Abstract

Automotive Software Architectures
As software is covering more and more functionality in cars, software architectures draw more attention. Software architectures represent the earliest design decisions in the development process. They have far-reaching effects on the quality attributes of the system and, thus, are extremely difficult to get right first and hard to change later on. The Architecture Trade-off Analysis Method (ATAM) developed by the SEI assesses the quality of software architecture early in the development process. ATAM is a scenario-based review method that uses business goals to evaluate the quality of software architectures.

Bosch Experience
Bosch uses ATAM for five years in reviewing important software and system architectures. The improvement of the method and the knowledge transition from the SEI to Bosch will be discussed in detail.

Benefits of ATAM
Benefits in using ATAM are not only the review results itself but a better documented and better understood architecture. We experienced that the most important benefit of ATAM is the rising stakeholders' awareness of architectural decisions, tradeoffs, and risks. It illuminates the software architecture better than any written documentation.
Outline

- Bosch and Software
- Automotive Software Architectures
- Architecture Tradeoff Analysis Method (ATAM)
- Bosch ATAM Experience
- Benefits of ATAM

Key Data

<table>
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<tr>
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<th>2002</th>
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<tr>
<td>Sales</td>
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<td>Sales outside Germany as percent of total</td>
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<td>Average number of associates</td>
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<td>in Germany</td>
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<td>outside Germany</td>
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<td>Investments in tangible fixed assets</td>
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<td>Expenditures for research and development</td>
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<td>Net income</td>
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Amounts in million euros
# Milestones in Automotive Technology

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<tr>
<th>Year</th>
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<tr>
<td></td>
<td>Low-voltage magneto for vehicles</td>
<td>High-voltage magneto for vehicles with spark plug</td>
<td>Diesel fuel-injection pump</td>
<td>Gasoline fuel-injection pump</td>
<td>Electronically controlled gasoline fuel injection (Jetronic)</td>
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<table>
<thead>
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<tbody>
<tr>
<td></td>
<td>Lambda oxygen sensor for vehicles</td>
<td>Antilock Braking System (ABS)</td>
<td>Combined digital control of gasoline injection and ignition (Motronic)</td>
<td>Electronic Diesel Control (EDC); Traction Control (TCS)</td>
<td>Controller Area Network (CAN)</td>
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<table>
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<th>Year</th>
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<th>2001</th>
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<td>Electronic Stability Program (ESP); Vehicle navigation systems with voice output routing</td>
<td>High pressure injection system Common Rail for diesel engines</td>
<td>Electro-hydraulic brake (SBC)</td>
<td>Electronic Battery Management (EBM)</td>
<td>Third generation of common rail, with piezo inline injectors</td>
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## Distribution of Sales 2003

<table>
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<tr>
<th>Business Sector</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Automotive Technology</td>
<td>23.6 %</td>
</tr>
<tr>
<td>Industrial Technology</td>
<td>8.5 %</td>
</tr>
<tr>
<td>Consumer Goods and Building Technology</td>
<td>4.3 %</td>
</tr>
<tr>
<td>Total</td>
<td><strong>65.0 %</strong></td>
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</table>

Total: 36.4 bn euros
Architecture Reviews @ Bosch

Associates by region

- Germany: 108,700 (46.9%)
- Europe: 57,450 (24.8%)
- North and South America: 31,200 (13.5%)
- Asia/Africa/Australia: 34,250 (14.8%)

Total: 231,600
As per January 2004

New York 1906: 160 West 56th Street
Software has become a core technology. Many companies never envisioned that they would participate in Software Business.

Bosch and Software?

- I can’t buy Bosch Software for my PC!
- I don’t buy Bosch Software in a shop!

⇒ ... but you use it every day
Example: Engine Control Software

- **Purpose**
  - Controls air, injection, ignition, and exhaust
  - User Interface: Pedals, Cruise Control
  - Theft Control, BUS-Gateway, ...

- **Size**
  - 250-400 kLOC per engine

- **Development Effort**
  - 0.5 - 10 Man-Year per engine
  - about 1,200 engineers

- **Number of Products**
  - 1,000 software products per Year
  - 30,000 control units per Day

Architecture Reviews @ Bosch

Complexity of Today’s Cars

- 61 Control Units
- 3 Bus-Systems, 1 optical Bus, Sub-Buses
- 2,500 Signals in
  - 250 CAN-Messages
- > 50 MB Memory
- 2,110 Connections
- 3,860 m Wire
"Explosion" of Functionality

Stand-alone systems (interactions by dedicated wires)  In-Vehicle networking  Vehicle linked to environment

Lines of Code*

10^10 10^8 10^6 10^4 10^2 10^0


*All systems in a car (Source: DaimlerChrysler 2002)
Bosch Software Product Lines across BUs

- Platforms are an **essential** concept of RB-development
  - Platforms in production 50
  - New Platforms currently under development >7

- Strong reuse culture within Bosch

- Bosch Initiative for software-intensive Systems (BISS)
  - Change Agent for systematic software product lines
  - Support organization in corporate research
  - Combined with Process Improvement (CMMI)

Autosar Partners and Members

Up-to-date status: see http://www.autosar.org
ATAM Overview

The Architecture Tradeoff Analysis Method℠

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, PA 15213

This work is sponsored by the U.S. Department of Defense.

Æ ATAM and Architecture Tradeoff Analysis Method are registered service marks of Carnegie Mellon University

Why Analyze an Architecture?

→ A software architecture
  - is the earliest life-cycle artifact
  - embodies significant design decisions
  - a good architecture is based upon good decisions

→ All architectural decisions
  - are choices among alternatives
  - involve tradeoffs

→ The purpose of the ATAM is:
→ To assess the consequences of architectural decisions
  in light of quality attribute requirements and business goals.
Purpose of the ATAM

- ATAM is an early lifecycle analysis method that is designed to:
  - Discover risks ñ decisions that might create future problems in some quality attribute
  - Discover tradeoffs ñ decisions affecting more than one quality attribute
  - Discover sensitivity points ñ decisions for which a slight change makes a significant difference in some quality attribute
- The purpose of an ATAM is NOT to provide precise analyses ... the purpose IS to discover risks created by architectural decisions.
- We want to find trends: correlation between architectural decisions and predictions of system properties.
- Discovered risks can then be made the focus of mitigation activities: e.g. further design, further analysis, prototyping.
- Surfaced tradeoffs can be explicitly identified and documented.

Stakeholder bring their Quality Scenarios

- CEO
- Architect
- COO
- Core Asset Developer
- Technical Manager
- Marketer
- Tester Engineer
- Calibration Engineer

Slide white box reused from Lindaës Product Line Standard Presentation (SEI)
It is an unbearable thought to me that while checking one of my products, somebody could show that I in some way performed inferior work. For this reason, I have always endeavored to only deliver work which will pass any objective test, work that is, so to say, the very best of the best.

*Robert Bosch, 1918*
ATAM Steps

1. Present the ATAM
2. Present business drivers
3. Present architecture
4. Identify architectural approaches
5. Generate utility tree
6. Analyze architectural approaches
7. Brainstorm and prioritize scenarios
8. Analyze architectural approaches
9. Present results


- Terms
- Roles
- Process
- Process Steps
  - participants
  - entry condition
  - inputs
  - activity
  - outputs
  - exit condition
  - next step or phase
- Templates

<table>
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<tr>
<th>Process Model for Phase 0: Partnership and Preparation</th>
<th>Step 3: Make a Go/No-Go Decision</th>
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<tbody>
<tr>
<td>Description</td>
<td>References</td>
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<tr>
<td>Participants</td>
<td>Table 15, &quot;Step 2: Describe Candidate System,” page 48</td>
</tr>
<tr>
<td>Evaluation organization members who attended the &quot;Step 2: Describe Candidate System&quot; step</td>
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<tr>
<td>Others empowered to contribute to or make a go/no-go decision</td>
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<tr>
<td>Entry Condition(s)</td>
<td>Table 15, &quot;Step 2: Describe Candidate System,” page 48</td>
</tr>
<tr>
<td>Evaluation organization representatives understood state of the architecture (as described in the previous step) well enough to make a decision</td>
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<td>Input(s)</td>
<td>Table 16, &quot;Step 2: Describe Candidate System,” page 48</td>
</tr>
<tr>
<td>ATAM Go/No-Go decision criteria</td>
<td>ARG page 310</td>
</tr>
<tr>
<td>Candidate system documents from &quot;Step 2: Describe Candidate System” step</td>
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<td>Activity</td>
<td>Table 17, &quot;Step 4: Negotiate the Statement of Work,” page 153</td>
</tr>
<tr>
<td>Apply Go/No-Go decision criteria</td>
<td>TD</td>
</tr>
<tr>
<td>If &quot;No-Go,&quot; develop plan of action</td>
<td></td>
</tr>
<tr>
<td>Output(s)</td>
<td></td>
</tr>
<tr>
<td>If &quot;No-Go,&quot; reject and re-engage processes</td>
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<tr>
<td>Exit Condition(s)</td>
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<td>Go/No-Go decision made</td>
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<td>Next Step or Phase</td>
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<td># &quot;Go,&quot; Step 4: Negotiate the Statement of Work</td>
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<tr>
<td># &quot;No-Go,&quot; stop.</td>
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ATAM Phases

ATAM\textsuperscript{SM} evaluations are conducted in four phases.

- **Phase 0:** Partnership and Preparation
  - Duration: varies
  - Location: primarily phone, email

- **Phase 1:** Initial Evaluation
  - Duration: 1.5 - 2 days each for Phase 1 and Phase 2
  - Location: typically conducted at customer site

- **Phase 2:** Complete Evaluation
  - Duration: varies
  - Location: primarily phone, email

- **Phase 3:** Follow-up

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**Time-Slice Real Time System**
- Several Years in a Product Line
- Architecture Development is introduced
- Reengineering of Architecture

**Component Base System**
- Domain Expertise: Prototypes
- Well established Architecture Development
- Exemplary Architecture Documentation

**SW Development staff:** 340
- Extensive preparation
- Big stakeholder group
- Organizational wide distribution of results

**Software Engineers:** 25
- Minor preparation
- Small stakeholder group
- Results did not spread around
Four Automotive Application Domains - 2

- Event and Periodic Time System
- Prototypes
- Architecture Development is established
- Sufficient Architecture Documentation
- SW-Engineers: 10 Research + 30 Business Unit
- small stakeholder group
- Organizational wide distribution of distilled results

- Time-Slice Real Time System
- Two Products in new Domain
- Architecture Development is introduced: first review
- Some Architecture Documentation
- SW-Engineers: 30
- adequate stakeholder group
- we don’t know

Statistical Data of ten ATAM cases

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Statistical Data of ten ATAM cases

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<td>31</td>
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</table>

2 days Duration of ATAM workshop

ATAM Cost of Evaluating*

*does not include effort or costs for the reviewers
ATAM Impact

➔ On Architecture
  • Risk avoidance
  • Better Documentation
  • Identification of non-risks

➔ On People
  • Disappointment
  • Consciousness and Influence of Architecture and of Business
  • More and documented insight

➔ Management
  • Long term adjustment of strategy (ATAM one piece in the puzzle)

ATAM Success Factors

➔ Having a well documented software architecture
➔ or having architects that are able to communicate the architecture in the workshop.
➔ Presenting a realistic and the real business case
➔ Do not just make scenarios. Refine and rework them to make good scenarios.
➔ Invite all software architecture related stakeholders to the workshop.
➔ Make management, sales, marketing participate at least for steps 1-3 and step 9.
➔ Facilitate active participations of stakeholders.
➔ Get hold of capable evaluation leader.
➔ Enforce the process strictly during the ATAM workshop.
➔ Make sure, every participant understands how ATAM works.
Unwritten Story of ATAM

→ Social Aspect!

- Some roles meet the first time ever
- What was important? - Talks during the break!"
Transition ATAM to Bosch

- **History**
  - First ATAM: Bosch Observers (2000)
  - ATAM Evaluator and Facilitator Training (2004-2005)
  - 5-x ATAM: Bosch Team (2004-)

- **Working style**
  - Cultural Differences overcome by Team in Frankfurt, Business units in Stuttgart (English vs. German, $$$ vs. Ä, Software vs. Bosch)
  - Meetings and Phone Conference
  - Partnership build on Trust

Make ATAM Industry Standard

- Bosch’s Interest is to make ATAM World Wide Industry Standard (like CMMI product suite)

- **SEI ATAM Challenges:**
  - Extensive Course & License Requirements:
    - Costs ($40k) and Time (34d) required for companies to adopt
  - ATAM is not wide spread enough wrt its maturity
  - Quality Assurance unclear
  - No service provider available today
  - Establish in the SEI Partner network (not only Academia)
Conclusion

- ATAM is a mature method, SEI Certification available
- ATAM has well defined process and roles
- ATAM is the right review method for product line architectures at important mile stones
- Not inexpensive, but good cost/benefit ratio
- Cost of evaluating and cost of communicating
- Bosch will continue using ATAM
- Transitioning ATAM to Bosch Corporate Research finished
- SEI needs more commitment to introduce ATAM into industry

- The most important benefit of ATAM is the stakeholders' awareness of architectural decisions, tradeoffs, and risks.