When things get complex

Complex Systems, challenges and where to focus

Georg Doll, Senior Expert, McKinsey Digital Munich
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As Member and Co-Lead of the EMEA Software Service line at McKinsey Digital, he supports clients along the product development LiveCycle. With his background of over 20 years’ experience in Automotive and embedded Software delivery and management of international teams. He supports clients in Market introduction planning, introduction of systems engineering, improving in project execution excellence and agile software development and talent management.

He has served Tier1s, semiconductor vendors and vehicle manufacturers around the world in Japan, Asia Pacific, EMEA and US.

In 2009 he was instrumental in setting up the GENIVI Alliance, and served as member of the Strategy Council and the Board for several years.
Abstract

Software is on the rise. Software is the no. 1 topic in the development of new functions. The software market is expected to grow from today to 2030 with an average CAGR of ~10%. So what could go wrong?

A closer look at the four major automotive trends shows that they depend on the success of software. OEMs and Tier1s have recognized the situation and are investing heavily in software.

To the extent that some speak of a "software defined car" or a "computer on wheels".

But where there is light, there is also shadow. Highly automated driving, connectivity, powertrain electrification and new mobility services introduce additional dependencies between functions.

Dependencies that – as we know continue to increase the system complexity.

The development of software is a constant challenge for projects. What seems trivial at first glance turns out to be a much greater challenge than many people expect. Falling productivity, increasing communication, declining quality, constantly rising development costs and project delays are omnipresent.

These challenges can only be tackled with a holistic approach.

Successful organization have mastered the most important dimensions. Development tools, program management and talent management are just some of this dimensions.
Software is on the rise..

and it is complex.
Christoph Grote
SVP Electronics at BMW

“Today **95% of innovation** in automotive is **software** based”

Olla Källenius
Chairman of the Board
Daimler AG and Mercedes-Benz AG

“**To stay relevant we have to control the Software in our vehicles**”

LinusTorwald
Principal developer Linux Kernel

“The value of Software is not in the code, **its in the head of the people** who developed the code”
Components

<table>
<thead>
<tr>
<th>Components</th>
<th>Estimated CAGR 2020 - 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software (functions, OS, middleware)</td>
<td>9%</td>
</tr>
<tr>
<td>Integration, verification and validation</td>
<td>10%</td>
</tr>
<tr>
<td>Electronics ECUs/DCUs</td>
<td>6%</td>
</tr>
<tr>
<td>Sensors</td>
<td>7%</td>
</tr>
<tr>
<td>Power electronics (excl. battery cells)</td>
<td>18%</td>
</tr>
<tr>
<td>Other electronic components</td>
<td>3%</td>
</tr>
</tbody>
</table>

Automotive sales USD billions

<table>
<thead>
<tr>
<th>Year</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>2,755</td>
<td>3,027</td>
<td>3,800</td>
</tr>
</tbody>
</table>

Estimated CAGR 2020 - 30: 3%
Components

<table>
<thead>
<tr>
<th>Components</th>
<th>Estimated CAGR 2020 - 30</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software (functions, OS, middleware)</td>
<td>9%</td>
<td>50</td>
</tr>
<tr>
<td>Integration, verification and validation</td>
<td>10%</td>
<td>34</td>
</tr>
<tr>
<td>Electronics ECUs/DCUs</td>
<td>6%</td>
<td>156</td>
</tr>
<tr>
<td>Sensors</td>
<td>7%</td>
<td>63</td>
</tr>
<tr>
<td>Power electronics (excl. battery cells)</td>
<td>18%</td>
<td>81</td>
</tr>
<tr>
<td>Other electronic components</td>
<td>3%</td>
<td>85</td>
</tr>
</tbody>
</table>

Automotive sales

- USD billions
- 2020: 2,755
- 2025: 3,027
- 2030: 3,800

Estimated CAGR

- 2020 - 2030: 7%
- 2020 - 2035: 3%

Components

- 2020: 2,755 USD billions
- 2025: 3,027 USD billions
- 2030: 3,800 USD billions
Autonomous Connectivity
Shared mobility Electrification
Autonomous Connectivity

Shared mobility Electrification
Emission regulations drive need for new power train solutions

Eco functions require tighter function integration

Eco functions bring the need for new sensors

Electrification brings new technologies into the car

Road safety requirements drive the need for new sensors

Connectivity introduces security threads

Connectivity brings new features to the fleet

ADAS functions increase safety levels of vehicle functions

Highly automated driving increases functional dependencies
Emission regulations drive need for new power train solutions
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Eco functions require tighter function integration
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Eco functions bring the need for new sensors
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Electrification brings new technologies into the car
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Road safety requirements drive the need for new sensors
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Connectivity introduces security threads
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Connectivity brings new features to the fleet
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ADAS functions increase safety levels of vehicle functions
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Highly automated driving increases functional dependencies

**SOURCE:** McKinsey Numetrics analytics on SW complexity and productivity in automotive
### Complexity Dimension

<table>
<thead>
<tr>
<th>Complexity Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional redundancy</td>
<td>Multiple applications covering same functionality redundantly in the portfolio. Overlapping functionality between components in the same system.</td>
</tr>
<tr>
<td>Versions variety</td>
<td>Multiple versions of the same application/system are “live” at the same time.</td>
</tr>
<tr>
<td>Interfering sub-systems</td>
<td>Multiple applications/sub-systems within a SW platform are competing for similar resources (compute, storage, power).</td>
</tr>
<tr>
<td>Closed systems</td>
<td>Components within a system are developed as monoliths impeding accessibility of single elements for updates/maintenanc and integration within new development.</td>
</tr>
<tr>
<td>Point to point interfaces</td>
<td>Unmanaged interdependencies between systems are developed as point-to-point interfaces leading to a high complexity and variety of interfaces within and beyond the system.</td>
</tr>
<tr>
<td>Multiple HW platforms</td>
<td>Operating system, HW complexity, and testing environment with strong influence on system complexity.</td>
</tr>
<tr>
<td>Code and documentation quality</td>
<td>Code size, quality, and documentation as further sources of complexity throughout the lifecycle.</td>
</tr>
</tbody>
</table>

### Lifecycle

- **Product**
- **Portfolio**
3 Interfering sub-systems

<table>
<thead>
<tr>
<th>Sub-systems</th>
<th>Test effort</th>
<th>Required tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large amount interfering systems</td>
<td>Rising exponentially</td>
<td></td>
</tr>
<tr>
<td>Small isolated systems</td>
<td>Rising linearly</td>
<td></td>
</tr>
</tbody>
</table>

Test complexity per function: The smaller is the isolated system, the smaller is the exponential part of the test complexity.
5  Point to point Interfaces

- Cloud platform
- Connectivity (back-haul)
- UI/UX/HMI
- Applications
- Artificial intelligence/Advanced analytics
- Middleware layer/OS
- E/E hardware
- Sensors | Actuators | Power components
- Vehicle
- Computer on wheels
- Centralized Computing
- Cross-functional connection
- Collaboration of ECUs
- Isolated Functions
How to standardize Software across my different product lines and product generations?

How can I ensure that my 1 billion USD software investment is delivered on time and on budget?

How to transform 10,000 hardware-oriented developers to an agile-minded, software-driven organization?

My software org is a black box to me. How do I assess and boost the embedded software dev. productivity of my 5,000 distributed developers and my suppliers?

How to organize software developers across my divisions?

How do I get access to the best software talent?

How to transform our management systems to drive world class embedded software performance?
Top organizations show the potential increase in Software development performance for average and bottom quartile organizations.

<table>
<thead>
<tr>
<th>Productivity</th>
<th>Development throughput</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complexity units per man week&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Complexity units per week&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Residual design defects&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>65</td>
<td>65</td>
<td>155</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>175</td>
<td>224</td>
<td>65</td>
</tr>
<tr>
<td>2,7x</td>
<td>3,4x</td>
<td>-83%</td>
</tr>
</tbody>
</table>

<sup>1</sup> Average indexed to 100

SOURCE: Numetrics embedded SW project database
Developer Velocity Index (DVI)

**Deep structured interviews**
100+ industry experts

**Comprehensive survey**
440 large organizations across 12 industries and 9 countries

**Statistical correlation analysis**
Business performance (financial performance, innovation, customer experience, brand, talent) against the various dimensions of DVI

**Technology**

**Working practices**

**Organizational enablement**
DVI is calculated as a weighted average of the scores for the 43 drivers across 3 dimensions.
1. Calculated using Johnson’s Relative Weights: % importance is relative importance of driver on business outcomes. Total sums to 100%. Higher % indicates stronger impact on business performance.

2. Average score for Innovation, Customer Satisfaction, Brand, and Talent.

Source: McKinsey Developer Velocity Survey, Expert Interview
Software is a people business

The key success factors
- Culture
- Talent Management
- Development Tools
- Product Management

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Principal developer Linux Kernel

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Thank You