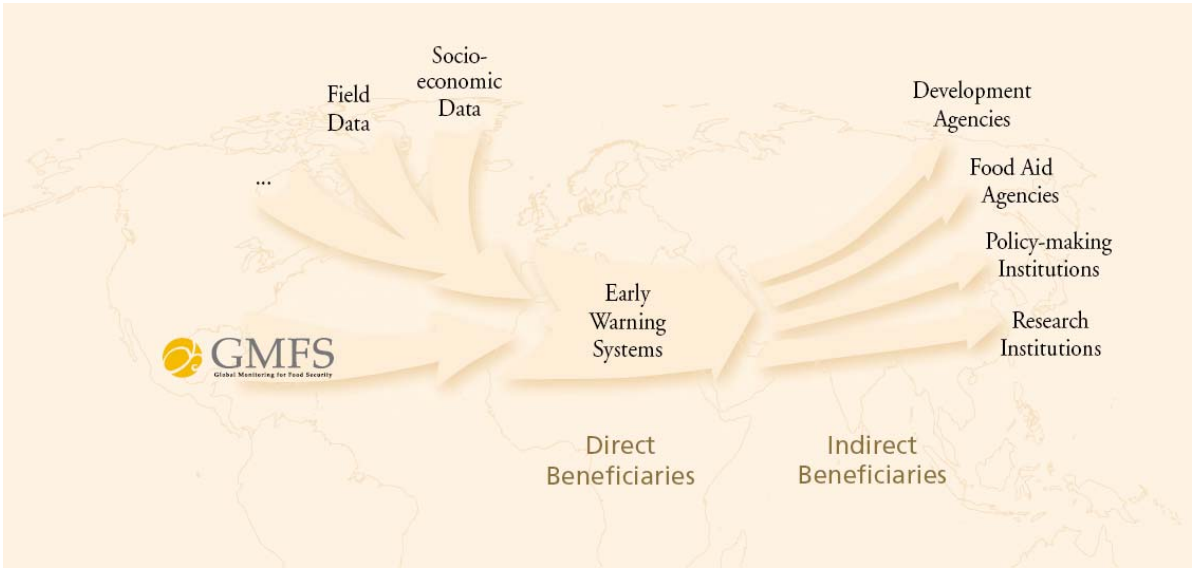

Figure 2.2.2: Schema presenting the role of GMFS in the international context [RD-16].

Specific services addressing these user needs are:

- **Support to Crop and Food Supply Assessment Missions (CFSAM).** The Geo-information packages provided contain a compilation of purely satellite derived data, differing based upon the specific requirements of FAO and WFP, the country considered and based upon the available data.
- **Early warning** with the Vegetation Productivity Indicator (VPI).
- **Agricultural mapping** with the products crop emergence date, cultivated area, extent of cultivation and agricultural productivity.
- **Crop Yield assessment** realized at (sub-) national level up to the departmental level.

2.2.5 GSE RISK-EOS

All countries are subject to natural hazards of different types, such as forest fires, floods, avalanches, landslides, earthquakes, volcanic eruptions and storms. Recent analyses, such as those ones conducted by re-insurance companies, have shown an increased number of natural disasters and in particular of meteorological events.

The increase of the population density and the development of our society have brought in many areas an increase of the threat caused by natural hazards. The topic of natural hazards related to meteorological events has come over the last years to the political agenda of most of the European countries and to the opinion of their citizens, due to a series of major events with large effects such as the repeated floods in Central Europe and the recent devastating forest fires in the Mediterranean countries. These natural hazards are a major cause of loss of life and property, and may also impact some important environmental resources. Hence the need to better manage these hazards through a more efficient use of geo-spatial observations, improving our ability to better predict, monitor, mitigate, and respond to these natural hazards. Reducing the impact of these disasters requires a better integration of observations from various Earth Observing systems, some improved predictive modelling, and the dissemination of timely and accurate information needed by all actors involved the mitigation of these disasters.

It is one of the objectives of GMES to set-up a European operational service capacity, taking benefit of Earth Observation capabilities in combination with other data sources and models, to help institutionally mandated organisations to better manage natural hazards, throughout the prevention, anticipation, response and post-response phases

Started in 2003, RISK-EOS aims at delivering operational geo-information services to support the management of meteorological hazards such as floods and forest fires and to a minor extent of other natural hazards throughout all phases of the disaster reduction (prevention, early warning, crisis, post crisis). The RISK-EOS services combine the use of satellite observation data (some provided in near real time, NRT) with exogenous data and modelling techniques. They are targeted to serve the needs of all risk management actors at European, National and Regional levels (Civil protections, fire fighting and rescue services, Land planning and risks prevention services, Territorial communities). Figure 2.2.3 summarizes the main services covered by GSE RISK-EOS.

Figure 2.2.3: Summary of the services offered by the GSE RISK-EOS [RD-17].

Amongst the operational services delivered by the RISK-EOS service network, those that shall be supported by Sentinel 2 observations are:

- **Assets Mapping:** yearly mapping of areas subject to natural hazards, to provide regularly updated cartography of urban areas, isolated buildings, infra-structures, and their evolution in time, by using high (HR) and very high resolution (VHR) optical imagery respectively for deca-metric products (5-10m resolution) and metric products (1-5m resolution). This multi-risk service aims at maintaining up to date information on assets, improving the knowledge of risk prone areas and the possible impact of natural disasters. This service is intended to be a local service, close to the users in order to be adapted to their local specificities, needs and existing data and standards (e.g. cartographic databases).
- **Flood Risk Analysis**: production and integration of geo-information data to support flood risk management activities. This service aims at providing geo-information about past and potential flood events as well as estimations of potential damages and losses. By integrating these data into management systems such as Flood Information Systems, an efficient and supportive use of flood-related information is enabled. This service is available on user request and builds on Earth Observation data as well as on ancillary data sets and modelling techniques. The delivered geo-information is targeted to support flood prevention and post-crisis management.
- **Burn Scars Mapping**: provision of seasonally (after the summer and winter fire seasons) information products regarding burned areas mapping and environmental loss estimates at high-

resolution to support fire fighting planning, environmental and natural resources planning and land conservation planning at regional/provincial levels.

- **Rapid Mapping**: dedicated to the response management of civil protection and rescue services, this service provides rapid mapping products showing the instantaneous extent and impact of natural disasters. First products are needed within 8 h after user request. These products are generated using any available and exploitable EO crisis image (HR/VHR, Optical/Radar). In the case of long duration disasters, daily products are required.

2.2.6 GSE RESPOND

The objective of this GSE [RD-30] is to increase the efficiency and effectiveness of the European and international humanitarian community through the appropriate and reliable application of geographic information. The main target users of GSE RESPOND are the EC (DG ECHO, DG RELEX, DG ENV/MIC), the UN (for instance the UN Office for Coordination of Humanitarian Affairs (OCHA), the UN High Commissioner for Refugees (UNHCR), UN Department of Peace Keeping Operations (UNDPKO), the Red Cross and NGOs.

GSE RESPOND provides a range of services supporting the entire humanitarian intervention cycle (Figure 2.2.4). GES RESPOND will provide support to humanitarian organisations throughout the intervention cycle. It will provide information for preparedness activities (pro-active) and for relief activities (reactive). GSE RESPOND supports both slow and fast onset crises (e.g. Famine – Slow, and Earthquake – Fast). Geographic Information (GI) has been proven useful to organisation working in this arena for a large variety of applications from ensuring the rapid deployment of relief following a disaster to planning reconstruction and development activities during long term recovery.

Figure 2.2.4: The humanitarian intervention cycle (source: UNITAR).

The GSE Respond service supports:

- Pure mapping as well as satellite derived information.

- Support services - training & in field support.
- Support to forecasting & alert services.

The intention is to seek to exploit economies of scale and improved information by supplying products to different types of users based on the same data components to provide a reliable and guaranteed service. Pure mapping as well as satellite-derived classification and change detection related information is used for the services, in complementing very high resolution missions as outlined in Table 2

GSE RESPOND supports these activities via 8 key services. These are:

- **Basic Mapping Service** (digital and paper maps and map archive utilising both EO and non-EO data sources and providing the baseline for other services)
- **Crisis and Damage Mapping Service** (digital and paper maps created quickly and detailing the effects of a given crisis)
- **Situation Mapping Service** (maps and GIS layers made available to field users for rapid update, these maps particularly rely on field information to ensure update accuracy)
- **Refugee and Internally Displaced People (IDP) Support Mapping Service** (includes both maps and GIS layers, detailing Refugee camps, water sources, health resources etc)
- **Thematic Mapping Service** (basic mapping with additional information such as health mapping, environmental mapping, maps for prevention/reconstruction purposes)
- **Alert Services** (complementing web alert systems with mapping information)
- **Communication / Reporting Services** (ad hoc mapping and graphics)
- **In-Field Data Collection and Field Mapping Service** (this supports the other services by providing information from the field, it also serves to train users/potential users during a crisis situation).

A large portion of the RESPOND portfolio of services is concerning emergencies: Crisis/Damage mapping service, Situation maps, Refugee camp monitoring, Alert services, Health mapping services. This is particularly the case with Crisis/Damage mapping services which are in response to either activations of the International Charter Space and Major Disasters or for other (non-Charter) activations e.g. conflicts in the context of humanitarian crisis events.

For these services concerning emergencies, timeliness of information supply is of the essence, hence rapid delivery of (fresh and archive) EO data is essential, within hours rather than days. When monitoring such situations a daily (or weekly) re-visit time is often required. Typically, disaster management organisations (e.g. typically European Civil Protection Authorities acting outside Europe, UN OCHA, WFP, etc) require background mapping ex-archive within 6 hours (typically 2 hours) and crisis/damage mapping information within 24 hours and on a daily basis.

Spatial scale requirements vary between services. In the case of high resolution basic mapping and refugee camp mapping, the primary source of EO data required are HRO and VHRO (in particular in the case of urban environment) with resolutions of 1-2.5m while for Crisis and damage mapping and situation mapping 2.5-10m resolutions are required.

2.2.7 GEOLAND

Geoland [RD-19] is a project carried out in the context of GMES. The ambition of the Geoland consortium is to develop and demonstrate a range of reliable, affordable and cost efficient European geo-information services, supporting the implementation of European directives and their national implementation, as well

as European and International policies. Thus, the GMES initiative is considered a unique opportunity to integrate existing technology with innovative and scientifically sound elements into sustainable services.

Two core services have been established within the Geoland project. These serve the Geoland observatories, providing them with basic geo-information products that the various services can build their individual efforts on:

- The Core Service Generic Landcover provides the Geoland regional observatories with harmonized, topical and geometric correct basic information on landcover.
- The Core Service Bio-Geophysical Parameters supplies generic information on bio-geophysical attributes of land surfaces at regional and global scales to the global observatories within Geoland.

The Geoland express two classes of requirements:

- European land cover mapping at continental scale with 10m to 20m spatial resolution with at least seasonal update frequency,
- Land cover of the 500 European major functional urban areas at local scale with 2.5m to 5m spatial resolution with an update frequency of several years.

2.2.8 DUE

The mission of the Data User Element (DUE) is to encourage the establishment of a long-term relationship between user communities and Earth Observation. The three major objectives of DUE, as stated in the Programme Declaration, are as follows:

- First, to create an environment allowing for the development of user communities for both institutional and commercial applications;
- Second, to support European companies in the development and demonstration of information products derived from current and future ESA missions;
- Third, to support industry - i.e. value adding and service companies - in establishing useful and cost effective services.

The two main DUE projects considered relevant for Sentinel-2 mission objectives are Globwetland and Desertwatch.

Globwetland aims at developing demonstration products based on Earth observation to improve the ability of wetland managers to better monitor and assess the condition of wetlands within their respective countries.

Desertwatch is a project with the aim of creating a standard and comparable geo-information products from country to country about the status and trends in desertification. The project also aims at creating a common framework for reporting to the UNCCD, the creation of a common basic infrastructure as a base for further developments where EO plays a key role and the development of a common methodological to assess and monitor the desertification problems and to identify trends and potential scenarios.

2.3 Summary of User Information Requirements

The user requirements coming from the GMES Fast-Track Services, GSEs and Geoland in terms of applications and associated Level 2/Level 3 products are summarized in Table 2.6.1. The requirements

concerning the GSEs described in this document are traceable to the related GSE End User Requirements surveys.

Service	Application(s)	EO Level 2/3 product	Spatial reso-lution*	Geographical Coverage	Update frequency
GMES Fast Track Services	Emergency Response	Overview reference and damage maps	5-10m	Global	on demand
		Detailed reference and damage maps	1-2.5m	Global	on demand
	Land Monitoring	Land cover, land use and geo-biophysical maps	10 - 20m	Europe	1 to 5 years
GSE Forest Monitoring	National greenhouse gas reporting	Land cover and forest map	10 m	Europe, parts of Asia, Africa and South-America	every 1 – 5 years
	Clean Development mechanisms, monitoring disturbances, inventory update	Land cover and forest map	5-30 m	Europe, , Russia, parts of Asia, Africa and South-America	every 1 – 5 years
GSE Land	Urban Atlas	Land cover map with emphasis on urban classes	1-2.5 m	European Cities	5 years
	Inland Water Quality	Land cover and land use map	10-25 m	Europe	3 – 5 years
	Water abstraction pressure by irrigation	Land cover and land use map	100-300 m	Europe	<= 10 days
	Impervious Areas / Soil sealing	Land cover map (national level)	20-30 m	Europe	3 - 5 years
		Land cover map (regional level)	10 m	Europe	1 – 3 years
GSE GMFS	Regional applications vegetation monitoring	Land cover map on continental and regional scale (vegetation state)	250 – 1000 m	Africa,	every 10 days
		Land cover map on national and subnational scale (crop/no-crop extent of cultivation, planting date, etc.)	20-30 m	Africa,	yearly
GSE RISK-EOS	Assets Mapping	HR urban area detection HR urban evolution	5-10 m 5-10 m	Europe	Yearly
	Flood Risk Analysis	Past event flood mapping Flood Event Simulation (LCM) Potential Loss Assessment (LCM)	5-10 m 5-10 m 5-10 m	Europe	Daily Annual Annual
	Burn Scars Mapping	Seasonal burn scar perimeter Seasonal fire damage assessment	10-15 m 10-15 m	Southern Europe (Mediterranean countries)	before / during/ after each fire season
	Rapid Mapping (flood monitoring)	NRT flood extent rapid mapping NRT flood impact rapid mapping Non RT flood extent mapping Non RT max flood extent mapping Non RT flood damage assessment Non RT flood duration per area	< 30m < 30m < 10m < 10m < 10 m < 10m	Europe	within 12h within 12h daily daily daily daily
	Rapid Mapping (large fires)	NRT fire extent rapid mapping Non RT fire extent mapping Non RT fire damage assessment	5-10 m 5-10 m 5-10 m	Southern Europe (Mediterranean countries)	within 1day 2 weeks after event
GSE RESPOND	Mapping, Damage Assessment & Thematic mapping for	Basic mapping at large scale	30-500m (5-15m for data capture)	Global	Weekly

	humanitarian aid and disaster management purposes (including services in rush provision)	Basic mapping at medium scale	10-30m (5-15m for data capture)	Global	Weekly
		Basic mapping at small scale	1 - 2.5 m	Global	Weekly
		Crisis/damage mapping (general case)	2.5m to 10 m	Global	Daily
		Crisis/damage mapping (Plain Flood Monitoring)	10-30m	Global	Daily
		Situation mapping – medium scale	2-25m	Global	Weekly
		Situation mapping – small scale	1-2.5m	Global	Weekly
		Refuge support maps- small scale	1-2.5m	Global	Weekly
		Refugee / IDP support maps – medium scale	2.5-5m	Global	Weekly
		Thematic mapping (including maps for prevention, reconstruction, health and environmental impact assessment) – small scale	1-2.5m	Global	Weekly
		Thematic mapping (including maps for prevention, reconstruction, health and environmental impact assessment) – small - medium scale	2.5-5m	Global	Weekly
		Thematic mapping (including maps for prevention, reconstruction, health and environmental impact assessment) – medium - large scale	10-20m	Global	Weekly
Geoland	Monitoring of land cover and vegetation	Land cover and use map	20m	Regional	Weekly
		Geo-biophysical variables	20m	Regional	Weekly

Table 2.6.1: Summary of the product requirements derived from the main GSEs and Geoland.

The need to assess simple processes and disturbances in vegetation and inland waters postulates the capability to quantitatively retrieve a limited set of vegetation, soil and water variables. They should be estimated at a regional as well as global scale given the appropriate temporal resolution.

Two priority main families of products have been identified:

- Generic land cover maps (for generic services such as GLC 2000 [RD-31] and CORINE [RD-32]).
- Maps of geo-biophysical variables (e.g. leaf area index or water content).

Given the temporal variability of terrestrial processes, land cover and associated geo-biophysical variables change rather rapidly. The priority products have therefore to be ensured at a timescale compatible with these processes and associated land cover change.

It should be noted that the availability of Sentinel-2 does provide the capability to deliver a range of further services outside of the two priorities listed above. Requirements for these services will be considered as additional capabilities not as driving requirements for the mission.

3 MISSION REQUIREMENTS

3.1 Introduction

The definition of the Mission Requirements for the Sentinel-2 mission is based on the user information requirements that were summarized in the previous chapter. The Mission Requirements cover the end-to-

end Earth observation system including high-level instrument requirements, mission operations, data product development and processing, data distribution and data archiving. Mission requirements should be traceable to information requirements defined and agreed with the users.

Defining mission requirements would be greatly simplified if the user requirements were less diversified and documented in detail, as they are for instance for meteorological services and sea ice services. Given the variety of terrestrial application-related services, the choice of spatial resolution and spectral bands is difficult to make. In addition, constraints that are not necessarily reflected in the user requirement specifications may also arise.

Considering this the Mission requirements as described in the following sections have been identified for the Sentinel 2 mission.

3.2 Continuity, Performance and Availability

Measurement continuity is needed to guarantee on-going services included in GMES. Continuity of data as provided by these missions is vital to ensure effective exploitation of user investment and any gap in data availability would affect on-going monitoring programs. In this line, continuity is required for services at high spatial resolution such as the ones provided by the SPOT and Landsat satellite systems.

Continuity also implies that the performance of the mission services available so far should, as a minimum, be maintained. This means that deviations from technical parameters such as spectral bands for observation and their resolution/sampling and spatial performance should be carefully analysed in order not to jeopardise established applications.

Although it may sound trivial it should be noted that an operational mission could only successfully support reliable uninterrupted services if the end-to-end system including space and ground segment is continuously available and robust with back up systems in case of failures. Conflict-free operations are essential.

MR-ID	Type	Value
MR-S2-01	Service continuity	Start of Operations in 2011/2012 in order to ensure continuity to currently existing sensors SPOT and Landsat.
MR-S2-02	Service performance	Provide continuity to services provided by exiting sensors (SPOT, Landsat) and enhance them to cover the user information needs expressed in the GSEs (GMES Service Elements) [RD-2], GMES Land Fast Track Services [RD-3] [RD-29], Framework Programme-VI Integrated Project Geoland [RD-4] and DUE (Data User Element) Projects [RD-5] Globcover, Globwetland and Desertwatch.
MR-S2-03	Availability	End-to-en product availability to the end user shall typically be better than 95%, i.e. the specified products shall provide the specified temporal and spatial coverage, comply with the specified product quality and be delivered to the user within the timeliness specification.

3.3 Revisit

The geometric revisit time represents the temporal periodicity of systematic acquisition of a given area disregarding cloud cover and under the same viewing direction. The effective revisit time represents the temporal frequency of systematic acquisition of a given area with cloud cover (excluding thin cirrus if thin

cirrus clouds can be detected and their effect corrected) below a specified threshold and under the same viewing direction. Based on European cloud cover statistics, a ratio of 3 between the geometric and effective revisits is considered adequate.

The revisit requirements here are driven mainly by vegetation monitoring for services included in the GSE GMFS, RISK-EOS and Land. In this context the observing system should be better than SPOT and Landsat as these systems have not high enough revisit frequencies.

It should be noted here that revisit requirements may necessitate a system with a constellation of more than one satellite operating at the same time. This would facilitate the satisfaction of the effective revisit requirements for all services relying on land surface classification and vegetation monitoring.

MR-ID	Type	Value
MR-S2-04	Geometrical Revisit	Not higher than 5 days (goal) / 10 days (threshold)
MR-S2-05	Effective Revisit	Not higher than 15 days (goal) / 30 days (threshold)

3.4 Coverage

The geometrical coverage time represents the temporal periodicity of systematic acquisition of a given area disregarding cloud cover and possibly under different viewing directions. The effective coverage time represents the temporal periodicity of systematic acquisition of a given area with cloud cover (excluding thin cirrus if thin cirrus clouds can be detected and their effect corrected) below a specified threshold and possibly under different viewing directions.

A weekly to bi-weekly data product update frequency is mainly driven by the GSEs GMFS, Land, and RISK-EOS (Table 2.6.1).

MR-ID	Type	Value
MR-S2-06	Geometrical Coverage	3 days (goal) / 5 days (threshold)
MR-S2-07	Effective Coverage	9 days (goal) / 15 days (threshold)

3.5 Accessibility

The geometrical accessibility time represents the temporal frequency of potential (non systematic) acquisition of a given area disregarding cloud cover and possibly under different observation conditions.

The accessibility capabilities are driven by the services included in INSCRIT (Information Service in Response to Crises, Disasters and Emergencies) and GSE RISK-EOS services.

MR-ID	Type	Value
MR-S2-08	Geometrical Accessibility	1 days (goal) / 3 days (threshold)

3.6 Time of Observation

Having an identical or similar observation configuration (i.e. illumination and viewing directions) allows a easier detection of changes on the Earth surface. Considering that the change detection maps is one of the main products required by the user community (e.g. in GSE Land for urban applications or GSE Forest

Monitoring), the mission should provide within a period as long as possible observations with identical (or similar) illumination directions (or local solar time) and with an identical (or similar) viewing direction. The periodicity of the identical viewing directions is given by the temporal revisit requirement. The illumination directions of two different acquisitions should be kept as close during the longest possible duration.

MR-ID	Type	Value
MR-S2-9	Time of observation	Maximize the number of acquisitions with identical (or close) observation configurations (i.e. viewing and illumination directions).

3.7 Instantaneous Coverage

The monitoring of variables such as vegetation properties associated with Food Security services, catchment properties for hydrological applications as well as the monitoring of natural hazards such as floods and fire risk areas postulate the availability of contextual and synoptic information, which is to a certain extent driving the width of the swath.

In the context of instantaneous coverage the influence of directionality on the observed reflectances and derived products should be minimized. For that purpose the observation zenith angle (OZA) should be kept below 15°. Even though not strictly required from a service point of view the flexibility of the mission to access areas rapidly owing to natural or manmade hazards/disasters would be highly desirable. For such non-nominal operation, which would pose a potential service for the International Charter 'Space and Major Disasters' [RD-8] a higher OZA can be accepted.

MR-ID	Type	Value
MR-S2-10	Swath Width	≥200 km
MR-S2-11	OZA	≤15° except for emergency situations requiring off-track pointing.

3.8 Timeliness

Timeliness is the temporal span between data acquisition and product delivery to the user. This is an essential requirement for operational services. In this respect, more demanding services are the so-called NRT (Near Real Time) which are included in the INSCRIT fast-track services and the GSE RISK-EOS. Requirements for these services correspond to a delivery of the Level 1c products within 3 hours. For the rest of products the delivery time can be relaxed up to 1 day.

MR-ID	Type	Value
MR-S2-12	Timeliness	Delivery of products up to Level 1c within 3 hours for NRT (Near Real Time) and 24 hours for the rest.

3.9 Geographical Coverage

The services provided by the user community include areas all over the world. Although a majority of the applications focus on Europe, still a significant amount of services (e.g. GSE GMFS, GSE RESPOND and Geoland) offer services over all continents.

MR-ID	Type	Value
MR-S2-13	Geographical Coverage	All land areas between 56° South latitude (Cape horn in South America) and 83° North latitude (north of Greenland) including major islands (greater than 100 km^2 size), EU islands and all the other small islands located at less than 20 km from the coastline. In addition it is required to acquire the whole Mediterranean Sea, all inland water bodies and all closed seas.

3.10 Spectral Sampling

The selection of the spectral sampling (i.e width and resolution of the spectral bands) closely depends on the focus of the multi-spectral imaging mission. Whilst for the purpose of merely detecting and mapping land cover/change a more conservative approach is adequate (i.e. a basic set of bands), an improved surface monitoring mission would need a higher amount of spectral bands with narrower widths for an adequate quantification of geo-biophysical variables. Hence, a larger number of bands will enable more accurate classifications, land use change mapping, as well as vegetation status monitoring for agriculture and forestry.

To a large extent, the Landsat and SPOT multi-spectral data have been used to develop most of the services included in the GSEs. It is therefore expected that Landsat-5 TM spectral bands would satisfy the current minimum service requirements in areas with extensive regional in-situ information. However, with a view to aspired service advancements in the future, e.g. for improved Land cover/change classification, atmospheric correction, cloud/snow separation and the quantitative assessment of the vegetation status, additional spectral channels are needed. Considering the user information needs for both basic and advanced services, the bands described in Table 3.10.1 are required to satisfy the mission objectives.

Band #	Center λcenter (nm)	Spectral width Δλ (nm)	Bandwidth knowledge ±nm	Purpose	Heritage
1	443	20	0.5	Atmospheric correction (aerosol scattering)	MODIS, ALI, LDCM
2	490	65	1	Sensitive to vegetation senescing, carotenoid, browning and soil background; atmospheric correction (aerosol scattering)	MERIS, LDCM, Landsat
3	560	35	1	Green peak, sensitive to total chlorophyll in vegetation.	MERIS, LDCM*, SPOT-5, Landsat
4	665	30	1	Max. chlorophyll absorption.	MERIS, LDCM*, Landsat
5	705	15	1	Position of red edge; consolidation of atmospheric corrections / fluorescence baseline.	MERIS
6	740	15	1	Position of red edge, atmospheric correction, retrieval of aerosol load.	MERIS
7	775	20	1	LAI, edge of the NIR plateau	MERIS, ALI
8	842	115	1	LAI	SPOT-5, Landsat
8a	865	20	1	NIR plateau, sensitive to total	MERIS, ALI, LDCM*

				chlorophyll, biomass, LAI and protein; water vapour absorption reference; retrieval of aerosol load and type.	
9	940	20	1	Water vapour absorption, atmospheric correction.	MODIS, MERIS
10	1375	20	5	Detection of thin cirrus for atmospheric correction.	MODIS, LDCM
11	1610	90	5	Sensitive to lignin, starch and forest above ground biomass. Snow/ice/cloud separation.	LDCM, SPOT-5 , Landsat
12	2190	180	5	Assessment of Mediterranean vegetation conditions. Distinction of clay soils for the monitoring of soil erosion. Distinction between live biomass, dead biomass and soil, e.g. for burn scars mapping.	LDCM, Landsat

Table 3.10.1: Spectral bands for Sentinel-2. Synthesis of purposes and heritage of the spectral bands of Sentinel-2. Symbol '' denotes bands that have same centre wavelength as LDCM but narrower spectral bandwidth.*

If we consider as reference, the 6 spectral bands of the Landsat series, the following first set of improvements has been considered:

- Narrowing the width of the spectral bands to limit the influence of water vapour and other atmospheric constituents. In particular, the original Landsat NIR band at 760-900 nm proved to be heavily contaminated by water vapour and to a lesser extent by oxygen absorption, contaminated by the red edge in case of senescent vegetation and too wide to be sensitive to iron oxide absorption between 850 nm and 900 nm. The narrow band at 865 nm (Band 8a) is essential in the NIR in order to avoid water vapour contamination, to represent the NIR plateau for vegetation and to be sensitive to iron oxide content for soil.
- Adding a spectral band in the blue domain at 443 nm (Band 1) is necessary for accurate aerosols correction. This band is already included in MERIS [RD-20] and is being operationally used in the Envisat ground segment for the calculation of the MGVI (MERIS Global Vegetation Index) [RD-13] and in the operational atmospheric corrections for the MODIS sensor [RD-21]. The atmospheric correction is in particular important over urban and coastal areas due to the high variability of aerosol load and types.
- Cirrus cloud presence is a very frequent phenomenon which needs to be considered in a global operational mission. Adding a spectral band at 1375 nm (Band 10) allows for cirrus detection and to correct for thin-cirrus using VNIR bands information. This band was already included in MODIS [RD-22], being used operationally there [RD-21] and is planned in all future US operational multi-spectral missions (LDCM [RD-23], VIIRS [RD-24]).

In addition, a SWIR-II band at 2190 nm (Band 12) is considered as value adding for the following goals:

- Improved assessment of Mediterranean vegetation conditions, as underlined in the GEOLAND Requirements on EO Space & Ground Segment [RD-19].
- Distinction of clay soils for the monitoring of soil erosion [RD-25].
- Distinction between live biomass, dead biomass and soil [RD-26], e.g. for burn scars mapping.

On top of these additional bands, the characterisation of the vegetation red-edge is considered in the framework of the GMES programme as highly relevant and important for the following applications:

- Vegetation classification. An additional number of spectral bands in the red-edge would allow increasing the number of classes and improving the accuracy of the land cover classification. The land cover map is one of the most important products in the GSEs [RD-2] and an improvement of classifications over vegetations would be specially appreciated by the GSEs Forest Monitoring (problems distinguishing forest and grassland using LANDSAT data are mentioned), Land, GMFS and RISK-EOS. Classification improvements using red-edge information have been demonstrated with airborne data (CASI [RD-27], AVIRIS, Hymap, etc.) and spaceborne sensors such as Proba/CHRIS, Hyperion [RD-13].
- Determination of the vegetation status and health. Forest and crop biophysical variables are required for some of the GSE applications [RD-2], e.g. National greenhouse gas reporting in GSE Forest Monitoring; Agro-environmental indicators in GSE Land; Regional applications for vegetation monitoring in GSE GMFS; Vegetation monitoring in GSE RISK-EOS.

The use of the red-edge information is already being operationally exploited by the Envisat/MERIS mission and an operational product is being distributed, the so-called "MERIS Terrestrial Chlorophyll Index" (MTCI) [RD-14].

Accurate vegetation characterisation and improved land cover mapping can be reached adding three spectral bands in the red-edge domain (705 nm, 740 nm and 775 nm) plus one band at 940 nm (Band 9) to correct from water vapour absorption effect. A water vapour correction band is already included in operational missions like Envisat/MERIS (located at 900 nm), MODIS or VIIRS.

Any operational mission requiring multi-temporal data comparisons and aiming at quantitative retrieval of operational land variables needs to produce bottom-of-atmosphere radiometric measurements. This objective can only be reached through a proper atmospheric correction by including the atmospheric correction bands.

If these bands to improve classification accuracy and exploit the red-edge information are added, we finally reach a final set composed of 13 spectral bands.

The final set of bands (Table 3.10.1) is recommended in order to satisfy a vast majority of the requirements expressed by the users. This set of bands covers the mission needs in terms of land use mapping, land cover change detection and retrieval of geo-biophysical variables. All the proposed spectral bands proposed have been implemented and operationally used (or planned) for the space missions listed in the right column of Table 3.10.1.

With a view to the relatively narrow bandwidths, aspired for improved land cover classification and geo-biophysical variable retrievals, high accuracy of position and width of the spectral bands should be ensured. In particular, for the 443nm spectral band for aerosol correction, an inaccurate knowledge of bandwidth and position would compromise the retrieval quality.

MR-ID	Type	Value
MR-S2-14	Spectral band characteristics	The required characteristics for the spectral bands are described in Table 3.10.1.

3.11 Radiometric Requirements

For the applications covered by this mission, previous studies [RD-10] show that the radiometric accuracy at TOA has to be not worse than 3% (goal) to 5% (threshold). For inter-band radiometric calibration 3% accuracy is also required.

The requirements for Signal-to-Noise Ratio (SNR) and minimum, reference and maximum radiance levels for each spectral band are presented in Table 3.11.1.

Maximum radiances correspond to a large range of radiance levels, which are required to avoid saturation (e.g. due to snow targets). Minimum radiance level is defined in order to give a chance to measure under low illumination conditions (i.e. with a low Sun elevation angle) and to observe dark targets (e.g. dense coniferous forests).

The polarization sensitivity and the polarization dependent loss in the instrument have to be limited in such a way that their contributions remain marginal source of uncertainty.

Band #	**Center λcenter (nm)**	**Spectral width Δλ (nm)**	**L_{min} W/m²/sr/μm**	**L_{ref} W/m²/sr/μm**	**L_{high} W/m²/sr/μm**	**L_{max} W/m²/sr/μm**	**SNR @L_{ref}**	**SNR @L_{high}**
1	443	20	15.97	129.11	n/a	587.87	129	n/a
2	490	65	11.70	128.00	n/a	615.48	154	n/a
3	560	35	6.49	128.00	n/a	559.01	168.4	n/a
4	665	30	3.31	108.00	n/a	484.13	142.1	n/a
5	705	15	2.61	74.60	n/a	449.55	117	n/a
6	740	15	2.06	68.23	n/a	412.92	89	n/a
7	775	20	1.67	66.70	n/a	387.08	105	n/a
8	842	115	0.95	103.00	n/a	307.80	174.6	n/a
8a	865	20	0.95	52.39	n/a	307.80	72	n/a
9	940	20	0.51	8.77	n/a	232.91	114	n/a
10	1375	20	0.00	6.00	n/a	83.00	50	n/a
11	1610	90	0.40	4.00	32.00	69.78	100	510
12	2190	180	0.10	1.70	11.00	24.60	100	480

Table 3.11.1: Band parameters for each spectral band.

MR-ID	Type	Value
MR-S2-15	Absolute radiometric accuracy	The absolute radiometric accuracy shall be 3% (goal) / 5% (threshold).
MR-S2-16	Inter-band calibration accuracy	The inter-band calibration accuracy shall be 3%.
MR-S2-17	Signal-to-Noise and radiance levels	Signal-to-noise ratio (SNR) and minimum, reference and maximum radiance levels for each spectral band are presented in Table 3.11.1.
MR-S2-18	Polarization	The polarization sensitivity and the polarization dependent loss in the instrument have to be limited in such a way that their contributions remain marginal source of uncertainty.

3.12 Quantization resolution

In order to ensure a proper sampling of the radiometric measurement the users require a quantization using at least 12 bits.

MR-ID	Type	Value
MR-S2-19	Quantization resolution	Radiometric measurements quantified using 12 bits.

3.13 Spatial Resolution

The GMES derived User Requirements for spatial resolution varies between 1m and 30m depending on the service required. The applications requiring very high spatial resolution (<10m) are usually associated to low product update frequency and to small geographical areas and can be covered in the frame of national missions e.g. by France (Pleiades, SPOT-5, Venus), Germany (RapidEye), UK (DMC) and Spain (Spanish EO satellite), or Third Party Missions (TPM) such as Kompsat-II or ALOS. In that respect, Table 3.13.1 summarizes the features of the main existing and foreseen very-high resolution optical imagers.

Mission name	Pan-chromatic Resolution (nadir)	Multi-spectral resolution (nadir)	Swath	Time frame	Panchromatic Band	Multi-spectral Bands
Pleiades	0.7 m	2.8 m	20 km	2009-	480-830 nm	Blue: 430-550 nm Green: 490-610 nm Red: 600-720 nm NIR: 750-950 nm
Rapideye	-	6.5 m	78 km	2007-2014	-	Blue: 440-510 nm Green: 520-590 nm Red: 630-685 nm Red edge: 690-730 nm NIR: 760-850 nm
Spanish Earth Observation Satellite	2.5 m	10 m	25 km	2010-	TBD nm	Blue: TBD Green: TBD Red: TBD NIR: TBD
DMC	4 m (optional)	36 m	600 km (MS)	2002-	-	Red: 520-600nm Green: 630–690nm NIR: 760–900nm
SPOT 5	2.5 m/5 m	10 m	2x60 km	2002-	480-700 nm	Green: 500-590 nm Red: 610-680 nm NIR: 780-890 nm SWIR: 1580-1750 nm
LISS-IV on Resourcesat-1	-	5.8 m	23 km (MS) 70 km (MS)	2003-	-	Green: 520-590 nm Red: 620-680 nm NIR: 770-860 nm
Quickbird	0.6 m	2.4 m	16.5 km	2001-	445-900 nm	Blue: 450-520 nm Green: 520-600 nm Red: 630-690 nm NIR: 760-900 nm
Ikonos	1 m	4 m	13 km	2001-	450-900 nm	Blue: 450-530 nm Green: 520-610 nm Red: 640-720 nm NIR: 770-880 nm

Table 3.13.1: List of current and future very-high resolution multi-spectral sensors satisfying cartographic requirements.

For instance, the LMCS [RD-3] and Geoland [RD-4] express two classes of requirements:

- European land cover mapping at continental scale with 10 m to 30 m with at least seasonal update frequency,
- Land cover of the 500 European major functional urban areas at local scale with 2.5m to 5m with an update frequency of several years.

The second class of products require data from very high resolution sensors. The first class can be covered with a sensor with the spatial resolution features described in Table 3.13.2. Bands 1, 9 and 10 are sampled at 60m spatial resolution as they are devoted to atmospheric correction purposes. Bands 2, 3, 4 and 8 are sampled at 10m to ensure higher resolution products for some specific applications (e.g. soil sealing mapping, forest mapping for Kyoto Protocol inventory). The rest of bands (5, 6, 7, 8a, 11 and 12) are specified at 20m spatial resolution that is sufficient for the rest of the applications.

Band #	Center λcenter (nm)	Spectral width Δλ (nm)	Spatial Resolution
1	443	20	60
2	490	65	10
3	560	35	10
4	665	30	10
5	705	15	20
6	740	15	20
7	775	20	20
8	842	115	10
8a	865	20	20
9	940	20	60
10	1375	20	60
11	1610	90	20
12	2190	180	20

Table 3.13.2: Spatial Resolution of the Sentinel-2 spectral bands.

MR-ID	Type	Value
MR-S2-20	Spatial Resolution	Requirements are described in Table 3.13.2. For off-track acquisitions in emergency mode a degradation of 50% of the spatial resolution is accepted.

3.14 Geo-location Requirements

The process of acquiring remote sensing images introduces a series of distortions coming from the observer (sensor and platform) and the observed (atmosphere and Earth) surface. The data acquired need therefore to be processed in a way to be exploitable by the final user as a geo-located data set, where each pixel can be annotated with its geographical coordinates.

The accurate geometric correction of remote sensing images is a key issue in multi-source and multi-temporal data integration, management and analysis [RD-11]. With the advent of GMES, geo-localization will be a central issue. Having a continuous, operational global monitoring concept postulates accurate automatic geo-location in order to reduce/avoid human intervention in the geo-location process.

For the VNIR and SWIR domains automatic geo-location accuracy should be better than ±1 pixel of the spatial resolution of the sensor. For multi-temporal observations the co-registration between two images acquired at different times shall be accurate to ±2 pixels.

MR-ID	Type	Value
MR-S2-21	Geo-location accuracy	The geo-location accuracy of Level 1c data (i.e. the ortho-rectified image) shall be better than or equal than ±1 pixel of the sensor spatial resolution without using ground control points (GCP).
MR-S2-22	Multi-temporal co-registration	The co-registration between two images acquired at different times shall be accurate to ±2 pixels

3.15 Service Data Products

Level 1a, 1b, 1c, 2a and a catalogue of Level 2b/3 products should be available to the service providers and final users. Service providers are officially recognised entities in charge of elaborating more refined products or products specific for some applications in the frame of the GMES programme). Final users are defined as any generic user benefiting from GMES monitoring data. Definitions of the product levels can be found in chapter 5.3 of this document.

The catalogue of the Level 2b and Level 3 products should include those in Tables 3.15.1 (main) and 3.15.2 (secondary/optional).

Abbreviation	Name	Description	Goal Accuracy
LC	Land Cover Map	Land cover with a set of generic classes compatible with those already used for generic services such as GLC 2000 and CORINE.	TBD
CDM	Change Detection Map	Product indicating major land use conversion processes.	TBD
LAI	Leaf Area Index	Map with the green leaf area per unit soil area.	10%
FVC	Fraction of Vegetation Cover	% of the land surface covered by vegetation.	TBD
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation	Fraction of the radiation in the photosynthetic domain (400-700nm) that is absorbed by leafs. Values range between 0 and 1. Product to provide continuity of MGVI [RD-12]. For Sentinel-2 this index would provide MGVI at high resolution.	RMS=0.05 S/N=21 [RD-12]
Cab	Leaf Chlorophyll Content	The amount of chlorophyll per square centimetre. This product would provide continuity of MTCI [RD-14]. For Sentinel-2 this index would provide MTCI at high resolution. This index is directly related to the chlorophyll content of vegetation.	TBD
C_w	Leaf Water Content	The amount of water in weight (grams) or volume (cubic centimetres) per unit leaf weight (grams) or volume (cubic centimetres). This parameter can be remotely sensed and is important in estimating the potential of transpiration and the vegetation energy balances.	TBD
SC	Snow Cover	Fraction of the surface covered by snow.	TBD

Table 3.15.1: List of Level 2b and Level 3 main products required for the Sentinel-2 mission.

Abbreviation	Name	Description	Goal Accuracy
FNPAV	Fraction of Non-Photosynthetically Active Vegetation	Amount of non-photosynthetically active vegetation measured in %.	TBD
SA	Surface Albedo	Fraction of the incoming radiation reflected by the surface.	TBD
BS	Burn Scars	Map of the areas affected by fire events.	TBD
FL	Fuel Load	Fuel load for wild artificial fires.	TBD
SFRI	Structural Fire Risk Index	For more details see Risk-EOS GSE report.	TBD
CD	Crown Density	For more details see Forest Monitoring GSE report.	TBD
FA	Forest Age	For more details see Forest Monitoring GSE report.	TBD
FRM	Flood Monitoring	For more details see Risk-EOS GSE report.	TBD

Table 3.15.2: List of Level 2b and Level 3 secondary/optional products required for the Sentinel-2 mission.

MR-ID	Type	Value
MR-S2-23	Data products	Users should have access to Levels 1a, 1b, 1c, 2a and a catalogue of Level 2b/3 products which is included in Tables 3.15.1 (main) and 3.15.2 (secondary/optional).

4 SUMMARY AND CONCLUSIONS

When analysing the current requirements, as established by the GMES Fast Track Services, FP-6 Integrated Project GEOLAND, GSE (GMES Service Elements), DUE (Data User Element) and European Environmental Policies, a multi-spectral imaging capability would be needed to cover all the terrestrial surfaces, and with a relatively high spatial resolution and observation frequency.

Given the fact that the current services are based on Landsat- and SPOT-type data, a service satisfaction could to a certain extent be expected by continuing these current mission programmes as a minimum scenario. However, with a view to required service improvements in the near future, however, an enhanced land surface monitoring system in terms of spectral, temporal and spatial coverage would be needed. It therefore appears necessary to implement a system with the mission requirements described in this document.

Despite the large diversity of the user information requirements (e.g. in terms of spatial resolution, revisit or spectral sampling), the system concept proposed is a trade-off which satisfies most of the foreseen applications. Indeed, only mapping services requiring very high resolution imagery (higher than 10m spatial resolution) will not be covered by Sentinel-2 but are still ensured in the frame of GMES by other missions (e.g. Pleiades, Rapideye). In addition, the land surface requirements for low spatial resolution and high revisit optical imaging will be covered in the frame of GMES by the Sentinel-3 mission.

The stated GMES objectives include ‘the provision and use of operational information for Global Monitoring of Environment and Security’ as well as ‘to ensure the functioning of the system and its

evolution'. The mission requirements proposed here give some margin for the evolution of the user information requirement specification.

In summary, Sentinel-2 will benefit from the experience and lessons learned from Landsat and SPOT and it constitutes a unique multi-spectral optical imaging mission in the sense that it combines high-spatial resolution, wide swath, dense spectral sampling, systematic geographical coverage and frequent temporal revisit. Mission requirements for Sentinel-2 are summarized in Table 4.1.

MR-ID	Type	Value
MR-S2-01	Service continuity	Start of Operations in 2011/2012 in order to ensure continuity to currently existing sensors SPOT and Landsat.
MR-S2-02	Service performance	Provide continuity to services provided by exiting sensors (SPOT, Landsat) and enhance them to cover the user information needs expressed in the GSEs (GMES Service Elements) [RD-2], GMES Fast Track Services [RD-3] [RD-29], Framework Programme-VI Integrated Project Geoland [RD-4] and DUE (Data User Element) Projects [RD-5] Globcover, Globwetland and Desertwatch.
MR-S2-03	Availability	End-to-en product availability to the end user shall typically be better than 95%, i.e. the specified products shall provide the specified temporal and spatial coverage, comply with the specified product quality and be delivered to the user within the timeliness specification.
MR-S2-04	Geometrical Revisit	Not higher than 5 days (goal) / 10 days (threshold)
MR-S2-05	Effective Revisit	Not higher than 15 days (goal) / 30 days (threshold)
MR-S2-06	Geometrical Coverage	3 days (goal) / 5 days (threshold)
MR-S2-07	Effective Coverage	9 days (goal) / 15 days (threshold)
MR-S2-08	Geometrical Accessibility	1 days (goal) / 3 days (threshold)
MR-S2-9	Time of observation	Maximize the number of acquisitions with identical (or close) observation configurations (i.e. viewing and illumination directions).
MR-S2-10	Swath Width	≥200 km
MR-S2-11	OZA	≤15° except for emergency situations requiring off-track de-pointing.
MR-S2-12	Timeliness	Delivery of products up to Level 1c within 3 hours for NRT (Near Real Time) and 24 hours for the rest.
MR-S2-13	Geographical Coverage	All land areas between 56° South latitude (Cape horn in South America) and 83° North latitude (north of Greenland) including major islands (greater than 100 km^2 size), EU islands and all the other small islands located at less than 20km from the coastline. In addition it is required to acquire the whole Mediterranean Sea, all inland water bodies and all closed seas.
MR-S2-14	Spectral band characteristics	The required characteristics for the spectral bands are described in Table 3.10.1.
MR-S2-15	Absolute radiometric	The absolute radiometric accuracy shall be 3% (goal) / 5% (threshold).

	accuracy	
MR-S2-16	Inter-band calibration accuracy	The inter-band calibration accuracy shall be 3%.
MR-S2-17	Signal-to-Noise and radiance levels	Signal-to-noise ratio (SNR) and minimum, reference and maximum radiance levels for each spectral band are presented in Table 3.11.1.
MR-S2-18	Polarization	The polarization sensitivity and the polarization dependent loss in the instrument have to be limited in such a way that their contributions remain marginal source of uncertainty.
MR-S2-19	Quantization resolution	Radiometric measurements quantified using 12 bits.
MR-S2-20	Spatial Resolution	Requirements are described in Table 3.13.2. For off-track acquisitions a degradation of 50% of the spatial resolution is accepted.
MR-S2-21	Geo-location accuracy	The geo-location accuracy of Level 1c data (i.e. the ortho-rectified image) shall be better than or equal than ±1 pixel of the sensor spatial resolution without using ground control points (GCP).
MR-S2-22	Multi-temporal co-registration	The co-registration between two images acquired at different times shall be accurate to ±2 pixels
MR-S2-23	Data products	Users should have access to Levels 1a, 1b, 1c, 2a and a catalogue of Level 2b/3 products which is included in Tables 3.15.1 (main) and 3.15.2 (secondary/optional).

Table 4.1: List of all Sentinel-2 mission requirements.

5 REFERENCES, ACRONYMS AND DEFINITIONS

5.1 References

Code	Value
RD-1	ESA/PB-EO(2004)76, rev.1
RD-2	ESA GMES Web Site http://earth.esa.int/gmes/
RD-3	GMES Fast Track Land Monitoring Core Service (LMCS). Executive summary of the Strategic Implementation Plan. By Prof. Dietmar Gruenreich for the Land Monitoring Core Service Implementation Group. GAC/2007/4.
RD-4	GMES Products & Services supporting the Implementation of European Directives and International Policies & Conventions linked to "land cover & Vegetation", http://www.gmes-geoland.info/project.php.
RD-5	Data User Element Web Site: http://dup.esrin.esa.it/.
RD-6	European Policies Website, http://ec.europa.eu/environment/policy_en.htm
RD-7	ESA/PB-EO (2004)48, rev. 1
RD-8	International Charter 'Space and Major Disasters'; http://www.disastercharter.org
RD-9	Reflection paper on GMES Initial Services, GAC(2004)4_Fin.(12.07.04).
RD-10	Schaepman, M., D. Schläpfer, and A. Müller, Performance Requirements for Airborne Imaging Spectrometers, Proc. SPIE, Imaging Spectrometry VII, Vol. 4480, 23–31, 2001
RD-11	Toutin, T. (2004). Review Paper: Gemometric Processing of Remote Sensing Images: Models, Algorithms and Methods, International Journal of Remote Sensing, vol. 25, no. 10, pp 1893-1924(32)
RD-12	Gobron, N., B. Pinty, M. Verstraete, Y. Govaerts, 1999. The MERIS Global Vegetation Index (MGVI): description and preliminary application. International Journal of Remote Sensing. 20 (9). 1917-1927.
RD-13	Root R., Zarco-Tejada P., Pinilla C., Ustin S., Kokaly R., Anderson G., and Hager S. Identification, Classification, and Mapping of Invasive Leaf Spurge Using Hyperion, AVIRIS, and CASI. EO1 Validation Report.
RD-14	Dash J. & Curran P.J. (2004) Evaluation of the MERIS Terrestrial Chlorophyll Index. Evaluation. ESA Envisat Workshop, Salzburg (Austria), ESA document SP-572.
RD-15	GSE Forest Monitoring website: http://www.gmes-forest.info
RD-16	GSE GMFS website: http://www.gmfs.info/
RD-17	GSE RISK-EOS website: http://www.risk-eos.com
RD-18	GSE Land website: http://www.gmes-gseland.info
RD-19	Geoland requirements on EO Space & Ground Segment, issued by the Geoland Executive Board Members, 10/02/2006, http://www.gmes-geoland.info.
RD-20	Envisat/MERIS Web description: http://envisat.esa.int/instruments/meris/
RD-21	MODIS ATBD Atmospheric Correction Algorithm Spectral Reflectances. ATBD-MOD-08. Version 4.0 04/30/1999.
RD-22	MODIS Web Site: http://modis.gsfc.nasa.gov/
RD-23	Landsat Data Continuity Mission (LDCM) Web Site: http://ldcm.nasa.gov

RD-24	VIIRS Web description: http://www.ipo.noaa.gov/Technology/viirs_summary.html
RD-25	Drake, N. A., Mackin, S., Settle, J. J., 1999. Mapping Vegetation, Soils, and Geology in Semiarid Shrublands Using Spectral Matching and Mixture Modeling of SWIR AVIRIS Imagery. Remote Sensing of Environment, Volume 68, Issue 1, April 1999, Pages 12-25.
RD-26	Mougenot et al., 2000. Applications of VEGETATION data to resource management in arid and semi-arid rangelands. SPOT-VEGETATION Workshop.
RD-27	Zarco-Tejada P. J., Miller, J.R., 1999. Land cover mapping at BOREAS using red edge spectral parameters from CASI imagery. Journal of Geophysical Research, Vol. 104, no. D22, pp. 27,921-27,933.
RD-28	IR Element Mission Requirements Document. ESA Document.
RD-29	GMES Fast Track Emergency Response Core Service (ERCS). Executive summary of the Strategic Implementation Plan. Prof. Bernardo De Bernardinis for the Emergency Response Core Service Implementation Group. GAC/2007/3.
RD-30	GSE RESPOND website: http://www.respond-int.org/
RD-31	GLC2000 website: http://www-gvm.jrc.it/glc2000/
RD-32	CORINE website at the EEA (European Environment Agency): http://dataservice.eea.europa.eu/dataservice/
RD-33	KYOTO INV Website: http://kyoto-inv.pisa.intecs.it/

5.2 Acronyms

Acronym	**Meaning**
BOA	Bottom-Of-Atmosphere
BS	Burn Scars
CD	Crown Density
CDM	Change Detection Map
C_w	Leaf water content
DU	Digital Units
DUE	Data User Element
EO	Earth Observation
ESA	European Space Agency
FA	Forest Age
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
FL	Fuel Load
FNPAV	Fraction of Non-Photosynthetically Active Vegetation
FRM	Flood Monitoring
FTS	Fast Track Service
FVC	Fraction of Vegetation Cover
GCP	Ground Control Point
GMES	Global Monitoring for Environment and Security
GSE	GMES Service Element
LAI	Leaf Area Index
LC	Land Cover
PB	Programme Board
S2	Sentinel-2
SA	Surface Albedo

SC	Snow Cover
SFRI	Structural Fire Risk Index
SPOT	Satellite Pour l'Observation de la Terre
TCI	Terrestrial Chlorophyll Index
TOA	Top-Of-Atmosphere
TPM	Third Party Missions

5.3 Definitions

Emergency
Unpredictable event that shall be sensed by the satellite and distributed as soon as possible to the user (e.g. civil protection).

Goal
The term "goal" denotes a non-mandatory requirement, the implementation of which shall be studied to allow for an assessment of the system impacts. The implementation or not of the goal requirements will be decided by the Agency after proper analysis of the implications.

Product Level 0
Raw data after restoration of the chronological data sequence for the instrument(s) operating in observation mode, at full space/time resolution with all supplementary information to be used in subsequent processing (e.g. orbital data, health, time conversion, etc.) appended. Level 0 data are time-tagged. The precision and accuracy of the time-tag shall be such that the measurement data may be localized to accuracy compatible with the users requirements.

Product Level 1a
Level 0 data with corresponding radiometric, spectral and geometric (i.e. Earth location) correction and calibration computed and appended, but not applied.

Product Level 1b
Level 1a data not re-sampled, quality-controlled and radiometrically calibrated, spectrally characterised, geometrically characterised, annotated with satellite position and pointing, landmarks and preliminary pixel classification (e.g. land/water/cloud mask). The Level 1b product consists of Top of Atmosphere (TOA) radiance ($W.m^{-2}.sr^{-1}.\mu\ m^{-1}$).

Product Level 1c
Level 1b data orthorectified, re-sampled to a specified grid. Image re-sampling shall be performed using a selectable re-sampling method including at least bi-cubic convolution interpolation and nearest neighbour.

Product Level 2a
Earth located pixel values converted to ground surface reflectance, i.e. after atmospheric corrections.

Product Level 2b
Earth located pixel values converted to geophysical variables (land cover or geo-biophysical variable maps).

Product Level 3
Spatially and/or temporally re-sampled biophysical variables and land cover maps.

Systematic Acquisition
Continuous and uniform operation of the instrumentation to allow carpet like uninterrupted acquisition.

Threshold
A requirement that is considered compulsory for the mission.