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Trusted Global Innovator

WHITEPAPER / AUTOMOTIVE

Application Lifecycle Management (ALM) for the Software-Defined Vehicle

Autonomous, **C**onnected, **E**lectric and **S**hared –
NTT DATA's Business Capability Model for ACES ALM

Content

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1. Introduction

Dear readers,

today's vehicles come with a fair amount of software. Automotive software development and also the respective Application Lifecycle Management (ALM) are subject to certain drivers that carmakers should take into account in an **A**utonomous, **C**onnected, **E**lectric and **S**hared (ACES) ecosystem. Professional, automotive-grade software engineering is the basis for the software-defined car. At NTT DATA, we provide a comprehensive analysis of the business capabilities required to develop and maintain automotive software over the lifecycle.

Business capabilities are the building blocks of the business, but they are abstracted from the organizational model in order to become more stable in times of continuous improvement, reorganizations and agile working models. Business capabilities describe the "what", not the "how". They are a proven method in Enterprise Architecture Management (EAM).

This whitepaper is based on our systems engineering consulting projects at major automotive OEMs and suppliers. More specifically, we extended our integration architecture blueprint SENSEI (**S**ystems **E**ngineering a**N**d **S**calable **E**nterprise **I**ntegration) in the area of PLM-ALM integration. Where systems engineering takes a holistic view by integrating disciplines such as mechanical, electrical/electronics and software, ACES ALM focuses on the one discipline that currently has board-level attention.

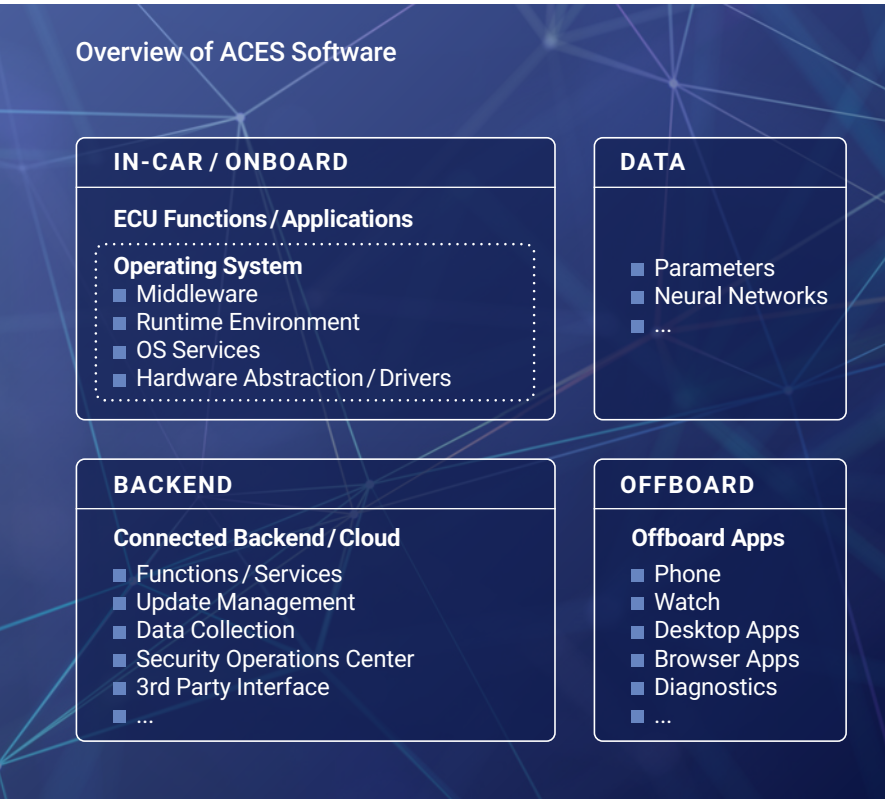
In this whitepaper, we will define ACES ALM before detailing the challenges in this area and introducing the ACES ALM business capability model. If you are involved in shaping processes, methods, tools or organization (PMTO) for automotive software, this whitepaper is for you.

We hope you enjoy reading it.

Jens Krueger, Head of NTT DATA Global Automotive Engineering Center of Excellence

2. What is ACES ALM?

Software for autonomous, connected, electric or shared functionalities is not your typical enterprise application. An accounting system or common office software has no brakes that can fail. On the highway, it is difficult to simply open the task manager to shut down an annoying process. In-car software is safety-critical, real-time embedded software running on electronic control units (ECU) in the vehicle.



ACES is short for Autonomous/Automated, Connected, Electric and Shared. The acronym ACES describes four major strategic pillars of automotive companies, especially OEMs. All four elements are part of the overall digitalization trend and require major innovations in IT hardware and software.

ALM is short for Application Lifecycle Management. As a process, ALM is about managing software from its initial conception, through the development and testing phase and ongoing support to its end of life. ALM tools provide support for activities such as software planning, requirements management, architecture design, software development, build, integration, test, deployment, operations and maintenance.

Combine the two and you get ACES ALM – ALM for ACES software.

ACES ALM is ALM for ACES software. Where traditional ALM focuses on enterprise software development, a major part of ACES software is based on in-car software development running in ECUs (Electronic Control Units) of the car. It is important that ACES ALM needs to support all areas in order to support the transformation to integrated mobility solutions:

- **"In-car or onboard software"** includes various layers of the software stack (hardware abstraction, device drivers, operating system services, runtime environment, middleware), functional and application software components running on an ECU.
- **"Data"** is mainly used to parameterize the ECU functions/applications, but can also include neural networks that are deployed to the vehicle for AI-based functions. This data is tightly coupled with the in-car software and needs to be managed together in order to ensure consistent configurations.
- **"In-car-related backend software"** includes connected backend / edge and/or cloud services typically provided by an OEM with functions such as software distribution, compatibility management and fleet management.
- **"Offboard apps"** is software that communicates either directly or via a backend service with the car.

3. Challenges? Opportunities!

Traditional ALM focuses on the performance of the software development process and the subsequent lifecycle management. Depending on the environment, the balance between speed, cost and quality is different. Where some Silicon Valley startups seemingly do not have to worry about cost as long as aggressive time-to-market goals are met, automotive suppliers for safety-critical applications are probably more cost-pressed and quality-aware. Drivers for ACES ALM are not different to traditional ALM, but there are a couple of factors that have to be considered in addition or with different weight.

To make ACES ALM a success, automakers must therefore keep an eye on a wide variety of aspects and fields, which can be divided into four clusters.

- **Engineering Business Drivers.** First, there are the ACES engineering business drivers, i.e. the fundamental technical interaction between software and hardware and their mutually dependent development including data-driven engineering.
- **Processes and Methods.** Second, the right processes and methods are needed to help with such development - from Model-Based Systems Engineering (MBSE) to variant and configuration management to scaled agile.
- **Regulatory Requirements.** Third, this technical-methodological complex is encompassed by regulatory requirements for hardware and software in vehicles, be it Automotive SPICE, cyber security or functional safety.
- **IT Strategy.** Fourth and finally, there is alignment with the company-wide IT strategy.

Drivers for ACES ALM

ACES ENGINEERING BUSINESS DRIVERS

- Separation of Hardware & Software
- Domain-Controller Architectures
- Integrated Enterprise & Embedded IT
- Data-Driven Engineering, e.g. ADAS Functions

PROCESSES & METHODS

- Model-Based Systems Engineering (MBSE)
- Process & Tool Baselines
- Variant & Configuration Management and PLE
- Scaled Agile

REGULATORY REQUIREMENTS

- Automotive SPICE
- Lifecycle Management/ Software Update Management
- Cyber Security
- Functional Safety

IT STRATEGY DRIVERS

- Cloud-Native Architectures
- Developer Experience

3.1 ACES Engineering Business Drivers

From the engineer's point of view, ACES disrupts major components of the product architecture. Powerful domain controllers allow the execution of multiple parallel functions, which in turn requires an unbundling of function software from dedicated ECU hardware. The onboard computers are working closely together with enterprise IT backends, for example to feed the data-hungry algorithms with sensor data.

Separation of Hardware and Software. Traditionally, tier-1 suppliers deliver ECU (Electronic Control Unit) hardware combined with software as a single package. This leads to complex distributed systems with 50-100+ ECUs connected via interfaces such as CAN bus or Ethernet. With OEMs focusing on software and even operating systems as a core competency, new models are created such as OEM-specific OS or sourcing of software only.

Domain-Controller Architectures. The 50 to more than 100 ECUs in traditional vehicles pose challenges in cost, weight, space, security and complexity in the vehicle network and the development process. That is why the automotive industry is focusing on domain or zonal controller architectures, where a single high-performance computer can potentially replace many ECUs.

For ACES ALM, this trend requires integrated design, development and test of several functions – potentially running concurrently with real-time constraints – with related signals, pins, protocols, sensors and actuators. Domain-controller architectures can also lead to the design of custom chips in order to optimize performance per watt and deal with shortages on standard chips, i.e. require PCB design capabilities.

Integrated Enterprise & Embedded IT. Modern cars are connected to an OEM backend and potentially several clouds for functions such as infotainment, navigation, emergency services or over-the-air updates. The user experience depends on an integrated system from the Human-Machine Interface (HMI) in the car over the connectivity to the backend implementation of the service in the enterprise IT.

ACES ALM needs to support integrated development of embedded software with related enterprise IT, e.g. by providing development environments with development instances and test data of the enterprise backends.

Data-Driven Engineering. Modern automotive functions such as Advanced Driver Assistance Systems (ADAS) use machine learning, e.g. for image recognition and the interpretation of scenarios. At the same time, cars are expected to provide sensor data in order to feed the enterprise processes and also various data-driven business models (e.g. real-time traffic information). Tesla's cars for example are constantly providing data on usage patterns, issues, preferences etc. Analytics is then applied to direct and prioritize the agile work within the company.

The ACES ALM environment must support this "big loop" of data collection, ingest, storage & management in the Petabyte range as well as the application of AI tools for the data scientists working on analytics, learning, development and re-integration into the car.

3.2 Processes & Methods

The growing importance and complexity of ACES software requires disciplined software engineering and configuration management practices as well as their integration into the existing product development process, for example using a Model-Based Systems Engineering approach. (Scaled) agile practices might need to be integrated into the traditional phase-gate product development process.

Model-Based Systems Engineering (MBSE). The model-based paradigm (as in MBSE) is becoming increasingly popular as growing complexity requires additional levels of abstraction.

In ACES ALM, this means e.g. code generation from models such as "MATLAB Simulink" or SysML (Systems Modeling Language). These models need to be managed including tracelinks to requirements and generated code. In order to realize the full benefits of this approach, the models should be executable for simulation in the verification & validation processes and integrated into the test automation toolchain.

Process & Tool Baselines. Especially for ADAS functions, the product liability risks for automotive companies are very high. One approach for risk mitigation is the ability to reproduce the used development practices for a given point in time, i.e. the ACES ALM environment should be able to persist baselines of a configuration of processes, methods and tools.

Variant & Configuration Management and Product Line Engineering. The management of versions, branches and builds for different OS platforms is a core function of traditional ALM.

ACES ALM also needs to manage code/parameters with respect to the vehicle configurations, including compatibility management. A vehicle configuration might be determined by model, drive, extras, production site, target country etc.

ISO 26580 focuses on feature-based Systems and Software Product Line Engineering (PLE) as a specialization of general PLE according to ISO 26550. Both documents describe concepts, methods and tools to increase re-use of engineering artifacts across variants.

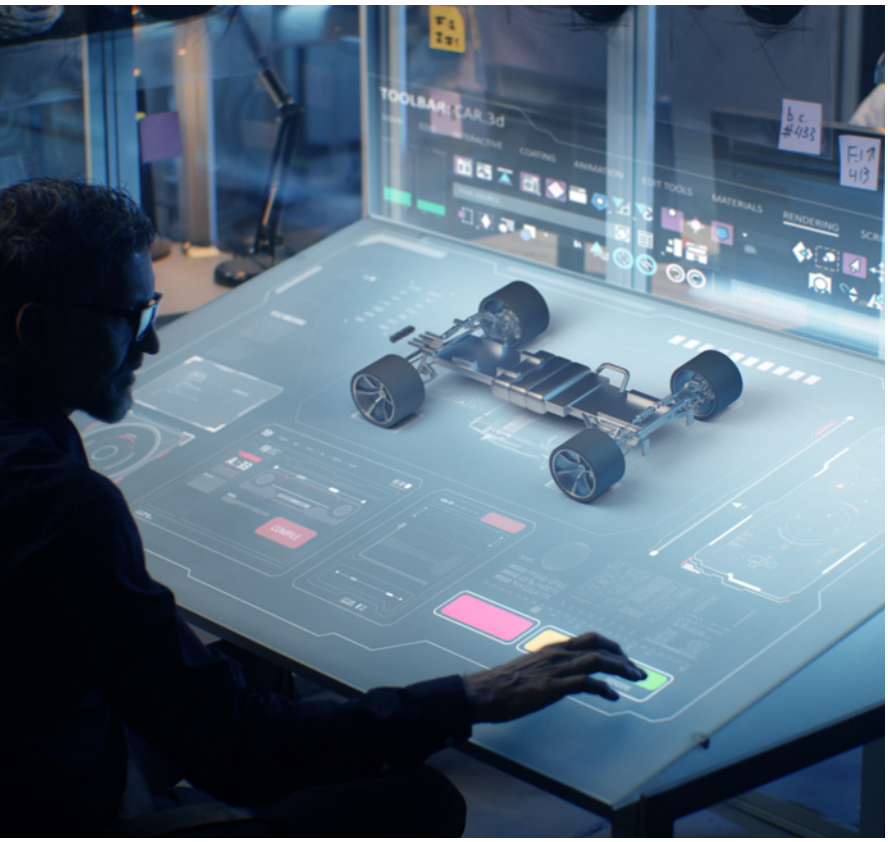
Scaled Agile. The complexity of automotive applications such as automated driving and connected services requires large teams of a few hundred to a few thousand people. Scaled agile frameworks such as SAFe support the scaling of basic agile principles to this size. Especially the project management and team collaboration modules in ACES ALM must support scaled agile methods.

3.3 Regulatory Requirements

Many regulations need to be considered for the development of ACES software. These include, for example, Automotive SPICE, UNECE SUMS (Software Update Management System) & CSMS (Cyber Security Management System) and ISO 26262 Functional Safety. At the same time, new regulatory requirements are also emerging. Meeting these regulatory requirements is critical for the type approval process (homologation), i.e. there are potentially different regulations for each market such as EU, China, US.

The ACES ALM environment needs to ensure the reliable provision of all current, relevant requirements for a given development scope. It further needs to support the traceable implementation and validation of these requirements and maintain an audit trail.

To support assessments or audits, an explicit process model with linked work products for each activity is desirable. Workflow management features make the process model executable, thus ensuring compliance.



Automotive SPICE. ASPICE maturity level 2+ has been required by OEMs for supplier qualification for a long time. By entering the field of software development themselves, ASPICE becomes an important tool for process quality also for OEMs. Explicit modeling of the processes as well as tools that produce and manage the required work products help during an assessment.

The ACES ALM environment also needs to support the vertical and horizontal traceability requirements of ASPICE, i.e. bidirectional traceability and consistency between requirements, design, code, tests etc.

Lifecycle Management/Software Update Management. Customers expect state-of-the-art infotainment functions in a car as well as constant fixing of bugs and security improvements. While software can change every month, the hardware in the car has a life cycle of over 10 years and a development process of over 3 years on top of that. OEMs need to manage these different lifecycles, but they also want to enable new business models based on software-defined functions and meet regulatory requirements for type approval such as UNECE R156 SUMS (Software Update Management System) and the upcoming ISO 24089 for Software Update Engineering. For this, OEMs need the ability to update the embedded software in the after-sales phase – ideally "over the air" (OTA) without having to call drivers into the workshop at great expense.

The ACES ALM environment needs to support the secure distribution and installation of updates in the car. This process needs to deal with compatibility of the software update with related hardware and software in the car. For UNECE SUMS, the mapping between software IDs and regulation IDs is required.

Cyber Security. Modern connected cars have several new potential security vulnerabilities, e.g. through USB, WIFI, Bluetooth and the OTA update process. The UNECE R155 CSMS regulation requires setting-up a Cyber Security Management System with risk management to be established throughout development, production and operations. With ASPICE CS, there is an extension of ASPICE for cyber security available. Another relevant standard in this area is ISO/SAE 21434 „Road vehicles – Cybersecurity engineering".

The ACES ALM environment needs to support the risk identification and assessment as well as traceability to related mitigation activities. It also needs to support implementation of secure coding guidelines and security testing incl. penetration tests according to the security concepts defined within the organization.

Functional Safety. ISO 26262 is a standard for safety-critical electrical/electronic systems in vehicles. It requires a comprehensive lifecycle and quality management. Some of the requirements are similar to Automotive SPICE, but the scope of ISO 26262 also includes production and operations, and the rigidity of the requirements depend on the ASIL (Automotive Safety Integrity Level).

The ACES ALM environment needs to support the execution of ISO 26262-specific processes such as HARA (Hazard Analysis and Risk Assessment) and FMEA (Failure Mode and Effects Analysis) and the creation of related information / documents depending on the ASIL. The tools and toolchains also need to be certified regarding "fitness for purpose".

3.4 IT Strategy Drivers

With embedded software becoming connected and data-driven, general IT trends such as cloud and AI apply in our field of ACES software. The IT strategy transforms these trends not only for enterprise IT, but increasingly also for the ACES IT.

Cloud-Native Architectures. Cloud-native is not a new or ACES-specific driver for ALM, but it is amplified through connected vehicles which are constantly sending and receiving data. This requires scalability and connectivity that is best provided with cloud-native architectures.

The ACES ALM environment needs to support efficient development in the cloud-native architecture. This might not be the case with traditional toolchains, which are targeted towards platforms such as Linux or Windows.

Developer Experience. Embedded software development is tough: developers have to deal with Assembler or C code under real-time constraints, limited computing resources and overwhelming regulatory requirements, but at the same time are expected to implement data-driven cloud-native architectures.

Given the scarcity of talent, the ACES ALM environment should guide developers through the processes and provide integrated toolchains with automation applied where possible.

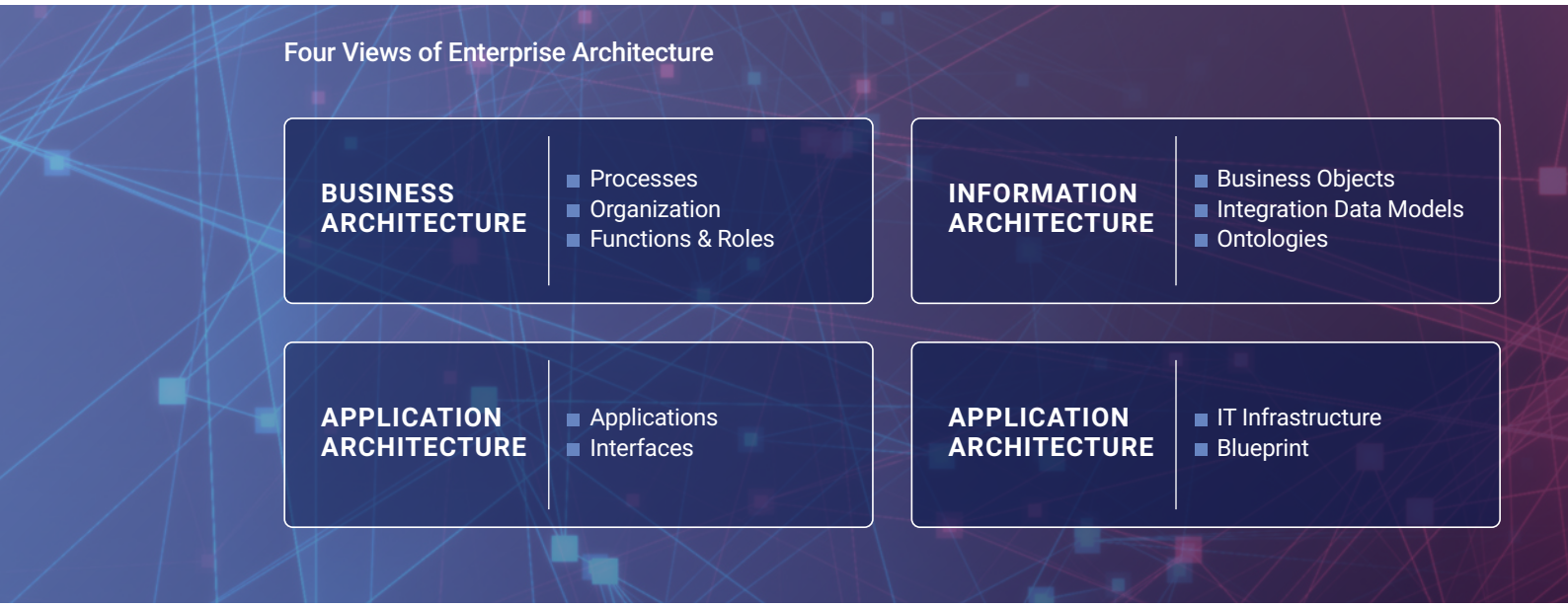
4. Business Capabilities for Automotive Software ALM

Definition

Business capabilities are "a particular ability or capacity that a business may possess or exchange to achieve a specific purpose or outcome". This definition is from TOGAF (The Open Group Architecture Framework), indicating the roots of this concept in Enterprise Architecture Management (EAM).

"What", Not "How". Business capabilities are the building blocks of the business, but they are abstracted from the organizational model in order to become more stable in times of continuous improvement, reorganizations and agile working models. Business capabilities describe the "what", not the "how". As an example, the capability "Software Development" can be realized with internal or external resources and can use traditional or agile methods.

Common Language and Structure. There are several use cases and benefits related to business capabilities. In general, they support the alignment between business and IT by providing a common language and structure for all four views of enterprise architecture, with *business* and *information architecture* being closer to the business stakeholders whereas *application* and *technology architecture* views are closer to the IT stakeholders.



Reducing Dependencies and Complexity. Business capability models are typically used in IT to structure the overall application landscape into smaller domains that have a high cohesion internally and loose coupling to other domains. This reduces dependencies and makes complexity more manageable.

Visualization with Heatmaps. Another major usage of business capability models are heatmaps, i.e. visualizations of specific aspects using colors such as red / yellow / green. Example heatmaps include business fit, technological fit or application lifecycle status. We have developed a quick check method to determine the maturity level per capability from a business process and an IT point of view.

Capability-Based Transformation Approach. For comprehensive transformation programs in enterprises such as establishing a new practice for ACES ALM or post-merger integrations, a capability-based transformation approach is suggested. TOGAF (The Open Group Architecture Framework) and ArchiMate provide a metamodel for strategic planning that allows the prioritization and mapping of business capabilities to elements such as processes, IT and other resources, value streams and courses of action. EAM tools such as LeanIX support this approach with features for roadmap planning and impact analysis of alternative scenarios.

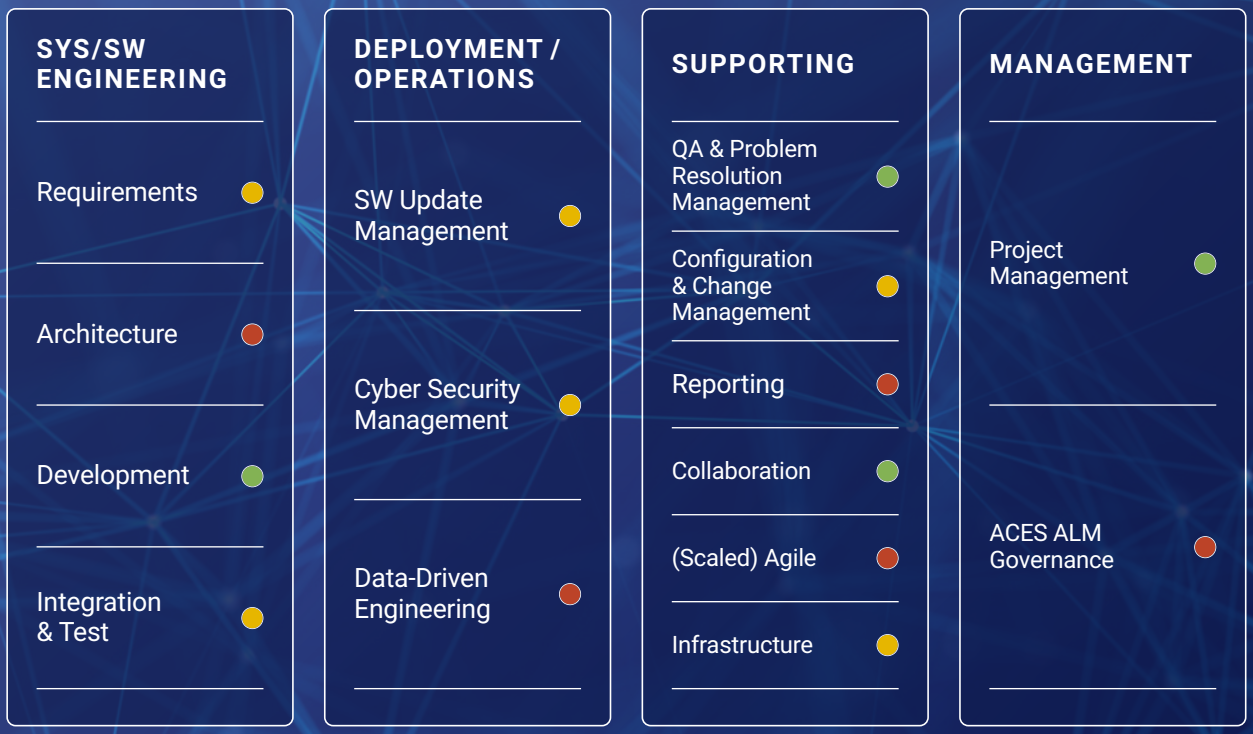
5. NTT DATA's ACES ALM Business Capability Model

Structure for Process Improvement. The NTT DATA ACES ALM business capability model is based on the Automotive SPICE process reference model in order to provide structure and traceability for potential process improvement or analysis activities. It also incorporates the ACES ALM drivers as described in the previous chapter and best practices from the automotive industry.

Example of our Model in Practice.
The model on the top layer 1 is structured into capabilities for

- Systems & Software Engineering
- Deployment & Operations
- Support
- Management

NTT DATA ACES ALM Business Capability Model – Example of a Heatmap Visualization



On the second layer, 15 business capabilities are described in detail including a list of potential layer 3 capabilities and typical IT tools (commercial-off-the-shelf and open source software) for the given capability.

Systems & Software Engineering. The primary life-cycle capabilities in the V model for *requirements* engineering, functional and logical *architecture* design, software *development* and *integration & test*. Please note that for complex systems such as automotive vehicles, these capabilities need to be implemented for multiple levels of the system, e.g. systems of systems, product, subsystems and components.

Deployment & Operations. The deployment of ACES software to the vehicles while respecting regulations for *software update and cyber security management* and while using the data collected during operations for *data-driven engineering*.

Support. The supporting capabilities for the primary systems & software engineering. *Quality assurance* is about the objective, independent assurance of the quality of work products. It is also about the resolution of non-conformances including future prevention. *Configuration management* ensures the integrity of all work products. It is applied over the lifecycle of work products / configuration items. *Reporting and collaboration* between globally distributed teams are transverse capabilities. *Agile* is not just a special project management discipline, but also a transformative business capability on its own. Enterprise-wide adoption requires scaled agile frameworks such as SAFe with an integrated set of processes, methods, roles etc. *IT infrastructure* for ACES ALM includes provision and management of resources such as compute, storage and networking.

Management. *Project management* capabilities are based on PMI body of knowledge "PMBOK" and include layer 3 capabilities such as management of scope, time, cost, quality, HR and risk. *ACES ALM governance* provides leadership, organizational structure and processes in order to ensure that the ACES ALM capabilities meet the companies' strategy and objectives.

Details beyond the map. A true business capability model needs more than the map. Each capability on layer 2 is detailed with descriptions, a list of layer 3 capabilities and example IT tools.

Example Description of the Capability "Development"

SYS/SW ENGINEERING

Requirements

Architecture

Development

Integration & Test

- A software detailed design including interfaces and dynamic behavior and the corresponding software units are created. UML is a common notation for the software design.
- The software detailed design is analyzed e.g. in terms of interoperability, interaction, criticality, technical complexity, risks and testability.
- Tracelinks according to [ASPICE] between requirements, software detailed designs and software units are created and maintained.
- DevOps is a special capability as it is not limited to the development scope but reaches also into integration, test and operations. We allocate this capability and the related tools to "development" as this is the starting point for DevOps.
- There are many domain-specific tools / toolchains for this capability, e.g. for entertainment, real-time, safety-critical, ADAS etc.

Layer 3 capabilities:

- SW detailed design (e.g. UML)
- Code authoring (IDE / SDK)
- Source code management
- Parameter management
- (Binary) artifact management
- Compile & Build
- Deployment
- DevOps
- CI / CD orchestration
- Code generation from models
- Code quality checking
- License management (incl. OSS)
- Documentation

Example IT tools:

- Sparx EA; MID Innovator
- Eclipse; Visual Studio
- Subversion, Git, Bitbucket
- Maven, Jenkins, CMake, Bamboo
- Artifactory, Nexus
- C, C++, Assembler, Python
- Targetlink
- Sonarqube
- FOSSology, Black Duck
- Swagger

6. Our Offering and Your Benefits

6.1 Portfolio

NTT DATA has more than 50 years experience in the automotive industry. As a Trusted Global Innovator, we offer a comprehensive portfolio of consulting and technology services with systems engineering as a focal point.

Strategy. Implementation of ACES ALM capabilities should be aligned with drivers and strategies of your business. An assessment of the existing process, method and tool landscape is the basis for strategic planning and prioritization. A clear roadmap shows the evolution of your business capabilities with integrated views for business, information and the related IT application landscape. NTT DATA offers strategy and business transformation consulting services in these areas.

Processes, Methods, Tools. Our systems engineering and ALM consulting practice provides consulting and technology services for all ACES ALM capabilities. This includes for example process improvements through (model-based) systems engineering or compliance to Automotive SPICE. It also includes implementation and integration of IT tools. For this, we maintain partnerships with leading ALM and PLM vendors in addition to our technology services practice for custom development.

Enterprise Architecture Management. Our EAM consulting practice provides the expertise in frameworks and notations such as TOGAF or ArchiMate. We can develop an ACES ALM business capability map for your company and model the capabilities in EAM tools such as LeanIX or Sparx EA.
With SENSEI, we offer a blueprint for systems engineering integration architecture.

OFFERING – OVERVIEW

Capability-Driven Transformation to ACES ALM

- Status Assessments, e.g. Quick Check
- Strategic Alignment of Capabilities with Business Drivers and Strategies
- Roadmap Development

PMT Consulting for ACES ALM

- Process and Method Consulting for Systems Engineering and ACES ALM
- IT Tool Consulting and Implementation

EAM Consulting

- Develop an ACES ALM Business Capability Map for your Company
- Establish Business Capability Management
- Model Capabilities in EAM Tools
- Systems Engineering Integration Architecture Blueprint (SENSEI)

6.2 Benefits

NTT DATA's Structured and Scalable Approach. Transforming your business into a software-driven business is a complex undertaking. It requires the development of new processes, methods and tools to implement the required business capabilities. With our ACES ALM capability model, we offer a structured and scalable approach to manage this complexity successfully.

Everything You Need to Get Started with ACES ALM. Based on proven EAM methodology, our comprehensive model with 130+ capabilities provides the content you need to jump-start your way to ACES ALM. With the quick check, you get an initial assessment of your company's status.

Generally Accepted Reference Model as Basis. A transformation can only be successful if the stakeholders accept and support the changes. Our ACES ALM capability model is based on Automotive SPICE as an universally accepted reference model. It provides the right level of abstraction for use by business and IT functions. Even for inter-company scenarios such as cooperation projects or joint ventures, a capability model supports the clarification of responsibilities and interfaces.

KEY VALUES

Reliable Transformation

- Structured and Scalable Approach to Manage Complexity
- Proven Enterprise Architecture Management Methodology

Jump-start Your Way to ACES ALM

- Comprehensive Model with 130+ Capabilities
- Quick Check Method

Gain Stakeholder Buy-in

- Transparent Status from Business & IT Perspective
- Aligned with Automotive SPICE as an universally accepted Reference Model

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Let's get started

See what NTT DATA can do for you.

- Deep automotive industry expertise
- Solid methodology for systems engineering, ACES ALM and EAM
- Quick check offering to start using the business capability model

Contact one of our authors, or visit **nttdata.com** to learn more.

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About NTT DATA

NTT DATA – a part of NTT Group – is a trusted global innovator of IT and business services headquartered in Tokyo. We help clients transform through consulting, industry solutions, business process services, IT modernization and managed services. NTT DATA enables clients, as well as society, to move confidently into the digital future. We are committed to our clients' long-term success and combine global reach with local client attention to serve them in over 50 countries.

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