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Data needs and availability

C12


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EXECUTIVE SUMMARY

This document addresses all issues concerned with the provision of the data inputs required to generate the Service Portfolio. This includes the appropriate data requirements expressed by those generating the products and the potential supply of data from the various data sources. The first of these issues is addressed using the information supplied in the Service Portfolio dossier (S5), Operational Scenarios dossier (C11) and Terrafirma Strategic Plan (S1). Analysis of the data supply is drawn from the Data Sources Inventory dossier (C10) and the Infrastructure Systems Analysis (S10).

The situations where requirements and supply are not compatible are highlighted.

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1 INTRODUCTION

1.1 Document Objectives and Structure

This document addresses all issues concerned with the provision of the data inputs required to generate the Service Portfolio. Both demand and supply side aspects of the provision of EO and non-EO data and their evolution over the time scales of the GMES program (10 years) are discussed.

- **Data needs.** The data required to fulfil the Terrafirma Strategic Plan (dossier S1) is identified. Data requirements are expressed in terms of data type and data quantity/timing, where data type information is provided in the Service Portfolio dossier (S5) and data timing/quantity in the Operational Scenarios dossier (C11).
- **Data availability.** The supply side of EO and non-EO data sources is analysed using the information provided in the Data Sources Inventory dossier (C10).
- **Gap analysis.** A comparison is made between the data required (data needs) to provide the products and services defined in the SP and the potential supply (data availability) of input data. Where inadequacies in supply are evident these are highlighted. This allows the identification of potential problems related to the type or quantity of data required for the successful implementation of the SP. Having highlighted potential problem areas, solutions can be proposed.

For each of the data types used in the generation of the SP, the three aspects described above are discussed. This information is organised in a chapter describing each data type: SAR, non ESA data.

1.2 Terminology and Acronyms

Global User Base	This is the complete set of all potential users (in the world) for a given set of services. It is made up of a collection of different user-segments.
End User Segment	A user-segment is a collection of end-user organisations that have something in common. (<i>eg; all needing same type of service; all from same geographic region; all reporting on the same environmental policy; all unlikely to use the service; etc..</i>).
Key User Segment	An End User Segment that has been identified as being of high importance and likely to constitute with the other Key User Segments at least 70% of the users likely to benefit from the service portfolio in the next five years.
Infrastructure	In the context of <i>Terrafirma</i> , this term is used to signify the complete range of man-made structures or interventions.

Acronyms

SP	Service Portfolio. Defined in dossier S5 – Service Portfolio Specifications
CUG	Core User Group consisting of: Arup, BGS, BRGM, Enel.Hydro, TNO
GUB	Global User Base
AP	Associate Partners

1.3 Applicable documents

The generation of this document has been completed with reference to the following dossiers:

- S5 – Service Portfolio Specifications
- C11 – Operational Scenarios
- S3 – Service Prospectus
- S10 – Infrastructure Systems Analysis
- C10 – Data Sources Inventory
- S1 – Strategic Plan

2 DATA OVERVIEW

2.1 Introduction

This chapter defines all EO and in-situ data that will be required to generate the Service Portfolio (S5) to the levels described in the Operational Service Scenarios (C11). The information provided here has been summarised from the following dossiers:

- S5 – Service Portfolio Specifications
- C11 – Operational Scenarios
- S3 – Service Prospectus
- S10 – Infrastructure Systems Analysis
- S1 – Strategic Plan

In accordance with the Operational Service Scenarios dossier, this document contains information on the three following scenarios:

1. Scenario 1: worst-case scenario (pessimistic scenario),
2. Scenario 2: conservative scenario (realistic scenario),
3. Scenario 3: best-case scenario (optimistic scenario).

Details of required data volumes and the availability of these data for the different stages of the GMES program, derived from the dossiers cited above, are provided. The tables presented here are based on the scenario models provided in the annex of the Operational Service Scenarios dossier (C11).

2.2 Product Timing

The generation of products described in the Service Portfolio (S5) dossier is analysed over the standard GMES program time scales:

- GSE Service Consolidation activities: next 2y (2003 – 2004)
- GSE Full implementation activities: +3y (2005 – 2007)
- GMES full system implementation: +5y (2008 – 2012)

A last period is also considered in the Operational Service Scenarios dossier (C11):

- Beyond GMES Implementation: +8y (2013-2020)

Analysis over these three program stages allows for current and future data needs to be calculated and for their evolution over time to be taken into account. In order to facilitate the presentation of product volume information in the next section of this document, only those products generated during each of the three project stages is provided. This time scale information is presented in the Table 1. The table key is provided below:

- 'X' indicates the corresponding product is generated during this stage
- 'ε' indicates the corresponding product is generated in a trial capacity or in small quantities during this stage

	Stage 1 to 2 years	Stage 2 to 5 years	Stage 3 to 10 years
Historical 1: H1	X	X	X
Historical 2: H2	ε	X	X
Historical 3: H3	ε	ε	X
Routine Updates of H1			X
Update: U1		ε	ε
Monitoring: M1	ε	ε	ε

Table 1 – Time scale information for the 5 products that make up the SP over the three stages of the GMES program. X – product is generated; ε – product is generated in a trial capacity or in small quantities

2.3 Required Data Types

For the set of products defined in the Service Portfolio dossier (S5) a number of different data types are required. Data types range from, for the generation of Level 1 products, raw SAR data to different geological data for the production of Level 2 interpretative and Level 3 modelling products. Table 2 summarises the main data types concerned, citing only the main geological data types.

	SAR data	Non ESA data	Non EO data
H1	ERS/ENVISAT/ RADARSAT	Optical e.g. SPOT, Landsat (optional)	<ul style="list-style-type: none"> • Topographic Map/Digital Elevation Model for H1a and H1b (optional) • A reference point (optional)
H2		<ul style="list-style-type: none"> • H1 products • Optical e.g. SPOT, Landsat (optional) 	<ul style="list-style-type: none"> • Topographic Map/Digital Elevation Model (optional) • Geological (appearing as 'Ground Motion trigger assessment data' in S5): 2D, 3D, Water table, geotechnical properties, borehole • Other: Critical structure data layers (listed in S5)
H3	as H2	as H2	as H2
U1	as H1	as H1	as H1
M1	as H1	as H1	as H1

Table 2 – The different data types required per product for the generation of the Service Portfolio

3 SAR DATA

3.1 Introduction

3.1.1 Data Sources

Terrafirma concentrates on “*the combination of multiple satellite SAR acquisitions using interferometric techniques*” (source: C10) as its principle source of information on ground movements. Over the three stages of the standard GMES program time scale, a number of sources are identified as having the potential to provide appropriate data. By far the most important current source has been identified as the ERS 1 / 2 archive which is capable of providing the data required to process around 200 towns identified for processing by the Terrafirma service. However, this source is not suitable for longer term use in Terrafirma as no monitoring or rapid response products can be generated. It should be noted (c.f. Service Portfolio Specification S5) that the different interferometric processing techniques measure relative movements and at least one stable reference point is required for these techniques to provide absolute movement information.

Other sources that might potentially provide SAR data are the ENVISAT and RADARSAT satellites although issues have been highlighted with both these sources. It is noted that while ENVISAT represents the most likely follow-on data source for Terrafirma providing continuity to perhaps 2010 according to ESA, there is a slight difference in operating wavelength, which introduces compatibility issues. These issues are currently addressed through research. Some interferometry has been successfully achieved through the pairing of ERS and ENVISAT images and tends to be considered as operational. Concatenation of separate interferometric processing is also an applicable work-around for this issue. There remains an issue with the accumulation of a suitable ENVISAT image archive; this is as yet unresolved with a background mission needing to be identified. Imagery from the RADARSAT system presents a similar problem: that of a limited archive due to the fact that no background mission policy was operated in conjunction with the programming of the satellite. Even if such a background mission were initiated immediately (and this applies to both sensors), it would take some time for a suitably rich archive (at least 12 images are required for the PS InSAR image stack) to be generated.

Long-term sources of SAR data have also been identified in the Data Sources Inventory dossier. This shows that a number of potential systems are anticipated that should guarantee the continuity of InSAR capable data in the next 15-20 years. However, a caveat regarding the access and acquisition policies and the inter-operation with current or past sensor systems is added. The conclusion is drawn that an “ERS Continuity Mission”, matching exactly the characteristics of the original system, would be the optimal data source.

The Data Sources Inventory dossier considers that the utility of in-situ measurement capability is not sufficient for such techniques to be included in the Terrafirma offer other than as initial validation sources. As a result, such data sources are not detailed.

3.1.2 Data Requirements

The volume of data required in order to enable the generation of the products defined in the SP to the levels described in the three operational service scenarios is presented by product and by stage in this section. All analyses assume the provision of full European coverage,

and are presented for the second operational scenario: the conservative (or realistic) scenario. For the other two scenarios, total volumes for each stage and product are provided.

Assessment of the SAR raw data needs is done independently of data sources and includes appropriate alternative sources of radar data that could be exploited where deficiencies in supply are identified. This assessment does not consider processing and re-processing, but only data quantities to be acquired / or retrieved from the archive. The main factors affecting the raw data requirements are:

- the model proposed for processing a city,
- the number of cities proposed per stage, and the assumptions made such as:
- assumptions on the geographical extent of the raw image footprint relative to that of a city,
- assumptions on the enhancement of the products using ascending and descending acquisitions,
- assumptions on the data continuity.

The complementary use of the VV-polarised data from the dual-polarised ENVISAT/ASAR data (APS) with the VV-polarised data in image mode for interferometric product generation is currently a research area. In the case of a gap in the ASAR archive (for example when a new city will have to be processed during stage 3 or beyond 2013), it may occur that for some important dates only APS data were available. However, assumptions on the use of APS data is not investigated in this dossier for two main reasons:

- data ordering must be forecasted for ASAR images fully compatible with ERS and already available ASAR data,
- ASAR-APS data are expected to be acquired in a punctual way, so that their, if it occurred, would be rather occasional.

The generated models are based on the assumptions set out here and in the following subsections. We have assumed that the volume of processing is the same as in the Operational Service Scenarios document (C11) but have quantified this in terms of the number of scenes rather than the number of cities. The assumption is made that the geographical extent of any given city is inferior to the area covered by a SAR scene and, as in the dossier S10 (Infrastructure Analysis), the figure of 60 SAR scenes per city for one series has been used as a basis for the numbers provided here. The update figures are based on "Section 6.2 Updating and Monitoring" of the Strategic Plan (dossier S1) in which it is stated that from Stage 3 (covering the period 2008-2012), it is "planned to update the coverage every three years". This rate of update implies the processing every year of a third of the scenes. Assuming that the minimum number of images required for an update to be useful for a given site over the three-year period is nine (three per annum), this gives us a figure of 3 scenes per site per annum to be processed in update mode.

In section "Non SAR data", the EO non ESA data corresponds principally to high resolution optical data used in the presentation of the ground movement results. As, generally speaking, high-resolution optical data is purchased by the square km, these are the units used in the table. An average figure of 200 km²s per town has been used in these tables. The other non SAR data include all the auxiliary data requested for various products.

The worst case and best case scenarios are intended to provide an indication of how work might progress given unfavourable or, inversely, particularly advantageous conditions. Levels of production are defined relative to the "conservative" scenario (cf. dossier C11: Operational Service Scenarios). Only global volume data is provided for the scenarios. For each scenario,

a different number of cities are processed per stage. These variations impact on the assumptions made and thus on the number of data required per city. One example of this is the situation where processing rates are higher than expected – the “best case” scenario. In this instance, it is found that more than one city can be processed in a single image scene or “footprint”. This implies that fewer images are required.

3.2 Defining the SAR data required for one city

The table presented here describes the assumptions in terms of the quantity of raw data required to generate each of the Terrafirma products from the SP for a single city. This information in conjunction with the number of cities to be processed allows the total raw data requirement to be estimated. The requirement of 10 new data/year/city is stated although this figure may be less in reality, due to ENVISAT acquisition constraints.

Scenarios	Models			Ref
	Historic products	Update product	Monitoring product	
Nominal	1 new city = 60 data to be acquired or extracted from archives	1 city = 10 data / year (reprocess every 3y)	1 city = 10 data / year (continuous monitoring)	S1, S5, S10
Least Data case	1 new city = 30 data products to be acquired or extracted from archives Potential technical improvements	Idem <i>could be reconsidered</i>	Idem <i>could be reconsidered</i>	
Most Data case	idem nominal	idem	idem	

Table 3 – Product-models used for definition of the required raw data for one city

Note that in this analysis, the SAR data required for the monitoring product is considered in the same global analysis as the H1 requirements. This is feasible as the only specificity is the time window where the number of new data products are acquired, i.e. 10 dates over 3 years. Last minute sensor tasking is available up to 36 hours before acquisition for ERS, and 2 days for ASAR. This sort of reactivity supports the possibility of a rapid response product. This product is again included in the H1 descriptions. Its specific requirements that should be considered include the necessary capability for the collection and distribution of large data quantities at high speed.

3.3 Defining the number of cities

As noted in the introduction, the number of cities to be processed in each stage depends on a set of assumptions that are detailed here. Table 4 provides the number of cities to be processed and the justification for these figures.

Scenarios	Number of cities covered	Justification	Ref
Nominal	369 34 processed in stage 1 + 185 new cities processed in stage 2 + 150 new cities processed during stage 3	The proposed coverage has been defined by the requirement to cover more than 225,000 people per city in order to achieve 20% coverage of European citizens. The threshold mechanism is a simple way for optimising the benefit to the maximum number of European citizens with the minimum product generation. The emphasis of these measures could be shifted to those regions that are most heavily affected by technological or natural geohazards.	U2, S10, C10, C11
Worst case	286 20 processed in stage 1 + 166 new cities processed in stage 2 + 100 new cities processed during stage 3	Defined according to C10, under the assumption that production of such a large number of cities is not possible. Possible reasons are: technical (gap in the series of data, too old for the users), or revision of the process of production of H1c	U2, S10, C10, C11
Best case	452 42 cities in stage 1 + 210 in stage 2 + 200 in stage 3	Defined according to the changing pressures of private and public spheres. In the private sector, the requirements for ground motion information are increasing: e.g. engineering activities are developing. In the public sector, the pressure of laws can help this trend, but not really before 2012. In order to prepare for these changes, the geological surveys wish to propose more integrated services for risk assessment to reduce the gap of in situ networks and risk surveys: i.e. by integrating some landslide, seismic-risk sites and coal mining areas. In addition, in terms of media, the common efforts in the CHART of spatial agencies could help the public to understand the main public stakes and the advantages of space-based techniques. But the larger number of cities to be processed also has an effect on the footprint (see below).	C10, C11, S1, S10, U1, U2 and DUP-Uramis market study

Table 4 – Number of cities to be processed for each scenario

3.3.1 Assumptions: raw image footprint

For certain cities that are in close proximity, it is possible to cover more than one city per raw image scene. This proximity effect reduces the ratio of images required per city from 1, to a fraction close to one depending on the number of cities included in a given scene coverage. The result is a reduced requirement for raw image scenes especially in heavily populated regions such Germany, the UK and Belgium. Table 5 shows the value of the ratio described for the three operating scenarios.

Scenarios	Ratio footprint to cities	Justification	Ref
Nominal	0,8	Existing heterogeneity of proposed coverage induces a reduction of footprint	C10
Worst case	1 then 0,8	If the number of cities is less than hoped, the spatial distribution could be spread out until they reach the number 200	
Best case	0,6	In certain areas of the UK, Belgium and Germany, this ratio is already of the order of 0,5 in the nominal case. The processing of more cities looked in these regions could reduce this value even more.	

Table 5 – Ratio of footprint to cities for the three operating scenarios (F1 factor)

3.3.2 Assumptions: ascending/descending paths

Until now most interferometric processing has been carried out on SAR images originating from the descending path of the satellite only. It may be possible to integrate data acquired during the ascending path of the satellite also thus providing more frequent data acquisitions. However the use of such data for enhancing Terrafirma products has advantages and disadvantages:

Advantages

- observed deformation in two directions, providing two components of the motion vector. This allows better access to the motion vector including partial access to the horizontal component
- increase in the repetitivity of the measurement

Disadvantages

- PS results from these two distinct data sources cannot be directly superimposed, so the efforts for standardisation of PS may suffer

It should be noted that the use of ascending path image data does not double the factor F2 as might be expected. This is due to the fact that fewer ascending images exist in the archive because of satellite on-board storage constraints during the ERS mission. It is possible however, that this constraint can be overcome during the ASAR mission.

Corner reflectors cannot be used with PS processing when ascending and descending path images are used as they do not appear the same position for both sets of images. A solution is the potential coupling with CATS (cf. chapter “Hybrid technology”). This solution is also useful in areas, which cannot be reliably monitored using InSAR techniques due to absence of image coherence or pre-existing point target structure. Table 6 sets out the evolution in the Ascending/Descending factor (F2) that is used to monitor the effects such changes will have on the raw image data requirements.

Scenarios	Ascending/Descending factor "F2" (used to scale scene requirements)	Rate of application to cities to be processed with asc/desc archive	Justification
Nominal	Stage 2: F2 factor = 1,5 Stage 3: F2 factor = 2	Over 10% of the cities Over 100% of the cities	To demonstrate the utility of the service When archive will be homogeneous and operational
"Worst" case	idem	idem	
Best case	Stage 2: F2 factor = 1.7 as soon as possible Stage 3: F2 factor = 2	Over 100% of the processed cities. The ascending mode archive is not as rich as the descending mode archive due to onboard recording limitations. This means F2 cannot have a value of 2. However, in stage 3 such limitations may be reduced for ASAR operation.	This will have an impact on the throughput of the processing system (see 3.4)

Table 6 – Definition of the F2 factor used to measure the effect of using ascending and descending path raw image data on the data requirements

3.3.3 Assumptions: sources/data continuity

The availability of SAR data in interferometric mode with a homogenous archive allowing either *a posteriori* study or monitoring is the most critical issue of the Terrafirma project (S1, S10, C10). However, there are a number of questions regarding the current supply of raw data, and the continuity of this supply in the mid to long term. Among the issues that have been identified are the following:

- When are ERS archives too old to be used?
- What is the minimum temporal coverage required to achieve a useful update product?
- Are there potential tools available for the continuity of ASAR?
- What are the alternatives?

According to C10 and S3, there are several options for ensuring the continuity of an interferometry-ready archive all with their own drawbacks. The criticality for the service prospectus is depending on this availability and the age of the available data. The third weighting factor (F3) is the result of this continuity issue and is used to model its effect on the number of required scenes for each of the different scenarios. It should be noted that the issues of reprocessing, merging and archiving during the hand-over between ERS and ASAR are not well known (these are the subject of tests in another ESA contract).

3.3.3.1 Conservative (and best case) scenario

Table 7 shows the F3 factor for the conservative scenario. Here, the following assumptions are made:

- Stage 1: only existing archive over a period window 1991-2001.

- Stage 2: the period officially covered is 1991-2004, but this may be slightly shorter depending on the operation of ERS2. Statistically among the ERS2 data acquired from January 2001, few images are exploitable due to the widely reported Doppler deficiency. In stage 2, the products cannot provide information over 2001-2007, which represents a period equal to the half of the window 1991-2001.
On the assumption that the potential concatenation of the new ASAR archive and the old ERS archive is feasible, F3 remains constant.
ASAR: the archive theoretically started in 2002, but it is not a complete archive until the now (04/04). It is hoped that in 2007 an appropriate archive will be available. Concerning the temporal coverage required for the Update product, the assumption is made in S5 that 10 image acquisitions per year per site will be available. It remains to be seen whether this rate is feasible. If not, this requirement could be reduced to 10 images in a 3 years period. In the situation where 10 images per year is not possible due to pressure from other data requests, it could be envisaged that the background has precedence on the descending path and other requests are satisfied on the ascending path of the sensor.
- Stage 3a: It is anticipated that this period is covered by the new ASAR archive.
- Stage 3b: measurement continuity is needed to guarantee on-going GMES services. Among the objectives of GMES, the deployment in the long term of a set of operational space missions (GMES Initial Period report 3.8) is announced: i.e. the development of a radar satellite providing high resolution imagery for continuity with ERS-Envisat – C band radars, with an interferometric capability is among the current priorities.

Stage	1		2			3a			3b	
Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Source: ERS?	YES	YES	YES	YES	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD
Source: ENVISAT?	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	YES	YES	YES	YES	TOO OLD	TOO OLD
Source: EW?	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	YES	YES	YES	YES
FACTOR F3:	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	despite ERS being too old									

Table 7 – Definition of the F3 factor used to quantify the effect of data source continuity on the data availability for the conservative (and best case) scenario

3.3.3.2 Worst case

In this case, the assumptions used to generate Table 8 are:

- Lack of continuity (interoperability) between ERS and ASAR
- No cross/handover between ASAR and EarthWatch (EW) mission

In the case presented here, the use of Radarsat data must be taken into consideration in other dossiers e.g. the Infrastructure Analysis dossier S10. The implications for the use of this data source are significant, especially in terms of access from a second image archive.

Stage	1			2		3a			3b	
Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Source available: ERS	YES	YES	YES	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD
Source available: ASAR	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	YES	YES	YES	TOO OLD	TOO OLD
Source available: EW	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	YES
Alternative Radarsat and concatenation of series					Planned background archive	Planned background archive	Planned background archive	YES	YES	YES
FACTOR F3:	1,00	1,00	1,00	0,50	0,50	1,00	1,00	1,00	1,0	1,00

Table 8 – Definition of the F3 factor used to quantify the effect of data source continuity on the data availability for the “Worst Case” scenario

3.4 Implications for required processing capacity

Given that the first processing will be carried out on the ERS archive, certain questions can be posed about the processing capacity. In all the scenarios, data processing for new cities within TF will significantly scale up between Stage 1 and Stage 2. Data processing dedicated to updating increases in time as a consequent number of new cities (at least 30) is expected to be covered by TF service each year until 2020. Table 9 does not take into account factor F2 (use of asc/desc data). Table 10 takes into account all factors. The main difference is that without F2 assumption, the data processing quantity tends to decrease after stage 2 in the nominal and maximal assessments.

Scenario	Stage 1			Stage 2			Stage 3		
	Nb of cities/year	Nb of scenes/year	Monthly capacity of cities	Nb of cities/year	Nb of scenes/year	Monthly capacity of cities	Nb of cities/year	Nb of scenes/year	Monthly capacity of cities
minimal assessment	20	300	1	55	~1500	2	20	~2500	1
nominal assessment	34	1020	3	61	~4000	5	30	~3700	3
maximal assessment	42	1260	4	70	~5300	6	40	~5000	2/3

Table 9 – Assessment of required processing capacity (figures adjusted by F1 and F3)

Scenario	Stage 1			Stage 2			Stage 3		
	Nb of cities/year	Nb of scenes/year	Monthly capacity of cities	Nb of cities/year	Nb of scenes/year	Monthly capacity of cities	Nb of cities/year	Nb of scenes/year	Monthly capacity of cities
minimal assessment	20	300	1	55	~2500	2	20	~4300	1
nominal assessment	34	1020	3	61	~4600	5	30	~7300	3
maximal assessment	42	1260	4	70	~5200	6	40	~7000	2/3

Table 10 – Assessment of required processing capacity (figures adjusted by F1, F2, F3)

If the rate of production in stage 1 is confirmed (more than 10 towns/year), the rate of production of Terrafirma planned in stage 2 does not seem too difficult to achieve given the participation of 4 VACs. However, figures on processing capacity quoted by the VACs quote the number of towns per month, not the number of scenes in a set.

3.5 Scenario: Conservative Case

This section presents the evolution in the data requirements and availability for SAR data over the lifetime of Terrafirma for the conservative case scenario. The assumptions used in the generation of the data presented in Figure 1 are detailed in the various sections of chapter 3 in this document. This data is provided in Annex 1.

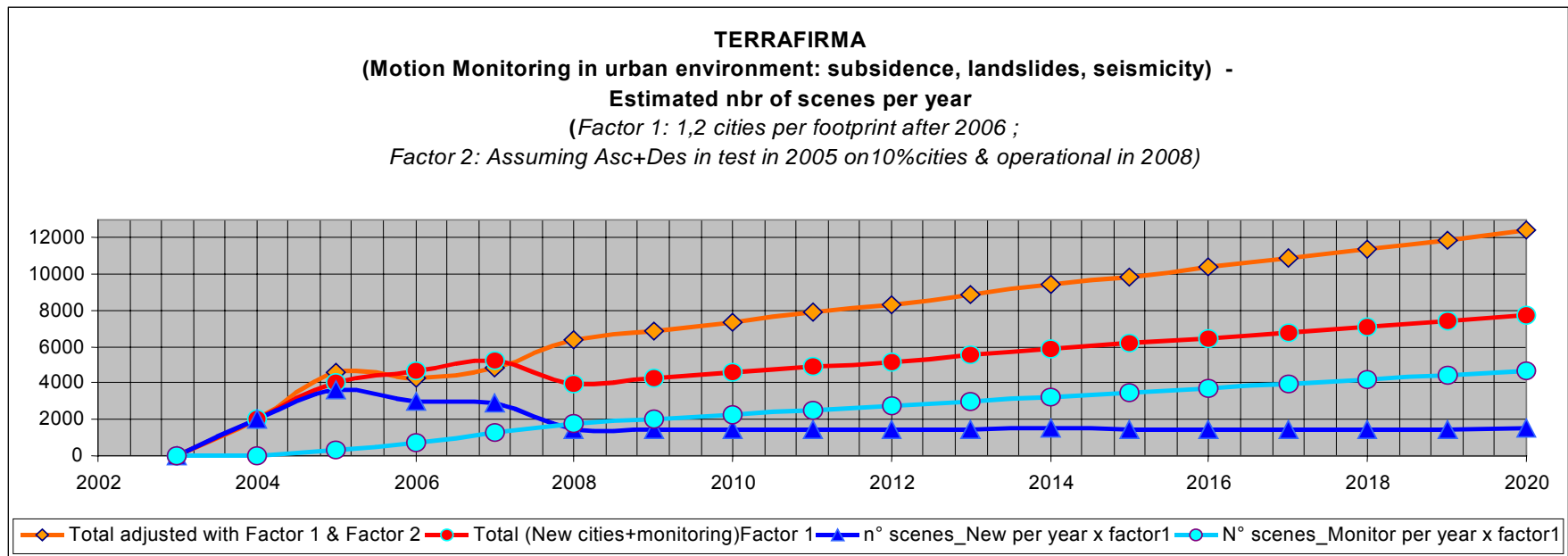


Figure 1 – The evolution of the data requirement for the conservative scenario over the lifetime of Terrafirma

3.6 Scenario: Worst Case

Figure 2 presents the evolution in the data requirements based on analysis of the requirements and assumptions regarding the availability of SAR data over the lifetime of Terrafirma for the worst-case scenario. The assumptions used in the generation of the data presented in Figure 2 are detailed in the various sections of chapter 3 in this document. This data is provided in Annex 1.

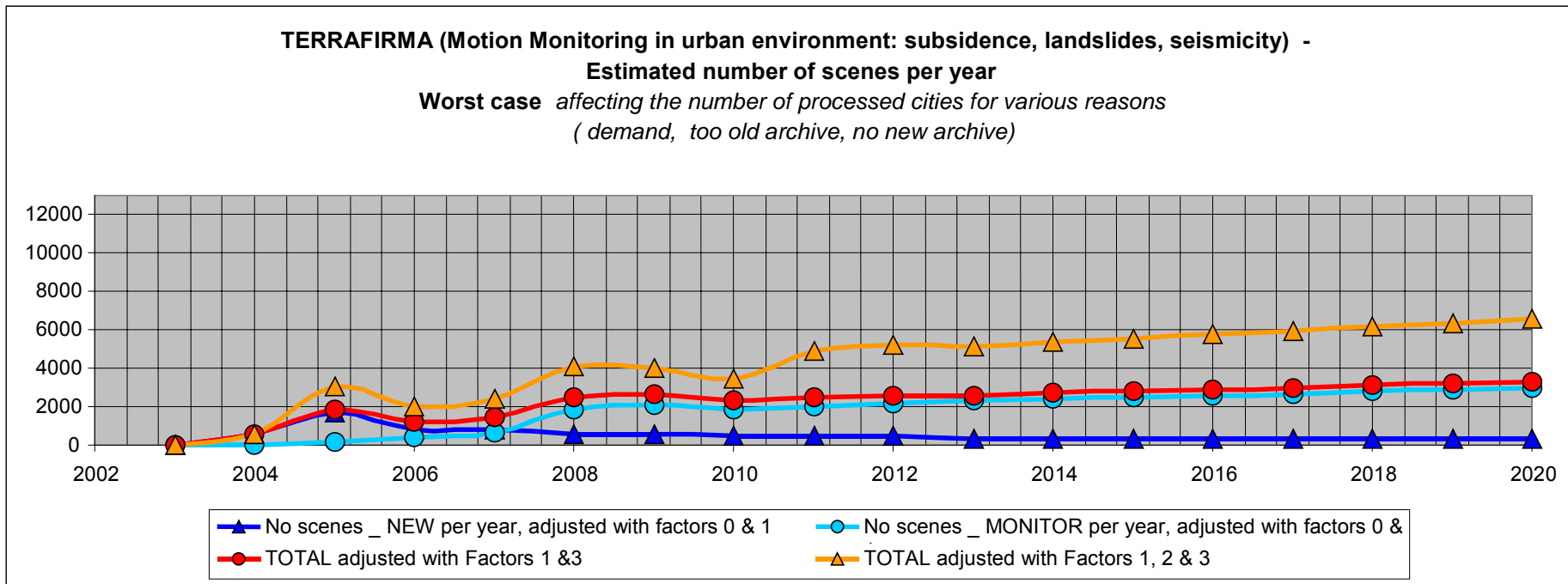


Figure 2 – The evolution of the data requirement for the worst-case scenario over the lifetime of Terrafirma

3.7 Scenario: Best Case

Figure 3 presents the evolution in the data requirements based on analysis of the requirements and assumptions regarding the availability of SAR data over the lifetime of Terrafirma for the worst-case scenario. The assumptions used in the generation of the data presented in Figure 3 are detailed in the various sections of chapter 3 in this document. All data is provided in Annex 1.

**TERRAFIRMA (Motion Monitoring in urban environment: subsidence, landslides, seismicity) -
Estimated number of scenes per year
Best Case (number of cities in expansion, goodbridge between archives, affected footprints, good ascending archive)**

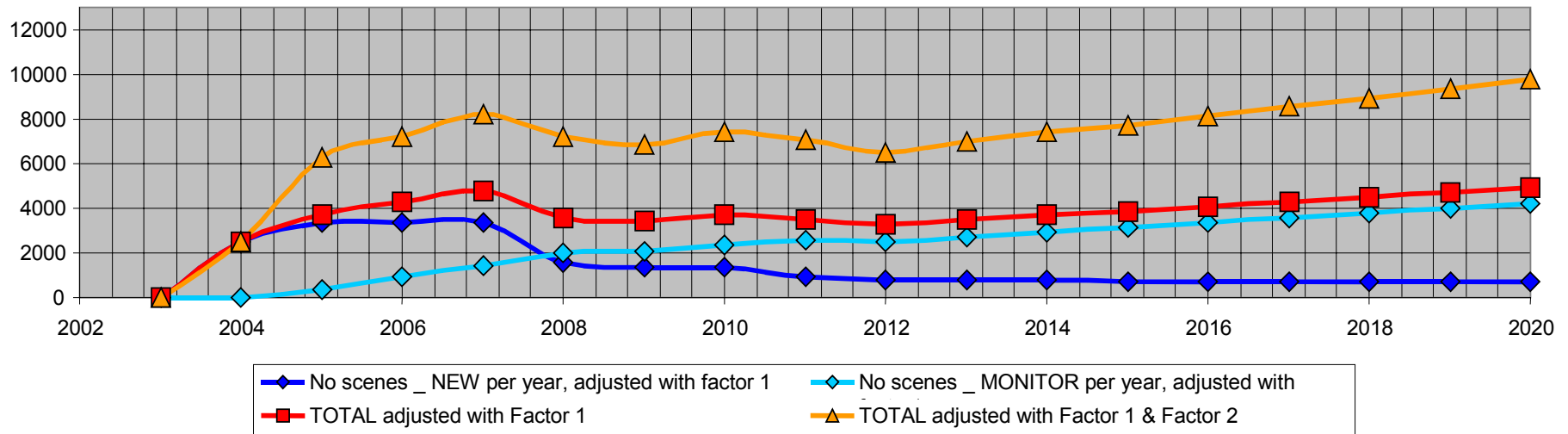


Figure 3 – The evolution of the data requirement for the best-case scenario over the lifetime of Terrafirma

4 NON SAR DATA

Data sources are required for measuring ground movement, providing context, explaining and modelling (c.f. C10, S5, S4, S10).

4.1 Data required for Historical H1 product and Update U1 product

Little external data are required for the processing. This reduces the risk of external data not being “fit for purpose” and facilitates the autonomy of the processing chain.

4.1.1 Topographic information/DEM (optional)

For H1a and H1b products, a DEM is required in order to compensate topographic fringes whereas it is not obligatory for PS techniques. It is also possible to produce DEM from tandem ERS pairs but would need an additional task. “A 3 arc second or better DEM is required although coarser DEM will still be of use” (S5). Availability is discussed in 4.2.2.

4.1.2 Reference points

The reference Permanent Scatterer is the point within the study area relative to which all ground velocity and height measurements are measured. Theoretically, only one reference point is required for the processing of H1. It is planned that the end-user will provide the location of the stable area including this reference point. The critical issue of this data is the **accuracy /quality** of the measurements, because a bad choice provokes a bias over the whole set of speed values by the addition of a constant error.

In a strategy where products are prepared in advance in order to be available off-the-shelf, several improvements should be encouraged:

- At least 3 or 4 reference points per site could enhance the accuracy of PS for limiting the effect of “floating” information
- A specific strategy has to be proposed for gathering this information. This has not been discussed until now in S3, S4, S5, and S10. Two possible (but incompatible solutions) are:
 - ◆ to gather those references from the user responsible of the utility report. It reinforces the sharing of responsibilities between VACs and Users. Questions remain about the properties of this value-added information and the possible commercialisation of the same product at another time.
 - ◆ to consolidate the sources of information about reference areas thanks to a specific link with geo-information provider IPs. Remaining questions are: are whatever IPs accredited for providing this information? Or is it within the role of the Geological surveys to provide this information?

4.2 Data required for Historical H2 – H3 product

In addition of H1 product (obligatory), a wide variety of external data is needed to generate H2 products (C10, S10, S5). In all cases, the availability of this data must be considered.

4.2.1 EO non ESA data

Spatial context is critical to the use of level 1 Terrafirma results and is achieved through addition of a spatial information layer. Such a layer might consist of spatial data such as topographic maps or optical EO data. The Data Sources Inventory dossier highlights the fact that given the spatial accuracy of InSAR results, (anything from 15 to 50m) a mapping scale of greater than 1:50 000 could result in data misinterpretations. It is envisaged that the most appropriate EO data providing spatial context would be from the Landsat or SPOT satellites rather than higher resolution products such as aerial photography or Ikonos / Quickbird satellite imagery. In addition to the compatibility in spatial resolution, Landsat and SPOT image products are relatively inexpensive.

But, in urban context it is clear that very high spatial resolution VHRS product enhances significantly the product, as demonstrated in S5. Such data is available for a large number European cities but may come from various sources and have heterogeneous formats. Needs for enhanced data quality can pass through a mixed prototype product with « VHRS ».

In the global assessment of data volume (Tables 12 and 13), the volume of this data is quantified in km². An average of 200 km² has been adopted to represent a city product. This volume figures will help the CBA cost benefit assessment but are not necessarily useful for the optimisation of a processing chain, as this depends on the number of potential providers (Geol Surveys GSs, Information Providers IPs, Civil Engineer).

Maintenance of the availability of this data is a major issue. Is this type of data to be centralised in the same way as the SAR archive with a direct access by the VAC, or retained by the owners of the data (or those that have the right to exploit). Access by the VAC to such data must be conditioned by an agreement on the properties and rights of its use.

The relevant reference dossiers generated by TF do not provide the answer to this dilemma, but introduce the possibility of a brokerage role for information providers (within scope of S10).

4.2.2 Topographic information/DEM

In addition or as an alternative to optical EO data, topographic information may be used to provide spatial context as shown in S5 where simultaneously DEM and topographic data are mixed for an example of an H2 product. This data source has the advantage of being well understood by the vast majority of citizens and provides useful location information.

A major disadvantage of such data is the heterogeneity of the coverage and cost across Europe. While coverage in an electronic format is available across most of Europe, symbology and survey methodology vary between national mapping agencies. This heterogeneity of formats and sources could complicate the gathering due to various MOU (Memorandum of Understanding) according to the providers. The pressure of initiatives such as INSPIRE should in the mid to long term alleviate such issues.

The volume figures quoted in Tables 12 and 13 are again quantified in km². An average of 200 km² has been adopted to represent a city product.

For this type of data, a similar discussion regarding the maintenance of availability exists as to that described for the "EO non ESA data". A suggested solution could be a general agreement between the Europeosurveys members with a European provider of DEMs: Such examples already exist at the scale of some member states. This idea has been already

launched in several EOI or pre-projects submitted to 6th Framework Program and may progress to the implementation stage.

4.2.3 Geological data sources

An important part of the Service Portfolio identified through the analysis of user needs concerns the generation of products that explain the potential trigger mechanisms of a given ground movement event. The list of geological data, also mentioned as “*ground motion trigger assessment data*” is described in S5. Considering 5 most used types of information to be taken into account, we discuss here the main issues in the development of products H2 and H3.

Geological data type	Percentage of land movement types where this data would be used in the investigation
Geological data in 2D	100%
Geological data in 2,5 or 3D	85%
Water tables	75%
Maps of Geotechnical properties	50%
Maps of local borehole	40%

Table 11 – The most used types of information in H2 and H3 products

- ◆ **2D Geological data** (conventional or digitised maps providing lithology, age of the deposits and structural scheme) is available at various scales. The main issue regarding the development of H2/3 products is the **availability** of this data. Several means of distribution exist such as “INFOTERRE” for BRGM, or “Georeport/geology map extract” for BGS. As an intermediate step, a metadata catalogue on a European scale has been proposed (GEIXS), however this database is currently far from completion. The strategy of Terrafirma in H2 production could potentially have a triggering effect on the development of an Europe-wide distribution strategy.
- ◆ **Geological data in 2.5 or 3D** represents a new product not usually available off-the-shelf. It provides in addition topological description of the various volumes of deposits. It is an emerging product well adapted to aid the understanding of movement mechanisms and so is ideal for H2/3 product generation. The main issue for this data type is the **delay**, due to the bottleneck induced by the large number of elementary data required as input in the geological 3D process: punctual, linear, volume,...
- ◆ **Water table** information is generally derived from regional networks of piezometers. In certain countries, e.g. Germany, the Geological Surveys are responsible for the acquisition, installation and maintenance of these networks and the publishing of the data. Coupling with InSar results could be an interesting way to combine in situ and spatial data over areas suffering of intense pumping for agricultural or industrial reasons (see S5).

Here, again the main issue the positioning of these networks are so the **availability** of this data.

- ◆ Maps of **Geotechnical** properties are very useful but not widespread. The main issues are the **availability** and the **reliability**, which depends on the rate of sampling and of the tools used for the investigation.
- ◆ Maps of local **borehole data** are very useful when available. The status of those data is very diverse according to the private or public management of the site.

Usually the data types described above are the preserve of national Geological Surveys or agencies. Despite effort of harmonisation, they are significant differences in standard and mode of access. But the Internet access to Geol 2D or 3D data is in rapid increasing and could reinforce the potential volume of production of H2 as standard product.

It is intended that H3 will remain a custom-made product including during the stage 3. Its development will accompany the development of 3D deterministic models of geomechanics and hydromechanics.

4.2.4 Terrestrial data sources:

Critical infrastructures data may also be required to help the assessment of the principal elements at stake such as exposed population, goods and equipment. In addition, the potential disruption of the operation of these elements can also be considered. Table 12 details useful infrastructure data.

Nature of required data	Potential sources
Population counts	National statistics
Building stock information	Insurers, Geological Surveys geoinformation providers,
Transportation of Network	Transport providers, geoinformation providers
Critical Facilities	Specific owners, civil security, City authorities, Geological Surveys
Sensitive structures	Specific owners, civil security, City authorities, Geological Surveys
Urban Land Use	Geological Surveys geoinformation providers

Table 12 – Infrastructure data required and their sources

Except the first data type, no standardised information are available at the scale of a Member State. Depending on the context (e.g. assessment of geohazard risks), Geological Surveys, Civil Security, City authorities or Civil Engineers, or also specific Information providers may be

in possession of this data. A specific service of geo-information provider could be to provide an improved support service.

As noted in the last S5 version, some of the external data (EO optic data, Specific owners, civil security, City authorities, Geological Surveys, topographic or DEM, critical infrastructures) could also enhance the H1 product if geocoded. Such an addition would impact on the chain of processing by reducing options for the automation of the products, but would also allow a wider range of bespoke products and facilitate the evolution of products integrating geological, topographical and other relevant information and expertise.

Because this sort of information is required at a generic level over the whole of Europe, a wider approach, incorporating other GSE dossiers could be proposed.

4.3 Data required for Update U1 product and Monitoring M1 product

In addition of known inputs such as H1 and reference points, the S5 document specifies that hybrid new technologies could reinforce the reliability of the products M1 or U1 particularly in case of rural environment with few natural permanent scatterers or in case of simultaneous use of ascending and descending paths.

4.3.1 CATS

There is not yet a conservative scenario in C10 including the use of CATs. We could assume that CATs will equip at least 20 points of an unstable site and a 1/3 of the sites in a given year. In this case the requirement for CATs will initially increase rapidly, flattening out at the end of stage 3, c.f. Figure 4.

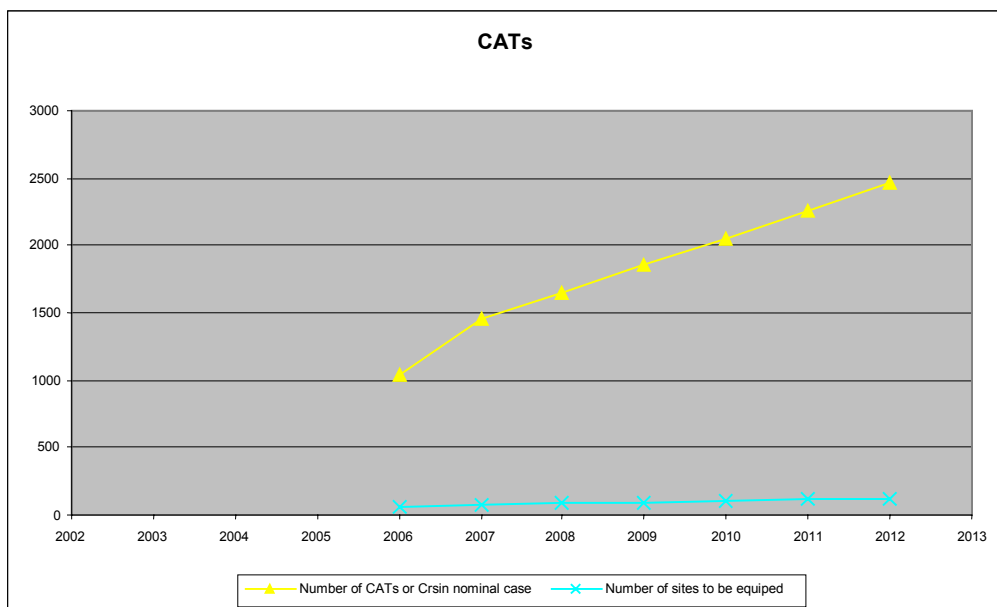


Figure 4 – The evolution of the requirement for CATs over the term of Terrafirma

In an optimistic scenario we can assume that CATs will equip all seismic sites, areas concerned by landslides and rural mining. This should reach a total at the end of stage 3 of more than 150 sites as described in S10. However, in a realistic scenario, this investment has

to be decided after a demonstration step and a full consideration of the cost benefit analysis of this technology.

4.3.2 In-situ monitoring

For the entire GMES program, the consensus is that the current situation with regards in-situ observing systems is considered a critical limiting factor. Within Terrafirma such application areas as landslides, seismic events and the behaviour of aquifers are concerned.

The development of H3 products or the deployment of Monitoring M1 products is also constrained by complementary information coming from in-situ monitoring. Prototype networks of in-situ acquisition coupled with spaceborne data could demonstrate the potential role of an efficient coupling between Terrafirma products and those in-situ data.

Examples of demonstrations, useful for M1 and H3, are clearly needed:

- ◆ Water table: Networks of piezometers in relation with central acquisition could provide hydrodynamic parameters to be used either as limiting inputs to 3D modelling or key validation data of the temporal deformation.
- ◆ Landslide in-situ monitoring: the installation of clusters of in-situ corner reflectors CRs or CATs to be exploited in the M1 product.
- ◆ Seismic events: coupling of the M1 product with networks of GPS

These demonstrations could be carried out in stage 2 enabling the elaboration of a strategy in stage 3.

4.4 Data volume requirements according to the operational scenarios

The reference dossier "Operational Service Scenarios" (C11) presents the assumption of 25% of processed cities H2 products in stage 2 and 50% in stage 3. Separately a proposal is currently being prepared by the GSs of the CUG to achieve, in stage 2, the more realistic objective of 6 cities in H2-b integrating 3D geological data. We can add to this the assumption that around 25% of processed cities H2-a products will be generated in stage 2, integrating 2D geological data or other auxiliary data. These figures are used in conservative case scenario in Table 12 below. One can hope that demand of H3 products will increase with 1 realised H3a product in stage 1, 10% in stage 2 and 25% in stage 3. All these figures are yet to be validated.

4.4.1 Scenario: Conservative Case

Table 13 presents the volume in km² of data of different types required for the conservative case scenario.

Product	Stage 1					Stage 2					Stage 3				
	Nb sites	non ESA optical	Non EO data			Nb sites	non ESA optical	Non EO data			Nb sites	non ESA optical	Non EO data		
			Ref Pt	DEM/TOPO	GEOLOG			Ref Pt	DEM/TOPO	GEOLOG			Ref Pt	DEM/TOPO	GEOLOG
Historic 1	34		34	6800		185		185	37000		150		150	30000	
Historic 2	12	2400		2400	2400	52	10450		10450	10450	75	15000		15000	15000
Historic 3	1	200	1	200	200	19	3700	19	3700	3700	38	7500	38	7500	7500
Routine updates of H1															
Update						on demand					490 on demand				
Monitoring	1					on demand					on demand				

Table 13 – Non EO data type volumes for the conservative case scenario

4.4.2 Scenario: Best Case

Table 14 presents the volume in km² of data of different types required for the conservative case scenario.

Product	Stage 1					Stage 2					Stage 3				
	Nb sites	non ESA optical	Non EO data			Nb sites	non ESA optical	Non EO data			Nb sites	non ESA optical	Non EO data		
			Ref Pt	DEM/TOPO	GEOLOG			Ref Pt	DEM/TOPO	GEOLOG			Ref Pt	DEM/TOPO	GEOLOG
Historic 1	42		42	8400		210		210	42000		200		200	40000	
Historic 2	15	3000		3000	3000	59	11700		11700	11700	100	20000		20000	20000
Historic 3	2	400	2	400	400	21	4200	21	4200	4200	50	10000	50	10000	10000
Routine updates of H1															
Update						on demand					520 on demand				
Monitoring	2					on demand					on demand				

Table 14 – Non EO data type volumes for the best-case scenario

5 CONCLUSIONS: GAP ANALYSIS

As has been highlighted by this dossier, the main constraint for the development of the service specified in S5 is related to the availability of the critical data source: the SAR data. A secondary issue concerns the exploitation of ground movement data for the generation of causal and modelled products. These issues are summarised in this section:

◆ Availability of SAR data for the generation of H1 products in stage 2 and 3

It is clear that around 2006 or 2007 the ERS archives will become too old for use. At that time, this will represent a gap of 5 or 6 years without useable ERS data following the present archive (1991-2001). This issue induces the question: **When are ASAR data ready for TF?** Information concerning the current status of ASAR archives (images acquired in ERS-like mode) could bring a new perspective to the next version of this document. The operation of a background mission for ASAR is an URGENT NECESSITY in order to allow the continued study of ground motion using interferometric techniques. This means that a priority must be defined between the building up of a homogeneous background archive and the satisfaction of ASARs other science missions. A certain number of potential solutions are discussed in this document.

Beyond stage 2, two parallel solutions have to be prepared if Europe wishes to avoid a significant investment without a clear future: the next EarthWatch mission, or, as an alternative, access to an appropriate Radarsat archive (as has already been negotiated by the Italian government and RSI). This second solution will involve a detailed analysis of the implications on the Terrafirma system architecture.

◆ Production quality

The production quality depends mainly on the interoperability of the various archives for the production of H1 products: recent experiments tend to prove the opportunity of **mixed datastacks (ERS-ASAR)**. However, such product accuracy has not been studied yet:

- Can we have the same confidence levels (in terms of the precision) in the products generated from a homogeneous ERS archive and a combined ERS/ASAR archive?
- If not, can the processing of new sites with ASAR begin in the short term, or must we wait 4 years (that is 2008 and at least 10 ASAR data) for the development of an effective archive? Is a short ASAR archive lead to more reliable products than the use of a combined ERS/ASAR archive?

The option of using both ascending and descending path image data is intended to increase the quality of the product, but the disadvantages of this approach, highlighted in this document, (e.g. PS results cannot be superimposed) suggests this option may be risky. Proof of the quality improvements using this option must be generated before systematic use is undertaken.

◆ **Prospective issue: the start of future attractive new value –added products H2 and M1**

The user needs, expressed by the CUG collectively and the new associated partners, confirm the importance of the production of H2 products. As important is the evolution of these products towards the integration of geological, topographical and other relevant information to provide explications and, ultimately, modelling and predictions. The critical issue is clearly the availability of homogeneous auxiliary data. However, at a European level this situation is in constant evolution.

Inside the GSE programme, part of the investment must be dedicated to a durable service and to the preparation of a wider range of bespoke products. Terrafirma has the opportunity to contribute to the design of a coherent European geohazard information system where H1-U1/H2 and M1 have a significant role. A specific assessment of the effort and proposed method are under study within Terrafirma. This will clarify the content and volume of products and services operated by the GS itself and insure delivery as an end-to-end solution.

Annex 1 – SAR Data Requirements

Conservative Case Scenario

Stage	1	1	2	2	2	3a	3a	3a	3b	3b	Later	Later	Later	Later	Later	Later	Later	Later
Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Year/Y1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Type of activity (processing a new city vs minotoring a city already processed)	NEW	NEW	NEW	NEW	NEW	NEW+REPRO	NEW+REPRO	NEW+REPRO	REPRO	REPRO								
No cities/y	0	34	61	62	61	30	30	30	31	30	31	32	31	31	31	31	31	32
Cities Cumul	0	34	95	157	218	248	278	308	339	369	400	432	463	494	525	556	587	619
No scenes _ NEW per year	0	2040	3660	3720	3660	1800	1800	1800	1860	1800	1860	1920	1860	1860	1860	1860	1860	1920
No scenes _ MONITOR per year	0	0	340	950	1570	2180	2480	2780	3080	3390	3690	4000	4320	4630	4940	5250	5560	5870
total stage H1		2040			11040					9060								15000
total stage U1		0			2860					13910								38260
Source available: ERS ?	YES	YES	YES	YES	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD				
Source available: ENVISAT ?	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	YES	YES	YES	YES	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD				
Source available: EW ?	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	YES	YES	YES	YES	YES	YES	YES	YES				
FACTOR 1: to account for similar footprint for different cities	1,00	1,00	1,00	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
TOTAL (= NEW CITIES+MONITORING)	0	2040	4000	4670	5230	3980	4280	4580	4940	5190	5550	5920	6180	6490	6800	7110	7420	7790
		2040			13900					22970								53260
TOTAL adjusted with Factor 1	0	2040	4000	3736	4184	3184	3424	3664	3952	4152	4440	4736	4944	5192	5440	5688	5936	6232
No scenes _ NEW per year, adjusted with factor1	0	2040	3660	2976	2928	1440	1440	1440	1488	1440	1488	1536	1488	1488	1488	1488	1488	1536
No scenes _ MONITOR per year, adjusted with factor1	0	0	340	760	1256	1744	1984	2224	2464	2712	2952	3200	3456	3704	3952	4200	4448	4696
		2040			11920					18376								42608
FACTOR 2: to account for ascending+descending acquisitions starting in Stage 2	1,00	1,00	1,50	1,50	1,50	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00
TOTAL adjusted with Factor 1 & Factor 2	0	2040	4600	4296	4812	6368	6848	7328	7904	8304	8880	9472	9888	10384	10880	11376	11872	12464
		2040			13708					36752								85216

Best Case Scenario

Stage	1	1	2	2	2	3a	3a	3a	3b	3b	Later	Later	Later	Later	Later	Later	Later	Later		
Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
Year/Y1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
Type of activity (processing a new city vs monitoring a city already processed)	NEW	NEW	NEW	NEW	NEW	NEW+REPRO	NEW+REPRO	NEW+REPRO	NEW+REPRO	NEW+REPRO	REPRO+NEW	REPRO+NEW	REPRO+NEW	REPRO	REPRO	REPRO	REPRO	REPRO	REPRO	
No cities/y	0	42	70	70	70	40	40	40	40	40	35	35	35	35	35	35	35	35	35	
Cities Cumul	0	42	112	182	252	292	332	372	412	452	487	522	557	592	627	662	697	732	732	
No scenes _NEW per year	0	2520	4200	4200	4200	1980	1980	1980	1320	1320	1320	1320	1200	1200	1200	1200	1200	1200	1200	1200
No scenes _MONITOR per year	0	0	420	1120	1820	2520	2920	3320	3720	4120	4520	4870	5220	5570	5920	6270	6620	6970	6970	6970
total stage H1		2520				12600					8580								4800	
total stage U1		0				3360					16600								25780	
Source available: ERS ?	YES	YES	YES	YES	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	
Source available: ENVISAT ?	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	YES	YES	YES	YES	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	
Source available: EW ?	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	
FACTOR 1: to account for similar footprint for different cities	1,00	1,00	0,80	0,80	0,80	0,80	0,70	0,70	0,70	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60	0,60
TOTAL (= NEW CITIES+MONITORING)	0	2520	4620	5320	6020	4500	4900	5300	5040	5440	5840	6190	6420	6770	7120	7470	7820	8170	8170	
		2520			15960					25180									30580	
TOTAL adjusted with Factor 1	0	2520	3696	4256	4816	3600	3430	3710	3528	3264	3504	3714	3852	4062	4272	4482	4692	4902	4902	
No scenes _NEW per year, adjusted with factor 1	0	2520	3360	3360	3360	1584	1386	1386	924	792	792	792	720	720	720	720	720	720	720	
No scenes _MONITOR per year, adjusted with factor1	0	0	336	896	1456	2016	2044	2324	2604	2472	2712	2922	3132	3342	3552	3762	3972	4182	4182	
		2520			12768					17532									18348	
FACTOR 2: to account for ascending+descending acquisitions starting in Stage 2	1,00	1,00	1,70	1,70	1,70	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	
TOTAL adjusted with Factor 1 & Factor 2	0	2520	6283	7235	8187	7200	6860	7420	7056	6528	7008	7428	7704	8124	8544	8964	9384	9804	9804	
total stage H1 modified by F1 & F2		2520			21706					35064									36696	

Worst Case Scenario

Stage	1	1	2	2	2	3a	3a	3a	3b	3b	Later	Later	Later	Later	Later	Later	Later	Later
Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Year/Y1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Type of activity (processing a new city vs minotoring a city already processed)	NEW	NEW	NEW	NEW	NEW	NEW+REPRO	NEW+REPRO	NEW+REPRO	REPRO	REPRO								
No cities/y	0	20	55	56	55	20	20	20	20	20	12	13	12	13	12	13	12	13
Cities Cumul	0	20	75	131	186	206	226	246	266	286	298	311	323	336	348	361	373	386
No scenes _ NEW per year	0	600	1650	1680	1650	600	600	600	600	600	360	390	360	390	360	390	360	390
No scenes _ MONITOR per year	0	0	200	750	1310	1860	2060	2260	2460	2660	2860	2980	3110	3230	3360	3480	3610	3730
total stage H1		600			4980					3000								3000
total stage U1		0			2260					11300								26360
Source available: ERS ?	YES	YES	YES	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD
Source available: ENVISAT ?	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	YES	YES	YES	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD	TOO OLD
Source available: EW ?	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	YES	YES	YES	YES	YES	YES	YES	YES	YES
alternative source Radarsat	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	NO ARCHIVE	Planned background archive	Planned background archive	Planned background archive	YES	YES	YES	?	?	?	?	?	?	?	?
FACTOR 1: to account for similar footprint for different cities	1,00	1,00	1,00	1,00	1,00	1,00	1,00	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
FACTOR 3: available archive	1,00	1,00	1,00	0,50	0,50	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
TOTAL (= NEW CITIES+MONITORING)	0	600	1850	2430	2960	2460	2660	2860	3060	3260	3220	3370	3470	3620	3720	3870	3970	4120
		600			7240					14300								29360
TOTAL adjusted with Factor 1 and Factor 3	0	600	1850	1215	1480	2460	2660	2288	2448	2608	2576	2696	2776	2896	2976	3096	3176	3296
No scenes _ NEW per year, adjusted with factors 3 & 1	0	600	1650	840	825	600	600	480	480	480	288	312	288	312	288	312	288	312
No scenes _ MONITOR per year, adjusted with factors 3 & 1	0	0	200	375	655	1860	2060	1808	1968	2128	2288	2384	2488	2584	2688	2784	2888	2984
		600			4545					12464								23488
FACTOR 2: to account for ascending+descending acquisitions starting in Stage 2	1,00	1,00	1,50	1,50	1,50	1,50	1,50	1,50	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00
TOTAL adjusted with Factors 3, 1 & 2	0	600	3053	2005	2442	4059	3990	3432	4896	5216	5152	5392	5552	5792	5952	6192	6352	6592
TOTAL STAGE:		600			7499					21593								46976