Chapter 1

Data Management Strategy for GNSS Services — The TRANSMIT Project Case

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Additional information is available at the end of the chapter

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1. Introduction

TRANSMIT project is a Marie Curie Initial Training Network (ITN), funded under the EU FP7 framework [1]. The programme vision is to act as the enabler of the IPDM network [2] which will deliver the state-of-the-art to protect the range of essential systems vulnerable to ionospheric threats.

TRANSMIT's primary mission is to provide Europe with the next generation of researchers, equipping them with skills, through a multi-disciplinary, inter-sectorial, comprehensive, coordinated, industry-led training programme. The training offered, should enable the new researchers to understand in depth, the threats that ionosphere poses on modern technological systems, and more importantly on GNSS Precise Point Positioning (PPP) value chain [3], and respond to the needs of various stakeholders for robust counter-measures to deal with these threats. The secondary mission of TRANSMIT project is to develop real-time integrated state-of-the-art tools to mitigate the ionospheric threats, and make these tool available and accessible to the various stakeholders, via the "*TRANSMIT Prototype*.

In this chapter we concentrate on the definition of the "*data management strategy*" or in simpler terms a plan for data management. In theory, data management (hereinafter DM) is defined as a function that includes "*the planning and execution of policies, practices and projects*", with aim of "*acquiring, controlling, protecting, delivering and enhancing the value of data and information assets*" [4].

DM is typically organized into ten basic components or functions, each consisting of a family of activities that belong to one of four groups [4]; planning activities (P) that set strategic and tactical course for other DM activities, development activities (D), undertaken within the system development lifecycle, creating data deliverables through analysis, design, building, testing, preparation and deployment, control activities (C) or supervisory activities performed on an on-going basis and, finally, operational activities (O) to include service and support activities performed on an on-going basis.

At the heart of any data related activity is Data Governance (DG). DG is the core function of DM that guides how all other functions are performed and it can be defined as "*the exercise of authority and control over the management of data assets*" [4]. DG consists of two groups of activities, namely planning and controlling. There are seven planning activities that comprise the DG function, and are typically implemented sequentially. The first two are relevant to our discussion, which are to understand the data/information needs, i.e. of the IPDM prototype, and based on these needs **to** *develop a data management strategy*. Moreover, the execution of the DG planning activities, and thus the definition of data strategy, should be driven by both business and IT strategies [4]. In Figure 1, we present a novel framework that captures this dependency by depicting the different components of the overall TRANSMIT project's strategy and the relationship between them. This novel framework is based on a proper combination of the framework for IT, Business and Data strategies', described in [4], with the IT, IS (Information System) and Business Strategies' framework in [5].

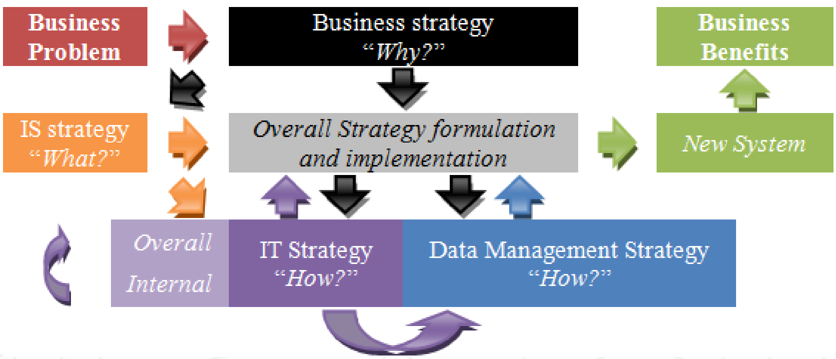

Figure 1. TRANSMIT project overall strategy approach

In sections 2, 3, 4 the TRANSMIT Business and IT/S strategies are described since are required inputs for the definition of data strategy. Finally, in section 5 we formulate the TRANSMIT data strategy, and provide in the closing section the state of art regarding the implementation status of this strategy.

2. Business strategy overview

The TRANSMIT business strategy presented in this section focuses on four themes which are the identification of the relevant business area and process, assessment of the business problem, a solution strategy and expected competitive advantage from the TRANSIT project, that can be further exploited by the future IPDM system, based on that strategy. The selection of appropriate business services (see section III) to support the given business problem is determined by the chosen business strategy and also drive the DG planning activities by providing the required data/information needs for which the data strategy is being developed.

The TRANSMIT project focuses on GNSS precise positioning business area. From a business perspective, PPP is a business process that outputs positions with high accuracy anywhere on the globe using a single GNSS receiver. To achieve that, a GNSS receiver on PPP mode relies on typical GNSS observables as well as input data products, i.e. precise orbits and clocks, provided by external entities, such as the International GNSS Service (IGS) [6]. More detailed information about PPP, can be found in [7] and [8].

In both single-(L1) and dual-frequency (L1+L2) PPP modes, and after the permanent removal of Service Availability (SA), the ionosphere has become the largest source of error that can potentially degrade the quality of the estimated user position. More specifically, and as described in [9], ionospheric scintillation, which is produced by ionospheric irregularities, affects GNSS signals in two ways, broadly classified as refraction and diffraction. A more thorough treatment of the effects of ionosphere on wideband GNSS signals can be found in [10].

At the application level, the refractive effect manifests as a group delay and phase advancement of the GNSS signal. A slower group delay velocity produces ranging errors while a faster phase velocity causes unexpected phase shifts. If the phase shifts are rapid enough, they can challenge the tracking loops in the receivers. In dual-frequency mode, the linear combination of observations and the formation of the so-called ionospheric-free observable, eliminates the biggest part, almost 99%, of this kind of ranging-error, however for very precise positioning, the remaining, higher-order terms need to be considered and compensated [11]. For the case of a single-frequency PPP mode, this ionospheric delay is typically corrected using available ionospheric models such as the Klobuchar, IRI and NeQuick ones [12], [13].

As far as the diffraction effect of the ionosphere is concerned, the situation is more complicated and influences the GNSS service availability. Compensation of the effect cannot be achieved, but only mitigation is possible. It should be stressed that in situations of severe diffraction, a total loss of signal at the receiver site can be caused, which make any mitigation technique useless. In these cases prompt warning of forthcoming strong signal scintillations, can provide valuable time to businesses to alter their service delivery strategy, e.g. switching from GNSS to other means of providing precise positioning.

There are different ways that TRANSMIT project could support GNSS service providers in dealing with the ionosphere as a potential risk. Here we refer to the lesson learned by collaborating with FUGRO Intersite B.V. [14], one of the biggest GNSS service providers which carries activities worldwide, focused on four key areas, namely Geotechnical, Survey, Subsea Services and Geoscience, and targeting markets such as the oil and gas, building and infrastructure, mining, renewable energy and other public and private sectors.

One of its main requirements towards the TRANMSIT project can be phrased as "*a business continuity planning (BCP) under severe scintillation regime*". This practically means the development of a plan which begins by firstly assessing Fugro's exposure to ionospheric threats, then requires the provision of effective prevention and recovery from them, while maintaining competitive advantage and value system integrity. An ionospheric risk management initiative should be part of such BCP, and as far as the TRANSMIT is concerned the chosen strategy was to mitigate ionospheric scintillation, targeting the PPP value chain, both at the hardware (receiver tracking) and software (stochastic model) levels, by incorporating into the process unique business services, enabled by the research conducted in two different fronts, as will be further discussed in the Information System strategy. Whether or not a full BCP will be finally realized by the TRANSMIT consortium is a decision which has not be made at the time of writing of this article.

To ensure the sustainability of the TRANSMIT endeavor, a clear differentiation of the TRANSMIT approach with respect to competitors have to be foreseen. In Figure 2, the *primary* strategic direction [15] that was chosen is the "customer intimacy" or "customer focus". This practically means that the business improvements offered in the form of services or products are tailored to the needs and processes of individual customers (i.e. Fugro) by solving their business problem. Product leadership, which implies continuous and rapid introduction of new products and services, was difficult to be achieved given the complexity of the business problem, the existing competition, such as NASA, ESA and NOAA just to name a few, and the nature of TRANSMIT project. In the next two sections however we will see how the operational excellence can be targeted/supported by the IS, IT and Data strategies, as a *secondary* improvement dimension, which in principle requires improvement/optimization of business performance.

Figure 2. TRANSMIT overall strategy orientations in order to create added value to the end-user and achieve a competitive advantage, based on the three dimensions defined in [15].

3. IS strategy

In broad terms, information systems (IS) strategy defines what kind of system is necessary to cover the business needs for the foreseeable future. It is based on proper analysis of the business, its environment and the general business strategy [16]. In this section we focus and outline some key features of the required TRANSMIT IS, and we outline the application portfolio [17] which contains the currently developing business services.

TRANSMIT IS will be realised as an "*internet-based, web-enabled, distributed system*" with the aim of providing *"decision support about selected ionospheric-related risks for the PPP business processes*". The above definition captures many features of the system, is compatible with the business needs, i.e. BCP, and for more details on decision support systems (DSSs) the reader is directed to reference [18].

As far as the TRANSMIT IS is concerned the functionality has been split into 4 layers following the multi-tier architectural paradigm. The data and presentation layers consist of one tier each while the business layer consists of various tiers, deployed on the premises of the Institutions partners of the TRANSMIT project [1].

The TRANSMIT IS will act as the demonstrator of the capabilities (business services) developed from the research base of the programme. The "prototype" term implies that the system will be intentionally incomplete, i.e. will capture only the essential features of IPDM [2], and is to be modified, supplemented, or supplanted [19] in order to realize the desired future state. For its development various methodologies exist [20], however the one that represents more adequately the philosophy of TRANSMIT project, is the evolutionary [20] presentation [21] prototyping. This iterative methodology allows flexibility in the software development process so that it can adapt to changing requirements, and also convince end-users of the feasibility of the system, as shown schematically in Figure 3 below. TRANSMIT IS prototype is based on a consortium that brings together some of the biggest GNSS Rx manufactures and precise positioning service providers, to act as the end-users (e.g. Fugro) as well as leading research institutes and universities around the Europe to lead the system development and provide the different services as well as the initial system and user requirements.

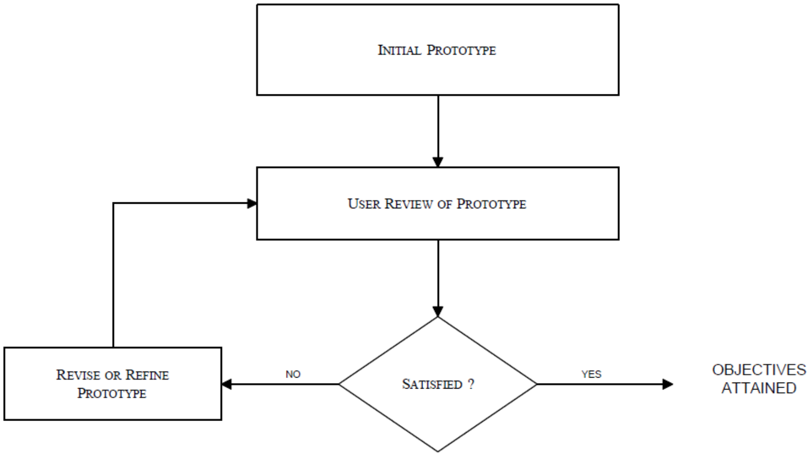

Figure 3. IPDM prototype system development methodology

For what concerns the application portfolio, i.e. business services, hereafter few examples are given as current services developed as part of the TRANSMIT IS with potential value in PPP business area for the end customers (e.g. Fugro). The first service aims to deliver improved estimation, after interference cleansing, and prediction of amplitude scintillation parameter, S4. The second concentrates on providing improved ionospheric delay estimation for different geomagnetic conditions. These services generally needs support and contributions from the TRANSMIT partners in terms of data (e.g. measurements from various ground-based and space-borne instruments, such as GNSS, ionosondes, and radio occultation) and modeling (e.g. advanced 3D tomographic techniques, forecasting, etc.

4. IT strategy overview

The IT strategy for TRANSMIT is split into two sections as shown in Figure 1: internal and overall. The internal is responsibility of the TRANSMIT partners participating to the TRANSMIT IS via a service [22]. The overall is defined by the developers of the prototype presentation layer. It is beyond the scope of this article to expand further on the overall IT strategy, however SOA (Service Oriented Architecture) is briefly recalled as one of the best practices that are used within the IT strategy and is known to generate real business value. Moreover SOA supports the so-called "*Workflow Systems*" (WSs) which allows for "*...building of software applications from a number of loosely coupled, heterogeneous, distributed services...*" [23] which is the case of TRANSMIT IS needs.

SOA represents a paradigm shift in applications design, which includes decomposing business functions and application features into a set of independent but cooperative subsystems or services. This helps businesses to gain flexibility, reuse, and interoperability [24], which in turn implies reduction of operational costs, acceleration of the development of new application by leveraging shared service capabilities, minimization of operating errors and reduction of risks and disruptions to business [25]. Finally, SOA can demonstrate business value and at the same time assess/fine-tune performance and model/modify processes through Key Performance Indicators (KPIs) [26].

No matter what the overall IT is going to be, SOA philosophy can be still applied for the development of various data services within the data layer. However it should be stressed that the development of the presentation and business layers dictated by the overall IT strategy, influences the developed of the data system which will realize the data layer, since it can pose unique requirements on the data system or require the design of new data services.

5. Results

The strategy adopted for data management in the frame of TRANSMIT is broad in scope to allow flexibility given the evolutionary prototyping development methodology of the TRANSMIT IS (see Figure 3). Such choice will also benefit the IPDM prototype development by providing the capacity to the data layer to accommodate further business and application layers needs in terms of data management services. We begin this section by discussing the data and information needs of the TRANSMIT IS which capture the state of the IPDM prototype at the time of writing of this article. These needs should be frequently re-evaluated and the data strategy should be kept up-to-date.

The initial survey conducted shows that the prototype system relies on a variety of proprietary data files in ASCII & Binary format, originating mainly from GPS and Radio occultation satellites as well as other Space-borne instruments. The input and output products have either spatial (e.g. global TEC maps) or temporal dimensions (e.g. complex GPS RF-data) or in some cases both (global TEC maps, predicted over time). Regarding the complex GPS data per se, the size of data files can generate a huge bottleneck, if data movement is scheduled during the operation of the distributed system. Finally, outputs from theoretical models, implemented in different programming languages, have to be also provided (such as the ionospheric models IRI and NeQuick2, just to name a few).

Based on the above needs we have developed a general **data management strategy** that includes, among the others [4]:

- A compelling vision for DM.
- The mission and long-term directional goals of DM.
- Strategy statement.
- Short-term SMART (Specific Measurable Actionable Realistic Time-bound) DM objectives.

The TRANSMIT DM vision and mission is to realize an intelligent DM system that will offer benefits to the enterprise and its customers and leverage existing IT/DM activities. The main mission of the DM function is to meet and exceed the data/information needs of all stakeholders in terms of data/information **availability, security and quality**. To pursuit our vision and fulfill our mission, our strategy is to establish the following data management initiatives:

- Data Architecture (DA) function
- Data Development (DD) function
- Data Operations (DO) function
- Content Management (CM) function
- Meta-data Management (MdM) function
- Data Security Management (DSM) function
- Data Quality Management (DQM) function

Finally, the short-term SMART DM objectives are listed below for each of the above-mentioned function.

Data Architecture (DA) objectives

- Define the “data model”

- Analyze and align with “business models”
- Define data technology architecture
- Define meta-data architecture

Data Development (DD) objectives

- Analyze information requirements
- Develop conceptual, logical and physical data models
- Design physical databases
- Design information products
- Design access services
- Implement development/test database changes
- Create test data
- Migrate and convert data
- Build and test information products
- Build and test data access services
- Validate information requirements
- Prepare for data deployment

Data Operations (DO) objectives

- Implement and control database environments
- Obtain externally sourced data
- Plan for data recovery
- Backup and recover data
- Set database performance service levels
- Monitor and tune database performance
- Plan for data retention
- Archive, retain and purge data
- Support specialized databases

Content Management (CM) objectives

- Implement management systems for acquisition, storage, access and security controls of unstructured data
- Backup and dispose unstructured data

- Retain and dispose unstructured data

Data Security Management (DSM) objectives

- Understand data security needs and regulatory requirements
- Define data security policy
- Define data security standards, controls and procedures
- Manage users, passwords and group memberships
- Manage data access views and permissions
- Monitor user authentication and access behavior

Meta-data Management (MdM) objectives

- Implement a managed meta-data environment
- Create and maintain meta-data
- Integrate meta-data
- Manage meta-data repositories
- Distribute and deliver meta-data
- Query meta-data

Data Quality Management (DQM) objectives

- Define data quality requirements
- Define data quality metrics
- Define data quality business rules
- Test and validate data quality requirements
- Set and evaluate data quality service levels
- Design, implement and monitor operational data quality procedures

6. Final remarks

In this paper we introduce the data management strategy formulated for the TRANSMIT project case. We hope that we achieved to clearly underline the overall requirements for both the IS/IT and data/information, and proposed feasible strategies to be implemented in TRANSMIT prototype in order to support the future GNSS services. To achieve the technical goals of TRANSMIT project, it is needed a flexible, secure, reliable, data system layer to be aligned with the business strategy and generate added value via operational excellence. The current development effort regarding the data system development is on the realization of meta-data repository, as well as on archiving of the necessary test-data, to be later on loaded on the database management system and become accessible from application developers. The data security function, has been implemented and its user interface can be accessed via [28]. Finally, data access services have been developed and tested for different application regimes.

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