NAF Based System of Systems Early Engineering Architecture Evaluation and Definition Method

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ABSTRACT

The economical context has induced a lasting tendency for reduction of defence budgets all over Europe. In the long term, cost drifting is to be considered unacceptable by national ministries of defence, therefore for each defence industrial. Decades of system engineering practice has proven that the one and only way to prevent drifting risks, during development and realization phases, consists in investing significant time and resources into Early Engineering.

This observation is nowadays well understood by the main industrials of defence and has led to the development of methods to identify projects risks, to study technical feasibility, to evaluate global cost of a project, all methods that contribute to un-risk the project on the lifetime of a system. Moreover, the NATO architecture framework has been developed to face the growing challenges of systems of systems engineering.

However, the Early Engineering methodological asset and the NAF present few obvious synergies: whereas Early Engineering requires quick- and easy-to-use methods, which are able to adapt to continual iterations between need elicitation and architecting, the NAF has been designed to describe static, consistent architectures. What's more, some industrials relinquish to invest the large amount of time and human resources required to design a consistent NAF architecture as soon as early phases of a project.

It is therefore necessary to think a better way to exploit the wide, proven potential of NAF for mastering systems of systems complexity, in the Early Engineering context. This new way is to be built on two driving ideas: classical engineering methods must be tailored to early phases time and resource constraints, and tools made compatible with an architecture described on NAF; architecting activities must be described and fully considered into a complete Early Engineering workflow.

Our first contribution has been to tailor methods to our context. We described how a creativity laboratory can ease the collect of operational need with the elaboration and validation of operational scenarios by all stakeholders. How the integration of formalized requirements into a concept of operations document can greatly ease the management of traceability during all the early phases. We tailored the concepts used by common vulnerability analysis methods to NAF vocabulary. We tailored decision-helping methods such as value analysis and multicriteria methods to NAF vocabulary (for example, we described how the generic concept of "function" can be adapted to a set of situations where various NAF elements cost should be evaluated) and formalism.

Our second contribution consists in describing a complete workflow for Early Engineering activities, compliant with NAF concepts, and also classical project management, system engineering and requirements engineering concepts. Our main innovation is the description of a tooled up iteration between the architecture and high-level, prioritized client objectives. This iteration allows to directly justify the costs induced by architecting elements toward prioritized needs of the client. It is therefore far easier for an Early Engineering team to stand up their architectural choices before their hierarchy, then the client; it is also easier to convince a client to cut useless and expensive elements of a system of systems.

A concrete overlook of the ready-to-deploy tool corresponding to our method would be a workspace using DOORS to manage prioritized requirements – these requirements are directly linked to the concepts of operation and high-level objectives of the client – MEGA to define alternative architectures into the NAF, and Excel templates able to import DOORS & MEGA data to produce reports that help architects into making decisions directly justified to prioritized client needs.

1.0 INTRODUCTION

More and more engineers committed in defense programs had to acknowledge their current system engineering practices aren't tailored to face the exponentially growing complexity of systems of systems engineering. Design optimal system can be considered as NP complete: to answer an operational need, harder and harder to express due to the new types of threats and theaters of operations, under the growing weight of budget, juridical, cooperation constraints, engineers shall be able to propose, among the exponential combinatorial of alternative systems of systems solutions, one optimal solution, making a trade-off between performances, cost, delays and risks.

Tools like the NATO Architecture Framework have been developed to face such new challenges, but, due to misfit allocated time and resources, often remains unexploited by industry during Early Engineering phases. Whereas one of the main system engineering prescription is that the most significant efforts should be carried during Early Engineering phases, before binding dimensioning decisions are taken and milestones are passed.

So that there is today an attested risk that Early Engineering practices take off in front of this increasing complexity. A situation which would mean that strategic choices would be made, and weapons programs launched without trustworthy estimations of cost, delays and performances (capabilities and quality factors satisfaction levels) of the to-be system of systems.

In the current context of defense budget cuts all over Europe, it is unthinkable that the community of defense becomes unable to deliver consolidated elements of decision to political authorities, and also unable to decrease program costs with ensuring a just enough performance.

The non-collaborative scheme of work adopted by defense agencies toward industry and armed forces, which allowed to decrease bid proposal costs thanks to harder competitions and scarcer collaborations, becomes inoperative in a double context of budget cuts and exploding complexity. In the context of bid elaborations, the time of contracting processes unduly takes on the time of engineering processes.

The time and resources an industrial spends into understanding specifications and answering with legal forms, isn't spent into crucial Early Engineering tasks, such as better understanding operational needs and the associated requirements, evaluate their solutions toward these needs, then optimizing the cost to the just enough performances. The time to elaborate a consistent, optimized bid proposal should be evaluated by defense agencies, then granted to industrial, not in order to please them, but to get better and cheaper proposals.

1.1 Main issue

Because of the bid proposal cleaver which congeals operational need, specifications, the solution, its performances and cost, all risks that haven't been considered before will last during all the life cycle of the system of systems. In order to provide decision makers un-risked, cost optimized, and performing alternatives at this key milestone, a new global system of systems Early Engineering process should be built then set up in concerned organizations.

1.2 Steps of our approach

Such a global process will be described in our article, including the step of its setting up. First, a local, lean manufacturing approach should be lead into each of the organizations (armed forces, defense agencies, industrials), in order to make them use the already existing tools during their Early Engineering activities. These tools must produce a local added value for each of these actors, and use interoperable formats. Secondly, the federation of these interoperable tools will support a one, global iterative process, concerning armed forces, defense agencies and industrials. Thirdly, we suggest solutions to make possible armed forces, defense agencies and industrials to cooperate into iterative engineering cycles, despite the linear, imposed time of contractual processes, and the legal requirements of government contracts.

2.0 IMPROVEMENT OF LOCAL PROCESSES

2.1 Principles

As set in introduction, the first step of our approach consists in an effort into improving local processes of Early Engineering through better fitted tools. The main issue is how we can make these new tools accepted by local engineering teams. To meet this objective, we suggest a lean approach for each team involved into Early Engineering operations. This transformation must be a rationalization effort: local organizations must find more efficient ways of working. Improvements can be new simplified procedures to organize engineering operations such as need collection, formalization of requirements, system architecting, architecture evaluation, or resort to operational simulations. Other improvements may be investing into new tools and the adequate formations for their users; generalization of best practices from other engineering teams; even the use of shared templates and rules of redaction for the most important working documents and deliveries.

We assess three major requirements for this step:

- A new referential of action must be defined, which follows not only prescriptions from international standards on system engineering processes (ISO 15288), requirements engineering processes (ISO 29148), and the NATO architecture framework referential, especially the NAF vocabulary (capabilities, operational activities, system processes, functional processes…), but also the enterprise project management referential of each organization.
- The tools and every improvement suggested to engineers must carry value for its users. Only tools able to help users in their daily working should be selected, so that tools users know their personal investment in learning and appropriating these tools pays off. Managers shall highlight the concrete improvements the new tools have allowed, in order to ensure the durability of their effective usage.
- Although these transformation are lead only at a local level, our approach has to be lead simultaneously and consistently between the various organizations involved (armed forces, ministries of defense agencies, industrials). They should agree on the nature and formalism of all entering and outing documents which circulate between them. Moreover, they have to agree on their referentials, and select the same international standards, and ensure of the compatibility of their business management processes. Finally, the improvement effort must be diligently carried by each stakeholder, in order to not blow off the value created by an organization with ineffective treatment of produced data in a second organization.

2.2 Concrete propositions

Before suggesting any improvement of local early engineering processes, we propose a generic model of these processes in the environment of weaponry programs. These processes are represented by arrows which transform a main engineering document in another.

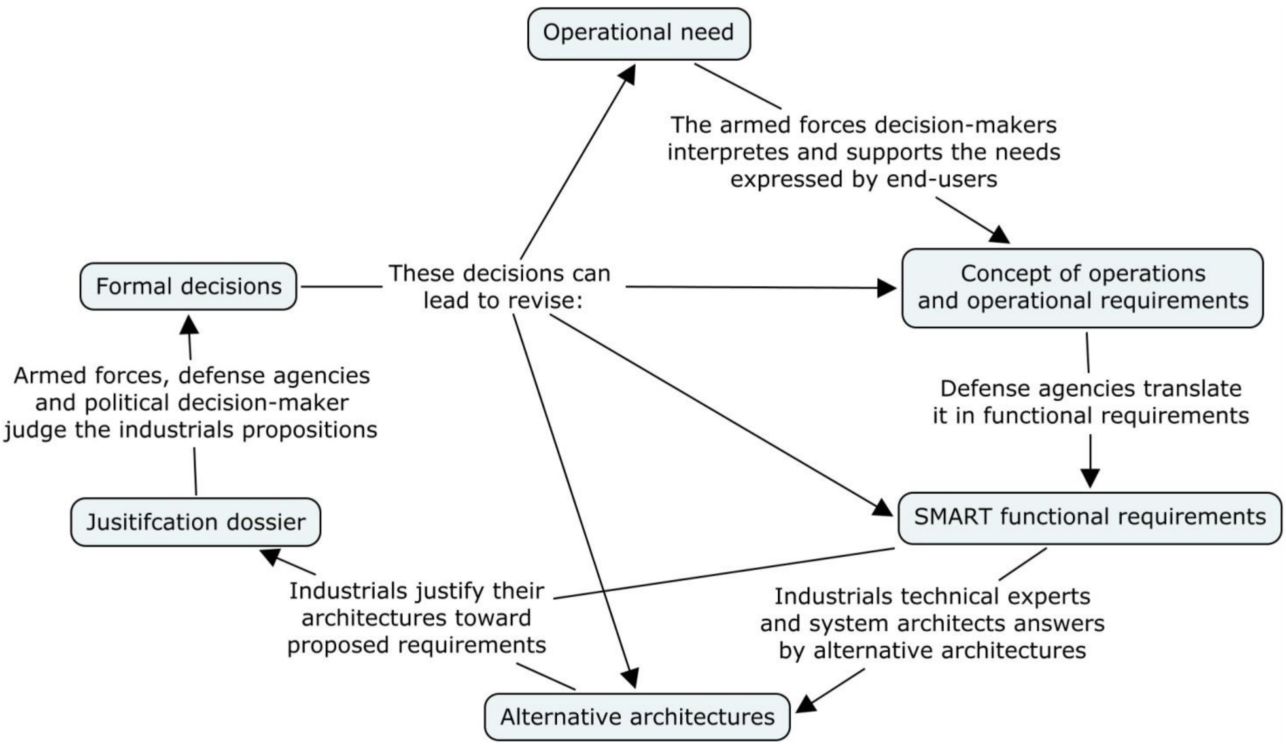

Figure 1: Early Engineering processes

For each of these processes, we propose the following actions:

- Need collection process: we can easily increase the level of traceability between the need and the concept of operations, by formalizing need into stakeholder requirements, and derive them into operational requirements; these operational requirements will be distributed into the different parts of the ConOps document, so that every aspect of need expression is to be allocated to precise requirements.
- Specification from the concept of operations process: we simply suggest a widespread use of requirements analysis tools such as DOORS, which exploits as an entry the operational requirements disseminated into the different parts of the ConOps.
- Building system architectures process: the main objective is to build architectures compliant with the specifications, so that a NAF-compatible architecting tool should be used. This tool must be completed with a bridge which allows tracing requirements from the specification to elements from the architecture. Then these architectures make sense only if they can be evaluated and justified toward user and client needs: we shall ensure that the architecting tool can easily export data to adequate evaluation tools.
- Architecture evaluation and justification process: To support this key process, which allows evaluating the consistency of need, requirements and alternative architectures, we suggest a systematic recourse to decision-helping methods. With simple-to-fill templates, it is made possible to quickly identify the necessary trade-offs between the systems functions, for each alternative architecture. Multicriteria analysis can also provide formal analysis of adequacy between expressed need and the answer to this need proposed by industrials. Our conviction is Early Engineering phases requires above all such simple but straightforward methods.

- Support decision-making: Raw data produced by such methods isn't enough to guide decision-makers who aren't involved in technical definition of the system. Decision-helping method must be coupled with sensibility analysis to explain how corrections on the architecture influence cost, delays and performance. Moreover, every method should be implemented by a tool able to produce graphical, easy to interpret data.

These concrete propositions can help Early Engineers to quickly produce decision-helping elements, identify the most dimensioning trade-offs and priorize their work, in a context of low time and resources.

3.0 DEFINITION OF A GLOBAL PROCESS

In Early Engineering phase, one should concentrate on high-level objectives of the client and end users.

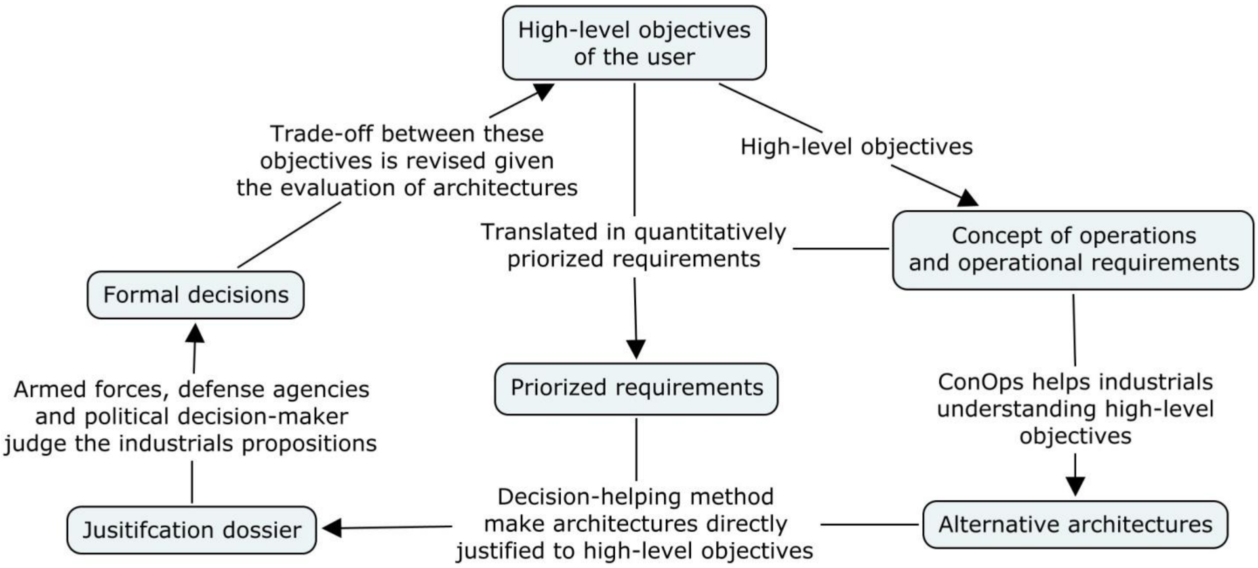

Figure 2: Global Early Engineering process concentrating on high-level objectives

That's why we propose this new workflow for Early Engineering: once all involved organizations have adopted new tools, it is possible to interconnect them to make them support a global and more efficient workflow. With automated bridges between tools, the loops between armed forces, defense agencies, industrials and decision-makers are far faster: industrials can correct their architectures with direct and regular commentaries from decision-maker and end users.

A concrete implementation of our global process would be a federation of a requirement analysis tool like DOORS, a system architecting tool like MEGA suite for NAF or Enterprise Architect, decision-helping tools like value analysis or multicriteria templates. Thanks to the unified referential used by the involved organizations, and the export functions of all these tools, it is possible to interconnect DOORS, MEGA, Excel analysis templates and produce graphical data able to orient decisions.

4.0 HOW CAN WE MAKE ENGINEERING AND CONTRACTING PROCESS BE CONSISTENT?

4.1 Currently applied solutions

We have described how a new, more efficient engineering cycle could be deployed simultaneously in various organizations such as armed forces, defense agencies and industrials. But we still have to describe how this engineering process can fit into a contracting process: our engineering propositions must comply with highly regulated public contracting processes.

Contracting processes are linear: organizations engaged into such processes must comply with successive milestones like launching a request for proposal, a request for information, answering such requests. But we need to make our engineering cycles iterate between different organizations which cannot cooperate easily outside these milestones. The more efforts and iterations are done, the more risks will be anticipated by the whole community of involved actors.

That's why solutions have been proposed and are still pushed by defense agencies, responsible for contracting between states and industrials:

- The first way is to multiply the contracted steps of the program: the more steps, the more milestones, and the more iterations. But defense agencies can't organize dozens of early contracts, and they can't be sure an industrial responding to one early contract will be the same for the second early contract, or the main contract itself.
- Defense agencies can concentrate their Early Engineering effort in contracting the search for precise engineering answers identified through the previous engineering cycle. But the results of the study will be used by the defense agencies in its following public request, and would an industrial gladly share the result of its work with its future competitors?
- Another solution is to lead informal discussions between public entities and some industrials, but such informal ways of working carries risk toward legislation, which regulates exchange of information between state organizations and particular interests.

So it seems that currently applied solutions to organize contractualization of weapon programs are unable to make our trans-organizations Early Engineering iterated cycle work.

4.2 Our suggestion: set a cooperation base of public data

Our solution is to define unambiguous data that can be shared by all organization, and which allow to capitalize their early engineering efforts in the interest of the whole program. But which type of data should we choose? We propose to capitalize operational scenarios, which would be validated by all stakeholders – for example, end users validate that these scenarios give back their operational need, armed forces validate that they are willing to acquire a system of systems able to satisfy these scenarios, defence agencies validate that it is able to pay for the system to-be, and the industrials validate that they can describe architectures from these scenarios. This base of shared operational scenarios would be created thanks to creativity laboratories deployed in emerging technical-operational laboratories. Then, into the simulation laboratory, these operational scenarios would be played according to the validation need of each stakeholder.

Such a cooperation base of shared and validated operational scenarios would offer new possibilities for Early Engineering efficiency: first, need collection would be summarized in a reduced base of highly relevant and explicit scenarios. Second, system architectures could be directly and quickly validated on this reduced base of operational scenarios representing operational need.

5.0 CONLUSION

Our NAF based system of systems Early Engineering architecture evaluation method intends only in exploiting at best well-known, existing methods and tools. A specific focus must be made on emerging technical-operational laboratories, which offer advanced, but not fully exploited, possibilities into collective creation of scenarios and their simulation. This simulation approach seems especially relevant in the case of system of systems architectures, whose parameters are often well-known system blocs, which are linked through various communication networks and protocols, so that simplified early architectures can be quickly evaluated through simulation of representative operational scenarios. Moreover, these facilities which have been thought to ease collaborative working should be perfect places to make armed forces, ministry of defense agencies and industrial cooperate to produce shared value.