ABSTRACT

Automotive systems are obviously becoming more and more complex. In fact, a typical vehicle is built using various communication networks, many electronic units and a never ending amount of software! The main problem automakers face now is related to the integration of different distributed functionalities, and often these functionalities are based on software. For these reasons it is very important to have an approach at “system” level in order to assure that the complete vehicle conforms to requirements and the statement of needs. It is also important that the testing phases assure a complete coverage of all requirements, in order to verify all system aspects.

In this context, the software, in general, plays an important role during all phases of system development: from requirement analysis, system architecture definition, system implementation and testing phases. The software is generally acquired by external suppliers and is already programmed in the electronic devices. Also in the case of internal software development, the supplier's role is very important in order to integrate all parts of software.

For these motivations, it is necessary to assure the quality of software acquired in order to manage the integration of the complete system. A possible approach used by OEMs (Original Equipment Manufacturers) to address this issue is to check the capability of the suppliers' software process. FIAT Group Automobiles (FGA), since the year 2001, has been taking proactive actions to address the situation. The basic strategy has been to set up criteria for qualifying software suppliers based on measuring the capability of their software processes.

In this article the policy defined by FGA to assess the capability of supplier's software processes is described in detail. The assessments made on the software process have allowed FGA to select suppliers on the basis of some objective and quantitative evidence of their level of quality. In addition, this initiative has been giving FGA a deeper knowledge of the way its suppliers produce, verify and maintain software. This is a fundamental step to building up the capability of monitoring, driving and improving the software projects in a collaborative effort with the suppliers.

The FGA policy is based on ISO 15504 (SPICE). In particular, FGA is using Automotive SPICE standard that has been developed by consensus of the European OEM. This article describes the assessment scope (what FGA evaluates), the assessment procedure (when the assessments are performed) and the relationship with project management activities used by FGA to evaluate supplier software development processes.

INTRODUCTION

The software complexity in automotive industry is increasing. New functionalities have been introduced in the past and new ones are expected for the future. Most functionality is based on electronic innovation: it is estimated that 90% of innovation will be electronics related and at least 60% will be in the area of software\(^1\).

This helps to illustrate that software is a good opportunity to realize better cars and vehicles, but it is necessary to manage it right way, in order to not decrease quality and reliability of vehicles! In general, software allows OEMs to increase the number of functionalities inside a vehicle and their

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\(^1\) Source: Reuse of Software in Distributed Embedded Automotive Systems, Audi 2004 - Embedded Automotive Electronics Symposium, Peugeot, June 23, 2004
complexity, but at the same moment, it is necessary to improve the capability to manage it.

For these reasons, it is necessary to introduce new methodologies, technologies and culture to manage the software development process in order to assure good quality in the products and guarantee that electronic systems are able to solve user needs.

SOFTWARE METHODOLOGIES USED IN FGA

In general, automotive electronic systems are characterized by high complexity, distributed architectures and high quantity of software. For these reasons, FGA has developed a “general software strategy” that concerns different aspects:

1). Requirements management: this task defines the system and component functionalities.

2). Requirements modeling and validation: validation is used to develop new functionalities and to improve the quality of requirements.

3). Software Project Management: methodologies to manage the software development process.

4). Supplier Process Assessment: SPICE or Automotive SPICE assessments are used to choose correctly the suppliers and help the Software Project Management

5). International standard: adoption of standard software modules that will be used in all ECUs. These modules concern both Software Component (SWC) and Basic Software (BSW) and are based on AUTOSAR specifications.

6). Software verification & Validation: FGA uses Software In the Loop, Model In the Loop and Rapid Prototyping and Hardware In the Loop methodologies in order to validate software during the development phases.

7). Software Development “In House”: FGA chooses to develop internally some software modules for specific ECUs, in order to increase the software reusability in different vehicle projects and protect Intellectual Property.

In this article only the points 3), “Software Project Management” and 4), “Supplier Process Assessment” are described.

SOFTWARE PROJECT MANAGEMENT

FGA has defined some methodologies to manage and control the software development. In particular, this approach is adopted when FGA acquires software or complete projects from suppliers.

In this case, FGA organizes several joint reviews during the software project life cycle. The main purpose of joint reviews is to monitor some critical characteristics of the software development process, in order to assure the product quality, assure the project time to market, control the development costs and analyze risks.

A software joint review is a systematic process for examining a project status at a given milestone. Software joint reviews combine both a management review and technical review into a single event. Effective software design reviews shall be prepared in advance by examining work products under review.

The anomalies and issues detected are referred to as Review Items Discrepancies (RIDs). A RID may refer to a document deficiency, a software problem, a misuse of a tool, a non conformance to a process rule, etc. A RID represents an issue opened by a software joint review and that has to be tracked until closure.

The following software joint reviews shall be planned for every software project:

Software Requirements Review (SRR)

This review shall ensure the correctness and completeness of the software requirements to be implemented. In addition the review will focus on project management.

Software Architecture Review (SAR)

This review shall confirm correctness and completeness of software architecture, agree on the technical approach and on implementation choices.

Software Test Readiness Review (STRR)

This review shall be conducted to confirm successful completion of coding, unit testing and integration testing and to gain confidence for the beginning of the software validation.

Software Validation Review (SVR)

This review shall be conducted to confirm successful completion of validation phase, and to gain confidence for the delivery to Fiat Group Automobiles. A successful validation review does not imply acceptance, as the software shall undergo a separate acceptance process after the validation review.

FGA organizes the different joint reviews during the development and verification phases of a project. Of course, the typology, the number, and the subject to analyze could
change depending on some aspects (for example, if the project is new or carry-over; if the project has to implement complex functionalities, etc.). In other words, to plan the software joint reviews it is necessary to analyze the project characteristics.

Moreover, the SPICE or Automotive SPICE assessment results are an important input to decide the effort necessary to dedicate to the joint reviews.

SUPPLIER PROCES ASSESSMENT: FGA POLICY

FGA has decided to use SPICE and AutomotiveSPICE methodologies in order to:

• Improve the FGA “Supplier Selection Process” and base it on supplier “software capability”
• Set up a methodology supporting the management of software projects and suppliers
• Analyze a “capability” and a “risk” level for each software supplier
• Identify the weak and the strong areas of the supplier's software development process
• Require suppliers to improve some areas of the software development process

AUTOMOTIVE SPICE: WHAT IS IT?

The Automotive SPICE has been developed by consensus of many OEMs (AUDI, BMW, Daimler, FIAT Group Automobiles (FGA), Ford, Jaguar / Land Rover, Porsche, Volkswagen, Volvo) within the Automotive Special Interest Group (SIG) of the joint Procurement Forum / SPICE User Group under the Automotive SPICE initiative.

Automotive SPICE is defined by these two kinds of documents:

• PRM - Process Reference Model
• PAM - Process Assessment Model

The Automotive SPICE Process Reference Model (PRM) is derived from Annex F and H of ISO/IEC 12207 AMD1: 2002 and ISO/IEC 12207 AMD2: 2004. It contains a sub set of the processes with minor editorial changes together with a number of other changes to reflect consistency in use of terminology and application in the automotive sector. The Automotive SPICE PRM uses the process capability attributes and rating scheme defined in ISO/IEC 15502-2 and provides a common framework for assessing the software process capability of automotive suppliers.

The Automotive SPICE Process Assessment Model (PAM) is available for use when performing compliance assessments of the software process capability of automotive suppliers according to the requirements of ISO/IEC 15504-2. The Automotive SPICE Process Assessment Model (PAM) comprises a set of assessment indicators of process performance and process capability. The indicators are used as a basis for collecting the objective evidence that enables an assessor to assign ratings. The Automotive SPICE Process Reference Model with the associated process attributes defined in ISO/IEC 15504-2 provides a common basis for performing assessments process capability, allowing for the reporting of results using a common rating scale.

The Process Assessment Model defines a two-dimensional model of process capability. In one dimension, the process dimension, the processes are defined and classified into process categories. In the other dimension, the capability dimension, a set of process attributes grouped into capability levels is defined. The process attributes provide the measurable characteristics of process capability.

For the process dimension, the Automotive SPICE Process Reference Model (PRM) provides the set of processes. The processes are classified into process categories and process groups. There are 3 process categories: Primary Life Cycle Processes, Organizational Life Cycle Processes and Supporting Life Cycle Processes. Each process is described in terms of a purpose statement. These statements contain the unique functional objectives of the process when performed in a particular environment. A list of specific outcomes is associated with each of the process purpose statements, as a list of expected positive results of the process performance.

For the capability dimension, the process capability levels and process attributes are identical to those defined in ISO/IEC 15504-2. Evolving process capability is expressed in the Process Assessment Model in terms of process attributes grouped into capability levels. Process attributes are features of a process that can be evaluated on a scale of achievement, providing a measure of the capability of the process. They are
applicable to all processes. Each process attribute describes a facet of the overall capability of managing and improving the effectiveness of a process in achieving its purpose and contributing to the business goals of the organization.

A capability level is a set of process attribute(s) that work together to provide a major enhancement in the capability to perform a process. Each level provides a major enhancement of capability in the performance of a process. The levels constitute a rational way of progressing through improvement of the capability of any process and are defined in ISO/IEC 15504-2. There are six capability levels:

- **Level 0: Incomplete process** The process is not implemented, or fails to achieve its process purpose. At this level, there is little or no evidence of any systematic achievement of the process purpose.

- **Level 1: Performed process** The implemented process achieves its process purpose.

- **Level 2: Managed process** The previously described Performed process is now implemented in a managed fashion (planned, monitored and adjusted) and its work products are appropriately established, controlled and maintained.

- **Level 3: Established process** The previously described Managed process is now implemented using a defined process that is capable of achieving its process outcomes.

- **Level 4: Predictable process** The previously described Established process now operates within defined limits to achieve its process outcomes.

- **Level 5: Optimizing process** The previously described Predictable process is continuously improved to meet relevant current and projected business goals.

Within the Process Assessment Model, the measure of capability is based upon the nine process attributes (PA) defined in ISO/IEC 15504-2. Process attributes are used to determine whether a process has reached a given capability. Each attribute measures a particular aspect of the process capability.

**FGA ASSESSMENT HISTORY**

The project has now been in place for 5 years, from 2000 to 2005.

During the first phase (2000 - 2003) FGA has selected SPICE assessment methodology, defined a first assessment scope and organized 15 SPICE assessments.

In the second phase (2003), FGA analyzed the assessment results and, then, defined a new assessment scope, new guidelines and a new policy.

Phase 3 (2004-2005) used these new guidelines to organize the other 12 assessments. From this phase, SPICE assessment became a standard activity to evaluate supplier's software capability.

The project finished at the end of 2005, and from January 2006 FGA requires that every supplier shall be assessed using ISO/IEC 15504 (SPICE) or Automotive SPICE in order to participate at sourcing phase (the requirement is stated in our Request For sourcing phase (the requirement is stated in our Request For Quotation or Proposal (RFQ / RFP) - formal document used to require technical and economical quotation).

During 2009, FGA analyzed assessment results, supplier feedbacks, improvement projects, etc. in order to define a new and more effective "Assessment Policy". At the end of 2009, FGA published the new standard that is now used to manage all vehicle projects. In this article, this new policy is described in detail.

**AUTOMOTIVE SPICE ASSESSMENT: FGA POLICY**

FGA policy defines the requirements of SPICE and Automotive SPICE assessment. This policy is part of the FGA RFQ, a document used to manage supplier offers.

The main idea for this policy is to use Automotive SPICE to evaluate a specific project and to determine if it is necessary to start an improvement plan. In particular, the FGA Policy establishes a method to evaluate the process capability level of a specific supplier at the end of a project. In this case, the assessment is done on a real project developed for FGA and it is possible to avoid too general evaluations. If the assessment results are not conforming to FGA requirements (see following paragraphs), the supplier has to define and implement an improvement plan.

This approach doesn't allow evaluating the capability level of a supplier before the “first project” (perhaps this one is the only disadvantage of this policy…), but the assessment results are used to select that supplier for following projects. As mentioned before, the FGA Policy and the assessment requirements are part of FGA RFQ contractual documents.

In the following paragraphs the main concepts of FGA policy are analyzed.

The main points of FGA policy are the followings:

1. The assessment scope shall be compliant with FGA Assessment scope (see paragraph “Assessment Scope”): both set of processes and expected capability levels.
2. The assessment shall be relevant to the Department / Office / Company that will actually be in charge of the software development.
3. The assessment results provided shall be recent (not more than three years old)
4. The assessment shall be repeated - at least - every three years.

5. The assessment shall be performed by an external, independent (third party) organization.

6. The assessors in the assessment team must be qualified according to an internationally recognized assessor qualification scheme (INTACS or IntRSA).

7. The assessment shall cover the complete supply chain, involved in all software development and verification phases.

FGA ASSESSMENT SCOPE

In order to evaluate the process level capability of a Company or an Organization, it is necessary to define a set of processes to assess and establish a “level capability” for each of them.

The process set and the level capability is called “assessment scope”. It is very important also to collect data, organize the assessment itself and compare the results of different organization. The assessment scope defined by FGA is based on Automotive SPICE PRM (Process Reference Model) and is summarized in Table 1:

<table>
<thead>
<tr>
<th>Process</th>
<th>Expected Capability Level</th>
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<tbody>
<tr>
<td>ENG.1: Requirements Elicitation</td>
<td>2</td>
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<tr>
<td>ENG.2: System Requirements Analysis</td>
<td>2</td>
</tr>
<tr>
<td>ENG.3: System architectural design</td>
<td>2</td>
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<tr>
<td>ENG.4: Software requirements analysis</td>
<td>2</td>
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<tr>
<td>ENG.5: Software Design</td>
<td>2</td>
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<tr>
<td>ENG.6: Software construction</td>
<td>2</td>
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<tr>
<td>ENG.7: Software integration</td>
<td>2</td>
</tr>
<tr>
<td>ENG.8: Software Testing</td>
<td>2</td>
</tr>
<tr>
<td>ENG.9: System integration</td>
<td>2</td>
</tr>
<tr>
<td>ENG.10: System Testing</td>
<td>2</td>
</tr>
<tr>
<td>MAN.3: Project Management</td>
<td>2</td>
</tr>
<tr>
<td>MAN.5: Risk Management</td>
<td>2</td>
</tr>
<tr>
<td>SUP.1: Quality assurance</td>
<td>2</td>
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<tr>
<td>SUP.3: Joint Review</td>
<td>2</td>
</tr>
<tr>
<td>SUP.8: Configuration Management</td>
<td>2</td>
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<tr>
<td>SUP.9: Problem resolution management</td>
<td>2</td>
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<tr>
<td>SUP.10: Change request management</td>
<td>2</td>
</tr>
<tr>
<td>ACQ.4: Supplier Monitoring</td>
<td>2</td>
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<tr>
<td>SPL.2: Product Release</td>
<td>2</td>
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</tbody>
</table>
Of course, this scope defines the minimum set of processes to be assessed. If a supplier wants to extend this scope, they are free to do so, but they must comply with this scope.

An assessment is successfully completed only if all assessed processes reach at least the expected capability level. If the capability level doesn't reach the expected one, the supplier shall define an improvement plan. This plan shall be agreed with FGA to validate the technical aspects and the time scheduling.

WHEN TO DO THE ASSESSMENT?

After the assessment scope definition, it is necessary to define when to evaluate the process capability. Obviously it is possible to do this evaluation in various phases of a vehicle project and with different target. FGA policy defines these aspects related to vehicle project life cycle. In particular, FGA has two macro phases: “concept set-up” and “vehicle development”. During the “concept set-up”, an important activity is to select the suppliers that will develop the ECUs of the electric / electronic system: this activity is called “Sourcing Phase”

During the “Sourcing Phase” of a specific vehicle project, the supplier shall show the result of a previous SPICE or AutomotiveSPICE or CMMI assessment (the CMMI standard is included because some supplier is using it to evaluate the maturity of his processes). This assessment result allows verifying the capability or maturity level of supplier's processes. In other words, FGA considers the assessment results as a criterion to select the supplier.

Depending on this assessment result, the following scenarios are possible:

1. If the assessment result **DOES NOT conform** to FGA requirements (see paragraph “Automotive Spice Assessment”) and if the **supplier has been selected** for a specific vehicle project, then the **supplier shall put in place an improvement plan** aimed to the specific vehicle project. At the end of the project the supplier will be assessed using **Automotive SPICE standard**.

2. If the assessment result **DOES conform** to FGA requirements (see paragraph “Automotive Spice Assessment”) and if the **supplier has been selected** for a specific vehicle project, then, at the end of the project, the **supplier could be assessed** using **Automotive SPICE standard**.

**NOTE:** if the supplier does not have a previous assessment result to show, the scenario (1) shall be used.

In the scenario (1), the assessment at the end of the project shall be:
- organized by FGA
- executed by assessors selected by FGA or agreed with FGA
- paid by the supplier

In the scenario (2), the assessment at the end of the project shall be:
- organized by FGA
- executed by assessors selected by FGA
- paid by FGA

Both in scenario (1) and in scenario (2), if the assessment at the end of the project does not conform to FGA Assessment Scope, the supplier shall put in place an improvement plan agreed with FGA. At the end of the improvement plan, the supplier shall be evaluated with a “delta-assessment” using Automotive SPICE standard.

In this case, both the improvement plan and the “delta-assessment” shall be:
- organized by the supplier
- agreed with FGA
- paid by the supplier

The “delta-assessment” shall be executed by assessors selected by FGA or agreed with FGA.

Figure 2. shows the flow for the two assessment scenarios:

**SUMMARY/CONCLUSIONS**

In general, in the automotive market it is possible to see that the electronic systems are more and more complex, the electronic architectures are distributed, the quantity of software is very high and a single vehicle project integrates many suppliers.

For these reasons, FGA has defined effective methodologies in order to manage a large spread of problems concerning electronics equipment software development, testing and maintenance.

SPICE or Automotive SPICE plays a very important role because FGA is using those methodologies to select suppliers and drive process improvement. FGA has developed their own specific policy in order to evaluate the capability level of a set of processes based on the Automotive SPICE standard. Since 2006, this supplier selection and the process improvement plan have been in place. The new policy, started in January 2010, confirms this decision.

The new 2010 FGA Policy has been developed in order to evaluate more stringently each software project. In fact, at the end of the project, an Automotive SPICE is organized to
evaluate if the projects has been developed applying correctly processes and base practices. This result is used not only to evaluate the capability level of the finished project, but first of all to have a concrete evaluation of the capability of supplier for future projects. Moreover, the assessment result is also used to start some “improvement plan” in order to increase the capability levels of a specific supplier: the improvements are evaluated with so called “delta assessment”.

REFERENCES
7. BS 7925-1, Glossary of Terms used in Software Testing
8. TFO 09001 - Electronic Software Capability Evaluation (FGA internal standard)
9. TFO 09006 - Software Design Review (FGA internal standard)
10. Automotive SPICE - Process Reference Model (PRM) - ver. 4.4
11. Automotive SPICE - Process Assessment Model (PAM) - ver. 2.4