Engineering and Architecting Multidisciplinary Systems

Volume 1

System Motion and Engineering of Systems

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Practical Guidelines

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FOREWORD

Purpose of this volume

"Innovation may be the most important factor that brakes competitiveness in many countries. The incapacity *to translate ideas into products and services* of high value is an issue that strikes advanced and emergent economies more and more. It becomes crucial to raise the innovating potential of companies, supporting the *creation of new ideas*, and installing a stimulating climate for businesses, in order to release productivity, to contribute to a better worldwide dissemination of knowledge, and to create more and better *opportunities* for everybody." - Benat Bilbao, Chief Economist of the competitiveness and comparative analysis world network inside the World Economic Forum.

Benat Bilbao and his economist colleagues have the right vision about the brakes on competitiveness, in particular about the innovation factor. It is actually fundamental to favour economic and social conditions that enable the creation of new ideas. First the concerned actors have to know and apply the methods to find new ideas, and to surely transform these ideas into high value products and services.

Systems engineering is the ultimate discipline that enables the creation of new ideas and their transformation into products, services and enterprises.

Economic conditions are not sufficient to innovate; they are necessary as a means or resource. One also needs the technical and technological skills, used by trained and motivated people. But, these two lines (economic and human) are not sufficient by themselves. A third line is missing, the method. In order that the so wished innovation may be effective, one needs a balanced triptych. For instance, let's imagine a group of people working with one or two of these lines:

- Financial resources can be spent; they enable action. But spending and acting to do what?
- Technical and technological skills allow the realization of products and services. But which products, which services, to which usage, to whom, at which price, with which return, which risks, in what time, etc.? And without the economical means, it is impossible to realise any product or service.
- Methods allow the organisation of the activities and actors, optimising the utilisation of resources, assessing solutions, managing means, solving problems, etc. But without technical and technological skills, one has nothing to organise. Having technical and technological skills, and methods, but no economical means, we remain in the abstract or just with ideas.

Methods for engineering associated to system vision enable the coverage of the triptych "economics – human/skills – methods" under the terms "systems engineering" or "engineering of system".

Systems Engineering is a methodology that is used to identify complex problems, to take up challenges facing opportunities, and to find solutions in terms of systems. It consists of:

- ♦ Establishing the functional and physical compatibility of the solution with the needs, expectations and constraints representing the problem, issue or opportunity.
- ♦ Balancing the global economy of the solution taking into account every system life aspect and stage.

- Searching to balance the expectations, constraints, effectiveness, costs, lead time and intrinsic risks of the solution.

This volume, dedicated to the Notion of System and Engineering of Systems, is part of the series of books entitled “Engineering and Architecting Multidisciplinary Systems”. It presents an overview of the engineering of systems, its fundamentals, and the means to set up, perform and deploy the discipline. The knowledge of these fundamentals and how to bring them into play, enables the avoidance of high level pitfalls that often crash, unfortunately, in all kind of projects, products, services or enterprises, not only in the industrial domain, but also in the domains of the civil society.

Content abstract

The present volume gets onto the basic notion of **system**, clearly distinguishing this domain from those of technologies such as mechanics, electronics, computing science, chemistry, ergonomic, etc. It describes its particularities, the consequences onto its **engineering**, as well as the classical analysis and modelling techniques or methods. Are mentioned:

- The notion of system: definitions, the particularities, the generalized system vision, the notion of system of systems, the usefulness of the notion of system, the notion of enabling system, the application to products, services, enterprises, organisations.
- An overview of systems engineering: a brief history, a terminology clarification and the origin of the term engineering, definitions and properties, the location of engineering in the system life cycle, the intellectual creation mechanism.
- Systems engineering means: the international standards and the guide to the body of knowledge (SEBoK); the notion of process, the development processes, the synthetic description of the main concerned processes; the notions of top-down engineering, bottom-up engineering, reverse engineering, re-engineering; representation and modelling techniques; the organisation of engineering activities, ontology elements, tools.
- Life cycle management: the notion of life cycle, the development project of the system, the differences between project management and engineering.
- Engineering of systems and of technologies: the projection of system architecture onto implementation technologies; the case of software engineering.
- Pitfalls, good practices, recommendations, FAQ, a case study to illustrate some core engineering activities.

Content of other volumes

The series of books entitled “Engineering and Architecting Multidisciplinary Systems” is composed of several volumes written to care about coherence of terminology and between mentioned notions, concepts and principles. The volumes 2 and 3 have been published as first version before the present volume 1, because they are part of the reference documents in the Guide to the Body of Knowledge (SEBoK) version 1 published end 2012. The other volumes are progressively published. Titles and summarized contents of the volumes are as follow:

- Volume 1 – System Notion and Engineering of Systems (the present volume)

- Notion of System; System vision; Principles for engineering a system; Means for engineering systems; Relationships to Project Management and technologies engineering; System life cycle management

- Volume 2 – Systems Opportunities and Requirements (published 2012 - 2013)
  - Mission Analysis; Business Opportunity Analysis; Operational Concepts; Stakeholder Requirements; System Requirements
- Volume 3 – Systems Architecture and Design (published 2012 - 2013)
  - System Logical Architecture Definition; System Physical Architecture Definition; Modelling and patterns; System Design and System Element Design
- Volume 4 – Evaluation and Proving of a System
  - System Analysis; System Verification; System Validation; System Integration
- Volume 5 – Engineering of Safe, Secure and Resilient Systems
  - Immunity, integrity, harmless aspects applied to systems; Extension of Systems Engineering to Dependability Engineering and integrated approach; FDIR approach and redundancy patterns; Assessment of dependable properties
- Volume 6 – System of Interest Life Management
  - Implementation Technologies; Integration, deployment, maintenance, disposal as enabling systems; System life cycle synthesis
- Volume 7 – Systems Engineering Ontology
  - Principles to establish a meta-data model; Semantic bus and engineering ontology; Detailed description of the generic engineering meta-data model used in other volumes

The practical guidelines of this series of books are intended primarily for professionals, either customer or supplier, who want to understand and apply daily engineering of systems; in other words for those who will have to define operational concepts, express stakeholder and system requirements, define candidate architectures, design and validate complex or multidisciplinary systems. In these guidelines they will find methods, processes, modelling and analysis techniques, reasoning elements, useful recommendations for application, as well as case studies or examples to use this approach.

Other people having to understand or to exchange with system engineers will find simple and concrete explanations. They will then be able to judiciously apply certain precepts and concepts to their own job. For example, they can be responsible for architecture, design, integration, verification and validation, program and project managers, technological study engineers, service developers; or they can be in charge of organising sets or complex enterprises whatever the sector (technical, commercial, military, academia, government, tertiary).

These guidelines are most useful to University professors who desire teaching Engineering of Systems, Architecting of Multidisciplinary Systems, to university students, and to researchers, as a certain number of topics discussed in these books could possibly lead to more extensive studies, as well as studies which have not yet been tackled by the engineering community.

These guidelines describe the fundamentals and the means that can be then peacefully deepened with discernment through the literature about these subjects. They include definitions, descriptions, discussions; examples and case studies illustrate practices. The case studies explain step by step how to perform the activities and tasks. Readers can directly transpose the step-by-step and use provided templates for their current or future projects.

CONTENT

FIGURES

3 NOTION OF SYSTEM, FOUNDING PRINCIPLES

This chapter presents the fundamentals related to the notion of system that one has to know in order to perform the engineering of any kind of system: a definition of the notion, the views of a system, the main characteristics of a system compared to other elements, its usefulness, the system vision, its usage through examples.

This chapter tackles the following topics:

- The definitions of the notion of system – section 3.1
- The multidisciplinary systems – section 3.2
- The characteristics of a system – section 3.3
- The generalized system vision – section 3.4
- The notion of system-of-systems – section 3.5
- The usefulness and limits of the notion of system – section 3.6
- The notion of enabling-system – section 3.7
- The application to examples of the selected definition – section 3.8

4 INTRODUCTION TO ENGINEERING OF SYSTEMS

This chapter presents the engineering of a system, its place in the life cycle of a system, the existing definitions and the main characteristics and properties. It describes development approaches through engineering and integration and provides the appropriate utilizations. It explains what the notions of concurrent or integrated engineering and simultaneous engineering cover and contain.

This chapter ends with the description of a model of the intellectual creation mechanism that prefigures and justifies the content of engineering activities and their grouping into processes.

The following topics are described and discussed:

- A brief history of Systems Engineering – chapter 4.1
- Vocabulary clarifications – chapter 4.2
- The characterization of engineering of systems – chapter 4.3, including:
  - The passage from the idea to realization – section 4.3.1
  - The place of engineering in the life cycle – section 4.3.2
  - Use cases of engineering systems – section 4.3.3
  - Definitions and properties – section 4.3.4
- The approaches and principles of engineering systems – chapter 4.4, including:
  - Top-down engineering, reverse engineering, re-engineering – section 4.4.1
  - The separation of the problem space from the solution space – section 4.4.2
  - The causal links between engineering activities – section 4.4.3
  - The transformational continuity and the semantic breaks – section 4.4.4
  - Concurrent engineering and simultaneous engineering – section 4.4.5
- Engineering systems and development approaches – chapter 4.5
- A model of the intellectual creation mechanism – chapter 4.6

5 MEANS TO UNDERTAKE ENGINEERING OF SYSTEMS

This chapter is the core of the present volume. It presents the set of necessary means to undertake engineering of systems within real projects: standards, processes, elements of ontology, modelling techniques and tools. These means are synthetically described; discussions or complementary explanations or advice is given, in order that the reader acquires the relevant knowledge fast. References to other volumes of this series of books, and to other books, are indicated to go into the notions and practices more thoroughly.

This chapter contains:

- An overview of the means to engineer systems – chapter 5.1
- A brief description of some international standards – chapter 5.2
- A summary of the guide to the body of knowledge: SEBoK – chapter 5.3
- The generic process approach and maps of processes – chapter 5.4
- Ontology elements related to processes for system definition – chapter 5.5
- The description of processes for concept and system definition – chapter 5.6
- The description of other processes for system development – chapter 5.7
- Some modelling techniques and methods – chapter 5.8
- Tools – chapter 5.9

6 LIFE CYCLE AND SYSTEM ENGINEERING

This chapter describes the differences and relationships between system engineering, system life cycle, programme management, project management, and technologies engineering.

This chapter presents:

- The notions of life cycle and development cycle – chapter 6.1
- The location of definition processes in the life cycle – chapter 6.2
- The difference between project management and system engineering; their complementarity – chapter 6.3
- How system engineering inscribes itself in programme management – chapter 6.4
- The transition from system engineering to technologies engineering – chapter 6.5

7 DEPLOYMENT OF SYSTEMS ENGINEERING

This chapter is a kind of conclusion of the present volume. Its presents the main lines of the systems engineering discipline deployment within an enterprise or a company.

This chapter describes:

- The general approach of the deployment – chapter 7.1
- The means to deploy the discipline – chapter 7.2

8 REFERENCES

The following books and documents may provide to the reader complementary understanding, certainties, details or syntheses. Some following books are cited in the present volume.

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