STUDY REPORT

STATE OF THE ART REVIEW OF SATELLITE APPLICATIONS

AEROSPACE VALLEY • APSAT PROJECT

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APSAT

aerospace valley

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OF SATELLITE APPLICATIONS

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STUDY REPORT

1. Context and Objectives

This report on the state of the art of satellite applications is a contribution to the APSAT project (Public action, satellite technologies and sustainable development).

Elected representative or technician of a local community, novice or expert in the field of satellite applications, this study report is for you. This document will give you a snapshot of the contribution of space technologies in the life of every day in the public service and services to the citizen. It brings an original perspective by analyzing what local governments can expect in return for investment in new technologies for the benefit of citizens. It is therefore necessary to read this document as a presentation of opportunities to develop the effectiveness of public services and the attractiveness of regions.The first step of this project, aims at selecting candidate useful for the local communities innovations based on space technologies.

The more the nature of the application, the required investment and operating cost, the ability to expand to various territories are accessible, the more it will interest potential users and public authorities.

In a second step, the project partners from local authorities and technical institutions will gather their expertise and implications in order to specify and ultimately implement some selected innovations.

The applications, to be considered, have to purportedly contribute to the improvement of public services within communities or regions, and the best candidates will be those which are likely to provide effective support to the implementation of strategic objectives of the SUDOE area actors, especially for sustainable development, in two thematic fields :

- Urban management (mobility, daily life, urban planning, urban risks)
- Management of territorial and environmental resources (agriculture, environment, transport, natural hazards, ...)

The present mission falls into this first phase of innovative applications selection.

It aims at identifying (explore and inventory) and then describe from a technical, sociological, environmental and economic perspective, about thirty existing or emerging space applications of interest for the APSAT project.

2. Method and production

The mission was conducted along two main phases

- 1st phase: identification and selection of the space applications of interest to be investigated

- 2nd phase: gathering resource material and contacts with interviews, in order to characterize the applications identified in the first phase.

2.1 Phase 1: identification and selection of applications

The first phase was conducted during the first 1.5 months (from May to mid-June 2011). It aimed at selecting 30 emblematic applications covering in a balanced manner, the three main satellite technologies, that could be of benefit to the community and allowing for an immediate or rapid implementation:

- Geolocation and navigation
- Telecommunications
- Earth observation.

A funnel sequence, covering various applications or projects was carried out.

A thematic classification was first established and then illustrated by various examples already known or found on the Internet

The identified themes are classified into three levels; the first two levels being:

- Geo-navigation
  - Land Geo-navigation
  - Sea and port Geo-navigation
  - Air navigation
- Telecommunications
  - Emergency telecommunications
  - Data measuring station transmissions
  - Collection of other specific data
  - Telemedicine via satellite
  - Standard telecommunication for non- or poorly covered areas
- Earth Observation (EO)
  - EO sea & fishing
  - EO agriculture and forests
  - EO Environment waters

- EO Risks
- EO Land Management
- EO Energy and utilities
- EO others.

This preliminary work resulted in information tables listing multiple application projects or operational services. These projects were identified by consulting different media (specialized journals, scientific papers, EURISY publications, consultation of GMES project sites or related ones, internet searches…) and by interviewing several recognized experts in the different areas covered, mainly located in Toulouse, including CNES, CLS, Cesbio, Spot Image, Telespazio, …

Many technical or commercial documents about these applications were gathered at this stage (see bibliography in Appendix).

This collection was then discussed during a meeting with APSAT members, and then completed on various points, especially on "tourism" applications and some very specific ones such as DGPS for port navigation or airport traffic assistance systems.

The tables produced corresponding to this scanning of "what exist", covered virtually all the areas of interest for the APSAT project, even though they provided only partial information on services and companies that address the various related applications.

On the basis of this initial identification work, 30 targeted applications were selected for a detailed analysis, which was realized during the next phase.

For each of the selected projects a standardized "fact sheet", organized along a list of topics to be addressed (from a preliminarily adopted description and evaluation grid), is produced.

The following evaluation topics have been selected:

- Description of the application and of involved actors: technology + technical players + service providers + service applicants and users / application holders, objectives, satellites used, combination of services, needed infrastructure,...
- Framework for utilization and targeted public: Territories addressed and their influence on the service value, typology and number of users
- Competition with non-satellite based services
- Innovative issues
- Economic models: costs of investment, of operation, funding sources…; can the service price be derived from these costs?
- Date and duration of service implementation, experimentation end date (if applicable, reason for discontinuation)
- Attempts for application extension (other public, other territories, expansion of the range of services…); difficulties encountered…
- Lessons learnt : findings by funders, users, operators, application holders; assessment of costs (within budgets or not,…)
- Key parameters for the sustainability of service provisions and use

2.2 Phase 2: collection of detailed information for the selected applications

The second phase was longer and lasted for 5 months (from July to early December).

The pre-selected applications have been investigated in detail according to the previously presented evaluation grid, with the production of detailed fact sheets.

For each application, a preliminary search for information was conducted, mainly on relevant dedicated operators or projects websites. Then, identified key people were contacted either by e-mail or directly by phone, in order to get answers to the still pending questions of our evaluation grid.

When the contact was unsuccessful or the contacted person did not wish to answer our questions (this was often the case when asking about economic issues), further research, mainly via the internet, were made in order to get the best possible figures for the development and implementation costs of the corresponding services.

We made for instance a large use of ESA or CORDIS (FP7) websites where the budgets allocated to the GMES projects are provided.

Finally, for several applications where the economical figures were not available, the author used his own past (but sound) experience within the space sector, to derive the application development and/or data processing costs as well as operation ones.

In total, 34 people were directly contacted to help us complete the detailed sections of the fact sheets; 27 answered to our requests by e-mail or telephone and 6 key experts were interviewed face to face.

The following table (in French) lists the produced fact sheets with the contacted persons and the interview mode.

Besides, during this work both for preliminary searches and fact sheet completion, some 50 publications, PhD theses or reports were consulted (downloaded) as well as hundreds of web sites providing information online.

THEME	SOUS-THEME	DESCRIPTION	Nom du Service / fournisseur(s)	Contact / mode obtention	N°Fiche
TELECOM / COLLECTE DE DONNEES	Télécom de crise, intervention d'urgence	Fourniture de services de Télécommunication de secours par satellite	Telecom Sans Frontières	M. Lanne Petit (visu) + JF Cazenave	12
	Télésurveillance-telegestion	Service de transmission de données de station de mesure ou de surveillance et distribution	SATMOS (Société)	O. Corbon (visu)	14
	Collecte de données de mesures (bouées, stations sols, animaux,...)	Service ARGOS de collecte / localisation et transmission de données pour l'environnement et la sécurité	CLS (société)	F. Jacq (E mail) / Inet + Bilan 2006 CLS	13
	Télémédecine	Service de télé santé en zones reculées	CNES / Guyane et Région MiP /CHU Toulouse	A Guell (visu)	27 & 27'
NAVIGATION /POSITIONNEMENT	Collecte de déchets / gestion de flotte	Service de gestion de flotte géolocalisées pour la collecte des déchets urbains	Exeo - Synoptis	F. Rodes (tel)	2
	Transport public	Voitures en libre service	Autolib' Paris	Inet (Site Autolib)	1
	Interventions / services d'urgence	Aide à la gestion des intervention de secours médicaux (SAMU 31)	Novacom (Société)	Marc Leminh (tel)	17
	Suivi de matière dangereuses	Suivi des matières dangereuses (camions)	SCUTUM / Telespazio	A. di Fazio (tel + Email)	17'
	Services portuaires d'aide à la navigation	Unités portables d'aide aux manœuvres protuaires	PPU / Marimatech	V le Gall - port de Nantes ; (Email) + Inet + Bilan société Marimatech	15
	Services aéroportuaires de localisation	Aide à la circulation en zone aéroportuaire	M3 System	P. Gruyer (tel + Email)	16
	Utilisations citoyennes	Service sur Smartphone pour faire remonter à sa collectivité des informations géolocalisées sur sa rue.	Jaimemarue (service)	O Chastres (Email)	10
		Information stationnement pour personnes handicapées	Handicap (service)	Inet	10'
	Tourisme	Transmission d'information touristique suivant géolocalisation	Applications Tourisme d'OOKAPI	G Giang-Ookapi (tel et Email)	30
OBSERVATION DE LA TERRE	Environnement marin et mer côtière	Service de détection et de suivi des pollutions marines pétrolières	service CleanSeaNet (CSN)	Inet + articles + Budgets organisme EMSA	3
		Service de détection d'efflorescences algales en pleine mer et services de bilans chlorophiliens à la côte	ACRI-ST + IFREMER (société)	A Mangin / F Gohin (tel et Email) / R Delmas (Hocer) visu	4
		Production de cartes d'aide à la navigation, avec bathymétrie des hauts fonds	MaxSea International	F. Pierrat (tel)	5
		Suivi d'évolution du trait de côte	Obs Littoral Aquitain (opérateur pour collectivité)	C Mallet (tel)	6
		Suivi des déformations des infrastructures côtières	TNO & Altamira (sociétés)	Inet + A Urdidoz et Jeraint Cooksley	7
	Mouvement de terrain	détection des subsidences en milieu ouvert ou urbain / gestion de chantiers	Altamira (société)	A Urdidoz (tel + Email) + Articles	19
	Forêt	Inventaires forestiers et estimation de la biomasse forestière	Service GMES FM / Geoland2 opéré par GAF et partenaires	Inet + rapport projet	8
		Suivi des Feux de forêt	Service GMES RiskEOS et SAFER (Infoterra et partenaires)	A Husson + Inet + rapport projet	9
	Urbain	Occupation du sol urbaine	Service Urban Atlas GMES par SIRS et Geoville	M Hoffman ; Email et tel sans réponse	20
		Produits d'aide à la planification urbaine	Service Spatial Planning (GMES) par Geoville	M Hoffman ; Email et tel sans réponse	20'
	Eau (Gestion de l'eau et des bassins versants)	Gestion des BVs et bilans hydriques : hygrométrie des sols - sècheresse-étiages cours d'eau, neige	expériences Cesbio / Service SIM de Meteo France	G Dedieu + articles	21
		Modélisation distribuée des BVs à l'aide de l'image satellite pour la prévision des débits	Pas de service spécifique : Méthodes d'études générales	F Bressand (visu) (SCP Grand Delta) + SCHAPI visu	21
	Environnement	Gestion des parcs naturels et zones protégées	Pas de service identifié (cf suivi forestier par GAF)	Na	22
		Qualité de l'air, indice UV	projet UFOS (Acri)	A Mangin / M Morel (tel)	23
		Emissions thermiques en milieu urbain	Pas de service identifié	NA	24
	Risques	cartographie des risques ; détection des zones affectées	Infoterra (RiskEOS; SAFER) ; CNES/SERTIT : charte Cat nat	A Husson (visu)	25
		Géo-épidémiologie (Paludisme , Fièvre du Nil, dengue...)	CNES (méthodologie)	Cécil Vignolle/ M Lafaye	26
	Agriculture	Contrôle PAC - MAE par satellite	AFS / SIRS (France)	E Delaroche / A Petitjean (AFS par Email)	28
		Service de support à l'Agriculture de précision	Astrium geoinformation services (Farmstar)	G. Denis (Email)	29

3. SYNTHESES

3.1 Technological state of the art

There is no doubt today that satellite-related technologies are mature and that applications are diffusing out of the scientific community toward a large set of economic and social sectors.

Schematically and synthetically, from a user point of view, satellite technology can be classified into three categories:

Permanent services (continuously provided) concerning, for simplicity, two technologies

- Positioning (GPS, Galileo, etc.) with permanent one-way signals collected and proceed by receivers
- Telecommunications (telephony satellite reception video-TV and data exchange) with one way or two-directional exchanges depending on the object of the application or on the ground terminal

Recurring services which are provided either by low or medium earth orbiting or by geostationary satellites performing their tasks automatically on the basis of a defined program. Data are processed and catalogued permanently and are generally available through authorized operators at low charges or freely.

- Earth Observation of meteorological data
- Low or medium resolution systematic data
- Atmospheric or terrestrial scientific measurements from various satellite specialized instruments
- Store-and-forward messaging services such as ARGOS which may be classified in this category

Requested services : They refer only to the production of high or very high resolution images provided by low earth orbiting satellites, both in optical (passive) or active Radar (SAR) technology; the scenes are specific and must be ordered and paid to the operator, who will program the satellite to process the request. However, as operators program their own satellites they may acquire valuable scenes in anticipation of future orders (images of the catalogues). Of course, existing images are sold cheaper than those to program.

3.1.1 Telecommunications

Satellite telecommunications are historically the first application of satellites and have been therefore fully operational for more than 30 years.

They are mainly provided by the geostationary (GEO) satellites for fixed or semi-mobile interconnection or transmission services (FSS), and by constellations of low Earth Orbit Satellites (LEO) for mobile services (MSS) of telephony or slightly delayed messaging (from 1 to 15 min).

Fixed Satellite Services: FSS

Television and Video broadcasting amount to 60% of the presently used capacities for FSS.

For the GEO satellites and FSS the main technical achievements of the last 30 years correspond to i) the bandwidth expansion (by coding, data compression, multiplexing techniques on carriers, the use of new micro-wave frequencies Ku,K,ka), ii) technologies of very directional active or semi-active antennas with multiple or steerable beams (allowed by enhanced techniques for better orbiting platform stabilization), iii) miniaturization of terminals and antennas and decrease of the needed power on ground, (and therefore electrical consumption) along with a simplification of the terminal use associated with their interoperability with other communication modes.

Competition and concentrations have reshaped the space actors' geography for satellite systems development, launching and flight/programming operations.

Current technologies both in manufacturing and launching, allow fortunately for heavier, more powerful and less expensive satellites and, at the same time, support multiple launches. It is then in line with the strong growth of bandwidth (TV & Internet) demand, and with the congestion of geostationary orbits, which pushes operators to require heavier platforms with more electrical power for more transponders (7 tons platforms and 25-30 KW).

The total bandwidth, shared between users, which is between 1 and 2 Gbps for the traditional satellites and goes from 10 to 20 Gbps on the first generation of Ka Band platforms, now reaches 70 Gbps with 82 beams with, for example, KA-SAT from Eutelsat and will be over 100 Gbps on the next Eutelsat satellite ViaSat1 scheduled for 2015.

Every type of link now provides individual or grouped services.

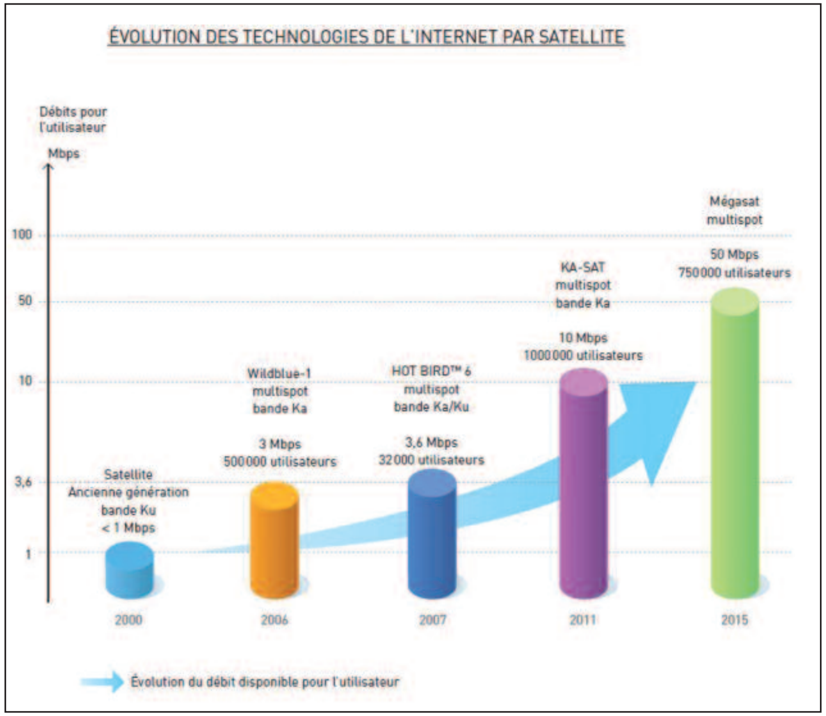
For individual solutions (with bi-directional antenna and modem), suppliers propose connections from 1 to 4 Mbps on conventional satellites and 10 Mbps in 2011 with KA-SAT. As with most technologies, including DSL, the flows are asymmetric, for example 3.6 Mbps and 512 Kbps respectively for download / upload bandwidth.

Mobile services: MSS

Data-voice, peer to peer (civilian) mobile telecommunication services (MSS), are provided either by geostationary satellites (GEO) as for example, the semi-mobile VSAT systems from Inmarsat, of by small low earth orbit satellites constellations (LEO) such as Iridium , OrbComm or Globalstar, which provide phone or shortly delayed message services.

Conceived and initiated in the 1990s, LEO constellations for telecommunications were soon rivaled by the widespread development of terrestrial networking infrastructures for the GSM throughout all continents. Still operational despite the resounding bankruptcies of operators, the LEO-based MSS show limited throughput capacities (the new generation of embedded systems will be much more efficient) when compared to GEO MSS services. They are useful mainly in ships, airplanes, or in white areas, or to secure communications, especially during crises.

Note that the military also make use of dedicated MSS systems (GEO) for "autonomous" weaponry guiding (missiles, drones, etc.).



Source : Carvea consulting : Livre blanc : L'internet par satellite (Le haut débit en zones rurales ; 2010)

3.1.2 Geo-location

The principle of geo-location (or geo-positioning) by satellite (GNSS) was initiated by the US and Russian armies with their GPS and GLONASS systems, then followed by the Chinese Beidou (COMPASS) and now European GALILEO systems. It is based on triangulation calculation made by smart GNSS specific receiver devices (fixed or mobile) which decode time stamped and modulated signals broadcasted by the orbiting satellites.

The triangulation computation relies on timed satellite position data encrypted within the emitted signal and may be done only if at least three or more satellites are visible from the receiver antenna without obstacles or interferences.

The integration of digital cartography within smart mobile devices makes it possible to position oneself on a displayed map and since the partial public opening of the GPS signal, using back and forth message exchanges, "Geo-nav" applications which allow for local and remote dynamic monitoring of receiver locations are becoming widely used.
Simple positioning (with 20 to 40m planar accuracy) for which equipment cost is now very low, has largely diffused among the public and geo-navigation applications impose themselves in transportation, logistics, security, all sectors which are related more or less with public action and sustainable development.
This "fifth utility" as Americans name it, generates today, as a result of its nearly universal adoption, a fast expanding market of applications and services drawn by mobility growth and communication technology sophistication, along with GPS receiver integration within smartphones.
The very precise geolocation (with accuracy from less than 1m to some cm) makes use of sophisticated techniques on the signal phases, of diffe-

rential correction techniques (DGPS) and/or secondary systems which "augment" the position quality (such as EGNOS which broadcast correction data to subscriber's terminals). These are still reserved, because of the related costs, to specific professional applications (public works, precision agriculture, vessel navigation aid, vehicle monitoring in airport areas,..), but could rather rapidly be adopted for new extended consumer services, such as unmanned urban transportation still at experimental stage.
In parallel, the convergence of GIS with ICT (Internet, mobile telephony) and geolocation systems (GPS) generates the emergence of new types of mapping and services (G-ICT) based upon WEB2.0 techniques and principles. G-ICT, coupled to GSM technology, is gaining ground and can be found in a large number of economic sector such as mobile telephony, tourism, urban management, or even banking. Digital mapping status is thus changing. It becomes altogether interactive, dynamic, multimedia-able, and its interconnectivity through the Web allows the general public to interact with maps.

Our study clearly showed that with G-ICT, emerged 3 to 5 years ago and at a pace going faster, a profusion of new geolocation based services associated with smartphones (offered almost exclusively, for the moment, by the American GPS). These are directly profitable or useful to the community, opening new societal perspectives (car-sharing, self-service cars, speed control, urban tolls, parking management; applications for citizens, tourists, banking...).

Less obvious to the public, a second more technological type of applications is developing toward professional uses associated with very precise positioning needs.

With the advent of Galileo in 2012 (simultaneous with GPS3) in addition to the guarantee of continuity of service, and a better accuracy and security of the signal, we will see a new generation of applications of this second type, certainly for transport and security (land, rivers, air and seas).
In addition to the subscription-free, basic positioning service, GALILEO will provide additional restricted services:

- The *Commercial Service* (CS) with user fees, based on two complementary signals encrypted and secured, for professional applications in various areas (banking sector, energy, public works, housing…)
- The *Safety-of-Life Service* (SoL) of higher quality, will provide timely warnings to the user when it fails to meet certain margins of accuracy or integrity (for e.g., aerial or harbor navigation)
- The *Public Regulated Service* (PRS) will provide position and timing to specific users (national security, civil security) requiring a high continuity of service, with controlled access.
- The *search and rescue service* will contribute to the COSPAS-SARSAT system. Galileo satellites will be able to pick up signals from emergency beacons carried on ships, planes or persons and ultimately send these back to national rescue centres.

In parallel, new national or transnational regulations for transportation and security concerning different issues like hazardous materials or sensitive products monitoring, positioning of ships at sea or in rivers (ex: RIS directive), vehicle speed control, etc. will also extend the development of geo-navigation applications in the public sphere.

3.1.3 Earth Observation

Earth Observation (EO) provides data at various scales, from global to local, in a recurring mode or on demand.

A/ Low and medium resolution sensors meet specific scientific needs for operational environmental uses (meteorology, vegetation indices, soil moisture, surface temperatures, sea surface salinity or ocean color) or global monitoring (climate change, altimetry and ocean circulation, aerosols and atmospheric pollutants, thien ozone layer, column water vapour...) which goes in general beyond the national framework. Their data exploitation remains dedicated to global issues and scientific problems although some limited commercial applications exist (Indices UV for tourism, regional statistics for agriculture...)

B/ Satellite imagery with its different components (medium resolution, high and very high resolution (VHR), low earth or geostationary orbits, scanners or CCD matrix systems, Synthetic Aperture Radars) has seen its technology greatly improved over the last ten years, with improvements in both geometrical and spectral resolutions of passive and active sensors. The satellite provides a number of advantages for the production of images and data over large areas but it shows its limits on some applications where aerial imagery (photogrammetry, ultra spectral and Lidar) or in situ measurement technologies remain more appropriate (hydrology-hydraulics and accurate assessment of flooding risks, forest biomass estimation, 3D representation of cities…).

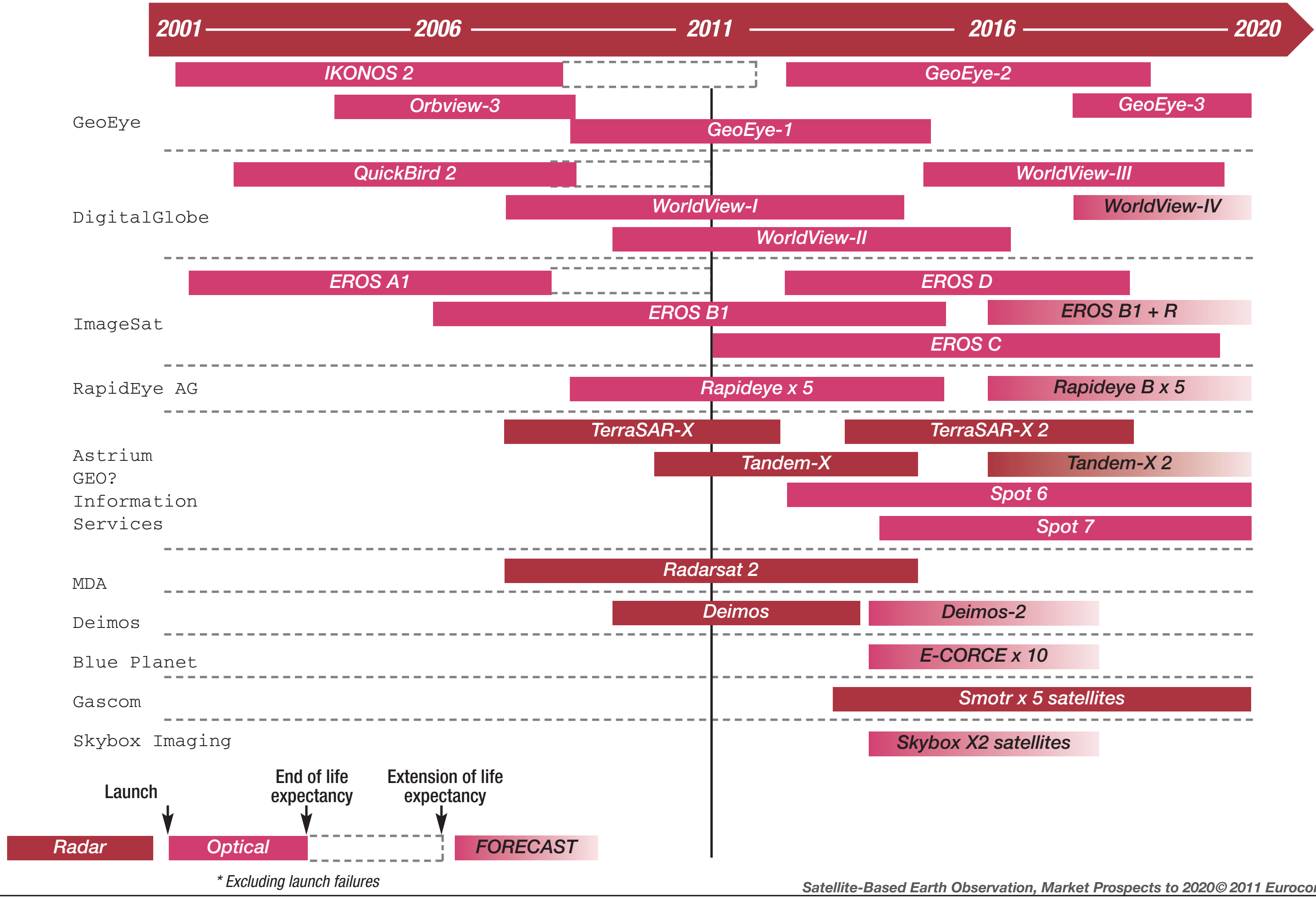
C/ In countries with either a reduced or inexistent public capacity for cartographic production, VHR satellite products can overcome deficiencies; however, this is not the case in western countries or e.g. in Brazil, where the cartographic production is made primarily from aerial images by geographical institutes with large financial means. In such cases, the main differentiating advantages of the satellite imagery are:

- The repeatability and flexibility of on-demand imagery allow controls and annual or even seasonal monitoring (what is not provided by aerial coverage done at most every 5 years by the national mapping institutes)
- The large extent of single scenes provides homogeneous conditions of illumination and environmental conditions within the image data, which offers the capacity of working on several scales with semi-automated treatments without having to manipulate multiple files eventually produced at different dates.

Satellite imaging with its repeatability, is therefore perfectly suited for dynamic monitoring of evolutions such as monitoring and characterization of urban expansion, control of building permits, management of land availability, land-use planning, damage assessment after natural disasters (e.g.: forest changes after fires or storms), continuity analysis of ecological networks for biodiversity, monitoring of coastline erosion, detection of marine pollution or bloom algae, etc..

As for meteorology, where assimilation of satellite data is done routinely within weather forecasting models, for some highly "technical" applications, satellite observations combined with ground measurements (land or sea) allow to spatialize local observations and adjust predictive models (water balance of agricultural areas, ocean circulation and coastal productivity, snow budgets of mountainous watersheds…).

Commercially Operated Satellites : Launched to 2010, Planned/Anticiped: 2011-2020



Satellite-Based Earth Observation, Market Prospects to 2020© 2011 Euroconsult

However this repetitiveness, which should still be increased to meet users' requests, remains constrained by the technology itself. Sun-synchronicity of the current VHR optical imagers, which is necessary for e.g. agricultural applications, exhibits several drawbacks: for instance, it is not possible for an optical image (acquired between 10 am and 12: 00 AM) to coincide with a spring high tide (always around 6 a.m. and 6 p.m. in western Europe) for coastline monitoring. Sensor pointing (which changes the image angle of incidence) operated by satellites for specific requests, will bias vegetation reflectance computation for agricultural applications. Stereo treatments accuracy for elevations is still limited to 2 m or more, which is inadequate for many applications requiring a finer resolution in altimetry as e.g. 25 cm for hydraulic risk calculations in flood prone areas. Last but not least, clouds are a very limiting problem for "urgent" imaging, for instance on activation of the International Charter on Space and Major Disasters during floods.

Synthetic Aperture Radars (SAR) may, for their part, "see" through cloud covers and, depending on the wavelength and/or polarization of their incident signal, they can theoretically go through and measure, at least partially, forest covers or snowdepth, record differential soil movements of less than 5cm, but until the advent of Cosmo Skymed constellation, their poor number and mission variability was such that unless lucky, one could not obtain the desired products for a given site. SAR images processing and interpretation are much more complex than those for optical image, while on the other hand, SAR allows for different and sophisticated products intended for very specific uses (differential interferometry or coherence products, centimetric ground movements monitoring, ship detection with speed and direction measurement, oil slicks detection,...).

3.2 The state of the art review, by application sectors

For this study many examples of application were scanned within different fields or specific sectors, which are: tourism, citizen actions, urban management, transport, security and risks, marine navigation, coastal monitoring, on-land environment, agriculture and fishing.

We voluntarily left aside applications for oil industry and mining, as well as those for pure mapping and the Earth atmosphere dedicated applications (climate, ozone layer, global warming) because they fall out of the scope of local community matters.

Though not directly treated, meteorology (see insertion hereafter) is considered as a transverse service within different sectors such as sea and coastal monitoring as well as environment, energy and risks management.

3.2.1 Transports

Geo-navigation combines GNSS positioning (GPS, Galileo, etc.) and telecoms, generally GSM but also, in specific cases, Irridium / Inmarsat satellites (e.g. for transcontinental journeys outside Europe, or sensitive material transportations) which allows the monitoring and guidance of vehicles from centralized stations, along inter or intra regional routes.

The offer is now mature and available from several suppliers.

THE ROLE OF SPACE TECHNOLOGY IN WEATHER FORECASTING AND CLIMATE CHANGE STUDIES

Atmospheric monitoring is essential to weather forecasting which relies largely (but not only) on recurrent images provided by geostationary satellites. No one ignores the current importance of weather forecasts for the economy and social life. We present further on, some examples of meteorological forecasts uses for land located risks or for sea and coastal phenomena.

Another example is the monitoring of cloud cover evolutions every 15mn with MSG images, which helps operators and distributors to better anticipate highs and lows of solar production within large territories.

Satellite observation is more generally highly necessary for atmosphere monitoring, for its components and pollutants, aerosols, temperature and winds in the higher atmosphere or ozone layer thickness, or else more simply the measurement of cloud albedo.

Numerous and various scientific sensors on board satellites (presently, nearly half of the instruments) scrutinize the atmosphere column from space, which is the only possible option for multiple parameters with an unrivalled terrestrial coverage, complementing ground based local measurements.

One peculiar data derived from these observations, the UV local index, is largely used and distributed daily through operators' Web services toward Internet and Smartphones.

Scientific data acquired for many years, allow to quantify both seasonal and interannual changes (monitoring the ozone layer is a good example of it), to theorize and validate new models and refine, in particular, parameters or even equations of the climate models which, inter alia, the IPCC/IPCC climate change forecasts are based upon. We should then better explain trends and causes of the current warming and anticipate as best it could, its possible evolution, as this global warming strongly affects our current policies relying on the IPCC scenarios, in particular for energy.

There are still some uncertainties in the climate models and parameters as, for example, the interrelation between the cloud formation and precipitation rate according to the atmospheric water vapour content (1), which increases with temperature (Clausius-Clapeyron relation).

(1) This is one of the issues raising the most questions: less or more precipitations in the future? But also: more clouds = increased albedo and less global warming. Satellite cloud cover rates observations by satellite over more than ten years may indeed question some assumptions made on this subject within the models.

For the transport of goods, in case of accident or serious incident, or even of theft or threats, detected immediately by sensors on the trailers, or issued by the driver, messages are transmitted toward the central monitoring servers in the next seconds or minutes. Messages can then be sent to the local authorities for action.

Centralized navigation applied to vehicle fleets allows in addition to optimize tours (with fuel consumption gains), to monitor speed, driving and rest time etc.

For extra-urban public transport, centralized navigation (as for taxi centers) allows to optimize routes and durations, to inform users about buses location, etc. It is therefore a particularly interesting solution for common on-demand transport systems which are developing in the suburbs of large urban areas including for persons with disabilities and reduced mobility. *In France, for instance, Veolia Transport, with its "Creabus" offer, provides this type of services to numerous communities.*

Finally, with more accurate and secure positioning systems coming, geo-navigation opens the way for new services, such as free service cars (cf. Autolib or Cartogo offers), or even, on adapted lanes, the introduction of shuttles without drivers (see for example, the Cybus experimentation in La Rochelle).

3.2.2 City, Town planning, Land management

While playing a minor role in city management, when considering urban development and planning, satellite telecommunications (excluding television) contribute notably to the opening up of isolated areas.

In rural undeserved "white" areas (as it is the case for isolated hamlets or small villages), for the provision of Internet, bidirectional links through satellite can be set up using VSAT solutions, which are perfectly operational since the 1980's, and may look better adapted today than optic fiber or broadband radio links (Wimax, Wi Fi hotspots). These last solutions present some important financial and technical constraints and drawbacks: urban regulations, impairment of landscape, microwave exposure of the public from antennas, high relative costs of wired networks installation against the number of served people in rural areas, etc.

Thus, satellite data transmission brings an answer, for example, to the medical desertification problem, as it provides a way to implement integrated solutions of mobile telemedicine where vehicles are equipped with various medical equipment for diagnosis connected to specialized centers. This type of services (eHealth), illustrated by the Diabsat project in Midi-Pyrenees, is being exported to developing countries where several similar projects or programs are in progress (EHealth, SAHEL,...)

For their part, satellite imagery and geolocation and/or navigation offer or open the way to multiple applications of multiple types for urban management.

We may indicate, among examples and beside applications related to intra or extra urban transport cited above, civic / city management applications:

- Initiatives are blossoming in several cities of Europe where applications are available for residents to report various issues (streets and sidewalks holes, urban furniture degradation, wild waste deposit, etc.) in their neighbourhood and to provide a georeferenced photo of it with their smartphone.
- Management of city tolls or parking meters: Montpellier City for example is having developed -with ExyzT company- an online payment solution with

Smartphones for the city parking spaces. The user transmits its car position and parking duration payment which will then be automatically registered and available to street controllers (it aims at reducing the number and therefore the costs of maintenance of the parking meter terminals).

- Collaborative online mapping (ex: initiative "Openstreetmap") i) from nothing using if necessary online satellite images or ii) correction of maps or city plans which can be collaborative or on another way done by postal services: UPS company, in particular, corrects US maps and city plans through its vehicle tracking system, reporting the errors found during tours on maps then re-broadcasts the corrections done to publishers.
- The control of building permits (swimming pools, constructions and extensions) and compliance of other urban rules by recurrent satellite imagery.
- Land availability studies which may rely in part on direct analysis of satellite images.
- Urban Land Cover maps at large scales (1/10 000), produced by Computer-Aided Photo-Interpretation (CAPI), allowing to derive indicators for urban densities, artificialisation rates, and differential evolution maps (see GMES - Geoland2 /Urban Atlas) or else, by combining them with other socio-economic data, derive various qualification map products of urban units in large cities (see for example the "space planning" service of the Austrian company Geoville provided within GMES-Geoland2 project).
- Monitoring land movements in urban areas, especially during underground infrastructure works (subway, large underground parking lots), using SAR interferometry; this is an emerging technology which is widely validated to identify centimetric subsidence (< 3 cm) upon large areas allowing infra-annual or annual monitoring at a much lower cost than surveyors on site measurements.

3.2.3 Tourism

While satellite telecommunications may play a minor role in this sector, this is not the case for geolocation applications: they are becoming a truly valuable asset for tourism activity, eventually combined with satellite imagery via, for example, 3D visualization applications, such as Google Earth, that allow “virtual fly-through” of areas with embedded auxiliary information.

After the explosion of NSS-enabled smartphones (GPS for the moment), the mobile Internet user crowd is targeted by multiple applications set up by public or private operators wishing to provide information associated with the travelers’ location.

After Google which is a major player in the sector, with its search engine linked with its applications Google-Maps® and Google-Earth® (information on hotels, local attractions or services, maps and route calculations,...), multiple downloadable applications are flourishing on Internet, some of them being funded by local tourist offices. They indicate, depending on the place where one is targeted, sometimes with pictures and videos, dynamically updated tourist information linked (click to call) with ancillary services. The user may then e.g. access online booking for hotels, room availability and display comments of other users of the place.

Another interesting service starts being generalized: solar UV radiation levels (derived from Earth observation sensors) are provided in particular along coastal areas, informing users of the index of sun protection to use according to the place of exposure (e.g. on Iphone: "Plages Landes" a multilingual application specific to the coast of *Landes* in France, providing also information on the water temperature, swell conditions, etc.)

Towns or districts which choose this innovative technology, provided by several suppliers, enhance their image; it allows them also to centralize all local information in databases, publicizing more confidential small local heritage and target an international young (or less young) clientele of higher than average socio-cultural level.

3.2.4 Risk and Security

This is one of the sectors where all components of satellite technologies provide essential services in particular for crisis management support, damage assessment, or to some extend prevention plans elaboration:

- Tele-transmissions for crisis communications and restoring links after severance.
- Satellite imagery to identify within 24 hours or 48 hours the damaged areas (International Charter on space and major disasters, "rapid mapping" and other crisis products as defined in GMES-SAFER);
- Collective geolocation and interactive mapping of situation elements (e.g.: Ushahidi platform associated with Google Map; OpenStreet Map initiative in Haiti) in addition to retroactive assessments (experience learning)
- Aftermath maps of damaged areas such as flooded zones, burnt areas by forest fires or storm devastated (see GMES-SAFER), to establish precise damage assessment and monitor recovery; *Following Klaus storm in 2009, satellite images were the main tool for rapid assessment of damages to the forest (SAFER).*

Note that weather forecasting, including provision of sea conditions at coast or in estuaries, is an important component of prevention in the implementation of forecasting and warning systems. Synoptic weather models, operated by the national institutes, make use, through assimilation procedures implemented in these models, of large sets of different data issued by satellites.

In addition, weather services provide different products derived from secondary models, coupled to the synoptic models, which exploit also recurrent satellite derived data of land cover and soil conditions , albedos, surface temperature, etc: for example, in France, the SIM chain (Safran Isba Modcou) outputs notably soil water content mapped products to SCHAPI (hydrological central service) who then dispatches them to the regional flood forecasting services. Meteosat satellite images are also part of the elements used by hydrologist forecasters of the specialized public (River-Basin SPCs) or semi-private services (e.g. Predict service in France).

During prevention phases, satellite optical imagery products are providing auxiliary information (when more specific sources do not exist) especially for land vulnerability assessment (floods, density of habitat etc.). For example, if combined with other sources of most needed data which can be themselves recorded and geo-located using PDA and GNSS receivers, *(e.g. height of door sills in flood prone areas, index of habitat with basement, density of shops in streets, or else vegetation moisture content for fire risk, etc)*, satellite images help establishing spatialized socio-economic indicators of risks to derive optimal cost-benefit strategies for protection or defence of these areas (see SAFER project).

Satellite images captured upon a sector during a flood event, will be valuable as a support to risk map elaboration for future events, and als (e.g.) as an element of comparison with hydraulic models outputs.

Medium resolution Earth observation sensors will produce, thanks to their high revisit rate, weekly or even daily (during summer) maps of drought index (NDVI / LAI) in forested or agricultural areas. From these, one can derive forest fire risk index maps (Italy, France,...) or monitor drought evolution and its impact on agriculture production, as well as provide valuable elements to early warning system for food security in semi-desert areas (see for example the FAO GIEWS system)

SAR data, finally, which are not impeded by clouds, and since the multiplication of radar satellites that greatly shortened delays to obtain them, are also a valuable tool for mapping during large flood events even though their interpretation is usually trickier than that of optical images.

Radar interferometry products can also be used (this is experienced in Italy and The Netherlands) for large scale monitoring of subsidence movements upon extended areas, often associated with flooding hazard especially in coastal or estuarine zones.

3.2.5 Coastal and Marine environment

Oceans and seas are a fertile ground for satellite technology where we could identify numerous examples of applications.

Ships exclusively use satellites for up and down communication links, (Intelsat, Irridium, inter alia) and now ascertain their position, with GNSS receivers. The AIS identification system, which is mandatory for vessels of more than 300 gross tons, also incorporate GNSS positioning and mainly use the messaging Orbcomm satellite for data transfer at sea.

For oil pollution detection, the European seas are monitored continuously by the Clean SeaNet system operated by EMSA since 2007, within GMES framework, which proceeds to a continuous acquisition and treatment of Radar images.

The flagship GMES project MyOCEAN *(which took over some previously programs such as SOAP which was conducted during years 90-2000 and initially funded by the military or institutes of climatology and Oceanography)*, operationally provides forecasts of the global ocean circulation, assimilating altimetry observations (JASON, Envisat, ERS2, Topex Poseidon,...) within the ocean models, with other data from satellite borne sensors, measuring surface temperature, salinity or water color.

Coupling synoptic ocean and weather models produced a leap forward for regionalized seasonal forecasts (anticipation of "el Niño" and "la Niña" and of the NAO for example) and the understanding of ocean-atmosphere energy exchanges, water evaporation, oceanic biomass production or the dynamics of currents, eddies and other "meddies". In addition the coupling of ocean and climate models allows to better model the regional effects of global warming forecasted by the IPCC models.

The still experimental system PREVIMER, which provides detailed coastal marine condition forecasts, is partially interfaced with MYOCEAN. It is coordinated and operated by IFREMER in France with numerous European partners. The forecasting system is made of several chained models, which may use temperature and ocean colour data issued by medium resolution satellite sensors (AVHRR, MERIS, MODIS,...).

Beside sea conditions, turbid plumes, pollutant transfers from inland watersheds or developments of oil slicks, the system also detects and forecasts potentially harmful algal blooms which may raise serious public health problems (shellfish and fish consumption or even bathing waters).

For application of the water framework directive (WFD), Water Boards in charge of monitoring the quality of water bodies along France's coastline, after several years of validation, are about to adopt the use of water colour satellite images from dedicated sensors (MERIS and MODIS) with treatments done by ACRI company and CERSAT (at IFREMER's premises) in order to better spatialize quality indicators issued by coastal measuring stations, which are too dispersed and inadequately dense for the number and heterogeneity of coastal water bodies.

Coastline erosion and cliff retreat is monitored and measured by various European organizations most often using satellite technology: the "*Conservatoire du Littoral Aquitain*", for example, proceeds every 2 years a complete record of dune toe conditions and foreshore profiles by GPS campaigns combined with satellite or airborne images, in order to assess risks and define the best strategies to deal with coastal retreat as observed on several sites. The "*Conservatoire du Littoral Aquitain*" has also been associated to one of the ORFEO projects (preparatory to Pleiades) which showed the feasibility of using VHR image processing techniques to identify and position automatically the coastal defence structures and the dune erosion bluffs sites.

However, European national agencies and corporations producing and distributing marine charts *(ex: Maxsea or SHOM in France)* make use very sparingly of satellite images *(unlike their Australian colleagues; see e.g. the Coral Reef Targeted Research program of the Global Environment Facility: www.gefcoral.org)* and despite several attempts, for retrieving shallow water bathymetry - which requires very clear waters as in lagoons - or to identify sand banks or reefs on their maps by CAPI, or even to simply provide image thumbnails on marina equipments.

Nonetheless, all bathymetric sonar campaigns of specialized companies rely today on satellite Geolocation. Sonar scanning technologies are also very close to SAR processing techniques and R & D engineers in both fields work together and share their technological advances (e.g.: Qinetic company in GB).

Professional GNSS systems with dynamic differential correction (RTK) integrating EGNOS data reception, opened the way to very precise portable devices, with centimetric accuracy, used for navigation aid during harbor approaches and within estuaries (PPU - Portable Pilot Units).

At coast, spatialized detection of subsidence speed for polders or coastal zones is now perfectly operational using interferometry processing techniques of SAR images, which allow to program consolidation or raising of dikes, in order to maintain protection levels for housings and other infrastructure, against marine flooding *(see our fact sheet on the subject on this service provided by : Altamira in Spain, FUGRO NPA and TNO in Holland or Telerilevamento Europa (TRE) in Italy).*

3.2.6 Environment and Energy

Applications using satellite technology for inland or atmosphere environment (marine applications have been exposed above) are extremely numerous and it was thus difficult to compile a comprehensive overview of them. The selected examples, which do not address atmospheric issues, (see insert above), give nevertheless a good idea.

For inland environment, on which we have focused our examples, satellite imaging (mainly optical) provides elements for various analyses and evolution monitoring:

- Calculation of various indicators of the segmentation of natural areas (ecological networks and corridors)
- Land Cover and Land Use intermediate-scale maps (e.g.: European reference data Corine Land Cover)
- Natural and agricultural land consumption by urbanization (Corine Land Cover and regional urban atlas)

- Soil sealing map products derived from Corine Land Cover since 2006.
- Characterization of forest cover and support to biomass inventories (ex: GMES - GSE FM and Geoland2);
- Deforestation monitoring in subtropical areas (Africa, Amazon region, etc.)
- Support for detection, delimitation and monitoring of wetlands (1/25000, with field studies)
- Control of agrienvironmental measures in agriculture
- Support to river flow forecasts and soil water content in large watersheds with applications for irrigation management and hydroelectric generation (snow budgets, water balances...),
- Support for hydro-morphological analysis and river mapping (DEM based mapping with DEM produced by stereo images or radar interferometry)

Geolocation is also used in many environmental activities where field survey and inventories with georeferenced pictures are recorded with PDAs integrating GNSS receivers:

- Statistical inventories (forests, biodiversity, land cover)
- Field campaigns of measurements or observations (characterization of environments in situ, thematic maps, etc.).

We also noted the emergence of so-called *e-environment* civic applications such as the Delphis operation organizing the observation of cetaceans in Mediterranean French-Italian waters promoted by ACRI and RIMMO.

Finally, satellite transmissions of often geo-located data are commonly used for environmental issues. For example:

- Data transmission from many various environmental measurement stations (inland or at sea) located out of reach by terrestrial networks (including measurement data in rivers or lakes).
- The Argos system, since 1978, with more miniaturized tags than ever, which send messages to LEO meteorological satellites, allows scientists and naturalist associations to follow multiple furred, feathered or scaled creatures around the world and to understand their migration geography and routes followed. The same system equips also many floating or drifting measurement buoys around the world.

3.2.7 Agriculture and Fisheries

The development of precision farming that aims at optimizing inputs in grain farms or wine-growing enterprises is a flagship example of the convergence of geolocation and satellite imagery technologies.

With the FARMSTAR commercial application, for example, subscribers may link sprinklers of their GPS-equipped tractor, with monthly maps provided by the service and derived from satellite observations, which indicate where to add more or less fertilizer along intra-field variations showing sanitary or growth problems.

The EU-MS control of farmer's statements for the Common Agriculture Policy subsidies has been operated for 15 years, at least partially, by photo interpretation of satellite images for summer cereal crops across Europe.

Agricultural statistics (grain production forecast) at a European scale, were produced between 1988 and 1993 by SPOT (and Landsat) image interpretations applied on multiple reference sites scattered across the continent. If the system was given up by the EU more than 15 years ago, (because the compilation of national agricultural statistics were considered precise enough), the method was exported or adopted in many countries such as Canada, the USA, Argentina, China or Brazil.

Specialized companies, such as GEOSYS in Toulouse, provide operators of derivative markets for raw materials with global crop forecasts by major region from the recurrent computation of spatialized vegetation indices using medium resolution satellite images.

Many projects around the world using EO data, are designed to optimize water resource management for agriculture, using agricultural land cover data, computed recurrent vegetation indices and estimation of water budgets and availability at the agricultural watershed scale.

The fisheries sector is also a major consumer of services derived from satellite technologies:

- Service companies (ex CATSAT) provide via satellite links, toward subscribed fishing fleets, daily maps derived from satellite imagery, identifying ocean thermal fronts and areas of planctonic production conducive to the fishing of pelagic species.
- in the framework of fish stock control policy, the ICCAT (International Commission for the Conservation of Atlantic Tunas) for example, has contracted CLS to provide an integrated system for fishing boat monitoring (for tuna), based on the processing of AIS data transmitted via satellite (see marine applications)

3.3 Economic models of satellite applications

The different types and examples of satellite application that were reviewed before generally rely mainly on one out of the three considered satellite technologies. Before turning to the next chapter, where the budgetary aspect of the selected applications are examined, it seems pertinent to first draw the macroeconomic pictures of these three technologies as provided by various documents that were consulted during this study in order to gather and check budgetary elements to be provided in the application “fact sheets”.

Therefore this section presents a global view of the market for each of the three technologies and shows to what extent and how the above considered applications fit into it.

3.3.1 Telecommunications [1]

The private satellite telecommunications’ market (excluding the military operated ones) is the only one from the satellite sector that fits into a standard supply and demand economic model.

The global turnover generated worldwide by this activity, including manufacturing of receptor devices, sales, subscriptions to services and facilities, is estimated at more than US$ 100 billion in 2010.

The net sales of the sole services from the 37 civil operators (which finance

[1] *(Main sources: Euroconsult, Eutelsat, sites Inmarsat et Irridium)*

the construction and launches of civilian satellites) are estimated at $11bn in 2010. This sector of services is largely profitable with a 5%, annual growth, and according to projections it should keep the same pace of growth for the next 10 years.

Note that the market segment of military telecom satellites (LEO and GEO) is larger (for platforms and associated systems) than the one of civil satellite, mainly because of the US DoD.

Armies (internationally) are also important bandwidth users on civil satellites (3 5% of existing capacity)

Fixed Satellite telecommunication Services (FSS)

The FSS market weights about $11bn a year. There were about 10 000 civil transponders in use in 2010 for 200 GEO generating $ 1.1 million each year as a mean (75% occupancy)

It may be divided in two segments:

- TV distribution, which represents 60% transponder occupancy; this segment keeps going well despite DTT deployment, which will certainly take some of its market share especially in Africa.
- FSS at fixed stations which concern international or regional data traffic through geostationary satellites. Corresponding offers are challenged since the 1990s by the increasing capacity of terrestrial networks and the adoption of fibre optic cables including in submarine ones.

In spite of this competition, so far, and thanks to the exponential growth of traffic, the sector remains economically profitable and is concentrated at 70% within three major industrial groups (Inmarsat, Eutelsat, SES-Global) that finance, operate and distribute the related services.

In this study we are concerned with this second, non TV, segment; *it will be considered that "Video on Demand" traffic, make part of the TV category.* This market segment is dedicated primarily to companies and civil organizations (using VSAT) for interconnection and bundling of communications (internet and telephone). It represents 25% of the total market for satellite transmission services, with 1850 used repeaters and 1.7 million terminals.

It keeps growing slowly (2.5% annual) for the moment. Used as second choice in western countries, FSS for corporate communications is mainly developed in the regions where the availability, quality or safety of data exchanges is not insured by the fixed networks.

However, the new HTS (high throughput satellites) using Ka-band with directive multi-beam antennas begins to boost this market. It opens the way in particular to the new commercial opportunity of individual Internet at very high speed (downlink). Already 1.7 million consumers use such connections and forward-looking analyses forecast an explosion of demand (x 30 vs. current).

The FSS market model is a standard supply and demand model, within a competitive framework of interoperability with other networking systems (telephony, IP, VoIP). The satellite choice depends, beside cost issues, (as it is generally less competitive in areas equipped with efficient wired networks), on considerations about availability, throughput capacity and security of transmissions.

Mobile satellite telecommunication services (MSS)

Satellite mobile communications are trusted by 6 companies, the top three sharing 90% of the market.

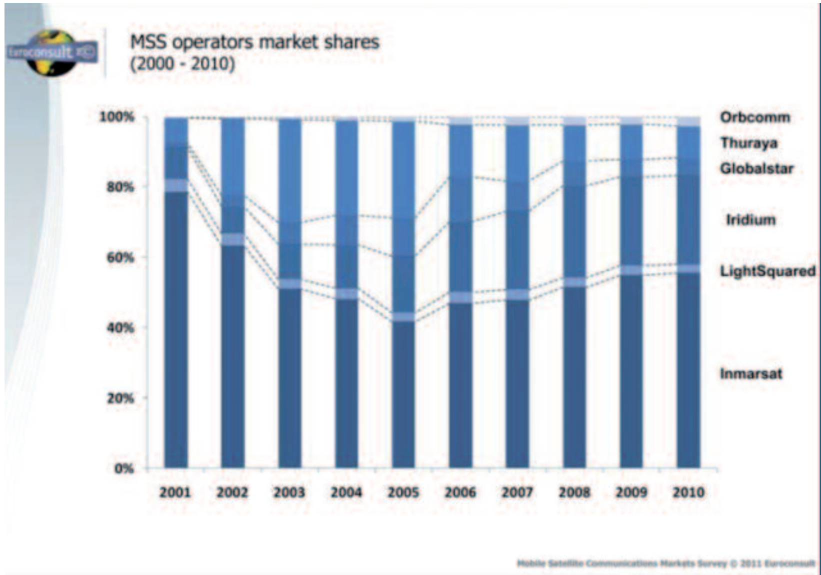
The MSS is characterized by store-and-forward messaging services or narrowband voice and data telephony (< 64 kb/s).

INMARSAT and Thuraya (Pleiades in Arabic) use GEO satellites while Iridium, Globastar and OrbComm use LEO satellites.

LightSquared (GEO) works in North America only, with some problems of implementation and authorization as its frequency may interfere with the GPS.

Iridium, Inmarsat and Thuraya offer, in addition to data transmission, good level telephony services with rather small handsets, barely twice larger than normal GSM phones, at a price of about $ 1 000 per unit, for subscriptions lower than $ 100 per month.

OrbComm and Globalstar provide delayed messaging services (AIS for ships, data from buoys, SMS, etc.) at very competitive prices.



Note that ARGOS is a dedicated system of store-and forward messaging, similar to OrbComm or Globalstar, based in this case, on environmental LEO satellites; it offers historically a direct geolocation service by exploiting the doppler shift induced by the speed of the satellite (which is not anymore a big advantage with the miniaturized GNSS receivers available today).

According to Euroconsult, the global market for MSS operators would be of $1.4bn in 2010 with approximately 45% of it for maritime, 35% for inland (in growth) and 20% for airborne uses.

There would be more than 2 million MSS terminals in operation worldwide.

Mobile phone services using autonomous handsets, account for 25% only of the MSS market, but they show the highest growth.

The MSS market, strictly speaking, is rivaled for data and internet links, with the miniaturization of needed antenna, by mobile VSAT solutions which appear globally cheaper, because of lower subscription prices and higher data traffic. The extension of HTS Ka-band on the GEO satellites allows MSS operators (including INMARSAT) to take market share on this particular segment.

Thus, the present trend for MSS is to increase data rates.

Mobile satellite transmissions applications are therefore totally available, open and interoperable with terrestrial communications systems.

This business is part of a strong and sustainable competitive market with many distributors of ready-to-use products. Selecting these solutions, which costs are quite acceptable, will mostly depend on the use and need contexts (necessity at sea or on land, need for security of transmissions and/or unavailability of terrestrial transmissions).

3.3.2 Geolocation

Unlike telecommunications, charged to users, the GNSS (GPS, Galileo) basic signals are issued for free. As indicated above, Galileo provides in addition coded signals for specific and critical applications, with subscriptions for commercial use.

Europe's investments in this field are quite heavy, with the funding of both EGNOS, and GALILEO programs.

The total cost of development for Galileo and EGNOS until 2011, including the construction of the satellites and before launching (and €1-2 billion more to position the constellation), is estimated at more than € 6 billion, and the subsequent annual cost is estimated to be €250 M / year to 2020

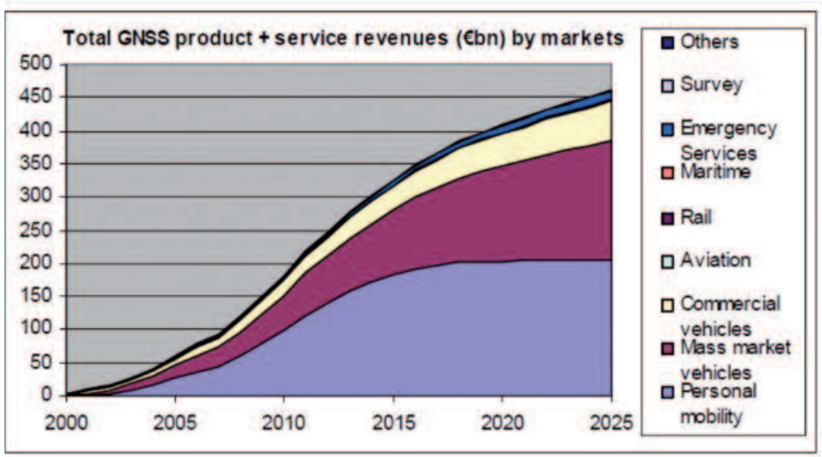
The global cost of the American GPS, funded by the DoD may be estimated to $ 10-15bn with substantially similar or even higher operation and maintenance costs.

The worldwide total governmental expenditures for GNSS are estimated between $2 and 3bn per year.

The market, when excluding construction, launching and satellite orbit monitoring contracts, can be reduced to manufacturing and sale of receiver devices (dedicated ones or integrated within broader use objects such as Smartphones) and above all to development and sale of applications or services generated by the convergence of this new "utility" with the advent of "G-ICT" and Smartphones.

This worldwide market of goods and services generated by geolocation and tracking ability is booming: it was estimated by several authors at € 20bn approximately in 2003, € 60bn in 2005 (with 44% for mobile phones and 53% for transport and public works) and analysts agree that it should exceed € 300bn by 2020, with more than 3 billion receivers available.

The receiver electronic components market share is low (1%), but in rapid growth because of the introduction of chipsets in Smartphones. A basic chipset costs €3-5. This chipset industry is already very concentrated and production costs make the difference between players.



Total GNSS revenues by markets segments (source GJU)

As shown through the examples of our study, limited to civil applications, this market is clearly divided into two branches:

1/ Low to medium value-added mass applications which geolocation ability made possible, driven by demand and responding to new needs, be they "B2B" or "B2C".. These applications are generally funded by individual consumers (navigation, everyday life...) who pay for a relatively cheap service (or free and funded by advertising) from a distributor or an operator which can be either a public body or a commercial company. The service can be developed internally (for public bodies) or contracted to an operator. The interest of principals and contracting actors is either financial (productivity gain), commercial, or even policy-making in the broad sense: tourism and consumption, citizenship, management and tracking of public or private vehicle fleets, field survey tools for collection of various geolocated data, etc. Offers abound in this branch of the market, which is highly competitive and very creative, and where a small economic bubble might occur.

2/ Very specific and technical applications, generally with high added value, driven by technology itself; these are designed for professional or institutional limited audiences, and meet new security or productivity needs or provide new alternatives to necessary and previously costly technologies. (ex : Bathy-topographic surveys, take-off / landing aids for aircrafts, piloting aid systems for vessels in difficult channels or harbors, (high)-precision agriculture, monitoring of airport vehicle fleets, derivative use of GPS for scientific measurements….). It is, therefore, a multiple niche-compounded market with a much lower economic potential than the mass-oriented previous one, but which pushes technology to open up new opportunities and generate multiple positive externalities for our society, such as safety improvements or pollution reduction; it even may open the way to future radical behavioral changes (ex : unmanned cars or shuttles...).

In all cases, one can estimate that, in the light of the size of the civil market, public investment on geolocation systems is already, and will be, largely profitable. The added value generated by applications, services and other manufacturing/sale of devices will quickly allow funders States of GNSS systems to recoup their investment through indirect consumption and business taxes as the market players are usually located in the in the countries that have funded the satellite systems, even if Europe is, to date, lagging behind the US in this area.

It is worthwhile noting the success of this model (the "fifth utility"), which may be compared to the road or motorway investments or even to the Internet when network operators were national bodies: a public investment

[2] *(Source: rapport du Ministère Fr. des finances, économie et industrie / CGTI)*

for a technology delivered free of charge generates value with a multiplier factor which is here close to 100 over 10 years.

Therefore, the "mass" GNSS application market, following the convergence from GNSS and G-ITC, has little need of prescribers to keep growing: its potential for applications is large enough for the developers of services to generate offers which meet new needs or improve already existing services (e.g.: fleet management, on-demand transportation) and/or just replace solutions or services about to become obsolete (tourism handy guides, paper maps, sextant and compass navigation for boating...).

Finally, it should also be noted that many critical systems worldwide are increasingly dependent today of universal time broadcasted signals from the GPS system, which is today very commonly used. Without backup systems to readjust and/or reset clocks in the concerned servers, the American GPS possible switch-off may create numerous problems or even block a multitude of common services (banking services, electricity supply, air or rail traffic management,...)

3.3.3 Earth Observation

The Earth Observation applications market is clearly distinct from the two previous ones.

We set aside, hereafter, the meteorological services market, where Earth Observation data, as we saw before, are mainly processed and used internally by national or multinational bodies.

EO market is not yet mature.

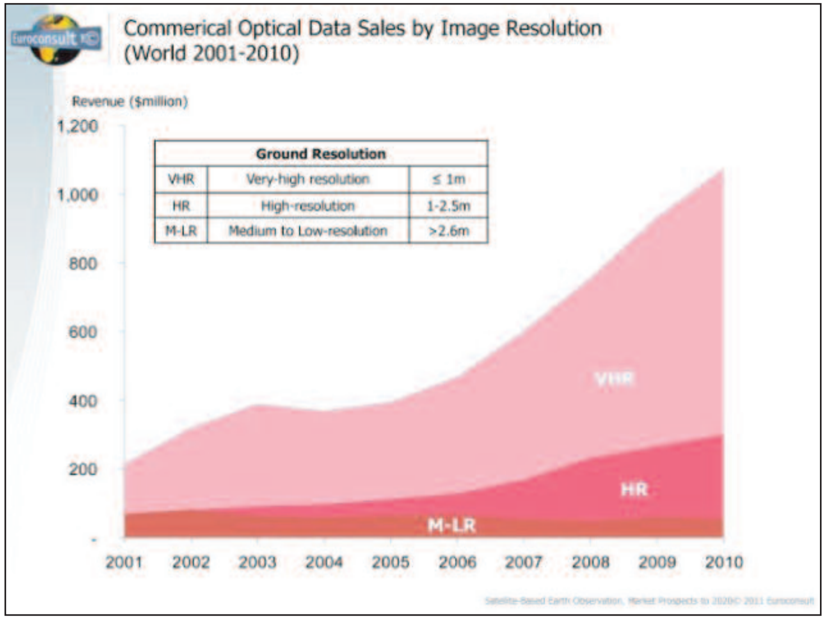
The image data sales are far from balancing the investments done for the design, construction and launching of the satellites. Downstream data sales, commercial offers of value-added services are fragmented within multiple small structures which are largely subsidized. EO services barely meet (or generate) a significant demand from potential users who are still perplexed about the benefits of this technology and reluctant to purchase both the data and the associated transformation service for a directly exploitable product.

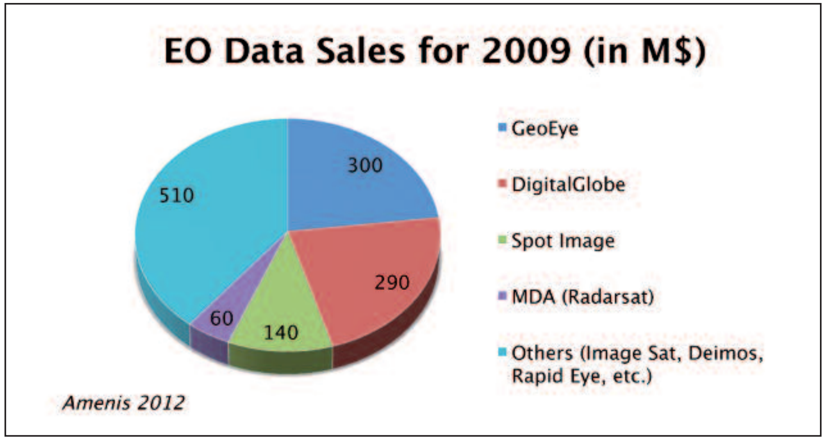
The figures speak for themselves:

In 2009, on a worldwide basis, the sector's weight was about $5 billion per year when including the budgets of national and multinational agencies (excluding meteorological and purely military satellites) while data sale (for 83% made of VHR images) was only $1.1 billion, from which 80 % were military purchases on civilian satellite images and 10% were public bodies procurements.

The private sector purchases only $110 million per year of EO data which is 50 times less (or 2%) than the overall weight of the sector.

Sales of Very High Resolution data are largely dominating because of the high military demand.





Chiffres d'affaire des principaux opérateurs satellites : vente d'images et services associés (Amenis 2012)

3.3.3 A A rather small value-added service market…

This state of the art review, including the economical analysis of the selected applications, has led us to investigate the publicized financial accounts of various companies offering applications or services from satellite images. Our findings show clearly that a large majority of users, or even the operators themselves, are within public bodies (e.g. in France: IFREMER, IGN, ASP, Universities...).

With some rare exceptions in Europe (the situation is similar in the rest of the world) commercial EO value added services companies are small specialized entities very closely linked with the scientific community or the space industry. They form a microcosm (or an "ecosystem" as stated in BOSS4GMES study) which gets its funding, mainly from the manna provided by space agencies and public programs sustaining this activity such as GMES or various European/national research projects.

The share of actually marketed satellite applications (excluding GMES projects) in the turnover of these companies appears to be very low.

SPOT Image, now integrated, since 2011, within Astrium GEO-Information Services, was the largest private provider for images and applications in Europe (and the 3rd in the world). Its turnover was, in 2010, EUR 100 million, while the total of European budgets, dedicated to Earth observation through funded programs and projects - military excepted - exceeds €2 billion per year.

Taking off the military sector, direct and effective data purchases are only made in a very limited number of sectors by clients (e.g. oil industry) with no other alternatives and for which the purchase price is quite small when compared to the related global financial challenges.

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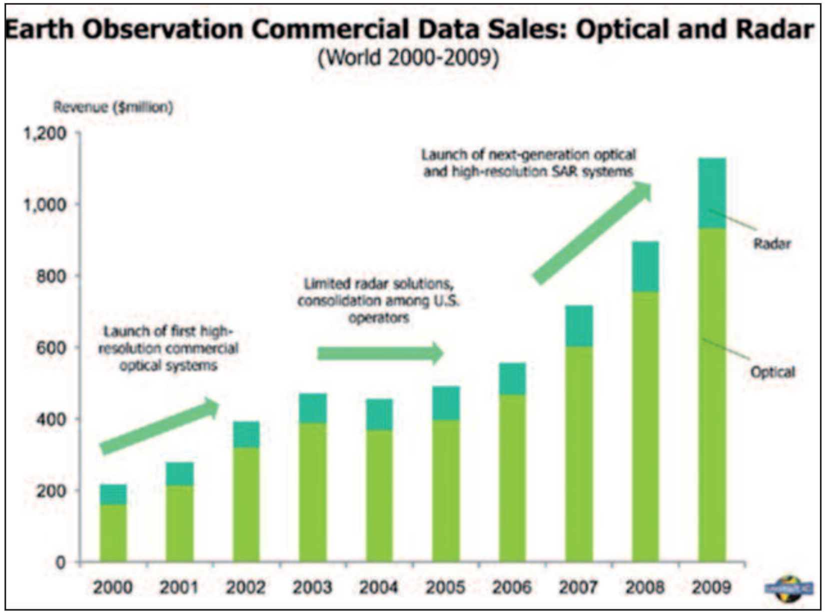
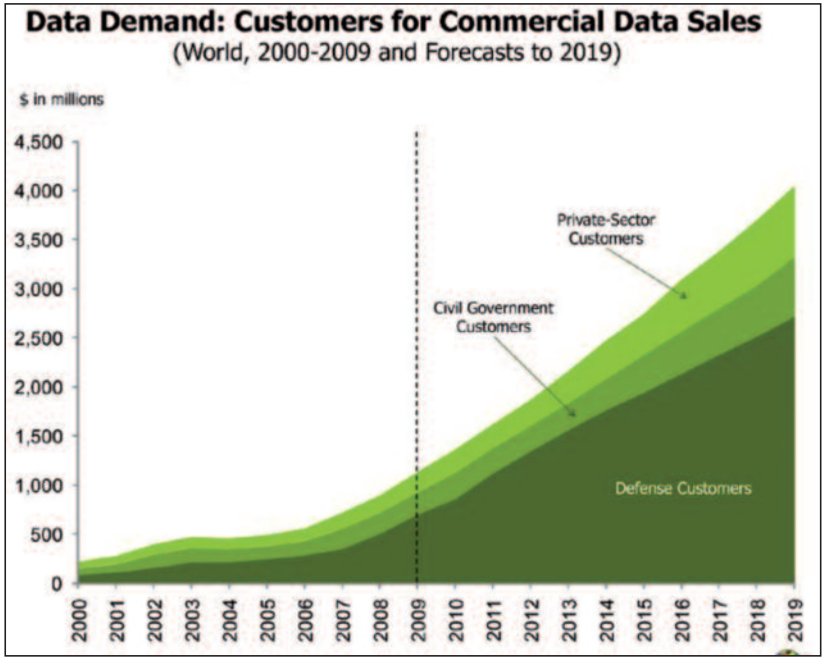


Evolution de la vente de données images (hors services) dans le monde (Euroconsult)

A few applicative "niches" are directly profitable however, as shown in some detailed examples provided in our fact sheets.

For non-optical HR images :

- From now on, some companies, such Altamira in Barcelona (recently acquired by CLS), reach annual contract amounts of more than €1 million on niche segments (ground movements monitoring using SAR interferometry) that are competitive.
- The fisheries sector takes full advantage of services provided by a few companies (CLS is on the driver's seat for this niche) that deliver recurrent forecasts for the presence of fish in different ocean regions, by exploitation of thermo-climatic and ocean color data (we estimated a maximum turnover of €2 million for the dedicated subsidiary of CLS).



If one zooms on France, he will see that private professional services based upon high resolution optical images are not much developed.

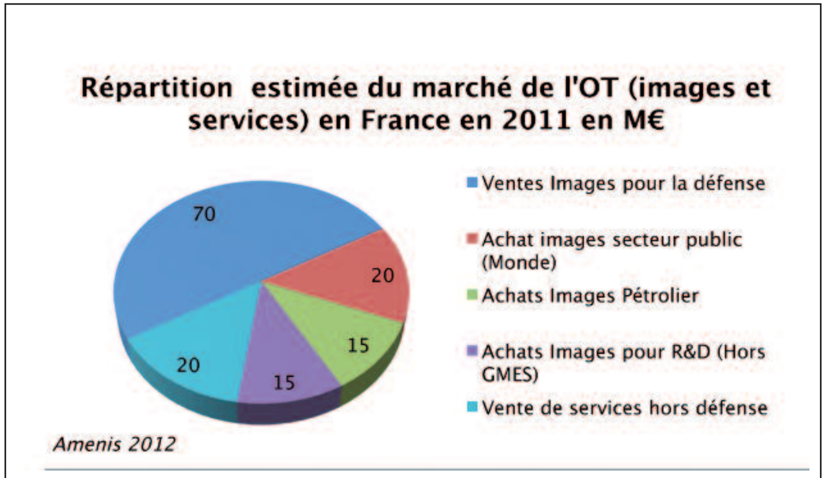
- Astrium-GI-Services provide commercial services for precision agriculture (FARMSTAR service) with a turnover of approximately € 4.5 million per year in 2010. After the merger with SPOT Image, which had, beside image sales, a "projects" activity with applications and/or data value-added services, the new entity should have a turnover of about €

10 million related with services (without accounting for EU/Fr. research programs).

- GEOSYS, SIRS, ITT Production or ACRI, also in France, provide altogether about 30% of the remaining commercial services, the rest being provided opportunistically by various Engineering companies, not-for-profit associations or semi-public agencies. The annual cumulated turnover of these four companies is about € 10 million from which 30% at most (excluding image data sale) should correspond to services based upon VHR satellite imagery, what makes € 3 million.

Therefore in France, the rough order of magnitude for contracted services directly associated with optical satellite images, shoul be at maximum € 15-20 million per year which may look like a paltry sum for the social utility of such products.

The distribution of the French market for image sales and associated value-added services would be according to our estimates, close to the following figure:



It is thus instructive that the largest player of EO commercial services in France is *Astrium GI services* (with service sales of €10 million approximately), which operates the SPOT satellites and, as a result, benefits from the marginal cost of images while keeping in-house the most sophisticated techniques of primary processing; it is instructive too, that other specialized companies, such Altamira, which succeed selling highly specialized services cheaper than non-satellite competing technologies, do it only with low price images (TerraSAR X images) usually subsidized by ESA.

The European strategy, supplemented by ESA and national agencies, who understand the problem, is to reinforce this "ecosystem" (or "microcosm") with the GMES program, betting on the abundance and adequacy of future data, and to have companies and end users working together during it; this is done through the funding of various EO services where the needed outputs are defined by users themselves, with data provided at very low costs.

In the near future, indeed, considerable progress will come with the GEOSS international program: Europe becomes a major player of it with Kopernikus (GMES - Sentinels). The resolutions of the European satellites being deployed will now compete with those of US satellites, at much more affordable prices (€5 per sqkm instead of €20-25).France, notably, is a powerhouse of this dynamic with the ORFEO bilateral program conducted with Italy (Pleiades and Cosmo-Skymed) and various other international collaborations (Venus; SMOS;..). The French ORFEO initiative in preparation for Pleiades, aims at defining and funding new services involving potential users upon different thematic issues (coasts, risks, environment, land planning, agriculture, hydrology, etc) to foster the use of VHR images to come.

A relevant illustration, highlighted in this study, is the forest product set carried out within GMES-FS and Geoland2, funded by ESA and the UE (FP7). These products and services encountered a large approval of professional users. In particular, forest inventories conducted by coupling CAPI on satellite images and classic field inventory, according to specific methodologies developed for GMES-FS would reduce by about 2 the cost of present day inventories for forest maps and available biomass statistics productions, which correspond to significant average annual budgets (€ 2 million for a country such as the Switzerland, and probably 8 to 10 times more for France or Spain).

Indeed, in the framework of the reorganization of public bodies which is being conducted in France, IGN and IFN merge in 2012, and a large part of aerial images used so far in a separate way for country land and forests mapping at medium and large scale will be replaced for rural and forested areas by VHR satellite images for production of maps and statistics.

3.3.3 B … But potentially, very important economic and societal benefits

If data sale and EO applications currently generate an apparent minor commercial market, compared with the amounts spent by the agencies, the everyday consultation of satellite images, within the public but also for business or administrative uses, following their diffusion via Internet consultation platforms like Google Earth, Bing Maps or other IGN GeoPortal, creates very clearly some significant additional benefits. However these benefits are very difficult to quantify as monetary values:

- What is the added value of the better quality of studies where satellite images have been used?
- Or, in a broader way, how one will estimate the side benefits - positive externalities in economics - from the use of these consultation portals in public life or participatory governance (ex: environmental associations who control regulation enforcements) or even in our everyday life, to travel, choose a touristic destination, a land parcel to build, or even detect some good spots for picking mushrooms?

Just taking the experience of the author, a weekly use, at minimum, of image visualization platforms revolutionized our practices, with strong productivity gains: how many heavy and time-consuming field visits were avoided thanks to these, in our studies of hydrology or urban planning?

Referring to our colleagues' reports, it can be said that at least 1/10 of the produced plans and other explanatory sketches from engineering studies conducted for land management, environment and urban planning (hydraulic studies, regulation mandatory studies for local planning and river protection, watershed management plans, etc.) using VHR satellite images (or aerial images and DTM) were provided by these platforms often as bottom layers, as illustration of studied options, or to update obsolete maps of built or forested areas, of biological corridors, linear hedgerows...

Here are some other personal indicative anecdotes:

In Bulgaria, during Maritza basin flood forecasting system development, all medium scale map of the watershed hydrological network (data were 70 years old) have been corrected –no other alternative – using SPOT and Landsat images available from the national Corine Land Cover project.

During the very same project: Surveyors responsible of river profiles delivery for river hydraulic models had had "forgotten" to carry out field survey nearly half of cross sections (i.e. 200 profiles over one third of the country) and had obviously made use of some old topographic map (1: 10 000) from the Soviet army to produce them.

With available satellite imagery, dubious surveys could be identified (river courses had changed) and we could impose the surveyors to redo the related surveys, which made us save thousands of non-budgeted Euros of field control.

An Australian 2010 study tried to answer these questions for the country.

Their general figures on the industry and specialized companies are in line with the elements provided above for France and Europe; in Australia, the market of specialized services and data sale is very low compared to investment and national budgets involved:

"The commercial sector which provides imagery and basic data processing only is estimated to have a turnover of $30-40 million per year in Australia; however if wider private sector EOS use is included the footprint would be a multiple of this".

The following table is extracted from their report: it provides 2008-2009 estimates of EO contribution to Australia GDP in all areas (the figures include satellite data exploitation for weather and scientific issues as well as for security and army).

Table ES 1 **The annual economic impact of EOS in Australia**

	2008-09 estimate
Direct contribution to GDP	$1.4 billion
Productivity impact on GDP	$1.9 billion
Other benefits – climate change, NRM, disasters	$1.0 billion

Data source: ACIL Tasman analysis

These estimates which combine different monetary approaches to figure out the GDP contributions may be seen as optimistic.

Indeed, for such a country as Australia, the low population density combined with region sizes and specificities with linked issues (as desertification, coral reefs monitoring, fishery control, pasture management, forest or bush fires in desert areas, etc.) certainly increase the use and therefore the value of EO services, at least twice as much a it should be in Western Europe (but certainly less in recent Eastern EU Member States).

It must be noted that Australia does not operate itself EO satellite and get images from external operators (including USA). Nonetheless this analysis on the EO_induced added value to the general economy of the country is quite impressive; moreover, they forecast a very strong annual growth of this contribution, close to 20% in the coming years.

This Australian report also states that for EO environmental uses, high resolution (HR-3 m to 50 m data from e.g. SPOT, ASTER and Landsat) is much more widely used that VHR (0, 5 m to 1, 5 m), in competition with aerial imagery that has equivalent prices and remains more flexible to call upon.

We may remember from this study that the overall contribution of Earth Observation might be of the order of 0.5% GDP in Australia, of which nearly half of it stands in productivity gains only -all sectors included- and about one third for direct uses, mainly in governmental agencies and communities. The increasing trend to provide free access to imagery appears to be a major reason of the observed growth of applications and uses in Australia.

Computed back to the European economy, with a GDP 20 times higher than Australia, and even reducing the Australian ratio to 0.2% for the European case, the EO contribution in the European GDP (excluding meteorological and military uses which make 50% of the total) could be of the order of € 15 billion (!) if the technology were as widely adopted as in Australia, especially in public administrations, which clearly is not (yet?) the case.

In addition, with Web 2.0 technology diffusing, including online GIS, and the upcoming profusion of images from scheduled non-commercial satellites, we could assist, here, to a larger growth than the 20% per year already estimated by the Australian study.

Previous figures, though questionable, show unequivocally that the best economic model to adopt for Earth Observation is - or should be-similar to the one adopted for GNSS which success is obvious.

[4] *(The economic value of earth observation from space ; ACIL Tasman co, for CRC-SI and Geoscience Australia ; September 2010).*

The funding of EO satellite programs can be financially supported only by the added value that EO generates or could generate downstream in the daily economy, through two major types of use:

- The myriad of "small" direct or indirect uses that would be generated by free - or almost free – availability of processed images (natural-colored, ortho-rectified products), through Internet platforms (e.g. Google Map/Earth or Microsoft Bing Maps)
- Their exploitation made by governmental or regional agencies departments (which may also lend their available data to private Engineering companies to carry out the work tendered), featuring higher technical level and higher added value applications, that are thus relieved from the discouraging overhead induced by the cost of the base imagery.

Though each generated added value is low, (from a few dozen to hundreds of Euros for the first type of use and tens of thousands of Euros in the second case) the resulting total should be very significant.

In support of this theory, it may be recalled here that the agreement of freeing Landsat image access, done 2 years ago by NASA, was followed by a huge inflation (x 100) of data downloads on the related servers (particularly in Brazil).

4. Techno-economic analysis of the selected applications

The following analysis of applications was made on an extended basis, beyond the identified and selected examples as detailed in the produced fact sheets: whenever possible, we attempted to generalize the chosen cases, as the collected information encompassed also other similar or competing applications.

The objective of this chapter is to present two specific aspects of our findings:

- a cost-benefit analysis (implementation costs and induced benefits)
- a product analysis (technical and commercial maturity)

We selected 35 generic applications, from the case analyses we carried out, distributed upon the different economic sectors listed previously, irrespective of the technologies used.

4.1 Techno-economic analysis

In order to quantify direct or indirect costs (and benefits), for comparative purposes, we had to apply our examples upon sized territories or according to quantities consistent with the targets of these applications aiming at communities: therefore, the applications' coverage were taken systematically to 10,000 km^2 (100 km x 100 km); the numbers of inhabitants for urban applications to 100,000 people; the numbers of vehicles for fleet management applications to 50 v., telecommunication units to 5 u, etc.

Product analysis comes down to one indicator only for maturity: either the application is operational and has already been implemented in one or more territories or is it still in research or experimental stage and then requires additional resources or developments being considered as a "mature" applications.

The indicator's value goes from 1 to 3. It is given according to the maturity assessments we could get during the study. However, it is possible that we missed some operational applications during our information gathering, so the corresponding indicator may be in a few cases under-rated.

- **1** means the application is experimental, with no defined commercial offer and still needing developments for more than 2 years.
- **2** means the application is being tested upon one or two locations and is still requiring developments, but that it should be operational within 2 years.
- **3** means that the application is already deployed on at least two sites with an identified service back up.

4.2 The monetary approach used in the cost-benefits analysis

The information collected for the selected applications, complemented by our own experience, enabled us to provide good enough cost estimates for the various operations and services making use of Satellite Telecommunications, Geo-Navigation, and Earth Observation data, as well as for those using alternative solution.

Besides, the precedent chapter raised questions about direct and indirect benefits of these applications either economically or for social and environmental matters.

A simple budget review of direct costs and benefits of applications for which there was often no equivalent alternative, seemed unsatisfactory. We therefore tried to estimate, when appropriate, the indirect social and environmental benefits of those applications using a monetary approach.

Such an approach is sensitive or even questionable as it involves a lot of subjectivity, but it is still very interesting as it obliges one to go beyond the basic accounting framework.

For economic externalities, the retained idea is to valuate one or more easily identifiable effects. For example we have valued at €10 per day the time lost together by the 30 or 50 car drivers, delayed in the morning by a single garbage truck in a city (which is not much). This, summed upon 200 days (collection day excluding summer periods) and multiplied by 50 trucks over 5 years, produced a quite substantial sum.

We used two approaches for environmental externalities: as the case may be, one will consider the application or service:

- To have a reducing effect on CO2 emissions (estimated using the price of €15 per ton on the carbon market, which corresponds to €0.03 per fuel liter or €0.002 per km).
- To bring an indirect welfare or satisfaction benefit to some part of the population, which monetary estimate is based upon an hedonic pricing approach: How many people are ready to pay and how much for one “service rendered”? A good example is given by Argos tags fixed on whales, turtles, bears or migratory birds; we made the hypothesis that 1% of the world population are ready to pay €10 cts in order that such studies may be conducted during 5 years, which values the beneficial effect to €6 million !

The hedonic approach, although the above example is a bit caricaturing, is a classical one in environmental economics.

Furthermore, it seems not meaningless, to estimate for example, the "hedonic value" of monitoring and conservation actions for a 200 km coastline to be €1 million (based upon €4 / year given by 50 000 people devoted to this place) or even, similarly, to give a €1 million value to the recurrent mapping work aiming at the conservation of natural environments (morphological maps of water courses and/or natural habitats) on living areas of 10 000 sqkm likely to host an average of 100,000 to 1 million inhabitants.

The ratio [(benefits-costs) / cost] may be considered roughly as an indicator of profitability. It may be used to classify applications according to this criterion.

Costs and benefits are calculated over 5 years, which is a little short for some applications which profitability may be growing over time.

Costs include an initial investment (design and implementation) and an annual cost for system operation and maintenance. Monetary depreciation is neglected.

The following tables present these various elements for the different applications ranked by their profitability indicator and showing their maturity level.

The considered applications are grouped by sectors even if some may straddle two or three of these (ex risks, environment, territories…)

Reading the tables: the ++ grade indicates the importance or intensity of the use of the technology in the application

GESTION URBAINE - TERRITOIRES

	Descriptif techno	TelSat	GNSS	OT	Invest init	Cout annuel	Coûts / Gains 5 ans			
					k€	k€	M€	M€	rentabilité	maturité
gestion Urbaine-territoires										
crise sécurité civile (télécom 5 postes)	matériel et abonnement	+++			15 k€	07 k€	0,05 M€	1,1 M€	21,000	3,000
Service Covoiturage Agglomération (100 000 h)	Webservices, messages, GNSS		+++		150 k€	20 k€	0,25 M€	1,35 M€	4,400	1,000
Observation foncière (OT)	PIAO Images + tournées sites		+++	+++	100 k€	100 k€	0,6 M€	2,5 M€	3,167	1,000
Produit de cartographie urbaine thématique (OCS- différentiel) 10 000 km2	PIAO Images + contrôle terrain		++	+++	250 k€	50 k€	0,5 M€	1,79 M€	2,583	3,000
E-santé (1 camion équipé dialise / diabète)	matériel médical+ abonnement telecom + technicien	+++			1000 k€	300 k€	2,5 M€	7,5 M€	2,000	2,000
télécom zone blanche 100 ménages	matériel et abonnement	+++			200 k€	100 k€	0,7 M€	2,05 M€	1,929	3,000
contrôle autorisations urbanisme (100 000h)	PIAO Images		++	+++	100 k€	40 k€	0,3 M€	0,63 M€	1,100	1,000
Application citoyenne (100 000 h) urbain	Webservices, messages GPS				70 k€	100 k€	0,57 M€	1,01 M€	0,772	2,000
Tournées déchets (50 V)	Système central et embarqué, GSM, GPS, cartographie, Backoffice				250 k€	30 k€	0,4 M€	0,71 M€	0,770	2,000
Parking : places de stationnement (2 000 places)	Système central, 2000 capteurs & GPS, Web2, backoffice		+++	+	1000 k€	150 k€	1,750	1,0 M€	-0,429	1,000

	Détail Gain estimé 5 ans					
	direct	addit.	explications	extern. envi	extern. Eco	explications
gestion Urbaine-territoires						
crise sécurité civile (télécom 5 postes)	100k€		pas de relais radio mobiles		1 000k€	5 vies sauvées; Sur 5 ans
Service Covoiturage Agglomération (100 000 h)	1 000k€		500 places de parking en moins (1% x 0,5)	50k€	300k€	CO2 + gains de temps (+) par réduction encombrements
Observation foncière (OT)					2 500k€	gains de 100000€ pour 5 opé immobilières / an
Produit de cartographie urbaine thématique (OCS- différentiel) 10 000 km2	41 529 €				1 750k€	réduction des couts de 10 études aménagement sur 5 ans + 100 opérations avec 25000€ de réduction des couts sur réseaux par optimisation
E-santé (1 camion équipé dialise / diabète)					7 500k€	15 vies sauvées / an sur 5 ans/2
télécom zone blanche 100 ménages	2 000k€		cout solutions terrestres dans conditions défavorables à celles ci (estimé)	50k€		externalité induite par atteinte aux paysages et contraintes hertziennes des solutions terrestres (arbitraire)
contrôle autorisations urbanisme (100 000h)	600k€		recouvrement taxes foncières sur 2% maisons individuelles (15 000 u) en 5 ans ; piscines et vérandas		30k€	dissuasion fraudes déclaratives en 5 ans
Application citoyenne (100 000 h) urbain					1 010k€	100 accidents évités / an avec coût de 2000€ + 10 000€ de réduction des pollutions par les eaux pluviales urbaines
Tournées déchets (50 V)	105k€	200k€	économie carburant 7% 2 véhicules en moins	3k€	400k€	réduction perte de temps automobilistes estimée à 200€ jour par véhicule en tournée
Parking : places de stationnement (2 000 places)					1 000k€	200€ /an pour 50% des places de gain de temps usager

TOURISME

	Descriptif techno	TelSat	GNSS	OT	Invest init k€	Cout annuel k€	Coûts M€	/ Gains 5 ans M€	rentabilité	maturité
Tourisme										
Information temps réel diverse et locale (commerces , activités spectacles)	Webservices, messages, GNSS, Backoffice		++	++	60 k€	30 k€	0,21 M€	1,05 M€	4,000	3,000
Informations localisées tourisme	Webservices, messages, GNSS, Backoffice		+++	+	40 k€	15 k€	0,12 M€	0,5 M€	3,348	3,000

	Détail Gain estimé 5 ans direct	addit.	explications	extern. envi	extern. Eco	explications
Tourisme						
Information temps réel diverse et locale (commerces , activités spectacles)	50k€	500k€	recettes publicitaires et fréquentation accrue de 5000 nuités / an		500k€	5001 nuitées en plus avec 20€ de VA pour collectivité / an
Informations localisées tourisme					500k€	5000 nuitées en plus avec 20€ de VA pour collectivité / an

TRANSPORT

	Descriptif techno	TelSat	GNSS	OT	Invest init k€	Cout annuel k€	Coûts M€	/ Gains 5 ans M€	rentabilité	maturité
Transport										
SAMU (urgence médicale)	Système, GPS, telecom mixte 3G, Web2, backoffice	+	+++		300 k€	80 k€	0,7 M€	2,31 M€	2,297	3,000
Tournées bus + Info (50 TAD)	Système, GPS+ 3G, Web2, backoffice		+++		500 k€	100 k€	1, M€	2,18 M€	1,177	2,000
Gestion flotte Sécurité / risques (50 Véhicules)	Système, capteurs, GPS, telecom, Web2, backoffice	+++	+++		300 k€	80 k€	0,7 M€	1,51 M€	1,155	3,000
Gestion des véhicules aéroportuaires	Système, GNSS augmenté, télécom radio ou Wifi		+++		200 k€	100 k€	0,7 M€	1,56 M€	1,229	2,000
Voitures libre service (urbain) 50u (surcoût GNSS + infra urbaine et subventions)	Système, GPS+ 3G, Web2, backoffice	+	+++		700 k€	100 k€	1,2 M€	0,55 M€	-0,538	2,000

	Détail Gain estimé 5 ans direct	addit.	explications	extern. envi	extern. Eco	explications
Transport						
SAMU (urgence médicale)	105k€	200k€	économie carburant 7% 2 véhicules en moins	3k€	2 000k€	10 vies sauvées / 5 ans
Tournées bus + Info (50 TAD)	95k€	80k€	économie carburant 7% 2 véhicules en moins	3k€	2 000k€	CO2 + Gain de temps usager 200€/an *2000
Gestion flotte Sécurité / risques (50 Véhicules)	105k€	200k€	économie carburant 7% 2 véhicules en moins	3k€	1 200k€	CO2 + 10 accidents / évènements sécuritaires circonscrits avec pertes évitées et 5 vies sauvées
Gestion des véhicules aéroportuaires	1 500k€		réduction des coûts des systèmes de radar Sol type ASDE-X		60k€	2 accidents relativement mineurs évités en 5 ans sur véhicules 1/100 accident(proba) avec avion évité sur 5 ans ; une vie sauvée sur 10 ans
Voitures libre service (urbain) 50u (surcoût GNSS + infra urbaine et subventions)	300k€		100 places de parking	4k€	250k€	CO2 + 5€ de retour coll. / jour et voiture

SÉCURITÉ ET RISQUES

Sécurité & Risques										
Communication de crise (5 terminaux V&D)	matériel + abonnement	+++	++		15 k€	07 k€	0,05 M€	1,1 M€	21,000	3,000
Suivi de mouvements de terrain annuel (25km2 1500 points)	Traitement OT SAR			+++	50 k€	25 k€	0,18 M€	0,38 M€	1,143	3,000
cartographie forestière post incendie/tempête 10 000 km2	PIAO Images			+++	100 k€	60 k€	0,4 M€	0,85 M€	1,125	3,000

	Détail Gain estimé 5 ans					
	direct	addit.	explications	extern. envi	extern. Eco	explications
Sécurité & Risques						
Communication de crise (5 terminaux V&D)	100k€		ajouts de relais radio mobiles		1 000k€	5 vies sauvées sur 5 ans
Suivi de mouvements de terrain annuel (25km2 1500 points)	375k€		cout suivi traditionnel 100 € le point / an moitié en densité.			
cartographie forestière post incendie/tempête 10 000 km2	850k€		cartographie aérienne annuelle			

MARITIME ET CÔTIER

	Descriptif techno	TelSat	GNSS	OT	Invest init	Cout annuel	Coûts / Gains 5 ans			
					k€	k€	M€	M€	rentabilité	maturité
Maritime et côtier										
Blooms Algae (détection précoce) 400km x 150km (service externe)	Traitement images satellite + intégration système		++	+++	300 k€	100 k€	0,8 M€	6,5 M€	7,125	1,000
Aide au pilotage portuaire et dans chenaux (PPU x 5)	matériel et logiciel	++	+++	+	200 k€	50 k€	0,45 M€	2,5 M€	4,556	3,000
Système d'information littoral et côtier avec relevés divers (200km de côte)	SIG, opérateurs terrain, GPS mobiles, Back office		+++	++	400 k€	200 k€	1,4 M€	3,73 M€	1,661	3,000
Système prévision marine régional 400 km de côte x 150 km Mer (système local indépendant)	Système, modèles et science, données in situ, images sat, prévisionnistes	+++		+++	20000 k€	2000 k€	30, M€	31,5 M€	0,050	1,000
Suivi subsidence des digues (10 000 m)	Traitement OT SAR			+++	30 k€	15 k€	0,11 M€	0,1 M€	-0,048	3,000

	Détail Gain estimé 5 ans					
	direct	addit.	explications	extern. envi	extern. Eco	explications
Maritime et côtier						
Blooms Algae (détection précoce) 400km x 150km (service externe)					6 500k€	3% activité conchilicole + 1 vie / an (intoxication létale évitée) + divers embarras de santé
Aide au pilotage portuaire et dans chenaux (PPU x 5)					2 500k€	1 échouage ou incident évité / an
Système d'information littoral et côtier avec relevés divers (200km de côte)	2 500k€		5% économie sur travaux maritime et littoraux	1 000k€	225k€	préservation du littoral sur 200km : 50 000 pers. x20€ + réduction des couts de 3 études / an
Système prévision marine régional 400 km de côte x 150 km Mer (système local indépendant)				500k€	31 000k€	sentiment de sécurité 20€ / 5 ans 10000p + 2% cout pour une marée noire + 5 vies sauvées/an (marins + surcôtes) + 5% économies sur travaux maritimes + 5% économie conchilicole + 5% interventions Secours maritimes
Suivi subsidence des digues (10 000 m)	100k€		levé traditionnel de 200 points par an au cm			

ENVIRONNEMENT

	Descriptif techno	TelSat	GNSS	OT	Invest init k€	Cout annuel k€	Coûts / Gains 5 ans M€	M€	rentabilité	maturité
Environnement										
balises Argos (5 balises sans compter actions terrain)	matériel + abonnement service	+++			10 k€	05 k€	0,04 M€	6,0 M€	170,429	3,000
Indic. d'artificialisation / consommation d'espace nat. ou Agr. (1/3 ans) 10 000km2	PIAO et traitement SIG		++	+++	100 k€	20 k€	0,2 M€	4,5 M€	21,500	3,000
gestion intégrée de l'eau dans bassins versants de piemont (10000 km2)	Système, modèles et science, données in situ, images sat, prévisionnistes	++	++	+++	1500 k€	500 k€	4,0 M€	66,75 M€	15,688	1,000
Cartographies spécifiques (milieux, géomorphologie) 10 000 km2 (1/5 ans)	PIAO images + SIG		++	+++	400 k€		0,4 M€	1,9 M€	3,750	3,000
Contrôles mesures agro-environnementales (10000 km2) (1/5 ans)	PIAO Images + relevers terrai + traitements SIG		++	+++	400 k€		0,4 M€	0,65 M€	0,625	3,000
Support inventaire forestier 10 000km2 (1/5 ans)	PIAO Images + relevers terrai + traitements SIG		++	+++	500 k€		0,5 M€	0,8 M€	0,600	3,000
transmission de données de stations isolées (5 stations)	matériel + abonnement	+++			25 k€	03 k€	0,04 M€	0,06 M€	0,600	3,000

	Détail Gain estimé 5 ans: direct	addit.	explications	extern. envi	extern. Eco	explications
Environnement						
balises Argos (5 balises sans compter actions terrain)				6 000k€		prix de la connaissance des migrations d'une espèce ? = 0,1€ pour 1% humanité
Indic. d'artificialisation / consommation d'espace nat. ou Agr. (1/3 ans) 10 000km2	500k€		Images aériennes		4 000k€	études locales évitées + optimisation foncier habitat (1000 logement 10%) + 1000ha agricole préservé 100€/ha (arbitraire)
gestion intégrée de l'eau dans bassins versants de piemont (10000 km2)				500k€	66 250k€	cout hédonique 10€/hab sur 5 ans + 5% rendement agricole + 3% rendement H-Elect sur 500GWh + économie AEP 1m3/p/an (20€)
Cartographies spécifiques (milieux, géomorphologie) 10 000 km2 (1/5 ans)	650k€		Images aériennes et minutes terrain papier sans GNSS	1 000k€	250k€	préservation améliorée des milieux 50 000 p. x 20€ + études locales évitées + 2% des couts induits par la pollution de l'eau (pour 50 000 personnes)
Contrôles mesures agro-environnementales (10000 km2) (1/5 ans)	650k€		minutes terrain papier sans GNSS			
Support inventaire forestier 10 000km2 (1/5 ans)	800k€		Images aériennes et minutes terrain papier sans GNSS			
transmission de données de stations isolées (5 stations)	60k€		1 relai radio +maintenance			

AGRICULTURE

	Descriptif techno	TelSat	GNSS	OT	Invest init k€	Cout annuel k€	Coûts M€	/ Gains 5 ans M€	rentabilité	maturité
Agriculture										
Contrôle annuel des cultures agricoles (10 000 km2 = 300 000 ha cultivés)	PIAO + relevés terrain		+++	+++		80 k€	0,4 M€	0,88 M€	1,188	3,000
Agriculture de haute précision (10 000 km2 ; 2500 exploitations	matériel + logiciel		+++		25000 k€	750 k€	28,75 M€	50,0 M€	0,739	3,000
Service d'aide à l'agriculture de précision (optimisation intrants) 10 000km2 ; 2500 exploitations	Abonnement service + matériel et logiciel		+++	+++	12500 k€	2500 k€	25,0 M€	34,38 M€	0,375	3,000

	Détail Gain estimé 5 ans					
	direct	addit.	explications	extern. envi	extern. Eco	explications
Agriculture						
Contrôle annuel des cultures agricoles (10 000 km2 = 300 000 ha cultivés)	875k€		contrôleurs à pied avec GPS.. 2j=100ha =700€ moins cher que l'avion			
Agriculture de haute précision (10 000 km2 ; 2500 exploitations					50 000k€	5% de rendement en plus pour 50000€ par exploitation + 15€/ha économie intrants
Service d'aide à l'agriculture de précision (optimisation intrants) 10 000km2 ; 2500 exploitations					34 375k€	2,5% de rendement en plus pour 50000€ par exploitation + 15€/ha économie intrants

PÊCHE

	Descriptif techno	TelSat	GNSS	OT	Invest init k€	Cout annuel k€	Coûts M€	/ Gains 5 ans M€	rentabilité	maturité
Pêche										
contrôle des pêches sur zones (100 kmx100km)	Système et opérateurs	++	+++	+	250 k€	40 k€	0,45 M€	2,25 M€	4,000	3,000
cartographie conchiliculture / aquaculture 1500 km2 = 150 kmx5 km (/ 2 ans)	PIAO		++	+++	100 k€	30 k€	0,25 M€	0,2 M€	-0,200	3,000

	Détail Gain estimé 5 ans					
	direct	addit.	explications	extern. envi	extern. Eco	explications
Pêche						
contrôle des pêches sur zones (100 kmx100km)	750k€		50% contrôle garde côte en moins / 5 ans par périodes de 2 mois	1 500k€		préservation ressource : 10% de 3000 t à 5€
cartographie conchiliculture / aquaculture 1500 km2 = 150 kmx5 km (/ 2 ans)	200k€		Images aériennes et PIAO			

5. Review of findings and public action recommendations for satellite application implementations

The applications were ranked along different criteria

We established an opportunity criterion corresponding to the maturity-weighted profitability indicator.

This way, a completely operational application (rated '3') will be three times more opportune than a still experimental application (maturity rated '1')

Beside, it seemed necessary to group applications by global budget classes, as cheaper ones present a much lesser degree of financial risk than the expensive ones in case of failure either when implementing them or for having people adopting the service.

We present hereafter this ranking within three budget groups, with some commentaries.

5.1 Ranking of small budget applications (< €0.3 million)

According to the criteria of opportunity, a first panel of 11 applications within €0.3 million of costs, is considered and ranked as follows:

A: The very opportune ones

1/ Argos beacons (with 5 units, excluding field work): by far the most profitable and less expensive application, with more than 25 years of operational use. This result is a bit artificial as only 5 beacons were considered to compute the costs. With 50 of them the ranking would have been different (ending up at 3rd or 4th position). Anyway, many uses of this application fall out of the study scope as communities do not have to finance or use such systems (except maybe for monitoring bears in the Pyrenees or wolves in the Alps).

2/ Measurement and monitoring of soil sealing / natural habitats and farmland consumption: this application is mainly based upon satellite images analysis; it comes out in prime position of this category because of the high societal and environmental costs induced by housing on land consumption. The application aims at a better balanced management of land and thus its consumption reduction induced by control and awareness of elected officials. The savings from land conservation may be quite large.

3/ Civil Security Crisis (5 satellite telephones): It is the cheapest of all applications. It allows otherwise cut communication between decision makers during large crisis and to organize field unit deployments. Has to be promoted or extended absolutely within communities and other civil security actors.

4/ Local dissemination of various updated information (retailers and businesses, activities and events, accommodations...) *see next.*

5/ Localized touristic information: these two applications (4 & 5) are actually very much the same technically speaking, and differ only by the disseminated content. They both involve the provision of targeted geo-located information toward subscribers. These are applications for Smartphones aiming at promoting places or events or at informing the service subscribers which will be offered, for example, by Tourist Offices from municipalities or districts. They allow retaining customers or attracting new ones in touristic areas

6/ Monitoring of ground movements (for 25 sq km & 1500 points): making use of Radar SAR images. This service maps centimetric ground movements on a yearly basis and appears to be very competitive compared to classic ground surveys solutions in particular for large areas (measurement of underground work disorders, of ground subsidence due to ancient mine galleries or soil compaction …)

7/ Ride-share or carpooling services in agglomerations (pop: 100,000): this involves setting up Web Services coupled with geo-location of Smartphones in order to link localized offers and demands of car-sharing almost instantaneously. This service would be highly "profitable" along our criteria (decongesting the cities, reduction of parking lots, CO2 emissions decrease, etc) the application already exist on the Internet for limited user communities. They do not yet integrate the instantaneous geo-location of demanding and supplying people, which would certainly multiply its use by a high factor. As such services are hardly sponsored to date, a pilot full size system experiment should be conducted by a local authority over its territory for promotion.

8/ Data transfer from remote stations (5 units). Data transmission by satellite allows installing at low cost measuring stations (for environmental or technical data collection) at places hardly served by terrestrial networks. Radio links are usually used due to habit, which means the installation of relay antennas both costly and disgraceful for our landscapes. Prescribers should be aware of satellite communication solutions and include these possibilities in the technical specifications within contract documents.

B : Less interesting at first analysis

9/ Monitoring subsidence of dikes (10 000m) using SAR images (see point 6). The application is fully operational. For monitoring 10km of dikes (or river embankments) linearly, the satellite data treatment appears to be more costly than standard ground surveys. However, if the concern is a coastal dike which subsides together with the surrounding land because of generalized ground compaction, radar technology becomes much less expensive for global monitoring.

10/ Mapping of shellfish and fish farming sites using CAPI (1500 sqkm = 150 x 5 km^2 / 2 years). If the mapping need is limited to implement an aquaculture control system, airborne images are certainly more appropriate because it is more flexible and finally cheaper than VHR satellite images which cannot be purchased as reduced to the simple coastal strip. This will change of course if satellite images may be used for other coastal or land management issues (Coastal observatory for instance) with lower prices induced by pooling.

11/ Town planning permission controls (pop: 100 000) : This involves using satellite images for controlling swimming pools, verandas, or property extensions which may have not been authorized or declared, thus avoiding taxes. A well adapted system (going beyond the simple use of Google Earth or Bing maps …) would be cumbersome to set up, rather tedious to operate and finally not much profitable as to results, when frauds may correspond to less than 2% of the extensions in countries, like France, where declarations by the contractors are mandatory. However, if associated with a system aiming at monitoring land availability (see App N°5 of the next category), which is much more profitable, this application would make more sense.

Intermediate applications (from 0.4 to 1 million €)

In this budget range, 16 applications out of the 36 analyzed are found. They are ranked again along the opportunity criterion.
The analysis shows that they all are opportune and largely profitable, with a 3 to 1 ratio for the indicator values. Actually, the application ranked 16th, at the bottom of this group, is already adopted in principle by several EU countries.

1/ Navigation aid for pilots in channels and harbours (PPU x 5): with 5 Portable Pilot Units devices, which are based upon augmented GNSS this application appears to be the most profitable from this category. Estuary and harbour pilots can monitor the ship trajectory with centimeter precision during manoeuvres in narrow channels and harbour entrances under tidal currents, until berthing. For a low price one will avoid this way the risks for grounding and collisions with wharves which may induce heavy costs. Prescribers are harbour authorities (who usually depend on Chambers of Commerce or on regional authorities).

2/ Algal blooms (early detection of) across a 400km x 150 km area provided by external services. Because of the increasing health risks (for tourism and shellfish consumption) induced by harmful micro-algae, which occurrences keep rising, as a possible result of climate change and growth of international trade, this service becomes necessary with a very high potential return on investment. It is close to be fully operational to date as data treatments from AQUA satellites of the NASA and MERIS on board ESA's Envisat are now achieved in less than 24 hours. Its economical interest lies in the simplification and reduction of delays for early warnings early warnings (still needing *in situ* verifications of algae blooms' nature) allowing for a better anticipation of sanitary risks, and possibly the sheltering of aquaculture production. Prescribers are sanitary or fishing authorities.

3/ Fishing zone controls (100 x 100 sqkm): this AIS based application allows monitoring locations and activities of fishing vessels in areas where resource exploitation is regulated. Its profitability comes from the reduction of aerial or maritime assets needed for controls; Prescribers are national or international fishing authorities.

4/ Specific mappings (natural habitats, geomorphology …) 10 000 sqkm (every 5 years) : these maps are produced partly by CAPI in association with in situ surveys using GNSS equipped collection devices and are intended to provide interannual monitoring tools (every 5 years for example). They aim at a better conservation of environmentally sensitive areas (wetlands, riparian forests, biological corridor, flood expansion zones, etc.), necessary for a number of reasons, e.g. to maintain equilibrium and heritage of our territories. Prescribers are environmental and land planning authorities.

5/ Land property observation (EO): involves the use of satellite images CAPI on an annual basis in order to identify land availability and purchasing opportunities for urban planning in cities or suburban areas. When used by communities, in a competitive context with private operators, such a tool will help strategies of land banking or freezing for future social housing projects or development programs.

6/ Thematic urban mapping products (land cover – differential) for 10 000 sqkm : aims at producing recurrent and global geographic information intended for various uses, within projects which may need for instance, preliminary diagnosis upon past evolutions or future evolution scenarios for land management or urban development. Communities will see a reduction of costs in studies and project related to their territories, which will avoid redoing again and again these analyses (inventories, observatories, ...).

7/ Emergency services monitoring: Application for monitoring and routing the intervention vehicles, (fire and rescue & Emergency Medical Services) and with itinerary optimization (coupled with urban traffic monitoring systems) and transport delay computations for decision support during operations. Such a well established system, available from specialized providers, may contribute to save several lives upon a period of

5 years with a better global efficiency. Its relative low cost should encourage authorities to at least examine its adoption.

8/ White zone telecommunications (100 households): satellite is the obvious response and certainly the cheapest one for the coverage of villages and isolated hamlets with broadband telecommunications for Internet, telephony and of course TV reception. The operators provide to date off-the-shelf packages which may be deployed very rapidly. It is a solution communities have to think of and promote beside terrestrial networks during contractual specification phases.

9/ Yearly control of agricultural declarations (10,000 sq km = 300,000 ha of cultivated lands) ; this is already operational and has been used for more than 15 years in the framework of CAP aid controls *(for the record).*

10/ Truck fleet management (Risks and Security; 50 Vehicles): system for the management of vehicles (truck-trailers) hauling possible dangerous cargo. Trailers are equipped with sensors linked with an integrated station in the cab, with GNSS location and communication capacities (GSM and Satellite). The station transmits its location and possible incidents toward a central office generally operated by a specialized provider, which relay by Internet bulletins toward the fleet manager.

11/Airport vehicle monitoring (20 vehicles): This is an application of augmented GNSS, which is provided (equipment and software) by a private company (M3S) to airport management services in order to monitor locations of maintenance vehicles on tarmacs. A dynamic geolocation system is integrated and interfaced with the other location systems for mobiles of the airport. The interest of this application is to increase location precisions when compared with other systems (when existing) such as ground radars and thus improve the vehicle and other mobiles security including the planes which may collide with them. It may allow, beside, to reduce the number of ground radars.

12/ Forest mapping after fires / storms (for 10,000sq km): CAPI of satellite images (ex-ante and ex-post) is worked out to delineate and estimate damages after a catastrophic event affecting forested areas. As this work is necessary, the benefit is mainly due to the difference of costs when compared with aerial imagery which is longer to set up and more expensive for large areas. The service, once it is established opens the way to an at least biennial monitoring of forest restoration. Satellite imagery use is clearly more efficient and faster than other techniques. It does not yet allow for real time monitoring during such crisis as big forest fires, because of the 1-2 day delay to have images delivered (cf SAFER); however this delay will be rapidly much shortened with Pleiades and Cosmo-Skymed satellites in operation.

13/ Civic Applications (pop: 100,000); users indicate pavement and street furniture problems to authorities using their Smartphones. This can be an integrated service provided by a private operator with the needed infrastructure and back office resources. Images of small damages or simple problems in the streets are sent by citizens toward the service which positions the picture on a map and relay the located incident toward the municipality technical services. This is quite efficient when considering that pavement problem or other damages generate nuisances or injuries (notably for bicycle or mopeds) with rather high societal costs when cumulated over several years.

14/ Waste collection monitoring (50 vehicles with centralized geo-navigation): an integrated service provided by private operators or else turn-key packaged systems provided off-the-shelf for communities. It allows optimization of routes and durations, with continuous analysis of other data for garbage and other recyclable waste. The service can be extended to individual pricing of the collected waste. Allows mainly savings on fuel and driven distances and ultimately to reduce the number of garbage trucks. Several private companies operating under concession contracts have adopted such systems, so communities which operate waste collection by themselves should consider doing the same.

15/ Control of agro-environmental measures (10000 sq km; 1/5 year through CAPI of VHR images) Such a system has been set up by authorities in charge of controlling CAP aids since 15 years. (for the record) Note that until 2011, VHR images for controlling the so called GAEC rules of good agricultural and environmental practices (2 nd pillar) were produced until recently by airborne imagery as costs and delays of delivery for satellite VHR images (from American satellites) were still unacceptable.

16/ Support to forest inventory (10,000 sq km ; 1/5 year through CAPI of VHR images) ; the GMES-FM project followed by GEOLAND2 succeeded in developing generalized methods at European level for doing forest inventories and biomass estimation with satellite instead of airborne images as used until now. The inventory results from GMES projects are compatible with the defined needs from the forest institutes of the different countries who participated to the project with lower costs. Wood inventory within forest plots stay necessary and are done using writing pads with GNSS chipsets allowing to capture distances and azimuths with high productivity gains. In all, forest inventory costs may be reduced notably with these methods.

5.2 Large applications (more than €1 million)

The timely systems which come out are:

1/ Integrated water management of foothill watersheds (10,000 sqkm): it could be the most profitable application if applied at a large scale on several water deficit basins when necessary data will be available routinely (which is not yet the case). High resolution multispectral images (20m) with recurrent acquisition (1 week revisit time) will allow the monitoring of cultural water requirement at agricultural parcel scale, using agro-meteorological water balance models coupled with forecasting models of river flows. Associated snow cover and water content models using also satellite images would improve the routine computation of river flows. Flow forecasts provide the necessary elements for optimal arbitrations between the different water needs, for irrigation along cultivation types, drinking water, hydroelectricity production, biological requirements. An optimization leading to 5% gains for agricultural and hydroelectric productions over a 100,000 sq km basin (e.g. upper Garonne) would generate about €60 million of added value on a 5 years period which fully justify the implementation by water boards of such systems with a close to ten cost-benefit ratio.

2/ E-health (1 van with diabetes/ dialysis facilities) : several experiments have already taken place for evaluation of such travelling systems performing examinations and treatments (which are remotely supervised by practitioners from specialized centres) in cut-off territories where health-care professionals and facilities are lacking. All these experiments were extremely positive and enabled in particular diagnosing people with life-threatening situations. Data transmission between the van and the medical centres are secured using mobile VSAT links.

3/ Information System for coastal zones with multiple surveys (for a 200 km coastline): taking the example of the Observatory of the Aquitaine Coast, the system should address particularly the annual or biennial monitoring of the coastline evolutions in order to quantify erosions, accretions, dune and cliff retreat. Surveys are done using differential GPS and in addition, every 2 to 4 years, VHR satellite or airborne images sets. Beside the collection of environmental data for additional knowledge, the goal is to highlight the coastal morphology dynamics both spatially and temporally, related with climatic events. One immediate benefit is that data stored for many years, aavoids the necessity to rework such analyses these analyses for every local shoreline study. But the main benefit is that, when facing coastline retreat, the quantified evolutions, as observed and measured, now allow realizing costs-benefits analysis in order to decide whether or not to protect sites with large assets and thus to elaborate sound strategies of coastal management.

Applications with differed benefits, from more to less appropriate on the long run

4/High precision farming (10 000sq km; 2500 farms); this is the version without satellite images, making use only of augmented GNSS in agricultural equipments to optimize inputs and irrigation inside the fields at metric precision. A stand alone agro-geographic information system for farm management has to be set up first which will be coupled with the GNSS system installed on the equipments (now standard on the harvesters and tractors with control or command of the grain production ratios or of nozzle flows). The system cost is then completely supported by the farmer who aims at having a higher production with fewer inputs, which is also positive, notably, to the aquatic environment.

5/ Services of precision farming with satellite imagery (10,000 sq km; 2,500 farms); this service aims at optimizing agricultural inputs and increase yields by locating intra-field variations during the growth cycle of crops using high resolution satellite images (notably SPOT5) acquired monthly. The farmer contracts most of the intra-field analysis to the service provider (e.g. FARMSTAR service). He uses onboard GNSS device capacity to apply thegeo-located treatment recommendation within the fields. The system cost is shared among the service subscribers who pay for it and may additionally equip their tractor and harvesters with sophisticated automatic control /command systems coupled with GNSS devices. Farmers may alternatively regulate manually in their tractors the recommended input quantities along their precise location. The induced reduction of agrochemicals inputs should justify by itself an adapted system of financial support of Water Boards to farmers in areas particularly sensitive to such pollutions (nitrates and pesticides).

6/ Bus routing with real time information (TOD 50 vehicles): the purpose is to set up a centralized system for optimal routing of on-demand transport shuttles (TOD) in the suburban agglomeration areas with a model similar to urban taxi companies. Software and on board systems already exist for this. The user indicates on a map (directly using his Smartphone or vocally to an operator) where he has to go and the pick up location within the next half hour. The central office computes every 5mn, for example, the new optimal journeys (with schedule constraints) from the last known locations and planned routes, then send the information to the on board driver's control unit. Users are notified by messages (Smartphones or screens located at shuttle stops) of the TOD time of arrival. This application becomes very rapidly costly if interactive terminals are installed at each shuttle stop. The solution with telephone messages (which is more classic) requires at least two or four operators daily for a community with 100 000 inhabitants. Using GNSS equipped Smartphones would reduce the number of call to operators. The continuous route optimization will reduce the fuel consumption as well as the number of needed shuttle buses and drivers. Urban transport authorities and operators may purchase or prescribe such systems.

7/ Regional near-coast marine forecast system (for 400 km coastline x 150 km offshore; independent local system); coastal assets and associated risks (health, environment or economy) justify the setting up of very global systems for monitoring and forecasting marine coastal zones conditions, coupled with meteorological observations and forecasts, making use also of the various physical and chemical data collected from available stations (e.g. PREVIMER in France). The system may use of course various data and image products from satellite sensors or use satellite links to collect in situ data from various localized measuring stations. The stakes are very high in light of the potential damages (oil slicks, shellfish and marine life poisoning, marine flooding, cliff crumbling, etc.) which are several orders of magnitude higher than the undoubtedly important investment associated with implementation and operation of such systems.

8/ Self service cars (for 50 units, in cities; overhead induced by GNSS and subventions for urban infrastructures): this type of service is appearing in some major cities (see AUTOLIB or CARTOGO examples). Such services cannot be initiated by communities without public-private partnerships as return on investment is very long and even negative when too small numbers of cars are considered (the number of 50 vehicles taken here is too low to make the service financially interesting).

9/ Parking space information for cities: provides location and availability of parking spaces within cities (for 2,000 lots). One will have to equip the parking space pavements with sensors that will send to central dedicated servers their availability status which will be forwarded to the drivers' Smartphones or GPS equipped communicating devices. This system is being tested for parking spaces for disable motorists. As such, it does not seem interesting, however, for a generalization to all motorists, because of the high cost of sensor installation in the street or parking lots pavements. Alternatively, another system with a much smaller budget, for parking fee payment using one's smartphone with geo-located spaces, can be considered (application developed by EXYZT Co. in Castres); it allows reducing the number of parking meters in cities and thus the related maintenance costs, and increases the payment rate.

6. Conclusions of the study

This study about the state of the art of applications responding to community concerns and which make use of at least one of the three main present satellite technologies (telecommunications, geo-navigation, Earth observation) led us to select a representative though not exhaustive panel of various services which financial and societal opportunity is analyzed and demonstrated.

The implementation of the most responsive and timely services which make the majority of this panel depends only, with a few exceptions, on local, regional or national political decisions or arbitrations allowing them to be adopted and of course financed, directly or in partnership with private operators.

In parallel the study highlighted several elements which are synthesized hereafter.

A : Satellite technologies are both very useful and high value drivers, particularly in Europe, but in different ways if we consider separately Telecommunications, GNSS and Earth observation.

1) Except at sea, satellite telecommunications are in competition with terrestrial technologies. The choice of satellite which technology is mature and perfectly operational is then a matter of competitiveness and other advantages. It will be to given priority for white zone coverage (cut-off areas), for secure communications (during crisis of various types, for critical data exchanges) or even for new services (E-health) while travelling and needing reliability and security.

2) GNSS is a new utility generally provided for free to users (it is charged for augmented and secured services), which revolutionizes a large set of different sectors with possibilities yet to be explored, which allows the present profusion of applications. Among these applications for tourism, transport, security, or urban management, a large number brings or will bring better services associated with cost reductions largely beneficial to communities. In a context of touristic competition, budget reduction and high civic demand, these new services are an opportunity to be seized by public decision-makers.

3) Satellite imagery, for its part (except for the military sector, meteorology and oil and gas industry which make a large use of them internally), generated until now only a small private market of (commercial) value-added applications with no established economical model yet, notably because of data access costs. Nonetheless the demonstration is done, thanks to the Internet geographical platforms, that the various uses of satellite imagery, now widespread in public or private sectors or in everyday life, provide direct or indirect social benefits and more productivity in multiple activities. Beside this, the market entrance of very high resolution images at a lower cost from the European "Sentinels Program" (Pleiades et CosmoSkymed) now opens the way to new perspectives. The regional political decision-makers should at least organize recurrent grouped purchases of satellite images for a shared use among the various actors of their territories for various applications.

B : Among the applications of the selected panel, a majority makes a combined use of two or even three of the considered satellite technologies : geolocation ("the fifth utility") is often associated with messaging solutions (by satellite or not) and satellite image interpretations is complemented or used for generalization of geo-located in situ surveys or measurements. In addition, geo-location is generally coupled with map consultation which synthetic information is clearly augmented when adding VHR satellite images over them.

C : The convergence of computer networking, telephony and G-ICT (technology of geographic information integrating GNSS and digital maps) opened the way for a new generation of inexpensive, easy to implement useful applications, which generate a wealth of offers from multiple players. Google, with its Google Map/Earth application available on Smartphones, has taken up a leading position in the online G-ICT market and has become *de facto* the provider of the most used satellite application in the world and certainly the most profitable!

D : If a (small) majority of the panel applications correspond to new services, several applications / services are in the competitive sphere and appear to be well positioned when compared to "traditional" technologies, which private actors have already understood. Satellite telecommunications are an example, but it is also the case for some applications of satellite imagery which generated profitable charged services in particular for agriculture, fisheries, and ground movement monitoring.

As a result, and in conclusion, only Earth Observation based applications really need an institutional impulse to be adopted and widely used, which would benefit to everyone. The use of other satellite applications based upon geo-navigation and/or telecommunications is becoming widespread as they are immediately and obviously "profitable" or competitive as shown in the detailed "fact sheets".

Despite the potential, it is clear from this study, that satellite images (optical and radar) and their derived products are, in Europe at least, not enough used by public bodies and authorities in charge of environment, land management and urban planning, while they are of widespread use and considered as cost-effective in the oil sector (the largest private purchaser of images) , agriculture (e.g. CAP aid controls, precision farming), for fishing assistance (free medium and low resolutions images), in some urban planning agencies and above all in the military sector that finances more than 50% of the images actually sold.

From the various investigations and reports on the subject, the main restraint to date for the use of EO in administrations and other public bodies, which are potentially the most important users, are: a) the access cost to this technology and the high-tech reputation related to their exploitation b) the purchase costs of satellites images and the license associated restrictions of use when in fact they are primarily funded by public budgets (including military).

The supporters of satellite image commercial sales should therefore think about the real economic model of this sector tentatively highlighted in this report. It seems clear that few civil EO applications are directly profitable, except, and significantly, some of the examples of the analyzed panel, and why is the EO associated market showing a large deficit when adopting a purely accountancy-based logic.

Private companies as Google or Microsoft heavily invest on mass applications offering free satellite image consultation coupled with ancillary geo-location services and advertisements, for which large purchase of images may be negotiated at rather low price.

They understood a major point with high commercial interest for them: just like GNSS (the American "5th utility"), the main benefit of making EO images available for all lies on the one hand in the productivity gains which can be generated for everyone (already the case, with the free consultation platforms which are used in various fields related to G-ICT or territorial studies) and on the other, in the societal gains it allows related with environment conservation and resources and land preservation.

An impulse is necessary for a widespread adoption of satellite imagery in public body missions, on at least two matters:

1/ At the national or regional level, public authorities should advocate or invest themselves, *taking as example the GeoSud initiative in 2010, with the purchase of a full coverage of France with RapidEye images*, so that the provision of satellite images can be virtually free for public use over large areas, with very few license limitations. Images should be pooled for a set of applications ranging from simple diachronic localized consultation to the generation of specific products, if necessary by specialized companies whose costs will thus be greatly reduced.

2/ At a more local level, political players must become aware of the potential benefits of using satellite imagery and thus encourage the development of a set of highly beneficial applications such as, for example, systems for water management in deficient basins, for land consumption monitoring, for the protection and monitoring of sensitive areas, or for the prevention of risks related to harmful algal blooms, for which we have indicated the related societal and financial issues at stakes.

In light of some interviews conducted in this study, and despite the 50 satellites already in orbit producing optical or radar images, it appeared that programs to come as ambitious as they may be, neither respond necessarily to the more pressing needs of important potential users nor to priority societal demands.

There are multiple expectations associated with HR and VHR satellite data and the offer which may sometimes be redundant should involve in the future a better international coordination in order to arbitrate between the assigned missions of the financed satellite programs.

We face, actually, several types of competing demands depending on possible applications:

- A demand for VHR images acquired yearly or biannually with nadir acquisition and providing full coverage of territories for applications related with urban planning, forest monitoring, land management controls or large scale mapping which could replace or complement airborne imagery.
- A demand for at least a weekly repetitivity (high temporal resolution with often associated cloud problems) with nadir sun synchronous lower resolution images (20 to 50 meters) but high spectral resolution (5 to 10 bands) and large swath (over 200km) for the monitoring and management of resources (agriculture and water notably)
- A demand for agility of acquisition for optical or radar VHR images (<2.5m resolution) for security applications (military, natural disasters) needing highly pointable sensors
- A demand of daily coverage for ocean applications with on the one hand hyperspectral imagery (8 to 20 bands or more), at medium resolution (about 250m) with large swath (300km at least) and on the other hand, radar imagery (SAR) to monitor sea conditions and oil pollutions.

Broadly speaking, one can therefore observe that
- While satellite telecommunications have entered the lives of many users, new uses are developed through innovative enterprises;
- The market for geo-location and navigation, based on free and open access to satellite signals, registers a boom of applications available locally or worldwide;
- The use of Earth observation data is democratizing thanks to pooling efforts for the diffusion or the access to images, higher flexibility for public services such as preferred rates (in France), or innovative means to access or process images with free software (OTB), information extraction routines, access platforms , etc. and an extra effort to give public agents appropriate training.The challenge now is to promote networking between companies developing space applications, supported by research laboratories, and public sector organizations.

To do this, it is in the interest of local communities
- To focus on satellite applications that already meet many of their needs,
- To analyze, express and spread the word on their needs, in terms of uses for the fields of their responsibilities and not in terms of technology,
- To pool their purchases
- To prescribe the use of such technology to their partners and providers,
- To integrate, or at least open to, space technologies the specifications of their calls for tender.

Working towards this dissemination, Aerospace Valley is also forging partnerships with other organizations such as aerospace clusters, in favor of their territories and their members. Initiatives from other European players as EURISY (eurisy.org) and DORIS - NET (doris-net.eu) must also be highlighted. Under the leadership of the Aerospace Valley cluster, partners of the APSAT project (www.apsat.eu) are thus contributing to the European development of practical space applications useful to the citizen. As this report demonstrates, they represent a wealth of opportunities for the economic growth of our territories, the job creation and protection of people and the environment.

ANNEXES

Produced fact sheets *(separately)*

1. Glossary

2D / 3D: In 2 / 3 Dimensions

AB, HAB: Algal Bloom; Harmful AB

ADSL: Asymmetric digital subscriber line

AEP: Adduction Eau Potable: Drinking Water

AIS: Automatic Identification System for vessels

APSAT: Acronym for: Action Publique, technologies SATellitaires et développement durable

ARGOS: System for messaging and location computation operated by CLS in France

ASI: Italian Space Agency

ASP: Agence de Services et de Paiement (en charge du paiement des aides PAC); French Agency in charge of CAP aid support and payements among other

ASTER: Advanced Space borne Thermal Emission and Reflection Radiometer; a high resolution imaging instrument flying on the Terra satellite

AVHRR: Advanced Very High Resolution Radiometer sensor carried on NOAA's Polar-orbiting Operational Environmental Satellites

B2B: Business to Business

B2C: Business to Consumer

Bands: C, Ku, K, Ka: Standard Radar Frequency Letter-Band along wavelength

Band Designator / Frequency (GHz) / Wavelength (centimeters):

L band / 1 to 2 /30.0 to 15.0 ; **S band** / 2 to 4 / 15 to 7.5; **C band** / 4 to 8 / 7.5 to 3.8 ; **X band** /8 to 12/ 3.8 to 2.5; **Ku band**/ 12 to 18 2./ 5 to 1.7; K band /18 to 27 /1.7 to 1.1; **Ka band**/ 27 to 40/ 1.1 to 0.75

GAEC: Good Agriculture and Environmental Conditions

WS: Watershed

CCD: Charge-Coupled Device; a major technology for imaging

CERSAT: Centre d'Exploitation et de Recherche Satellitaire; Center for Satellite Research and Exploitation; a unit of IFREMER in Brest

CESBIO: Centre d'Etudes Spatiales de la BIOsphère (in Toulouse)

CHU: Centre Hospitalier Universitaire (French Hospital Centers associated with Universities)

CLS: Collecte et Localisation par satellite (a well known French Company specialized in space Oceanography operating the Argos system)

CNES: Centre National d'Etudes Spatiales: The French Space Agency

COMPASS / Beidou: The Chinese GNSS

CORDIS: Community Research and Development Information Service (incl. European E&D program databases)

Corine Land Cover (CLC): a land cover database produced at European level by CAPI of satellite images

COSPAS SARSAT: an international satellite-based search and rescue (SAR) distress alert detection and information distribution system

WFD /DCE: Water Framework Directive / Directive Cadre sur l'Eau

DoD: Department of Defense (US)

EGNOS: European Geostationary Navigation Overlay service

EMSA: European Maritime Safety Agency:

ENVISAT: Environmental Satellite (ESA)

EOS: Earth Observing System; a NASA's coordinated series of polar-orbiting and low inclination satellites for long-term global observations of the land surface, biosphere, atmosphere and oceans

EPS/METOP: Eumetsat Polar System / METéorologie Opérationnelle;

ESA: European Space Agency

EUMETSAT: European Organisation for the Exploitation of METeorological SATellites

EURISY: European International Space Year: a European non-profit organisation which promote the full access of Society to the benefits of satellite information and services.

EUTELSAT: EUropean TELecommunications SATellite organisation

FAO:	Food and Agriculture Organisation: UN agency
FP7 (FPn):	Framework Program N°7: (7th R&D European Program)
FSS / MSS:	Fixed/ Mobile Satellite Services
GALILEO:	The European GNSS
GEO (1):	GEOstationnary satellites
GEO (2):	Group on Earth Observations: intergovernmental group leading a worldwide effort to build a Global Earth Observation System of Systems (GEOSS)
GEOLAND2 (GMES):	One of GMES projects related to Land Observation applications
GEOSS:	Global Earth Observation System of Systems
GLONASS:	Russian GNSS system Globalnaya Navigatsionnaya Sputnikovaya Sistema
GMES:	Global Monitoring for Environment and Security: EU contribution to GEOSS
GMES FM:	GMES Forest management; one of GMES Projects funded by ESA
GNSS:	Global Navigation Satellite System; The generic acronym for GPS, GALILEO, GLONASS, BEIDOU, …
GPS:	Global Positioning System from United States / constellation NAVSTAR
GSM:	Global System for Mobile Communications, (originally Groupe Spécial Mobile) A technology for cellular network telephony including 1G, 2G.. 4G
HR/VHR:	High / Very High/ Resolution
HTS:	High Throughput Satellite
ICCAT:	International Commission for the Conservation of Atlantic Tunas
IFN:	French Forestry Institute
IFREMER:	French Research Institute for Exploitation of the Sea
IGN:	French Geographic Institute)
IP:	Internet Protocol
Kopernikus:	the new name of GMES Program

LAI:	Leaf Area Index; computed from reflectivities between different wavelength
LANDSAT:	The Landsat Program is a series of Earth-observing satellite missions since 1972, jointly managed by NASA and the U.S. Geological Survey
LEO:	Low Earth Orbit (satellites)
bn:	billion
MERIS:	MEdium Resolution Imaging Spectrometer; Instrument on board ESA's Envisat satellite
MF:	Météo France; French Meteo Service
DTM:	Digital Terrain model
MODIS:	Moderate-resolution Imaging Spectroradiometer; NASA's Aqua & Terra satellites' instrument
MSS:	Mobile Satellite Service (Telecom)
NASA:	National Aeronautics and Space Administration (a US Agency)
NDVI:	Normalised Difference Vegeation Index: provides a measure of vegetation evapotranspiration
NOAA:	National Oceanic and Atmospheric Administration (USA)
OCS:	Occupation du Sol; Land Cover/land Use Products
ORFEO:	Optical and Radar Federated Earth Observation, Dual optic-radar French-Italian system composed of both Pleiades et COSMO-SkyMed (CSK) constellations
EO:	Earth Observation
CAP:	Common Agricultural Policy
CAPI:	Computer Aided Photo Interpretation
GDP:	Gross Domestic Product
PLU:	Plan Local d'Urbanisme; Urban regulation document in France
PPU:	Portable Pilot Units; handsets and associated systems for channels and harbors navigation support using GNSS
PRS (Galileo):	Public Regulated Service;
RADAR :	Radio Detection And Ranging

RIS:	River Information Services; EU Directive for the implementation and use of harmonized RIS
RISK-EOS:	a GMES Project focusing on Risks'management
RTK:	Real Time Kinematic; Dynamic correction method for GPS
SAFER:	Services and applications For Emergency Response ; GMES project
SAMU:	French EMS (Emergency medical services)
SAR:	Sythetic Aperture radar; A technology of imaging from alongtrack radar echos synthesis
SCHAPI:	Service Central Hydrologique et d'Appui à la Prévision des Inondations ; French central service for hydro-meteorological forecasts support
SHOM:	Service Hydrographique et Océanographique de la Marine ; French Navy Service for Hydrography and Oceanography.
GIS:	Geographic Information System
SIM:	Acronym for the chain of models SAFRAN ISBA MODCOU at Météo France
SMIAR (FAO):	Système Mondial d'Information et d'Alerte Rapide; Worldwide System for Information and Eaurly Warning - Food and Agriculture Organisation.
SPC:	Service de Prevision des Crues; Local French services for flood forecasting
SPOT:	Système Pour l'Observation de la Terre; EO satellite constellation operated by Astrium GEO-Information Services
SUDOE:	Sud-Ouest Européen; South Western Europe program of territorial coopération « Interreg »; funded by FEDER
ODT:	On-Demand Transport
VHR:	Very High Resolution (< 1.5m)
ICT:	Information and communication technologies
G-ICT:	Geographic ICT
TNT:	Terrestrial Numerical Television
EU:	European Union
UV:	Ultra-Violet
VA :	Value Added

VoD: Video on Demand

VoIP: Voice on IP

VSAT: Very-Small-Aperture Terminal

WEB 2.0: An evolution of Internet application methods with better interactivity

ZAC: Zone d'Aménagement Concertée; a specific localized land development procedure in France

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