ESA STUDY CONTRACT REPORT

ESA CONTRACT	SUBJECT	CONTRACTOR	
No 2033/06/NL/HE	Application of concurrent engineering methodologies to improve the treatment of anomalies during a project life-cycle (CEMAT)	**Thales Alenia Space Italia S.p.A.**	
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ABSTRACT:

ESA CEMAT Study objectives are to investigate the state-of-the-art in both space and non-space domains, to provide recommendations and to define a software application able to demonstrate some of the investigated concepts on a real case.

This document reports the summary of the ESA CEMAT Study results.

The work described in this report was done under ESA contract. Responsibility for the contents resides in the author or organization that prepared it.

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1. INTRODUCTION

The CEMAT (Concurrent Engineering Methodologies applied to Anomaly Treatment) Study has been carried out under the ESA contract No.20033/06/NL/HE "*Application of concurrent engineering methodologies to improve the treatment of anomalies during a project life-cycle*" by an industrial consortium including Thales Alenia Space in Turin as prime contractor, EADS Astrium Satellites in Friedrichshafen and Università del Piemonte Orientale (UNIPMN) as subcontractors. The study was also supported by the Computer Science Department of *Università degli Studi di Torino* and by the Aeronautics and Space Engineering Department of *Politecnico di Torino*.
The contract is part of the ESA General Study Program (GSP) and covers an 18 months time frame starting from October 2006.

This abstract is to report the results of the Study, whose objectives were to investigate the state of the art in both space and non-space domains, to provide recommendations and to define a software application able to demonstrate some of the investigated concepts on a real case, i.e. the GOCE spacecraft.

2. CEMAT APPROACH

The term "Concurrent Engineering (CE) Methodology" refers to a set of techniques in which a multidisciplinary team of experts works together in a concurrent way and in real time. These techniques are successfully used in many domains. They have widely proven their efficiency and advantages, leading to the creation of different facilities over the world, especially for the preliminary phases of the project. CE aims to minimize the project timescales by maximizing the degree of overlap of activities, to minimize the associated cost of the activity and to improve the quality of the results. This approach is opposed to the serial approach in which each discipline in turn analyzes the problem or designs the system.
Anomalies happen at each stage of the project lifecycle and they cause impacts on time and cost. The term "*Anomaly Treatment*" (AT) refers to the process that starts after the detection of an anomaly during design, manufacturing, integration/testing or operations phases.

The hypothesis that is at the basis of the study is that the application of CE methodologies to AT may be particularly useful during the investigation of causes, consequences and actions to be implemented to resolve the anomaly, especially when a large number of disciplines are involved. The scope of the CEMAT AT study was to investigate the AT process, to identify possible benefits through the use of CE methodologies and to demonstrate them through the development of a software prototype.

3. RECOMMENDATIONS FROM THE STATE-OF-THE-ART SURVEY

The study started with the collection of data for the identification of the state-of-the-art in the application of CE to AT, which is derived from an international survey conducted by spreading a questionnaire to selected companies in both space and non-space domains. Results have been integrated with information coming from publications.
The questionnaire was sent to 55 companies worldwide, from space and non-space domains.

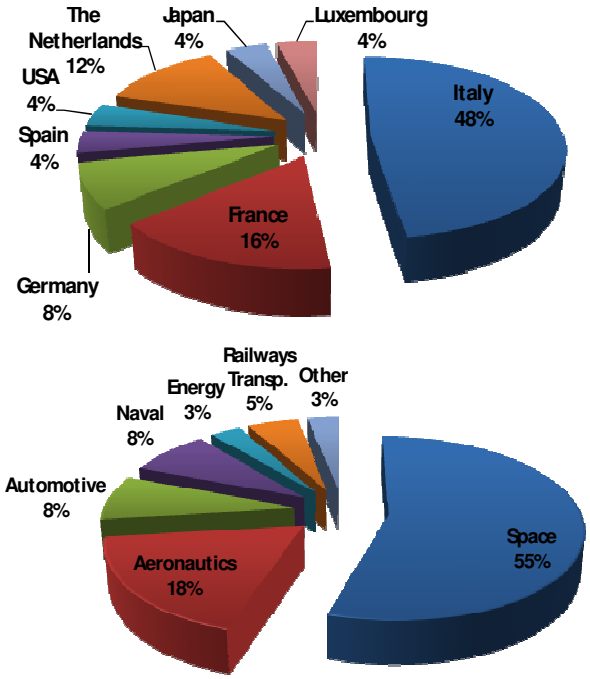
Contributors to the SOTA (State-of-the-art) survey in the space domain have been selected considering:

- Companies operating both in ground testing and flight operations
- Different Working Units (e.g. concerning different spacecraft classes)
- National and International Space Agencies and related centers devoted to ground testing and/or flight operations

Contributors to the SOTA in non-space domains have been selected from European and international companies, operating in an operative context similar to space in terms of complexity, time and cost constraints. In particular the questionnaire was sent to representative companies in the following domains: automotive (especially companies involved in races and competitions), aeronautics,

railway transportation (high speed, automatic vehicles), naval, energy (nuclear, oil, gas).

Survey results are due to the involvement of 31% on the total of the companies selected whose distribution is shown in the below figures.



Obviously the survey results do not represent a totally comprehensive "state-of-the-art" on CE/AT methodologies and processes. They do not provide the complete overview of the activities of all the companies dealing with Anomaly Treatment. In fact it is difficult to obtain specific information about activities associated to product quality, as manufacturers are constrained about the disclosure of company confidential information. Likewise it is difficult to obtain information about advanced research fields and about a technologies and activities that fall under export controls and restrictions related to ITAR (International Traffic in Arms Regulations) restrictions in the USA. Furthermore some companies do not consider themselves as advanced or they do not share the appreciation of applying CE methodologies and therefore refused to participate, regretting they cannot help the survey. Finally, time constraints due to the study schedule permit only about one month of time to provide an answer and the questionnaire may require more than 15 minutes to be filled in (depending on the sophistication of the answers), so it is highly probable that very busy people (e.g. near a project milestone) were unable to reserve sufficient time or attention to serve this purpose in parallel to their operations.

Only 20% of the participants declared a high familiarity with CE techniques and the use of PLM (Product Lifecycle Management) enhanced solutions in their companies. Regarding the low familiarity and appreciation of CE in AT (almost three out of four respondents denied to use any CE methodologies during the AT process), it is astonishing that the use of PDM (Product Data Management) and automated data sharing between applications, especially for I&T (integration and testing) activities, was reported to be widely in use. On the other hand the usage of PLM in AT was found to be significantly low (less than 10%).
The responses to the questionnaire highlight the fact that CE may provide benefits for anomalies in all the phases of the project (e.g. design, integration, testing, operations). This is based on both actual results and on the participants' personal appreciation. The extension to the overall lifecycle is limited by the lack of standards for a comprehensive life-cycle data exchange, by the elevated cost related to the application of innovative methodologies, by workers opposition against to the introduction of new processes and by a company-level opposition due to the lack of awareness of the benefits.

Responses to the questionnaires were integrated with information derived from publications. As an example, reports and publications about the following projects were investigated: European VIVACE (Value Improvement through a Virtual Aeronautical Collaborative Enterprise) Project, IIP (Integrated Information Platform for Reservoir and Subsea Production Systems) project, IAEA(International Atomic Energy Agency) "best practices" reports on the handling of anomalies, NASA-ARC ACES (Anomaly Consequences Evaluation Tool), CAIB (Columbia Accident Investigation Board) and Diaz Team reports.

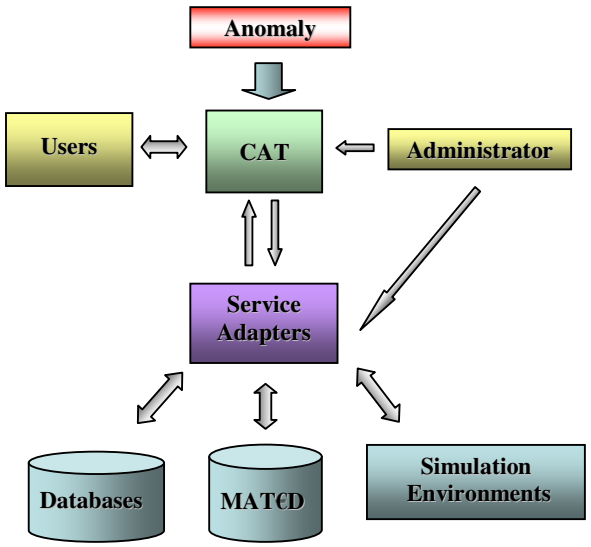
Near-term, mid-term and long-term recommendations were derived through the analysis of the state-of-the-art and of the evaluation of benefits and limitations of the use of CE in AT in the space domain.
The full profit of CE in AT is clearly submitted to the existence of a complete project lifecycle management (PLM), or in other words a data/models/knowledge database based on an integrated philosophy. In that direction are mostly oriented mid-term and long-term recommendations. While the PLM concept is in application through the space domain and its full implementation may be supposed in the mid/long term, the main objectives in the near-term are mainly founded on these aspects:

- Enhancement of data mining from different sources to enhance ease of retrieval of needed information
- Development and Integration of advanced collaborative IT (Information Technology) tools in the AT process
- Reuse of simulation environments used during the design phases to support AT investigation in all the subsequent phases. To that purposes it is necessary to take into account the possibility to reuse the simulation environments for AT purposes during their development.

In order ì to assess in which case it should be possible to experience a wider benefit, the AT process was focused on AIT activities and near-term recommendations during the study. These were then translated into requirements for a prototype tool (CAT – Collaborative Anomaly Tool), able to demonstrate the concepts and to provide a first assessment of possible benefits.

4. DEVELOPMENT OF THE C.A.T. PROTOTYPE

A prototypical implementation of the S/W tool (CAT – Collaborative Anomaly Tool) has been developed by Thales Alenia Space - Italia in collaboration with UNIPMN, according to the requirements developed during the first phase of the study. The implementation of the prototype aims to demonstrate the feasibility of the theoretical concepts rather than to provide a fully functional implementation of the methodology. Nonetheless, the outline of the final product is presented in a preliminary form so to show the feasibility of the implementation.
The prototype tool is intended to act as a centralized resource manager. It allows multiple actors to connect simultaneously, to share resources, to request further analyses, to inspect results of those analyses, to provide feedback to those who carried out the analysis, and, in particular, to better cooperate towards the common goal of solving the anomaly.
The anomaly is the input to the prototype tool and it generates the beginning of the investigation process. The prototype tool gives assistance to the user, helping him to solve the anomaly using external resources (data extracted from DB's, data exchanged to/from Simulation Environments, etc.). A logic schema is depicted below.



CAT is constituted by a collaborative layer which permits real-time exchange of information, a repository of relevant resources of the AT investigation process and the interface to external services that may be databases, data repositories, applications (e.g. simulation services) available through internet, company's intranet or dedicated connection. The interface with these services is guaranteed by the development of dedicated service adapters which

define the possible inputs/outputs from/to the CAT System. The development and the control of the service adapters is a responsibility of the owner of the service itself.

CAT tracks the process, simplifies the cooperation between the different involved actors and provides easily historical information retrieval, in order to speed up the investigation process using analyses based on service dependent engineering parameters.

In synthesis, the tool has the following macro functionalities:

- an easy exchange of information between actors;
- the upload and download of "resources" (requesting remote services by means of web-services);
- a common data interface (through Service Adapters) between CAT application and the Analyses/Simulation environments
- a web-service (e.g. public: the MAT€D, or local NCRDB search tool) simplifying the retrieval of similar NCR available in relational databases.

Through the intensive use of this tool, the above functions may provide better results, especially to the purpose of historical data mining.
The effective use of CAT, and especially of web-based services, is submitted to company-level choices on security and privacy of data. During the study recommendations were provided for the final implementation of the tool as a product, emphasizing what is necessary to provide a high security level. However, decisions made at company-level are the real constraints to the final utilization.

5. STUDY RESULTS

The study ended with a practical demonstration of the developed tool through three test cases chosen from real anomalies on the GOCE satellite that was under final AIV activities during the study.
GOCE (Gravity Field and Steady-State Ocean Circulation Explorer) is developed by Thales Alenia Space-Italia (Prime contractor) in collaboration with EADS Astrium Germany (for the Platform). It was chosen as the pilot project because both TAS-I and EADS Astrium were involved, the related AIT teams were operative and totally identifiable during the study, it is a multi partners project and for its complexity that guarantees the necessity to solve multi-disciplinary anomalies.

Three test cases were used to show the use of the CAT application and, at the same time, to demonstrate the occurrence of possible benefits. The benefits measurement was based on the comparison with data coming from the related non-conformance report or from the experience of the AIT team.

The three test cases were used to evaluate:

- Access and data mining of an historical database (ESA-MAT€D – Model and Test Effectiveness Database).
- Request of an online simulation service (TAS-I-CODE – COncurrent Design Environment)
- Request of an offline simulation service (EADS-Astrium MDVE – Model Based Development and Verification Environment)

The use of these three test cases demonstrates a large save on time related to the easily retrieval of information, on the common collaborative layer and on the possibility to recover concepts from past investigation activities.

Time saving may be quantified in minutes, hours or in days of investigation, depending on the case. It has to be counterbalanced with the time requested for the initial training and for the service adapters development and maintenance, which could be considerable in the first phases of utilization, but minor for a regular utilization.

Another important benefit derives from the wider availability of data sources coupled with the use of a single interface. This aspect may cause time savings and/or an improvement of quality of the investigation results, due to the possibility to check in real time different data sources.

6. RECOMMENDATIONS FOR THE FUTURE

The results coming from the final demonstration validate some of the near-term recommendations and in particular the benefits coming from an advanced collaborative IT tools with data-mining functions and with interface with engineering. However, both of these two functionalities require further work to be implemented for an effective usage during AIT activities.
In general, the interface with simulation environments would definitely profit from the standardization of product data-exchange methods and e.g. from the consequent usage of standardized/custom viewers able to process in an immediate way data coming from simulation and/or test logs.

The developers of simulation environments used for B/C phases should take into account the possible usage of their products during the AIT (or operational) phase and to provide, when possible, the service adapter for an automated analysis.

The enhancement of the CEMAT methodology should be facilitated with workshops on the subject, so to create a transversal working group across companies, academia and agencies and through the monitoring and analysis of upcoming methods and standards proposals.

From the software point of view CAT is not intended as a finished product. On the contrary, it is a prototype aiming at showing that the required functionalities are indeed worth of the efforts needed for their implementation and that their implementation is feasible.

Among what is needed to be addressed before CAT can be considered usable in the large scale, the primarily problem is that currently it is easily compromised by security problems. Changing this situation may require a small effort, even though it requires collaboration between system managers, CAT software developers, and external services developers.

Apart from security considerations, the improvement of CAT functionalities can be provided through an enhancement of data mining services and of trace management. The last one, if coupled with the effective usage of CAT during the AT activities of one or more projects, would provide a large amount of tracked data, especially for services request. It should definitely help to define what kind of data is needed and provide a tangible help/test bench for the definition of a standardized data-exchange method.

7. TEAM CONTACTS

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