A Methodology Proposal to Design Radars - Systems Approach

Antonio Sallum Librelato[1] and Osamu Saotome[2]
1 EThICS Engineering - Rua Prof. Maria Lima Cesar, 181, Ap. 12 - CEP 12216-141 - São José dos Campos - SP - Brasil
2 Instituto Tecnológico de Aeronáutica - Praça Marechal Eduardo Gomes, 50 – Vila das Acácias – São José dos Campos – SP - Brasil

Abstract — When creating new systems, it is recommended that, before starting the engineering development phases of the project, the concept phase be executed. The proposed Systems Concepts Research (SCR) method was structured by one of the authors[1] and refers to the concept phase of the project life cycle, in special when applied to systems based on complex and critical technologies, like radar systems. Additionally to the usual specialized tasks of systems development, this method integrates the specialized tasks of systems and products assurance. The objectives of this article are:

- ***To present the steps and tasks of the SCR method;***
- ***To reinforce the advantages of doing it before the system development phase; and***
- ***The convenience and advantages of the integrated and simultaneous execution of the analysis of risks, cost-effectiveness and system assurance, as part of the SCR method.***

Keyword — research, assurance, radar.

I. INTRODUCTION

Motivations for the Systems Concepts Research (SCR) method:

The project of complex and critical systems, like radars, is submitted to challenging factors presented by the current environment. These factors are the main motivations to adopt the SCR method, as follows [2]:

- Increasing systems complexities.
- Evolving technology changes.
- Extended systems life cycles.
- Shorter technologies life cycles.
- Constantly changing requirements.
- More emphasis on "systems" (versus components).
- Greater utilization of commercial off-the-shelf (COTS) products.
- Higher overall life-cycle costs.
- Increasing demand for mitigation and control of uncertainty and hazard risks during the development phase, mainly when based on new and not well mature technologies [4].

In the reference [1], the main tasks of the concept development comprise needs analysis, concepts exploration and definition.

A. S. Librelato, a.sallum@uol.com.br, Tel +55-12-39418277. O. Saotome, osaotome@ita.br, Tel +55-12- 39475818.

In the reference [2], the system engineering processes comprehend mainly the definition of the problem, needs, feasibility, functional and performance analysis, the operational and logistical requirements, resulting on the system synthesis, analysis and design optimization.

The reference [3] presents the System Architecture Development, comprising requirements, operations, behavior and physical elements of systems.

Reference [4] considers the importance of the systems and products assurance technologies, like quality, reliability safety, maintainability, and others, considering also their combined effects and influence on the system cost-effectiveness and risks.

The reference [5] presents a methodology for radar systems analysis, considering the systems, requirements, and parameters for the development of new radars.

There is a consensus among those references that the phase of system concept definition must be executed before the beginning of the phase of system development, and that, doing so, it will result on reducing costs and risks, with better effectiveness of systems. Nevertheless, none of the mentioned references establishes a clear integrated method to do this, and that is the purpose of the present work..

The proposed SCR method was structured to create an appropriate framework to permit the practical benefits of those principles, by:

- Comprising all the tasks usually recommended by the references for the concept phase, as above, and
- Additionally integrating the tasks necessary to assure best results on the cost-effectiveness of systems, comprising:
  - Management of:
    - ✓ Systems and Products Assurance,
    - ✓ Risks,
    - ✓ Cost-effectiveness,
    - ✓ Configuration,
    - ✓ Software Assurance,
    - ✓ Rights and Penalties of Assurance and Warranties.
- Engineering of:
    - ✓ Quality,
    - ✓ Reliability,
    - ✓ Maintainability,
    - ✓ Safety,
    - ✓ Security,

- ✓ Human Factors,
- ✓ Supportability and logistics,
- ✓ Sustainability,
- ✓ Verification and Validation, and
- ✓ Other analogous.

By acting in advance to the development of systems and products, the SCR creates opportunities for:

- Consolidating the requirements, since the beginning of the project studies.
- Active participation of the main stakeholders on the project.
- Reduction of the future life cycle costs of the system.
- Reduction of hazard and uncertainty risks.
- Improvement of the effectiveness of solutions.
- Analysis and evaluation of the required and available knowledge and technologies for the execution of the project.
- Conscious and comparative selection of the most adequate solution, from distinct alternatives.
- Reduction of the management and engineering efforts to develop the system.
- Direction and recommendation of actions to mitigate and control of risks, costs, and systems assurance.

II. BRIEF DESCRIPTION OF THE SCR METHOD

Principles of SCR:

The SCR method comprises a series of interactive tasks. It will require specialized knowledge and skills on management and engineering of systems, requirements, risks, product assurance, costs and project planning and product development. Depending on the specific conditions of procurement and supply of systems, the work share between client and manufacturer (or supplier) will vary. Anyway, the complete composition of tasks is practically the same.

The SCR method brings great benefits on obtaining the best solution for the needs, reduction of time and costs, increase on the system assurance, performance and effectiveness, and better satisfaction of customers, users and producers [1] [4].

Phases of the SCR:

The method here presented consists of four steps, where the specialized tasks of systems, requirements and systems assurance engineering are integrated and executed, as follow:

- NRA - Needs and Requirements Analysis
- SCE - Systems Concepts Exploration
- SCD - System Concept Definition
- SRAA - Systems Risks and Assurance Analysis

Purposes of SCR:

As part of the life cycle of projects, the SCR aims to:

- Create a clear definition about which system concept shall be developed, according to which plans and conditions, to well attend the needs, requirements and cost-effectiveness established for the project and system.
- Assure that a real and valid need exists, with at least one feasible solution to attend it.
- Define a valid set of operational, functional and performance requirements to be attended by the concept.
- Explore technologies and systems capable to fulfill the needs and requirements.
- Select the system concept that best accomplish the established needs, requirements, restrictions, assurances, and balance of cost-effectiveness.
- Planning the subsequent phases of development, production, support, usage and discard of the selected concept.

III. NRA - NEEDS AND REQUIREMENTS ANALYSIS

Purposes of NRA:

- Understand what the problem to be solved by the future system is.
- Establish that a necessity for a new system really exists and is valid.
- Establish that the desired system is technically and economically feasible.
- Elicit and analyze the requirements applied to the project and to the system.

Steps and Tasks of NRA:

- **Vision of Problem:**
  - Description of the motivations, nature, magnitude, and context of the main problem to be solved.
  - Evaluation of the risks derived if the problem will not be solved.
- **Needs Analysis:**
  - Description of the needs, goals and objectives to be attended.
  - Description of the suppositions and restrictions to be considered by the project of the system.
  - Identification of the system stakeholders and definition of interests, responsibilities and authorities.
  - Definitions about the required system life cycle, use start date, useful life span, and operation and maintenance cycles.
- **Operational Analysis:**
  - Analysis of the objectives and goals of the operations.
  - Description, dimensioning and scenery profiling of the system mission.
  - Description of the system operational concepts.
  - Description and space and time values of the environmental conditions, during the operations.
  - Architecture concept of the system and subsystems, and their space distributions for the operations.
  - Definitions about internal and external interfaces among systems and subsystems.
  - Statement of the main expected benefits.

- **Functional Analysis:**
  - Description of the system functional concepts and requirements:
    - ✓ Translation of operational objectives into system functions.
    - ✓ List and flux of functions (specific, primary and secondary).
    - ✓ Reasons to exert each function.
    - ✓ Description of why, when, where, duration and frequency of the functions.
  - Allocation of functions to the system and subsystems elements.
  - Simulation of the functions isolated and combined.
- **Feasibility Definitions:**
  - Description, analysis and evaluation of the currently available solutions.
  - Comparison of the available solutions with the system concepts requirements.
  - Evaluation of feasibility of each system functional concept.
- **Needs Validation:**
  - Characterization and validation of the needs to be satisfied, presenting their evidences.
- **Operational Requirements Synthesis:**
  - Elicitation, analysis and validation of all operational requirements and constraints.

IV. SCE - SYSTEMS CONCEPTS EXPLORATION

Purposes of SCE:

- Present a variety of alternatives as solutions of system concepts, which will attend the established requirements and restrictions.
- Explore which are the potential concepts of systems that may attend the needs.
- Formulate and validate a set of system performance requirements for each of the system concepts.

Steps and Tasks of SCE:

- **Operational Requirements Analysis:**
  - Critical analysis of the operational objectives.
  - Detailed revision and analysis of the operational concept and requirements.
  - Feasibility analysis of the operational requirements.
- **Performance Requirements Formulation:**
  - Derivation of subsystems functions and performance requirements.
  - Formulation of performance characteristics.
- Implementation Concepts Exploration:
  - Assessment and analysis of technologies and systems possibilities.
  - Formulation of alternatives of implementation concepts.
  - Execution of proof-of-concepts experiments, to evaluate the exequibility of the alternatives.
- **Performance Requirements Validation:**
  - Evaluation of performance and cost-effectiveness characteristics of each alternative.
  - Definition, integration and validation of the performance characteristics.
- **Performance Requirements Synthesis:**
  - Description, classification and qualification of each alternative.

V. SCD - SYSTEM CONCEPT DEFINITION

Purposes of SCD:

- Select the best solution of system concept to attend the established requirements and restrictions.
- Select a preferable (most attractive) system concept.
- Define its basic architecture and functional characteristics.
- Develop a detailed plan to the subsequent phases of system and product development, manufacturing and implementation.

Steps and Tasks of SCD

- Performance Requirements Analysis:
  - Analysis and refinement of the performance and functional requirements.
- Functional Analysis and Formulation:
  - Definition and simulation of the functional components.
  - Modeling and demonstrations with prototypes of the alternatives.
- Implementation Concept Selection:
  - Selection and justification of the preferred system concept.
- Concept Validation and Description:
  - Modeling of system concept and its environment.
  - Functional and architectonic specifications of the system concept.
  - System concept validation and description.
- System Development Planning:
  - Planning for the system development, production, support, use and discard.

VI. SRAA - SYSTEMS RISKS AND ASSURANCE ANALYSIS

Purposes of SRAA:

- Assure and validate that the requirements and restrictions of systems assurance and cost-effectiveness could be attended by the selected system concept.
- Evaluation of risks and cost-effectiveness.
- Validation of system assurance requirements.
- Recommendations for mitigation and control of risks, costs and system assurance, for each alternative of system concept.
- Execute this step in parallel and simultaneously with the other three steps of the SCR.

Steps and Tasks of SRAA

- **During the Needs and Requirements Analysis (NRA):**
  - Risks classification and analysis criteria.
  - Assessment and evaluation of the potential risks for the project, the system, and the operations.
  - Assessment, limits characterization, and evaluation of the main system assurance requirements, comprising:
    - ✓ Configuration management, software assurance, rights and penalties of assurance, verification and validation.
    - ✓ Quality, reliability, maintainability, safety, security, human factors, supportability and logistics, sustainability, and other analogous.
  - Preliminary evaluation and analysis of the TCO - Total Cost of Ownership perceived by the market.
  - Go-No Go decision.
- **During the Systems Concepts Exploration (SCE):**
  - Characterization, evaluation and comparison of risks and system assurance parameters of each alternative of system concept.
  - Analysis and evaluation of each trade-off solutions.
  - Analysis of viability of accomplishment of the system assurance requirements and of the cost-effectiveness balance.
  - Go-No Go decision.
  - Recommendations for the mitigation and control of risks.
  - Recommendations for the provisioning of systems assurance and cost-effectiveness.
- **During the System Concept Definition (SCD):**
  - Detailed analysis and revision of the terms of assurance and cost-effectiveness.
  - Go-No Go decision.
  - Detailed recommendations for mitigation and control of risks for the selected system concept.
  - Detailed recommendations for the achievement of system assurance and cost-effectiveness elements of the selected system concept.

VII. CONCLUSIONS

The main structure of steps and tasks of the Systems Concepts Research (SCR) method was presented, ready to be applied to a general radar project case. As it is a generic framework, it will be necessary to adequate the terminology to each specific application, according to types of systems and technologies, to apply to other cases.

The level of details and assessment shall also be tailored to each case, in conformance with the degree of uncertainty, difficulty and newness.

The four steps of the SCR method comprise the most common tasks recommended for the concept of systems, as well as to include and integrate the risks, cost-effectiveness and assurance disciplines, simultaneous with the systems and requirements engineering tasks.

Taking radar systems as a goal of systems concept, the SCR method will permit a structured and complete analysis and synthesis, including the flexibility to look for the most recent technologies available for radar systems, like the Software Defined Radio (SDR) technology and method.

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