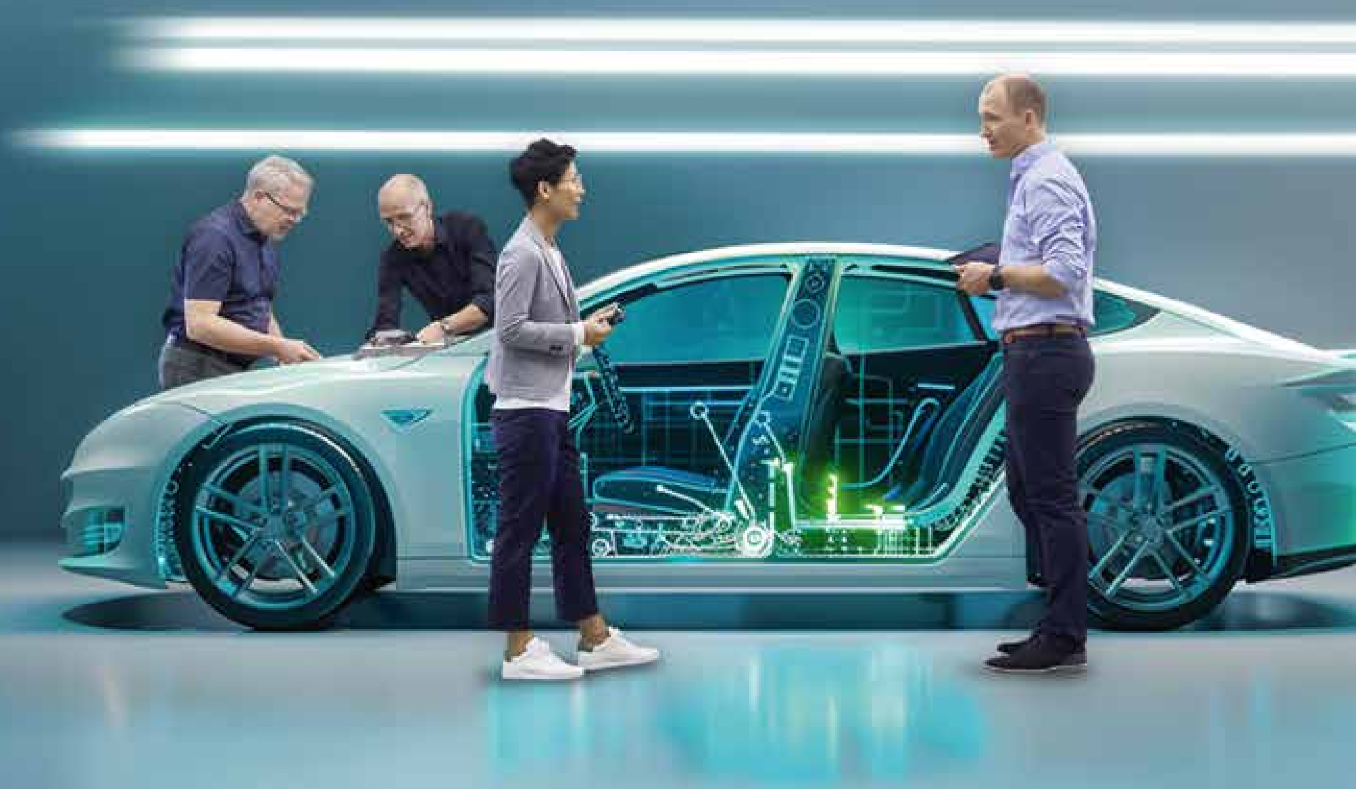
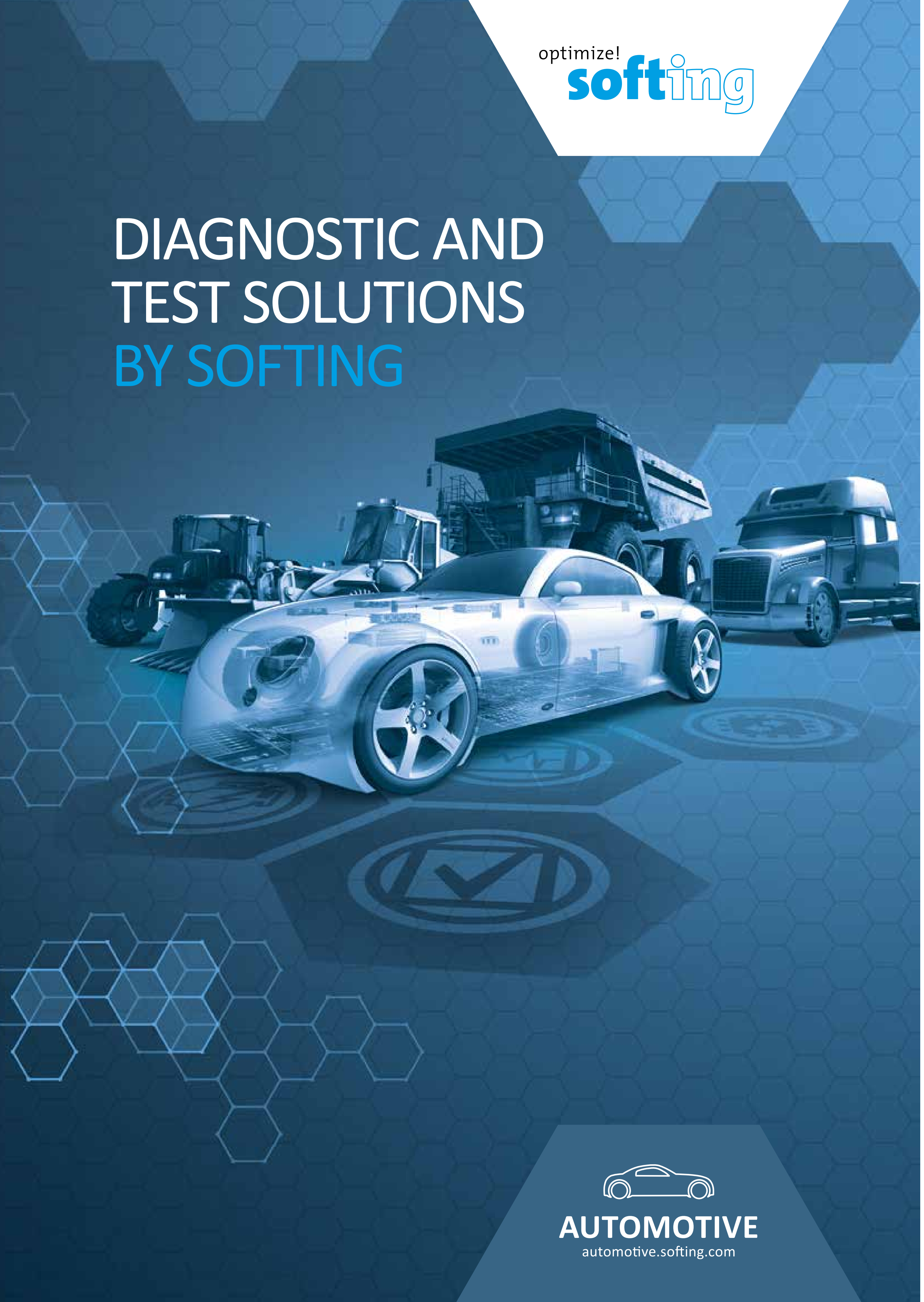
ASAM:GUIDE

ACCELERATE ENGINEERING FOR MOBILITY



ASAM
Association for Standardization of Automation and Measuring Systems



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ASAM

WELCOME

MARIUS DUPUIS
Chief Executive Officer (CEO)
ASAM e.V.

A lot has changed since the last guide by ASAM was published in 2021. Automated driving has entered a post-hype phase and is now characterized by steady, well-engineered progress and deployments in commercial products. L3 systems can be ordered from various OEMs, and L4/L5 systems are made available to the public in dedicated areas. Simulation has become a commodity and an inherent part of vehicle function development. The quest for identifying the unknown unknowns is still going on, but the methodology has gained considerably more structure. Starting with the definition of the operational design domain (ODD), deriving scenarios from it, and testing for optimized coverage of both is now state of the art.

The vehicle itself is undergoing fundamental changes. Large numbers of dedicated ECUs are getting replaced with zonal layouts based on few HPCs. Layered architectures with a clear separation of operating system and applications will enter the market. The borders between the physical vehicle, its digital twin, the data management on premise, in the cloud and in the vehicle are blurring. The vehicle's functionality will not so much be defined by its ECUs but by its software. Deploying and updating functionality over the air will become a core feature of tomorrow's vehicles as we start to hear messages like "this will be OTAed" at trade shows (e.g., CES 2024). Security aspects will play an ever-increasing role in this context.

The bigger picture beyond the vehicle is mobility. Worldwide urbanization was 54% in 2015 (see statista) and is expected to reach almost 70% by 2050. Countries like Germany are already at an urbanization level of 75% and more, today. For this reason, we expect intermodal mobility solutions to become an inherent part of our daily life, shifting our role from vehicle owners and drivers to passengers in various (autonomous) ways.

These trends have not been without influence on ASAM. Let's start with mobility: in a joint strategy workshop in September 2023, the ASAM Board of Directors, the Technical Steering Committee, and the Office defined a new vision for our association: "**Accelerate engineering for mobility**". We aim to take ASAM's portfolio into a future where today's dominant role of the vehicle might be replaced with a more holistic view on the needs of the individual for personal mobility.

Changes in vehicle architecture have shown how important it is for ASAM to stay ahead of the crowd and to adapt early with standards like our service-oriented vehicle diagnostics (**ASAM SOVD**). It has not only become a best-selling standard of recent years but its transfer to ISO has also opened the door for regulators to reference this technology-agnostic API in their frameworks.

As much as the automated driving technology has become a commodity, so have the standards around simulation. ASAM OpenDRIVE, ASAM OpenSCENARIO XML and ASAM OpenCRG – combined the nucleus of the **ASAM simulation domain** – are mature standards, supported in one way or the other by the majority of tools. This ecosystem has been largely expanded across various aspects with, among others, ASAM OpenLABEL, ASAM OpenODD, ASAM OpenSCENARIO DSL, and ASAM OpenMATERIAL 3D.

At the same time, we continue to make sure that well-established **standards across all our domains** not only stay up to date but are well-prepared for the future. Just look at the recent developments in ASAM ODS, ASAM XIL, ASAM MDF, ASAM OTX Extensions and many more. Recent discussions on using ASAM MCD-1 XCP in virtualized environments point to a future with highly scalable implementations.

Implementing standards means translating their specifications into actual code. This might create ambiguity and undermine the basic idea of standardization. With the **ASAM Quality Checker** framework and its checkers, we are taking our responsibility for well-defined standards to the next level and go beyond providing the specifications only.

The reason why this brochure is called *ASAM:GUIDE* is that we see our portfolio as a holistic approach to developing, testing, deploying, and maintaining vehicles and their data. One example is the **ASAM Test-Specification project**. Building on the results of the preceding ideation and concept projects, this initiative aims to align multiple ASAM standards with the goal to streamline test processes, enhance the reusability of test artifacts, and facilitate validation.

Most important of all, though, is that ASAM is an association of growing relevance. Membership has grown across all regions to more than 400 active member companies. China is a huge market and one of the regions with fastest growth for ASAM. Japan provides excellent analytical input to our standards and has, again, initiated new standardization projects. Europe, still, is the heavyweight of our activities, and North America with its tech industry plays a key role in on- and offroad solutions.

Therefore, we tried to make this *ASAM:GUIDE* as comprehensive a brochure as we could – across our entire portfolio, and across all technologies and geographies. We hope you enjoy reading it as much as we enjoyed pulling the information and stories together.

Marius Dupuis
CEO, ASAM e.V.

DEAR READER

In 2023, ASAM celebrated its 25th anniversary. Looking back, I am proud to say that over the past 25 years, ASAM has grown into a globally significant standardization organization in the automotive and mobility industry, particularly in testing and validation, but also in the development of modern automotive technology as a whole. While we have already accomplished much, we will continue driving innovation by delivering standards that help the industry shape the future of technology and transform the way we move.

Since its initiation in 2018, our domain "Simulation" has seen tremendous success with a steadily growing user base and many supporters who help to drive standardization in this area. However, ASAM is active in many more domains, be it "measurement & calibration", "diagnostics", "test automation", "data management & analysis" or others. I feel that it is not easy to fully grasp the full potential that ASAM provides with its standards. That is why we have sharpened and redefined our vision:
"Accelerate engineering for mobility."

For the same reason, we are publishing this ASAM:GUIDE – to help you understand the use and benefits of all ASAM standards. I invite you to take a look at this 10th edition of our solution-centric guide which – among other interesting topics – contains many examples that demonstrate how ASAM standards from different domains are applied successfully.

One of the biggest challenges we face today is applying our established standards to new, emerging technologies and concepts that are transforming the automotive industry, such as

- *deterministic programming and AI,*
- *functional safety and SOTIF,*
- *simulation and validation in real operation,*
- *requirements-based software engineering and continuous software development,*
- *homologation and continuous integration.*

ARMIN RUPALLA
Chairman of the
ASAM Board of Directors

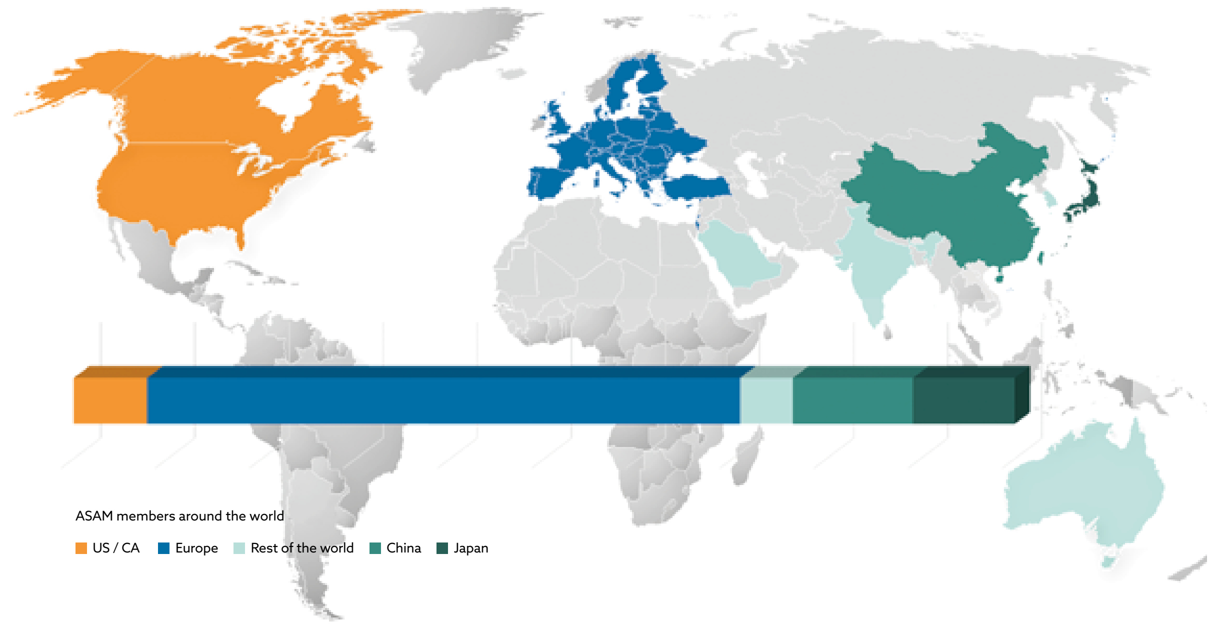
ASAM is committed to overcoming these challenges by creating standards that bridge the gap.

This brings me to an important matter: ASAM's success relies on the active engagement of its members. I would like to take this opportunity to thank all those who contribute to our projects every day, who drive standardization and solve shared challenges. I am proud to say that ASAM has a very engaged and active global community. With your help, we will ensure that ASAM standards drive mobility to the next level.

I hope you enjoy reading this issue as you learn more about the ASAM portfolio, take a look at vehicle testing with ASAM standards from different angles, and read about ASAM's stake in the software-defined vehicle (SDV).

Armin Rupalla
Chairman of the ASAM Board of Directors

ABOUT ASAM



ASAM INSIDE – VISION, MISSION AND IMPACT

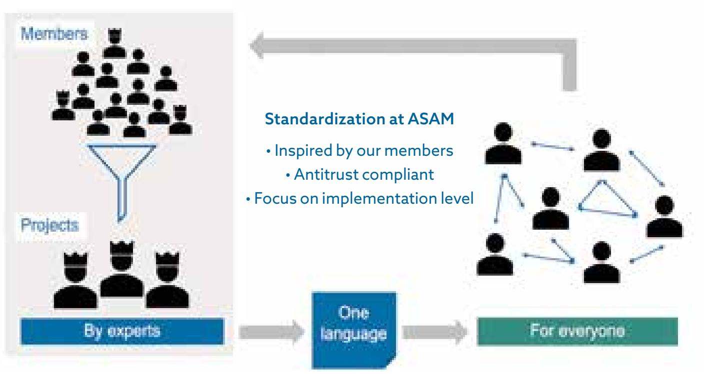
"Accelerate engineering for mobility" – This vision summarizes what ASAM stands for: As a not-for-profit organization, ASAM provides an antitrust-compliant space where companies of the mobility industry can meet and drive projects that facilitate pre-competitive collaboration across the entire landscape. The key to achieving this goal is our concentration on one specific topic: the definition, maintenance, and dissemination of implementation-level standards.

A description of ASAM and its spirit wouldn't be complete without a mission statement:

"Our international community of experts creates and establishes standards. ASAM standards enable interoperability and seamless exchange of information across toolchains in the mobility industry. The ASAM organization drives initiatives from ideation to release with well-proven, efficient processes and expertise. Collaboration and networking across the entire ecosystem ensure that ASAM's standards are well-established."

What might first read like a collection of isolated statements is a single, consistent and comprehensive statement of what we try to achieve with our daily efforts. This mission is what makes our members commit their financial and personal resources to our common cause and what makes the employees of ASAM work for our association with a clear purpose in mind.

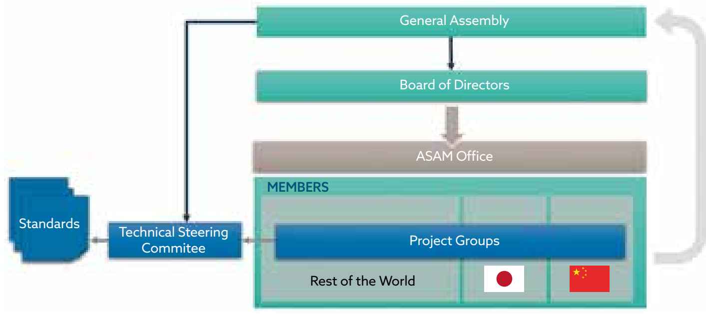
Our members define the "one language" for a given technical aspect that everyone in the industry shall speak to foster seamless communication among participants, devices, and tools. By not only being creators of our standards but also their users, our members have a high interest in making sure that our standards can be applied to a large variety of use cases and open a market for everyone who speaks "the language".



ASAM members
Defining "one language"

At the beginning of 2025, ASAM has around 400 member companies across the industry and across the globe. Almost half of them are located outside Europe with China and Japan being heavyweights in Asia. The ASAM headquarters are in Germany. A subsidiary, ASAM Japan G.K., has been established in Japan, and the operations in China are managed via a collaboration agreement with CATARC. A large share of the globally relevant automotive OEMs and Tier-1s as well as leading service and tool providers and academic and research institutions are ASAM members and include ASAM standards in their products, services, and research operations. By this, "ASAM inside" is a feature of millions of devices which are deployed not only in vehicles around the globe.

ASAM members initiate and participate in standardization projects, network at ASAM events, and use ASAM standards in their products. The membership fees are spent to a large part on technical projects and running the organization itself. The "ASAM Office", around one dozen employees of ASAM, provides additional support for the projects which are staffed and led by volunteering representatives of ASAM member companies. With this leverage, a few hundred participants can work on the future of standardization while a handful of employees provide the backbone.



ASAM organization
Shared responsibilities – combined forces

Further volunteers from the member base serve on the Board of Directors (five persons) and the Technical Steering Committee (twelve persons). These are legally responsible for the association itself and for the product portfolio, respectively.

ASAM – A GLOBAL ORGANIZATION WITH STRONG REGIONAL FOOTPRINTS

	Representation	Regional meeting	Trade shows	Projects	Commitees
	ASAM Japan G.K.	✔	✔	ASAM SCDL ASAM OpenMATERIAL 3D Ideation projects	ASAM ODS Study Group OEM Commitee
	Business Partner iVH	✔			
	Business partner Deepen AI	✔	✔	ASAM OpenX standards in offroad applications	
	C-ASAM Work Group	✔	✔		Advisory Committees CDSC-lab

The German name of our association "Verein für die **internationale** Standardisierung von Automatisierungs- und Messsystemen" already points to the international, i.e., global, scope of ASAM. With almost half of our members being located outside Europe, ASAM has established several forms of engagement in non-European key regions.

JAPAN

ASAM e.V. has established a subsidiary, ASAM Japan G.K., in 2015. Its representative is responsible for managing business development, projects and committees. The efforts in Japan blend perfectly into the other parts of ASAM.

An **OEM Committee** was established in Japan as a platform where Japanese OEMs – both members and non-members – can meet and exchange ideas around standardization. This serves as a high-ranking, continuous ideation opportunity as well as a forum for feedback to the organization.
The **ASAM ODS Study Group**, in contrast, is a project group composed of representatives from OEMs, Tier-1s and tool vendors who focus on the adoption of the ASAM ODS standard in its latest version and who propose, among other things, implementations of ODS in contexts like PLM/ALM systems. The ASAM ODS Study Group reports on a regular basis to the ASAM Technical Steering Committee (TSC).

A series of **standardization projects** have been (co-)initiated from Japan, for example ASAM SCDL (Safety Concept Description Language), ASAM HMS (Hex File Management System), and ASAM OpenMATERIAL 3D. ASAM holds an annual **Regional Meeting** in Japan, is a recurring exhibitor at JSAE, and participates as presenter and guest in various conferences.

CHINA

ASAM is represented in China by the **C-ASAM** work group which is located at our partner CATARC in Tianjin. This partnership was established in 2019. At that time, interest was especially high in the area of simulation and the so-called "ASAM OpenX standards". Therefore, most of the early membership growth in China has come from companies in this part of the business.

CATARC is not only partner to ASAM but with its other partnerships and roles also a potential gateway into SAC (Standards Association of China), ISO and other local and international institutions. Therefore, the opportunities lie beyond the scope of "only" creating ASAM standards.

ASAM holds an annual **Regional Meeting** in China and has established various working groups like the "Advisory Committee for Advanced Driving Simulation (ACADS)" in 2023 and the "Joint Laboratory for the Certification of Data Standard Compliance (CDSC)" in 2024. C-ASAM holds quarterly user meetings, and ASAM staff joins key conferences in China either as remote speaker or, where feasible, in person.

Active participation by Chinese members in actual standardization projects is still work in progress, but with high adoption rates for existing ASAM standards, there is confidence that new ideas will emerge from current implementations. A Chinese representative in the ASAM TSC is a significant first step into this direction.

NORTH AMERICA

ASAM has a long history in North America. Not only because several US OEMs and Tier-1s have joined ASAM early-on but also because there have been Board and TSC representatives from the US and even an office (ASAM LLC) for some time. As of today, business in North America is formally handled by the ASAM headquarters in Munich. Local representation and assistance are provided by strategic partners in the US.

ASAM is guest at various US conferences over the year, either as speaker or exhibitor. Recent events are SAE On-Board Diagnostics, AutoSens USA, and ADAS & Autonomous Vehicle Technology Expo. The ASAM **Regional Meeting North America** is a key event for ASAM to meet with interested parties from this region, even though it may not be held on an annual basis.

ASAM projects frequently include representatives from North America, some are even led by them (like the project "ASAM OpenX in off-road applications").

SOUTH KOREA

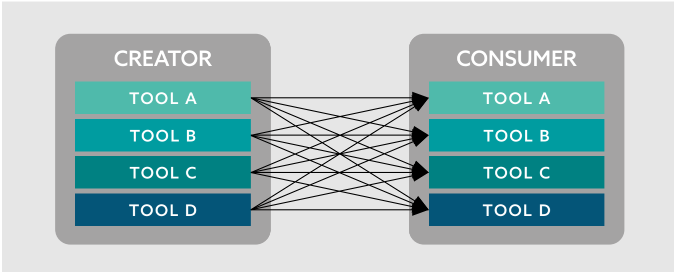
ASAM held its first **Regional Meeting** in South Korea in 2023 and plans to repeat this success on a biennial basis. The response to the first meeting showed the high interest of the region in ASAM's standards and the world-class work performed by South Korean companies across the ASAM portfolio.

ASAM is at a rather early stage of establishing a significant presence in South Korea, but with the assistance of a highly qualified business partner work has started on study groups, translating documents into local language, and making sure our standards are seen at relevant trade shows and conferences.

STANDARDS – A BUSINESS CASE CONSIDERATION

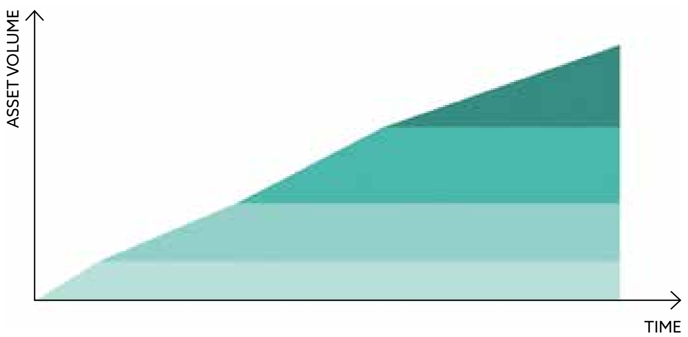
The business case

Standardization is a business case. By creating standards for data formats, protocols, and APIs, the involved parties agree on a single language they use for communication between devices and tools. Everyone speaking and understanding this language can compete in a market where data creators and consumers meet as well as tool suppliers and their customers.



Vendor lock-in is avoided as the market grows in size and scope. Customers for data and tools can select from a variety of offers, and providers can supply their artifacts and services to a sizeable number of potential customers. The only prerequisite for market access is that they all speak, i.e. understand and implement, the respective standardized "language".

Data owners can create and accumulate standard-compliant data assets over time irrespective of the specific tools that may be required in a specific development stage. Not having to re-create or convert assets upon switching tools is a huge monetary value in that it means huge savings in working hours and can help releasing products earlier. Strong standards with high adoption rates are a prerequisite for this ecosystem to work.



With standards
Continuous build-up of assets across vendors

Standards foster quality. Making your tools and data standard-compliant still means that you have to develop, implement, and debug your artifacts. But you do it only once and for one data format / protocol / API only. This gives you a great incentive to spend all the effort you need on the quality of a single implementation instead of spending in total more time on various implementations – which come, on average, at a lower quality and maturity level.

Commonly agreed quality requirements and understanding of a standard can enable reference implementations and reference data. New adopters will be able to implement their solutions at a faster pace with these aids and all market players can benchmark their solutions against the references.

Where markets and quality are facilitated by standards, independent marketplaces can be established. Of course, it only makes sense for third parties to provide ready-made data, software and tools if there is a sufficiently promising and sizeable customer base, but marketplaces thrive around well-established standards as growing shares of the industry adopt them. At the same time marketplaces can also drive the establishment of standards by providing an exchange and sharing platform for early adopters.

Collaboration

Standards foster collaboration. Not only do de facto standards like the ones issued by ASAM, thrive from collaborative development and wide-spread implementation. They can also be the means that enables two parties to exchange data and ideas. Entire alliances are built on the principle that they can exchange information seamlessly; that may be in the domain of software-defined vehicles, diagnostics, or automated driving, just to name a few examples.

Adoption strategies

There is not "the" ideal time to jump on the standardization train. When entering a market as a new player, something we frequently see, for example, in the SDV domain, you might want to look into standards rather earlier than later since it will save you time to use something that already exists and is well-accepted.

On the other hand, if you already have established and deployed products based on your own data formats etc., you might be reluctant to change route. For sure, this will work for some time, but with an increasing adoption rate of standards, you might want to reconsider the costs for doing in-house development vs. benefiting from crowd intelligence baked into a standard. Identifying the sweet spot for optimum transition from your own IP to a standard might be impossible. But experience dictates that earlier is better – provided that the respective standard is sufficiently mature.

The best case, both for a company as well as for a standardization organization, is to transfer your IP to the standardization organization and make it a standard for the whole industry. In order to prevent unfair competition, ASAM has very strict rules for this process. The more open external IP has been handled before being transferred to ASAM, the easier it will be. ASAM OSI, ASAM OpenMATERIAL 3D, and ASAM MDF are examples of successful transfer of projects that had already been driven by significant communities before becoming ASAM standards. For all other cases, ASAM has established rules to initiate new standards.

JOINING ASAM – WHY IT MATTERS AND HOW TO CONTRIBUTE

Are you still wondering why becoming an ASAM member is worthwhile? The answer is simple: only as an ASAM member can you leverage the full potential and unlock significant benefits:

Actively contribute to standards development: The full potential of standards opens up when you help to define them, contribute your requirements, and make sure your needs are represented.

Be one of the first to know: Taking part in a standardization project also gives you the chance to be an early adopter and integrate standardized solutions into your tool pipeline at an early stage, providing you with a first-to-market advantage.

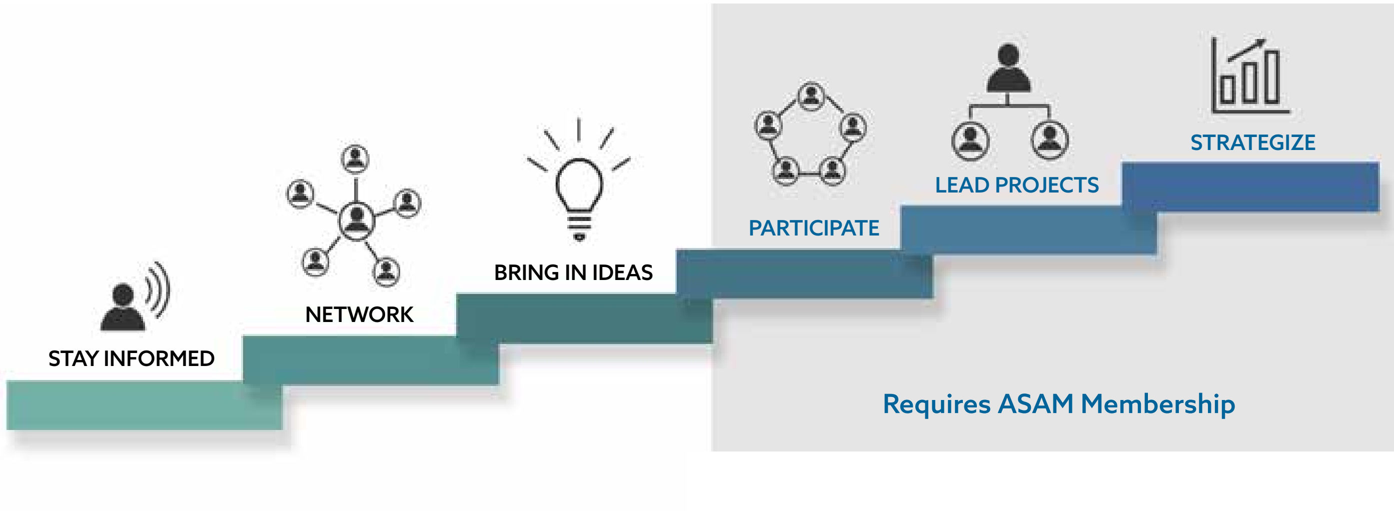
Take advantage of a pool of experts from more than 400 member companies: Standardization projects are based on the collaboration among all stakeholders. Project members gain valuable insights from each other, share their knowledge (in non-competitive areas) while working on shared challenges and developing innovative solutions together. This engagement with industry leaders and researchers not only helps members stay ahead of industry challenges and emerging technologies, but also drives innovation and creates valuable partnerships and business opportunities.

Stay ahead in competition, innovation and compliance: ASAM members will be informed about all standard developments and strategic decisions, gaining early insights into the directions and innovations shaping the industry. This enables them to proactively respond to new trends at an early stage and helps them to ensure that their products always comply with the latest standards. This way, they can position themselves as innovation leaders and strengthen their competitive position on the market.

> *"For us, as a start-up company, ASAM is a hidden treasure. It provides access to a user community where we can directly learn about their needs and challenges. It connects us with solution providers and tool vendors so we can collaborate or learn from them how to address these challenges. And in the end, ASAM standards enable us to integrate seamlessly into existing systems within the OEM and user community."*

GIL AMID,
Foretellix

Different levels of getting involved with ASAM



"For me, ASAM is a great opportunity to collaborate with other experts. ASAM brings together professionals who might not otherwise join forces, as they typically work on parallel projects. But here, we come together to share insights and create additional knowledge."

JANN-EVE STAVESAND,
dSPACE GmbH

How to get involved in ASAM

There are many ways to get involved with ASAM, some require membership, while others do not. Some demand only minimal engagement, while others may take more of your time. Irrespective of the level of involvement, each opportunity is definitely worth it!

If you are not yet an ASAM member, we encourage you to participate in our workshops, seminars and conferences. These events offer valuable insights into our standards and their latest developments while providing opportunities to network with experts, peers and researchers in the community. You may also decide to bring in new ideas for standardization or share your requirements in a proposal workshop.

The first thing everyone needs to do is subscribe to the ASAM newsletter and/or follow us on LinkedIn, our primary channels to update on activities:

Newsletter

LinkedIn

However, only **as an ASAM member** can you actively contribute to and influence a standard. If you want to make an even greater impact, you might consider leading a project, an opportunity that enhances both your and your company's visibility. Or you can run for a position on the ASAM TSC or the ASAM Board of Directors, where you will gain deeper insights into ASAM's decision-making processes. **Join us and make a difference.**

ASAM IN RESEARCH PROJECTS

Research projects

Government-funded research projects offer a great opportunity for the involved parties to convene in a quasi-neutral environment and to dig deeper into technical aspects of selected topics. The way the work is conducted in these projects is very similar to ASAM's project groups for standards.

ASAM has always stuck to a policy of not becoming itself a formal (i.e., funded) partner in these projects. Instead, we support our members by becoming an associated partner in selected research projects. The benefit is twofold: for our members who are also part of a research projects, it becomes easy to share and use ASAM IP in the project, even if companies, which are not members of ASAM are involved; for the projects, ASAM's involvement by providing access to its standards, training and support means that they can avoid to reinvent the wheel and can start to use what is state-of-the-art from day one.

This latter aspect is crucial. In the past, we have frequently met the situation that only by introducing ASAM at an early stage of a project, we could prevent the project from spending time and money on things we already had in our portfolio. Not everyone is aware of ASAM and its offers. Getting that information out early on is essential.

There is also a significant return on our investment in research projects: their topics and, more importantly, their findings are good indicators of where the industry is moving. Therefore, feedback from research projects about the applicability of ASAM standards and requirements for their adaptation is invaluable.

In the following, we highlight briefly a few of the research projects ASAM is or has been collaborating with recently. As you will see, most of them are (co-)located in Germany. It is, therefore, in our interest to broaden our engagement with research projects also beyond Germany and Europe in the future.

KisSME

Germany, until 2023
www.kissme-projekt.de

The goal was to reduce data collection during test rides and perform large-scale recording only for scenarios that might turn out as critical. For the identification of these scenarios, AI-based technology was used. ASAM supported this project with its ASAM OpenX standards (ASAM OpenDRIVE, ASAM OpenSCENARIO) and was present at key events. The extraction of sensor data and the recording of test rides offered further touch points for ASAM standards.

SIP-adus

2nd phase, Strategic innovation program – Automated driving for universal service
Japan, 2018–2022
en.sip-adus.go.jp

The second phase of the project had, among other things, the goals of defining rules for the development and verification of automated driving systems, the development of platform technologies, and the enhancement of international cooperation for research and development in the field of automated driving.

ASAM was invited as an associated partner at key events. Several participants of the SIP-adus project were also members of ASAM and promoted ASAM standards for the project. With simulation being one of the topics of the project, ASAM could support with its ASAM OpenX standards. The activities around DIVP (Driving Intelligence Validation Platform), a safety assurance environment platform in a virtual environment, used ASAM OpenDRIVE, ASAM OpenSCENARIO, and ASAM OSI. Even more important, discussions around functionalities for sensor simulation led to the kick-off of the ASAM OpenMATERIAL project. SIP-adus is an excellent example of standardization being (co-)inspired by a research project.

AVEAS

Absicherungsrelevante Verkehrssituationen Erheben, Analysieren, Simulieren;
Germany, 2021-2024
aveas.org

This project focused on collecting, classifying and re-simulating scenarios that might be relevant for validation and homologation. Data from infrastructure sensors was evaluated as well as data from actual vehicles. The standard ASAM OpenLABEL was introduced at the first project meeting and was accepted as the key format for structuring the gathered information. With the built-in flexibility of ASAM OpenLABEL, the project was able to define and use its own taxonomy. The findings of the project are introduced into a DIN specification. ASAM supported this project with expertise, participation at key events, and gave it a platform at the ASAM International Conference in December 2024.

SET Level

Simulationsbasiertes Entwickeln und Testen von automatisierten Fahrzeugen, 2019 – 2023
www.setlevel.de

SET Level is one of the follow-up projects of the original PEGASUS project (https://www.pegasusprojekt.de) which was looking into the real-world and virtual methods for testing and validating highly automated driving functions. PEGASUS ended in 2019. In SET Level, the focus was on the simulation environment's architecture and models for virtual testing and validation of L4/L5 functions. Key findings included the so-called "credible simulation process". ASAM was mostly represented by the key members of the project but also participated in numerous key events. The ASAM OpenX standards (e.g., ASAM OpenDRIVE, ASAM OpenSCENARIO, ASAM OSI) were used throughout the project.

VVM

Verification and Validation Methods, 2019-2023
www.vvm-projekt.de

VVM is another project of the PEGASUS family. It complements the previously mentioned SET Level project by focusing on the methodology for scenario-based validation and verification of automated driving functions. Most of the project's participants were ASAM members, therefore guaranteeing that the potential of ASAM's standards was clear to the projects. VVM used the full suite of ASAM OpenX standards (ASAM OpenSCENARIO, ASAM OSI, ASAM OpenDRIVE, ASAM OpenXOntology, ASAM OpenCRG, ASAM OpenLABEL) and provided also some of the inspiration for the standard ASAM OpenODD. ASAM representatives participated in key events.

TECH INTRO

Collaboration is essential for advancing automotive standardization. A lean, structured, and transparent standard development process is key, so industry experts can drive the development of standards and their integration into solutions worldwide.

ASAM'S STANDARDIZATION FRAMEWORK

The automotive industry is undergoing a significant transformation with the rise of software-defined vehicles (SDVs) and data-driven development. This shift is reshaping vehicle development, deployment, and maintenance. ASAM, with its strong data-centric foundation and guiding principle of „we follow the data", is uniquely positioned to address these challenges and to „accelerate engineering for mobility".

As a member-driven organization, ASAM's strategy evolves in response to our members' needs and market trends. Currently, we are observing a growing need to facilitate processes that integrate multiple standards and to ensure that our standards can effectively support complete toolchains in automotive development and testing. Initiatives such as ASAM TestSpecification and the ASAM OpenX proof-of-concept are addressing these needs and make sure that ASAM standards remain aligned with industry requirements.

Looking ahead, we recognize that the automotive landscape will continue to evolve, with new trends emerging while others may become obsolete. However, by actively engaging with our members and continuously assessing the changing needs of the industry, we are confident that these changes will be reflected accordingly in the structure of our member basis, allowing us to consistently engage the right parties to address today's and tomorrow's challenges.

ASAM'S COLLABORATIVE STANDARDIZATION PROCESS

Having the right parties at the table is crucial, but equally important is the process that enables these experts to effectively develop standards. ASAM is dedicated to providing a robust and proven standardization process that not only supports our members but also enhances collaboration.

1. Key principles

ASAM follows a lean, structured, and transparent development process to create standards that meet the needs of its members and the broader mobility community. Our development process is continually being refined to ensure efficiency, collaboration, and alignment with industry requirements.

1. **Member-driven initiatives:** Standards are developed based on proposals from ASAM members, ensuring relevance and practical value.
2. **Collaborative workgroups:** Development is conducted by expert workgroups comprising members from diverse organizations.
3. **Structured phases:** The process follows clearly defined phases, from proposal to publication, ensuring quality and consistency.
4. **Compliance with anti-trust regulation:** The admissibility of the ASAM standardization process under EU Competition Law has been legally verified.

2. Development phases

All standards and ASAM products begin with an idea, be it for a new feature or a concept for a new standard. An idea can be submitted by anyone, even non-members or individuals. The ASAM team works with an idea contributor to bring a market relevant idea to the attention of the global ASAM community, helping to identify other potentially impacted stakeholders for joint scoping. Once an idea is formalized into a proposal document, where project scope and requirements are set, it is submitted to the TSC for approval. On approval, a project is brought to life, and the proposed content is developed, followed by the review and release phases to ensure quality and alignment with ASAM's guidelines.

1. **Proposal:**
   - Members submit project proposals, outlining the need for new standards or revision.
   - Proposals are evaluated by the TSC.
2. **Development:**
   - Project groups collaborate on drafting the standard, leveraging industry expertise.
   - Iterative reviews and feedback cycles ensure alignment with objectives.
3. **Review:**
   - Release candidates undergo rigorous review by the ASAM community.
   - Finalized standards are submitted to the TSC for final review.
4. **Release:**
   - Published standards are made available to members and the public.

The development process in all its details is described in the **ASAM Project Guide**:

3. Pilot: Revised development approach

In 2025, ASAM initiated a pilot project to explore a revised development approach. It aims to

- lower the barrier of entry to contributing to ASAM's projects,
- improve long-term planning and alignment of ASAM's standards,
- lower the administrative workload of project participants,
- establish standing bodies to provide continuous oversight, alignment, and transparency across projects,
- increase transparency by regularly communicating the latest developments within the domain.

The pilot is limited to the Simulation domain to allow controlled experimentation. Regular evaluations and member feedback will guide adjustments, and the results will determine feasibility for broader adoption within ASAM.

4. Conclusion

ASAM's development process is integral to its mission of advancing automotive standards. While the core approach has proven effective, the revised pilot aims to address emerging challenges and opportunities. By incorporating static groups, more flexible projects, and enhanced oversight mechanisms, this dual strategy ensures ASAM remains at the forefront of standardization efforts, delivering value to its members and the industry.

OPEN SOURCE AT ASAM

1. Offerings by ASAM

ASAM is expanding its presence in open source, both through open-source implementations of tools supporting its standards and a growing list of open-source standards. Our organizational open-source presence, also referred to as the ASAM Open-Source Software Platform, is located on GitHub. There we host and facilitate various types of open-source initiatives to support the automotive community and promote the adoption of our standards:

- **Open-source standards:** ASAM publishes open-source standards such as:
  - ASAM OSI (Open Simulation Interface): Developed in ASAM projects and openly available, ASAM OSI serves as a critical component for simulation interoperability, aligning with ASAM's mission to enable efficient development and testing workflows.
  - ASAM OpenMATERIAL® 3D: A standard developed within ASAM projects, promoting transparency and collaboration in material simulation and data exchange.
- **Open-source tools:** These tools are developed in ASAM projects and directly complement the use of ASAM standards. Examples include:
  - ASAM Quality Checker Framework: A framework that allows the configuration, execution, and reporting of checks based on rules defined by ASAM standards, enabling users to validate conformity of files and implementations.
    - qc-opendrive: A specific checker bundle for ASAM OpenDRIVE.
    - qc-openscenarioxml: A specific checker bundle for ASAM OpenSCENARIO XML.
  - Wireshark Plugin for ASAM iLinkRT: Enables the popular network protocol analyzer Wireshark to dissect ASAM iLinkRT frames, facilitating the interpretation of command requests and data telegrams.
- **Links to third-party tools:** ASAM provides references to tools maintained by external parties. These tools, though not hosted by ASAM, may be helpful to users of ASAM standards and the broader automotive ecosystem. Examples include:
  - odsbox: A versatile toolbox for exploring and analyzing ASAM ODS (Open Data Services) data, offering convenient access to data visualization and query functions.
  - Converters, visualization tools, and test frameworks that align with ASAM standards.

2. Licensing and contribution of tools

ASAM ensures that all open-source tools and standards it hosts adhere to commonly accepted open-source license models, fostering transparency and collaboration. Contributors are required to follow ASAM's Contribution Guidelines, which outline the process for submitting code, documentation, or other resources.

For tools developed in ASAM projects, ASAM retains ownership and responsibility for maintaining these resources. For third-party tools hosted by ASAM, ownership and maintenance remain with the respective contributors, though ASAM provides a platform for visibility and collaboration. Linked third-party tools, not hosted by ASAM, are offered as references to benefit users but remain outside of ASAM's direct governance.

This structure ensures a clear distinction of ownership and responsibilities while enabling the mobility community to leverage a wide range of resources to enhance interoperability and efficiency.

3. Plans for open-source engagement

ASAM continually reviews its engagement in open-source tools relevant to its standards. We aim to curate and organize these resources into a structured repository, made accessible on ASAM's GitHub . Our efforts take inspiration from established frameworks like Awesome Lists. An excellent example is the member-driven Awesome OpenX, which serves as a curated resource for open source tools and projects in the OpenX domain.

Continuous improvements in our offerings shall lead to
- enhanced discoverability of tools that complement ASAM standards,
- categorization based on use cases, such as simulation validation, and data processing,
- intensified collaboration with ASAM members and the broader community to ensure completeness and relevance.

ASAM is committed to fostering an open and collaborative ecosystem that benefits the entire automotive community. By making these resources widely available, ASAM continues to strengthen its role as a hub for standardization and innovation.

For further context, refer to the following resources:

ASAM on GitHub

Contribution guidelines

ASAM'S POSITION IN THE STANDARDIZATION LANDSCAPE

ASAM's key collaborations with standards organizations

ASAM focuses on the creation of **de facto** standards, bridging the gap between industry needs and practical, implementable solutions. Unique in its close connection to real-world applications, ASAM standards are not only designed for interoperability across the mobility landscape but also tailored to support seamless integration with tooling, software, and hardware implementations.

Collaboration is central to ASAM's approach: we actively engage with other organizations to minimize overlap and to clarify roles in an otherwise fragmented standardization landscape. Unlike broader frameworks or best practices from other standards bodies, ASAM's standards often address specific technical requirements, such as data exchange, communication protocols, and application-specific interfaces, which enhance compatibility across domains.

One core tenet of ASAM's application areas is to "follow the data", covering use cases that span from vehicle ECUs and diagnostic systems to complex simulation environments where sensors interact with ground truth data. To facilitate these diverse use cases, ASAM publishes a variety of standards formats, including APIs, protocols, data exchange formats, and domain-specific languages, all designed to ensure seamless, effective data flow within the automotive industry. In collaboration with bodies such as ISO and SAE, ASAM's standards often build on foundational best practices while delivering direct, implementable solutions compatible with other organizations' specifications.

In the particular case of ISO, there is a bi-directional transfer of content and contributions to standards. Over the past 25 years some standards released at ASAM have also been released at ISO. This allows companies in the industry to best leverage the strengths of the respective organizations: the development processes of ASAM to accelerate the time-to-market, together with the global reach of ISO for regulatory purposes.

The following section describes ASAM's active partnerships with other organizations, highlighting specific initiatives and working groups where alignment and joint development are ongoing. The listing below (in alphabetical order) is by no means exhaustive.

AUTOSAR (Automotive Open System Architecture)

www.autosar.org

AUTOSAR is a worldwide development partnership of vehicle manufacturers, suppliers, and other companies in the automotive electronics industry, focused on creating and establishing an open and standardized automotive software architecture.

AUTOSAR Adaptive Platform
- **Service-Oriented Architecture:** Provides flexible, scalable software architecture for high-performance automotive computing. Several of ASAM's diagnostic standards align with AUTOSAR's adaptive services, enabling streamlined system communication. A key feature within the Adaptive Platform is the Run-Time Interface (RTI), which standardizes the communication between applications and the underlying platform middleware, enabling real-time data exchange across different software modules and ECUs. ASAM ARTI (ASAM Run-Time Interface) complements RTI by extending its capabilities to simulation and testing environments. This ensures that data exchange in real-time between virtual models and physical ECUs remains consistent, supporting high-fidelity testing and validation across development and production phases. The integration of ASAM SOVD within AUTOSAR Adaptive allows for seamless data exchange and unified diagnostic access across different ECUs, supporting real-time diagnostics and condition-based maintenance. This integration is particularly valuable in the Adaptive Platform's context, where remote diagnostics, over-the-air updates, and dynamic service management are key.

AUTOSAR Classic Platform
- **Real-Time ECU Communication:** Optimized for ECUs with real-time constraints, AUTOSAR Classic supports deterministic and robust vehicle networking.

AUTOSAR Automotive API
- **Standardized Access to Vehicle Functions and Data:** The Automotive API is a set of standardized interfaces that provide access to key vehicle functions and data within a unified framework, enabling seamless integration and communication across applications on the Adaptive Platform. By offering a consistent API structure, the Automotive API simplifies development and supports the modular design of software-defined vehicles. This initiative is a good candidate for alignment with ASAM SOVD.

BSI (British Standards Institution)

www.bsigroup.com

BSI is the UK's national standards body, responsible for creating and maintaining standards that ensure safety, quality, and interoperability across industries. BSI's work in autonomous and connected vehicle standards, especially through Publicly Available Specifications (PAS), supports a shared framework for operational design domains and automated driving systems, which ASAM complements with its application-specific standards.

- **BSI PAS 1883 Operational Design Domain (ODD) Taxonomy for Automated Driving:** PAS 1883 provides a hierarchical taxonomy for defining Operational Design Domains (ODD) in automated driving systems, outlining environmental, spatial, and operational parameters. ASAM OpenODD aligns with PAS 1883, enabling machine-readable ODD definitions that can be shared across automated driving applications and systems.
- **BSI PAS 1889 Safety Argument for Automated Driving:** PAS 1889 offers a framework for developing and documenting safety arguments in automated driving systems. It guides manufacturers and developers in presenting safety evidence to meet regulatory requirements. ASAM's simulation and testing standards, such as ASAM OpenSCENARIO, support the practical implementation of PAS 1889 by providing detailed, machine-readable scenario descriptions for rigorous safety validation and testing.

COVESA (Connected Vehicle Systems Alliance)

covesa.global

COVESA, formerly known as the GENIVI Alliance, is an open, collaborative platform focused on standardizing connected vehicle systems. COVESA develops open standards to promote interoperability across vehicle ecosystems, with a strong emphasis on enabling data sharing, service integration, and flexibility in vehicle software architectures. COVESA's initiatives are aligned with ASAM's efforts, particularly in the area of standardized diagnostics and vehicle data access.

There is a potential overlap between some activities within COVESA and ASAM with regards to accessing in-vehicle data; discussions are underway to clarify this in further detail.

Vehicle Signal Specification (VSS)
- **Unified Data Model for Vehicle Signals:** VSS defines a common data model for vehicle signals, providing a standardized structure for organizing and accessing in-vehicle data. By creating a harmonized signal structure, VSS enables cross-OEM compatibility, allowing developers and service providers to create applications that can interact with vehicle data in a consistent format. ASAM SOVD aligns with VSS by supporting structured access to vehicle diagnostic data, ensuring that diagnostic interfaces work seamlessly with the VSS data model for standardized diagnostics and real-time data retrieval.

Vehicle Information Service Specification (VISS)
- **Standardized Vehicle Data Access Protocol:** VISS builds upon VSS by providing a standard API to access vehicle data remotely or locally. This specification allows applications to retrieve or monitor vehicle signals defined in VSS over the internet, enabling real-time access to data for applications in areas like fleet management, maintenance, and diagnostics. ASAM SOVD complements VISS by standardizing diagnostic access, allowing applications that use VISS to access consistent diagnostic data, improving the integration of condition-based maintenance and remote diagnostics in connected vehicle applications.

DIN (German Institute for Standardization)

www.din.de/en

DIN is Germany's national standards organization, responsible for developing standards that contribute to safety, quality, and technological innovation across industries. In the automotive sector, DIN plays a vital role in supporting Germany's leadership in vehicle technology, collaborating with ASAM to ensure compatibility and efficiency in areas such as vehicle diagnostics and in-vehicle communication.

DIN SPEC 91381
- **Road Vehicle Safety and Data Communication:** This specification covers data interfaces for automotive safety systems, particularly for diagnostics and data exchange. ASAM's MCD standards are closely aligned with DIN SPEC 91381, enabling standardized diagnostic tools and ensuring interoperability across systems developed within Germany's automotive industry.

DIN SPEC 70121
- **V2G Communication Interface:** Defines communication standards for Vehicle-to-Grid (V2G) applications, enabling electric vehicles to interact with energy systems. Although primarily focused on electric vehicle charging, ASAM's data formats for simulation and diagnostics support similar communication structures, helping align testing protocols with these energy systems interfaces.

Eclipse Foundation

www.eclipse.org

The Eclipse Foundation is an open-source software foundation known for hosting projects across multiple industries, including automotive. Eclipse provides collaborative open-source development environments that support the software-defined vehicle (SDV) movement.

Eclipse SDV (Software-Defined Vehicle)

Vehicle Software Architecture: Supports the development of software-defined automotive functionality (see page 48).

Eclipse SUMO (Simulation of Urban MObility)

Traffic and Mobility Simulation: An open-source traffic simulation platform, SUMO supports large-scale urban traffic modeling. Often users employ SUMO as a traffic simulator together with ASAM's simulation standards for scenario and road network description.

ISO (International Organization for Standardization)

www.iso.org

ISO is an international standards body that publishes global standards to ensure safety, quality, and interoperability across various industries, including automotive and mobility. ASAM collaborates with multiple ISO committees to align standards for diagnostics, simulation, autonomous driving, and communication protocols.

ISO TC22 (Road Vehicles)
This committee oversees standardization related to all aspects of road vehicles, including safety, performance, and data communication.

- **SC 33 Vehicle dynamics, chassis components and driving automation systems testing**
  ASAM has a C Liaison with WG9 (ADAS/Automated Driving Systems), which focuses on defining terms, scenarios, and requirements for automated driving systems (ADS), with particular emphasis on operational design domains (ODD) and scenario testing.
  - **ISO 34501/34502 (Test Scenarios for ADS)** Establishes terminology and frameworks for ADS test scenarios, with ISO 34501 focusing on terms and definitions and ISO 34502 on an engineering framework. ASAM's OpenSCENARIO formats support these standards, providing a machine-readable structure for ADS scenario modeling and simulation.
  - **ISO 34503 (Operational Design Domain)** Defines machine-readable ODD representations for automated driving systems. ASAM OpenODD aligns with ISO 34503 to ensure consistency in defining ODD across different platforms.

- **SC 31 Data communication** ASAM has an A Liaison with this committee. Discussions for simplifying the legal framework for collaboration are under way.
  - **ISO 22900 (Modular Vehicle Communication Interface – MVCI)** Specifies a modular communication framework for diagnostic services across vehicle manufacturers and systems. ASAM MCD-3 D is integrated with ISO 22900, enabling consistent diagnostics and vehicle communication protocols.
  - **ISO 22901 (Open Diagnostic Data Exchange – ODX)** Defines a structured XML-based data format for vehicle diagnostics, allowing manufacturers to standardize diagnostic data across tools and systems. ASAM MCD-2 D supports ISO 22901 by enhancing vehicle diagnostic interoperability through structured data definitions.
  - **ISO 13209 (Open Test Exchange Format – OTX)** Provides a standard format for creating and exchanging test sequences in diagnostics. ASAM OTX Extensions expand this standard by adding use cases and functionality tailored to automotive diagnostics and are later contributed to ISO as ISO 13209 Part 4.
  - **ISO 17978 (Standardized Onboard Diagnostics – SOVD)** Standardized data format for onboard diagnostics. ASAM SOVD is published as part 3 of this ISO standard and specifies the API itself.
  - **ISO 23150 (Logical Interface for Sensor Fusion)** Defines the logical interface for data fusion systems in automated driving, providing a framework for sensor and data fusion interoperability. ASAM OSI (Open Simulation Interface) aligns with ISO 23150, enabling a standardized interface for integrating sensors with data fusion systems in autonomous vehicles.

Intelligent Transportation Systems (ITS)

www.its.dot.gov

The ITS Joint Program Office, often working with standards bodies like ISO and IEEE, is a public-sector organization that coordinates research and development on intelligent transportation systems, aiming to improve the safety and efficiency of transportation through advanced technology and connectivity.

ITS Joint Program Office
- **Connected Vehicle Standards:** ITS standards ensure secure data exchange between vehicles and infrastructure. ASAM's diagnostic and simulation data formats (e.g. ASAM OpenDRIVE) can integrate with ITS standards, supporting real-time data flow for V2X communication.

Modelica Association

modelica.org

The Modelica Association develops open standards for modeling, simulation, and system integration. Modelica standards are used widely in automotive, aerospace, and other industries for real-time and multi-domain simulations.

Functional Mock-up Interface (FMI)
- **Model Exchange and Co-Simulation:** Defines standards for sharing dynamic models in simulation environments. ASAM OSMP (ASAM OSI Sensor Model Packaging), an extension of ASAM OSI (Open Simulation Interface), leverages FMI to package sensor models for seamless integration in simulation environments. Through FMI, OSMP standardizes the interaction of sensor models with simulation platforms, enabling the co-simulation of perception models within autonomous driving and ADAS development. This setup allows developers to integrate complex sensor models into simulations, enhancing the testing and validation of sensor fusion and perception algorithms under realistic conditions.

System Structure and Parametrization (SSP)
- **Tool-Independent System Structuring:** Provides a format for system configuration and parameter management.

Distributed Co-Simulation Protocol (DCP)
- **Real-Time System Integration:** DCP is designed to enable the integration of models or real-time systems across different simulation environments, supporting a range of underlying transport protocols like TCP, UDP, or CAN. ASAM's alignment with DCP ensures smooth co-simulation and real-time data exchange between diverse automotive systems and models.

OGC (Open Geospatial Consortium)

www.ogc.org

OGC is an international organization that develops open standards for geospatial content and location-based services. OGC's standards foster interoperability between systems, supporting various industries from mapping to autonomous driving.

OGC CityGML
- **City Geography Markup Language:** Provides a standardized framework for 3D city modeling. ASAM is running a project to more closely investigate the benefits of linking this framework with ASAM OpenDRIVE and to leverage the respective strengths of the standards.

OGC NDS (Navigation Data Standard)
- **Standardized Map Data:** Enables seamless map data integration for in-vehicle navigation systems. Tooling from third parties is available to convert between ASAM OpenDRIVE and NDS formats.

SAE (Society of Automotive Engineers)

www.sae.org

SAE International is a professional association focused on advancing mobility knowledge and solutions. Its standards span the automotive, aerospace, and commercial vehicle sectors, with an emphasis on technical standardization and professional education.

SAE AVSC (Automated Vehicle Safety Consortium)
- **Best Practices for AV Safety:** AVSC defines best practices for safe operation of automated vehicles, including ODD (Operational Design Domain) requirements. Both ASAM OpenSCENARIO XML and ASAM OpenSCENARIO DSL support AVSC practices through scenario simulation and safety testing formats.

SAE ORAD (On-Road Automated Driving)
- **SAE J3016:** Provides a taxonomy for driving automation systems. ASAM standards, such as ASAM OpenODD and ASAM OpenLABEL, help ensure consistent definitions for automation levels.

- **SAE J3164:** Defines autonomous driving maneuvers and behaviors. ASAM's OpenSCENARIO standards support this by facilitating shared scenario descriptions and behavior modeling.

VDA (German Association of the Automotive Industry)

www.vda.de/en

The VDA represents Germany's automotive industry, including manufacturers and suppliers, and focuses on improving standards for automotive development, safety, and quality. The organization collaborates with ASAM to support vehicle safety, interoperability, and connectivity within German and international automotive markets.

VDA Recommendation 305-100
- **Automotive Diagnostic Interfaces:** This recommendation standardizes diagnostic interfaces, enabling manufacturers and service providers to communicate consistently across vehicle systems. ASAM MCD-2 D standard aligns with VDA 305-100, providing a compatible framework for diagnostics across German-manufactured vehicles.

VDA Leitfaden (Guidelines for Automated Driving)
- **Testing and Safety Requirements for Automated Driving:** VDA's guidelines for automated driving cover testing and operational safety standards, which align closely with ASAM OpenSCENARIO and ASAM OpenODD standards.

ASAM PORTFOLIO

ASAM offers a wide range of standards that support the development, testing, validation, and diagnostics of ECUs and HPCs, as well as infrastructure standards for handling, structuring, and evaluating data.

The following chapter provides an overview of the complete ASAM portfolio, along with a closer look at specific standards that have recently been or will soon be further developed or maintained.

HOW DOES IT ALL WORK TOGETHER?

With 40 released standards, ASAM has a rather small portfolio compared to other standardization organizations. This reflects ASAM's focus on a limited number of domains and its specialization in implementation-level standards:

SIMULATION

OpenCRG | OpenDRIVE | OpenLABEL | OpenMATERIAL 3D | OpenODD | OpenSCENARIO DSL | OpenSCENARIO XML | OSI

MEASUREMENT & CALIBRATION

ARTI | CDF | CMP | CPX | HMS | MCD-1 CCP | MCD-1 POD | MCD-1 XCP | MCD-2 MC | MCD-2 CERP | MDF

DATA MANAGEMENT & ANALYSIS

CEA | ODS

DIAGNOSTICS

MCD-2 D | MCD-3 D | SOVD

TEST AUTOMATION

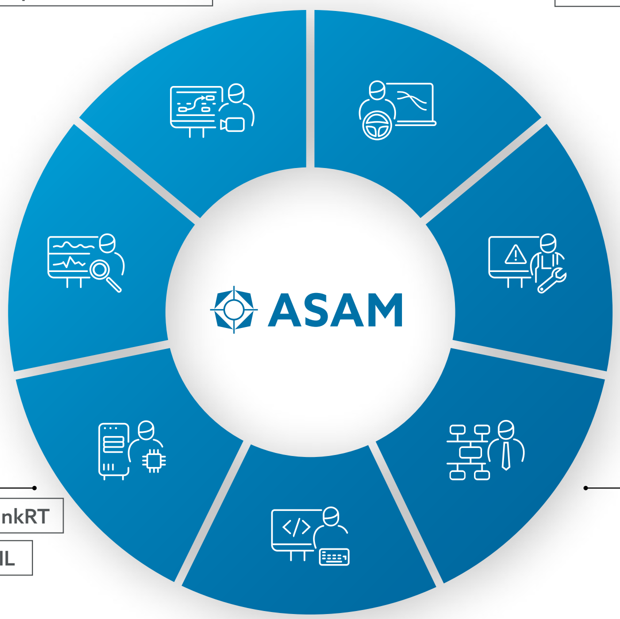
ACI | ASAP 3 | ATX | GDI | iLinkRT | MCD-3 MC | OTX Extensions | XIL

ECU NETWORKS

MCD-2 NET

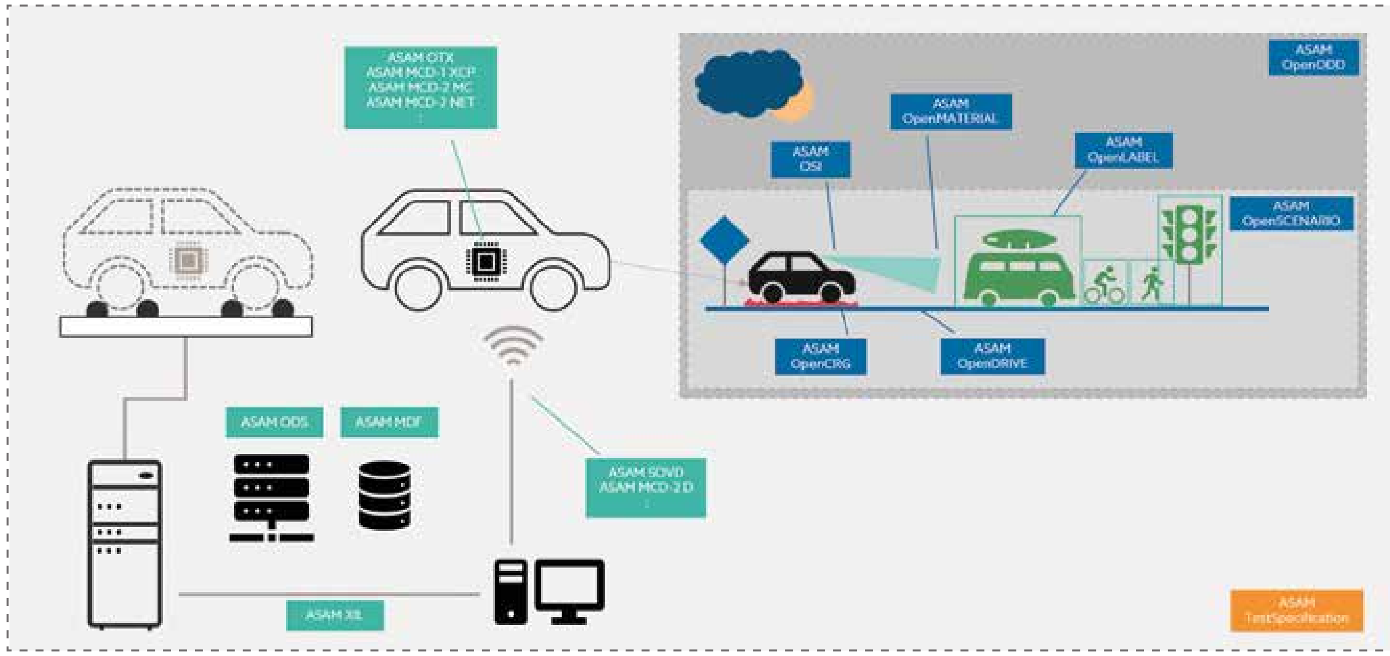
SOFTWARE DEVELOPMENT

CC | FSX | ISSUE | LXF | MBFS | MDX | SCDL



The strength of this portfolio lies in the coherence and alignment of the individual standards. Together, they create a coherent framework, a big picture, which is far larger than the sum of its parts.

ASAM's offer – A selection of ASAM standards inside and outside the vehicle



ASAM standards can be used throughout the entire vehicle life cycle. Early stages of the development will rely mainly on **virtual** methods. These require descriptions of the environment as they are supported by ASAM OpenDRIVE and ASAM OpenCRG for roads, and ASAM OpenMATERIAL 3D for any kind of objects (figure above, top right).

Both virtual and **real-world** testing require scenarios that are described with ASAM OpenSCENARIO XML and ASAM OpenSCENARIO DSL, two complementary formats for a similar purpose. While the XML variant is mostly used for logical and concrete scenarios, its DSL sibling finds its primary application in functional scenarios where large numbers of variants need to be described in an easily manageable language.

Runtime data during scenario execution may be transmitted and/or recorded using the ASAM OSI protocol. This includes but is not limited to sensor data. Where sensors are involved, it is necessary to describe perception and, thus, the objects that have been identified. That is the purpose of the ASAM OpenLABEL format: It has applications beyond labeling, e.g. for tagging scenarios and the same. It is kept rather generic so that any taxonomy may be referenced by it. But the clear focus of ASAM OpenLABEL is on sensor and scenario data.

Finally, ASAM OpenODD describes the operational design domain of a vehicle and/or its function, including statements about road and weather conditions, etc.

While the above standards focus primarily on the **interaction of the vehicle with its environment**, ASAM also provides a range of standards **dedicated to ECUs and HPCs throughout the entire vehicle life cycle** (figure above, left side). ASAM standards in the Measurement & Calibration domain as well as in Diagnostics are found on board and in the respective development and test environments. ASAM SOVD (service-oriented vehicle diagnostics) also enables over-the-air communication with the vehicle to query diagnostics information and to push data onto the car.

Data that is recorded in measurement campaigns, for example, may be stored in ASAM MDF files. ASAM ODS (Open Data Services) focuses on the persistent storage and retrieval of testing data, independent of the underlying IT architecture and with a highly adaptable yet still well-defined data model. An API for the communication with servers running ODS databases is also part of the standard.

Calibration and testing of vehicles are facilitated by ISO OTX (open test sequence exchange) which was originally developed for ECU diagnostics testing. But only with ASAM OTX Extensions did the application and exchange of data across a wide range of tools become possible. Test benches (back-end) and test automation tools (front-end) are often provided by dedicated, specialized suppliers. The ASAM XIL API ensures that devices and tools from either end understand each other and can be combined seamlessly.

Looking at the full scope of testing itself, the ASAM TestSpecification will ensure that test methods and test environments can be paired in the most efficient way and that the ASAM standards facilitate the design and execution of test campaigns.

ASAM SCDL (safety concept description language) assists in creating a system architecture that is compliant with functional safety requirements along ISO 26262.

This brief overview of ASAM standards presented above is far from complete but it gives a good impression of the mutual alignment of standards and of ASAM as an organization that is concerned with ensuring interoperability across its portfolio.

ASAM STANDARDS PORTFOLIO

ASAM standards are designed to ensure effective communication between development parties and technologies, enabling them to speak the same 'language' and collaborate efficiently. To support this, ASAM standards define APIs, protocols, data exchange formats, and domain-specific languages.

ASAM standards are structured into seven domains, each addressing specific aspects of automotive development, testing, validation, or diagnostics. The following list highlights how each standard contributes to ensuring interoperability and efficiency across the industry.

MEASUREMENT & CALIBRATION

STANDARD	TITLE	LATEST VERSION	TECHNICAL SPECIFICATION	TECHNOLOGY REFERENCES	CONTENT
ASAM ARTI	ASAM Run-Time Interface	1.0.0	Format description		Exchange format for embedded operating system trace data
ASAM CDF	Calibration Data Format	2.1.0	Format description (XML)		Exchange format for calibration data
ASAM CMP	Capture Module Protocol	1.0.0	Protocol		Definition of communication framework between capture modules and data sinks
ASAM CPX	Calibration Process Exchange Format	1.0.1	API Format description (XML)		Exchange format for calibration process sequences as OTX extensions
ASAM HMS	HEX File Management System	1.0.0	REST API		API linking external systems and HEX management databases
ASAM MCD-1 CCP	CAN Calibration Protocol	2.1.0	Protocol		CAN-access to ECUs from an application system (MC System)
ASAM MCD-1 XCP	Universal Measurement and Calibration Protocol	1.5.0	Protocol		Universal access to ECUs from an application system (MC System)
	AS: CAN Transport Layer	1.5.0	Transport layer specification		Describes how ASAM MCD-1 XCP is transported on CAN and CAN-FD as transport layer
	AS: Ethernet Transport Layer	1.5.0	Transport layer specification		Describes how ASAM MCD-1 XCP is transported on Ethernet as transport layer
	AS: FlexRay Transport Layer	1.5.0	Transport layer specification		Describes how ASAM MCD-1 XCP is transported on FlexRay as transport layer
	AS: SxI Transport Layer	1.5.0	Transport layer specification		Describes how ASAM MCD-1 XCP is transported on SPI and SCI as transport layer
	AS: USB Transport Layer	1.5.0	Transport layer specification		Describes how ASAM MCD-1 XCP is transported on USB as transport layer
	AS: Software Debugging over XCP	1.1.0	Protocol extension		Debugging of ECUs based on ASAM MCD-1 XCP
ASAM MCD-1 POD	Plug-on Device Interface	1.0.0	API Protocol		API between an ECU application and a plug-on device (hardware adapters)
ASAM MCD-2 CERP	Calibration Expert System Rule and Product Format	1.0.0	API Format description		Exchange format to formalize calibration expert nowledge as OTX extensions
ASAM MCD-2 MC (aka A2L / ASAP 2)	Data Model for ECU Measurement and Calibration	1.7.1	Format description (non-XML)		Exchange format for description of measurements and characteristics
ASAM MDF	Measurement Data Format	4.2.0	Format description (binary)		Data exchange format for highly efficient storage of binary data
	AS: Bus Logging	1.0.1	Format description (binary)		Exchange format for describing traffic for common bus systems
	AS: Classification Results	1.0.0	Format description (binary)		Exchange format for the storage of classification results
	AS: Measurement Environment	1.0.0	Format description (binary)		Exchange format for the storage of measurement environments
	AS: Naming of Channels and Channel Groups	1.0.0	Format description (binary)		Exchange format for the Unique identification of channels and channel groups

DIAGNOSTICS

STANDARD	TITLE	LATEST VERSION	TECHNICAL SPECIFICATION	TECHNOLOGY REFERENCES	CONTENT
ASAM MCD-2 D (aka ODX)	Data Model for ECU Diagnostics	2.2.0	Format description (XML)	Communication Parameter Specifications	Exchange format for description of diagnostic services
	AS: Authoring Guidelines	1.0.0	Format description (XML)		Common ODX recommendations
ASAM MCD-3 D (aka MVCI D-Server API)	Application Programming Interface for MVCI Diagnostic Server	3.0.0	API	COM/DCOM, JAVA, C++	Diagnostic API for MVCI-D servers
ASAM SOVD	Service-Oriented Vehicle Diagnostics	1.0.0	REST API		Diagnostic API for software-defined vehicles

ECU NETWORKS

STANDARD	TITLE	LATEST VERSION	TECHNICAL SPECIFICATION	TECHNOLOGY REFERENCES	CONTENT
ASAM MCD-2 NET (FIBEX)	Data Model for ECU Network Systems	4.1.2	Format description (XML)	Communication Parameter Specifications	Exchange format for the description of bus configuration and parametrization

SOFTWARE DEVELOPMENT

STANDARD	TITLE	LATEST VERSION	TECHNICAL SPECIFICATION	TECHNOLOGY REFERENCES	CONTENT
ASAM CC	Container Catalog	3.0.0	Format description (XML)		Description of engineering objects and meta information
ASAM FSX	Functional Specification Exchange Format	1.1.0	Format description (XML)		Functional specification of ECU software systems
ASAM ISSUE	ISSUE Exchange Format	3.2.0	Format description (XML)		Exchange of issues between different issue tracking systems
ASAM LXF	Layout Exchange Format	1.0.0	Format description (XML)		Description of a layout in XML syntax
ASAM MBFS	Model Based Function Specification	1.0.0	Blockset specification	MATLAB, Simulink	Standard library of blocksets
ASAM MDX	Meta Data Exchange Format	1.3.0	Format description (XML)		Metadata exchange for software module sharing
ASAM SCDL	Safety Concept Description Language	1.6.0	Format description (XML)		Notation to describe safety architectures

TEST AUTOMATION

STANDARD	TITLE	LATEST VERSION	TECHNICAL SPECIFICATION	TECHNOLOGY REFERENCES	CONTENT
ASAM ACI	Automatic Calibration Interface	1.4.0	API	Corba	API between automatic calibration system and automation system
ASAM ASAP 3	Automation Access Protocol for MC Server	3.0.0	API		Definition of communication framework between MC client and MC server
ASAM ATX	Automotive Test Exchange Format	1.0.1	Format description (XML)		Description of test data between different test systems
ASAM GDI	Generic Device Interface	4.5.0	API	C++ API	Vendor-independent APIs to connect measurement and control devices and test bed automation systems
	AS: COM Communication Type	3.0.0	Transport layer specification		Platform Adapter Extension to access COM
	AS: IP4 Communication Type	3.0.0	Transport layer specification		Platform Adapter Extension to access IP4
	AS: LPT Communication Type	3.0.0	Transport layer specification		Platform Adapter Extension to access LPT
	AS: SoftSync Communication Type	3.0.0	Transport layer specification		Platform Adapter Extension for the software synchronization of function objects
	AS: USB	3.1.0	Transport layer specification		Platform Adapter Extension to access USB
	AS: Chassis Dyno Device Capability	1.0.0	Application area companion	Skeleton	Functionality set for chassis dyno test beds
	AS: Crash Device Capability	1.0.0	Application area companion		Functionality set for measurement devices used for crash tests
	AS: MCD-3 Device Capability	2.1.0	Application area companion	Skeleton	Functionality set for MCD-3 server
	AS: MDAQ Device Capability	2.0.0	Application area companion	Skeleton MDAQ Definition	Functionality set for multi data acquisition measurement systems
ASAM iLinkRT	High-Speed Automation-Access-Protocol for MC-Server	3.0.1	Protocol		High-speed protocol for measurement and calibration data exchange in test systems
ASAM MCD-3 MC	Application Programming Interface for Measurement and Calibration Server	3.0.0	API	COM/DCOM	API between test automation systems and MC servers
ASAM OTX Extensions	Open Test Sequence eXchange Format	3.2.0	API Format description (XML)		Domain-specific programming language to describe test cases
ASAM XIL	Generic Simulator Interface	2.2.0	API	.NET (C#), PYTHON, XIL Software	API between test automation tools and test benches for reuse of test cases

TEST DATA MANAGEMENT & ANALYSIS

STANDARD	TITLE	LATEST VERSION	TECHNICAL SPECIFICATION	TECHNOLOGY REFERENCES	CONTENT
ASAM CEA	Components for Evaluation and Analysis	2.2.0	API	JAVA, .NE	API to integrate software components into applications
ASAM ODS	Open Data Services	6.2.0	API	HTTP-API, CORBA API, RPC API	Storage, exchange and retrieval of test data in IT-independent architectures
	AS: Big Data Connector	1.1.1	Format descriptions		Access to export ODS data to big data environments
	AS: Bus Data Model	1.0.2	Format Description (NON-XML)		Application model for bus data
	AS: Calibration Model	1.1.2	Format Description (NON-XML)		Application model for calibration data
	AS: Geometry Model	1.0.2	Format Description (NON-XML)		Application model for geometry data
	AS: Instrumentation	1.1.0	Format Description (NON-XML)		Application model for instrumentation data (components and settings)
	AS: NVH Model	1.5.3	Format Description (NON-XML)		Application model for noise, vibration and harshness data
	AS: Workflow Model	1.0.1	Format Description (NON-XML)		Application model for workflow data

SIMULATION

STANDARD	TITLE	LATEST VERSION	TECHNICAL SPECIFICATION	TECHNOLOGY REFERENCES	CONTENT
ASAM OpenCRG	Curved Regular Grid	1.2.0	Format description		Static road surface description
ASAM OpenDRIVE	---	1.8.0	Format description		Static road network description
ASAM OpenLABEL	---	1.0.0	Format description		Labeling for objects and scenarios
ASAM OpenMATERIAL 3D	---	1.0.0	Format description		Material properties and 3D model structures
ASAM OpenODD	Operational Design Domain	1.0.0	Format description		Defining the operational design domain for automated vehicles
ASAM OpenSCENARIO XML	---	1.3.0	Format description		Dynamic scenario description
ASAM OpenSCENARIO DSL	---	2.1.0	Language specification		Abstract dynamic scenario description
ASAM OSI	Open Simulation Interface	3.7.0	API		Interface for simulation

SOFTWARE

NAME	CHECKED STANDARDS	CHECKED VERSION	CHECKED FILE FORMATS
ASAM MCD-2 MC Checker	ASAM MCD-2 MC	V1.7.1, V1.7.0, V1.6.1, V1.6.0, V1.5.1	a2l files, aml files
ASAM Quality Checker	ASAM OpenDRIVE	V1.4.0, V1.5.0, V1.6.0, V1.6.1, V1.7.0, V1.8.0	Xodr files
	ASAM OpenMATERIAL 3D	V1.0.0	Xom files
	ASAM OpenSCENARIO XML	V1.0.0, V1.1.0, V1.1.1, V1.2.0, V1.3.0	Xosc files
	ASAM OTX Extensions (Short representative list of check examples, no reference implementation)	V1.0.0	Otx files

ASAM STANDARDS IN DETAIL

On the following pages you will find an overview of selected ASAM standards. The descriptions provided here reflect the status at the time of writing this guide. ASAM is continuously maintaining and extending its standards portfolio. An up-to-date and comprehensive overview of all ASAM standards can be found on our website.

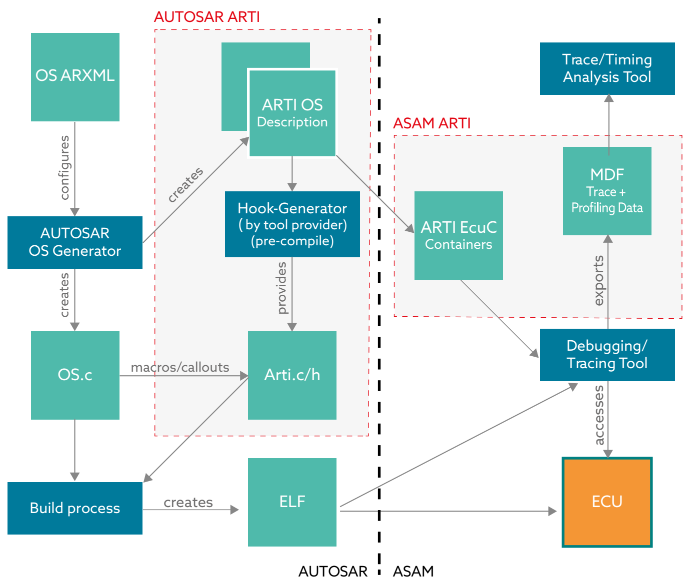
www.asam.net/standards

MEASUREMENT & CALIBRATION

ASAM ARTI

The ASAM ARTI (ASAM Run-Time Interface) standard is an interface framework designed to collect and analyze run-time data from embedded systems, with a particular focus on automotive applications. Building upon the ASAM MDF (Measurement Data Format), it streamlines the storage and retrieval of scheduling trace data and performance metrics. This provides developers with essential tools for effective debugging, optimization, and software verification in real-time operating environments.

Modern automotive applications often utilize multi-core processors, introducing complexities that require comprehensive debugging and precise traceability. Previous standards, such as the OSEK Run-Time Interface (ORTI), lacked the capabilities to handle multi-core and real-time operations across networked Electronic Control Units (ECUs). Embedded systems frequently need traceability at the operating system level, including the ability to capture state transitions and timing data across multiple processors. In real-time systems, measuring and optimizing task performance is crucial, and ASAM ARTI addresses this need by offering detailed timing metrics to analyze software efficiency and improve timing accuracy.



To enhance debugging and traceability, ASAM ARTI builds on ASAM MDF, a binary format optimized for high-frequency time-series data. It organizes trace data into channel groups (CGBLOCKs) for each trace class, simplifying categorization and retrieval. This organization supports the capturing of detailed events like task state transitions and interrupt handling across multiple ECUs. ASAM ARTI also provides advanced timing and performance metrics, offering insights such as Core Execution Time, Response Time, and Core Utilization to analyze the timing behavior of tasks. These metrics are stored as both time series and aggregated data, allowing for detailed or summary analysis based on development needs. The standard enables the calculation of derived metrics, such as core load and task preemptions, which are crucial for performance evaluation in multi-core systems.

Additionally, ASAM ARTI allows the attachment of Executable and Linkable Format (ELF) files and AUTOSAR XML configurations, enriching trace data with software context. It integrates closely with AUTOSAR standards, ensuring compatibility with industry tools and easing implementation within existing automotive workflows. The technologies utilized include the ASAM MDF (Measurement Data Format), suited for storing large volumes of real-time data in automotive applications, and channel groups (CGBLOCKs) that aid in structured and efficient data handling by organizing trace data by class type. Derived metrics, such as Execution Time and Preemption Time, are included as detailed time series for in-depth analysis or as aggregates for summary evaluation.

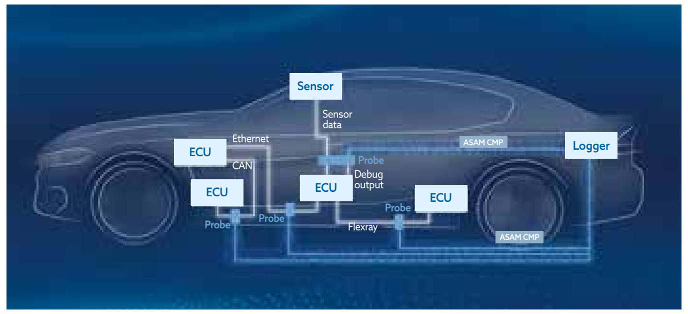
Full title ASAM Run Time Interface
Standard type File Format

Application areas
- Trace / Timing analysis tools
- Debugging tools
- Tracing tools

Latest version | Release date
ASAM ARTI 1.0.0 | Feb 28, 2020

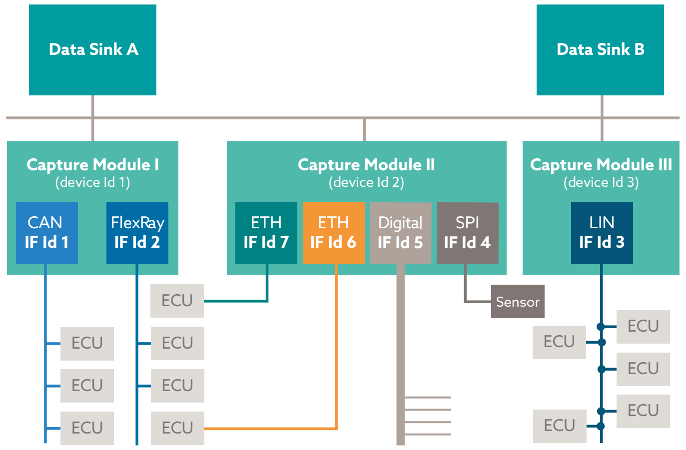
Current project
P_2024_03_ASAM_ARTI_V2.0.0_F
Start date: Oct 2024 | Planned release: Dec 2025

ASAM CMP



ASAM CMP (Capture Module Protocol) defines the communication framework between data sinks and capture modules in automotive environments. It facilitates the transmission of in-vehicle data through an Ethernet-based decentralized network and ensures that data from various communication interfaces (e.g., CAN, LIN, FlexRay, Ethernet) can be captured, transmitted, and analyzed effectively.

ASAM CMP supports data messages, status messages, control messages, and vendor-specific messages. It enables precise time-stamping, synchronization, and configuration mechanisms, ensuring interoperability and reliable data handling. It addresses the complexity of capturing and processing data from diverse interfaces by streamlining the protocol layers and structures, making integration across different automotive data-capturing devices efficient.



Capture modules / devices and interfaces

Full title Capture Module Protocol
Standard type Protocol layer

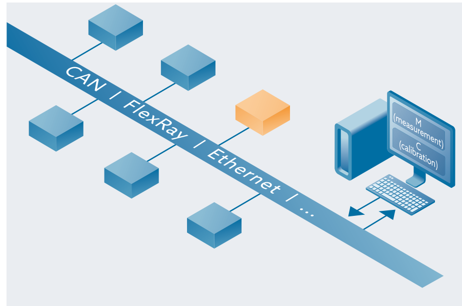
Application areas
- Automotive testing and validation
- In-vehicle communication analysis
- Sensor data acquisition and processing
- Debugging and system diagnostics

Supplementary
The standard references complementary specifications like ASAM Data Types and integrates technologies such as IEEE 802.3 for Ethernet-based communication.

Latest version | Release date
ASAM CMP 1.0.0 | Mar 31, 2022

Current project
P_2024_07_ASAM_CMP – Extension data sending
Start date: Feb 2025 | Planned release: Nov 2025

ASAM MCD-1 XCP



Universal measurement and calibration protocol to access ECUs from an application system (MC system)

ASAM MCD-1 XCP defines a bus-independent, server-client communication protocol to connect ECUs with calibration systems. The primary purpose of ASAM MCD-1 XCP is to adjust internal parameters and acquire the current values of internal variables of an ECU. The first letter X in XCP indicates that the protocol is designed for a variety of bus systems. ASAM MCD-1 XCP consists of a "base standard", which describes memory-oriented protocol services without direct dependencies to specific bus systems. Several "associated standards" contain the transport layer definitions for CAN, FlexRay, Ethernet (UDP/IP and TCP/IP), serial links (SPI and SCI) and USB.

ASAM MCD-1 XCP defines access to parameters and measurement variables with the help of memory addresses. The properties and memory addresses of this data are described in the A2L-file format, which is standardized through the ASAM MCD-2 MC standard. The A2L-file contains all information necessary to access and correctly interpret data that is transmitted via the ASAM MCD-1 XCP protocol. Therefore, this A2L file provides access to a specific parameter or variable, without the need for a hardcoded access in the ECU application software. In other words, the ECU contains only a generic XCP-protocol stack, which responds to memory access requests from the calibration system. Different calibration and measurement tasks can be performed by different configurations of the calibration system without recompiling and reprogramming the ECU application code.

The associated standard "Software Debugging over XCP" extends the ASAM MCD-1 XCP protocol layer specification by software debugging features for ECUs. For a variety of debugging use cases, these features allow a debugging tool to access and debug an ECU using an ASAM MCD-1 XCP communication channel, instead of connecting a debug probe to the debug interface of the ECU.

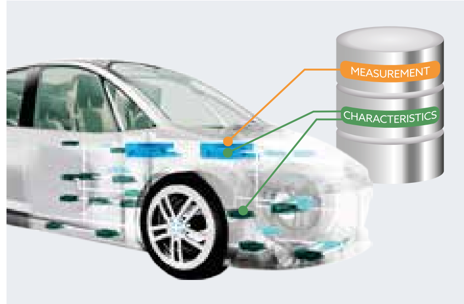
Full title Universal Measurement and Calibration Protocol
Standard type Protocol and transport layers

Application areas
- Stimulation of ECU variables
- Measurement of ECU variables
- Calibration of ECU parameters
- ECU programming

Supplementary
AML sources

Latest version | Release date
ASAM MCD-1 XCP 1.5.0 | Nov 30, 2017

ASAM MCD-2 MC



Description of a data model for ECU measurement and calibration

ASAM MCD-2 MC defines the description format (*.a2l and *.aml) of the internal ECU variables used for measurement and calibration. Measurement & calibration (MC) systems require this description for both the parameterization of scalar constants, curves, maps and multidimensional cuboids of the ECU software and for recording the system's response via measurement variables during real-time testing. The description contains information about data types, dimensions, record layouts and memory locations of ECU variables. The standard also describes how the variable values are converted into human-readable quantities and displayed in an MC system.

The support for automotive-specific processes and working methods is one of the major strengths of ASAM MCD-2 MC. The standard defines extensive support for lookup tables (up to 5 dimensions) with static or calculated axis points and static, measured, or calculated calibration parameters. Calibration and measurement variables can be hierarchically grouped via various means to support function-oriented calibration. The standard allows to fully specify how data is displayed in an MC system, independent from ECU-internal data formats. The data description is achieved via computation methods, format definitions and the definition of units. This approach enables calibration engineers to work with data formats they understand and find meaningful. The standard also allows to describe memory segments in the ECU, including their location inside the address space, memory type, and access method. Additionally, it describes the device interface between MC system and ECU for read and write access (IF_DATA section described in AML). Thus, the ASAM MCD-2 MC description contains all information in one place for access, modification, interpretation, and display of ECU-internal variables.

The data description is written in a structured ASCII format (*. a2l), which can be easily parsed and imported. The BOM (Byte Order Mark) mechanism permits the use of the UTF-8 character set. Include statements collect descriptions from different sources. The standard is technology- and vendor-independent. Due to its completeness, versatility, and maturity, the standard is widely used and is supported by virtually all major MC systems on the market today.

Full title Data Model for ECU Measurement and Calibration
Standard type File format (NON-XML; *.a2l)
Application area MC Systems

Supplementary
- A2L-Checker (supports versions 1.5.1, 1.6.0, 1.6.1, 1.7.0, 1.7.1)
- Example file ECU container

Latest version | Release date
ASAM MCD-2 MC 1.7.1 | Jan 30, 2018

ASAM MDF

Data exchange format for highly efficient storage of binary data

ASAM MDF (Measurement Data Format) is a binary file format to store recorded or calculated data for post-measurement processing, offline evaluation and long-term storage. The format has become a de-facto standard for measurement & calibration systems but is also used in many other application areas, e.g. test data management and data logging.

As a compact binary format, ASAM MDF offers efficient and high-performance storage of huge amounts of measurement data. ASAM MDF is organized in loosely coupled binary blocks for flexible and high-performance writing and reading. Fast, index-based access to each sample can be achieved by loss-less re-organization (i.e. sorting) of the data. Distributed data blocks even make it possible to directly write sorted ASAM MDF files. The file format allows storage of raw measurement values and corresponding conversion formulas; therefore, raw data can still be interpreted correctly and evaluated by post-processing tools.

ASAM MDF has been developed in close alignment with other ASAM standards such as ASAM MCD-2 MC and ASAM ODS. Consequently, ASAM MDF supports special data types and information particularly required in the automotive area, e.g. structures and arrays (curves/maps), bus events, and synchronized video data.

In addition to the plain measurement data and all necessary meta information for its interpretation, ASAM MDF can also store descriptive and customizable supplementary data within the same file. ASAM MDF offers flexible extensibility via generic XML fragments and a range of features like custom signal grouping, events or attachments.

Full title Measurement Data Format
Standard type File format (Binary; *mf4)

Application areas
Logging of ECU data and bus traffic in the automotive area

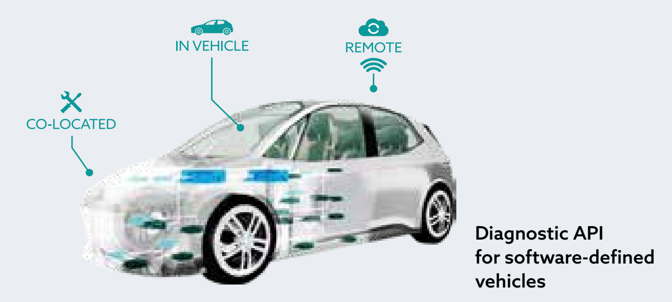
Supplementary
- XML schema files for meta data description
- Example files

Latest version | Release date
ASAM MDF 4.2. | Sep 30, 2019

Current project
P_2021_04_ASAM MDF Image, Radar, Lidar, Sensor Logging
Start date: Jun 2021 | Planned release: Jul 2025

DIAGNOSTICS

ASAM SOVD



ASAM SOVD (Service-Oriented Vehicle Diagnostics) defines an API for diagnosing and communicating with vehicles, including emerging technologies like software-defined vehicles. It is a flexible standard that provides uniform access to the diagnostic content of high-performance computers (HPCs) and their related applications, as well as to the diagnostic content of dedicated ECUs.

As we move towards autonomous driving, the vehicle becomes increasingly complex and more software-driven: new architectures based on HPCs, multiple operating systems (OS), the different applications and their dependencies pose a major challenge to diagnostics. The focus of diagnostics extends from identifying hardware errors to analyzing software issues. This is particularly challenging as the type and extent of data held in vehicles change dynamically. Besides all this, the spectrum of diagnostic tasks increases when diagnostic communication is used to control complex update processes in the vehicle.

Today, diagnostics is still ECU-centered and heavily relies on the unified diagnostic services (UDS) protocol. UDS is a static approach to diagnostics which contrasts with the dynamic software tasks. Therefore, extending the UDS protocol for HPC diagnostic requirements would not be flexible enough to meet the necessary software analytics requirements.

This is where ASAM SOVD comes into play. The standard aims at providing one API suitable for all diagnostic purposes as well as for software updates (cross-vehicle). It is a consistent approach that is used for new systems as well as for traditional sensor / actuator systems. ASAM SOVD can be used for all three application scenarios: co-located, remote, and in-vehicle. It is a self-describing HTTP/REST API that, unlike today, also enables diagnostics without an external description file. JSON is used for encoding transmitted data.

ASAM SOVD was developed with the intention to meet the challenges described while keeping existing procedures, technologies, and methods in mind. For that reason, ASAM SOVD covers both traditional use cases (data access, fault information, variant coding, control of internal software functions) as well as HPC-related diagnostic use cases (vehicle software updates, logging, tracing, access to system information, dynamic discovery of content). Another aim was not to replace widely used technologies like the UDS protocol but to coexist while enhancing the functionality for diagnostic communication. Therefore, the classic diagnostic adapter describes how HTTP methods will be mapped to UDS services. This encapsulates the signal-based and stateful communication for the user. But one major advantage is that there is no automotive stack required on client-side.

The ASAM SOVD API is written in the form of an OpenAPI specification which can be used as offline and online capability description. As many ECUs are based on AUTOSAR implementations, ASAM SOVD is supported by the Diagnostic Manager.

Full title Service-Oriented Vehicle Diagnostics
Standard type API

Application area
Diagnostic API for software-defined vehicles (SDV)

Supplementary
- Open API (as yaml files)
- json example files

Latest version | Release date
ASAM SOVD 1.0.0 | Jun 30, 2022

Current project
P_2022_05 ASAM SOVD 1.1.0
Start date: Sep 2022 | Planned release: Jun 2025

SOFTWARE DEVELOPMENT

ASAM SCDL

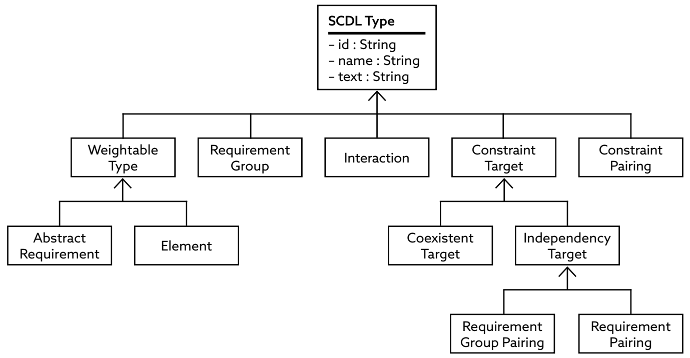
ASAM SCDL (Safety Concept Description Language) is a semi-formal notation to describe ISO 26262 safety architectures, namely safety concepts. This includes safety requirement specifications, element architectures, requirements allocation on elements, ASIL assignments, decompositions for safety mechanisms and others. Tools based on ASAM SCDL support the development, design, analysis, and verification of ISO 26262 artefacts. It allows for interoperability and exchangeability of methods and artefacts.

ASAM SCDL defines the three constituents: Requirement, Requirement group and the relationships among several critical elements in the context of system safety. It establishes how interactions between system components are modeled and analyzed. The system boundary interaction outlines how the system interfaces with external elements, ensuring all inputs and outputs are well-defined for maintaining safety. The freedom from interference arrow is used to depict the assurance that different system functions operate without unintended interference, crucial for maintaining functional safety. The requirement group pairing line links related safety requirements, demonstrating how they collectively address specific safety goals. Finally, the connecting line from constraint illustrates how certain constraints or limitations are directly tied to specific system components or interactions, showing their impact on the overall safety design. ASAM SCDL (or a notation method, notation language) is intended to be applied for the description of specifications, i.e. to develop, verify, and reuse safety architecture effectively and efficiently. It is also assumed that ASAM SCDL is applied for architecture description of safety-related portions with some parameters related to safety design such as weighting.

ASAM SCDL simplifies the representation of safety mechanisms by addressing redundancy and constraints between requirements. It also explains the derivation of safety requirements, incorporating safety mechanisms and safety analysis. Additionally, it provides a clear method for grouping safety requirements, aiding in the identification of targets or scopes for dependent failure analysis across related requirement groups.

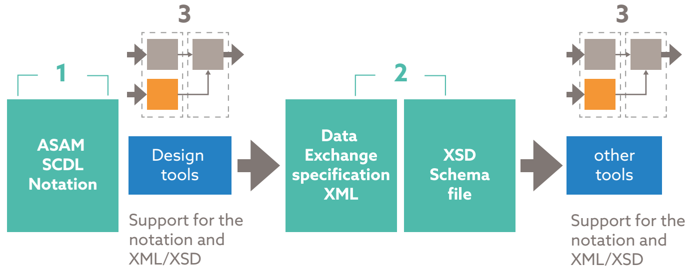
The language visualizes the source of weighting, showing how requirement allocations or freedom from interference requirements determine the weighting. It supports consistent development from the system level down to implementation levels, including software and hardware. The grammar and notation of ASAM SCDL are based on modeling functionality realized through a software tool, ensuring practical application and integration in the safety life cycle.

ASAM SCDL metamodel-examples:



This figure shows basic hierarchical relationships among the constituents of the ASAM SCDL metamodel.

The first version of ASAM SCDL was developed and released by the Safety Concept Notation Study Group (SCN-SG), which also oversaw updates to the specification up to version 1.5.0. Given its anticipated widespread adoption and increased utilization in the future, the standard has been transferred to ASAM.



1. Notation of symbols and diagrams
2. Data exchange format
3. Design tools and the other tools can support the notation and the data exchange specification.

TECHNOLOGY:
- The data exchange specification is defined by XML technology.
- XSD schema is used for the implementation.

Full title Safety Concept Description Language
Standard type File format (xml)

Application areas
- Functional safety (ISO26262)
- Safety architecture
- Safety system

Latest version | Release date
ASAM SCDL 1.6.0 Nov 2021

TEST AUTOMATION

ASAM iLinkRT

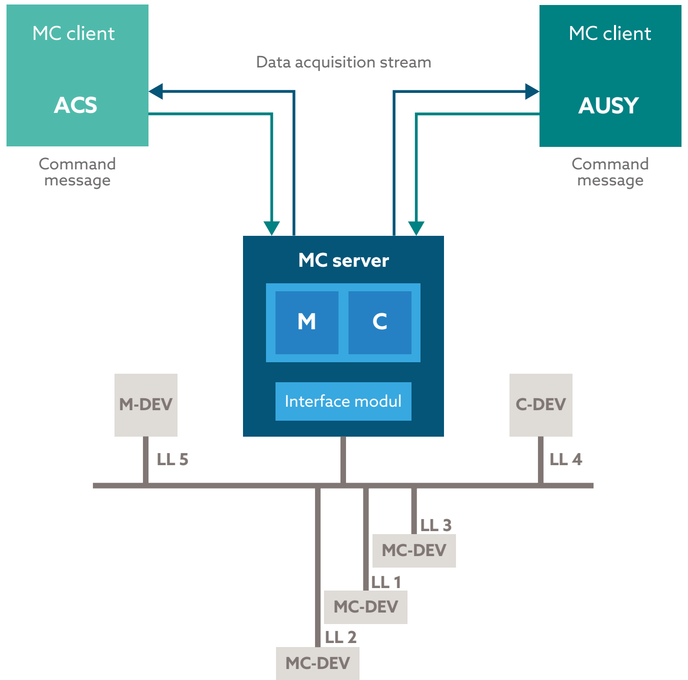
High-speed protocol for measurement and calibration data exchange in test systems

ASAM iLinkRT defines a protocol for high-speed measurement and calibration (MC) data exchange in test automation systems. The protocol is typically used to connect MC clients with MC servers. MC clients are automation systems (AUSY) and automated calibration systems (ACS).

ASAM iLinkRT uses an efficient protocol-based and event-triggered communication method. The transport layer is Ethernet (UDP/IP), which is the communication backbone in today's testing labs. MC clients can establish multiple point-to-point connections with MC servers, using standard IPv4 or IPv6 addresses and UDP ports. Each connection consists of two channels: one for sending commands (configuration and parameterization), and one for data acquisition and event handling. The data acquisition channel uses an event driven DAQ mechanism, similar to ASAM MCD-1 XCP, which ensures that the measurement data is transferred with minimum delay. Multi-casting is supported to achieve higher throughput when multiple clients are connected to one server. Calibration data can be uploaded and downloaded via the command channel. Measurement data objects and calibration data objects are supported, as known from ASAM MCD-2 MC. The data exchange can be configured for physical or hex value data transfer.

Besides measuring and adjusting, the standard also supports recording as well as MC server configuration and parameterization and defines the behavior for usage in multi-client multi-server environments. This allows to select the required measurement sequences together with a raster reference by each MC-client as well as the complete reconfiguration or query of existing configurations. The MC server informs all MC clients about status changes in the form of events. The standardized support of pre-configurations enables the client application to operate with simple command sequences. To enhance the clarity of the standard, the introduction of state models and sequence diagrams for typical use cases has been incorporated.

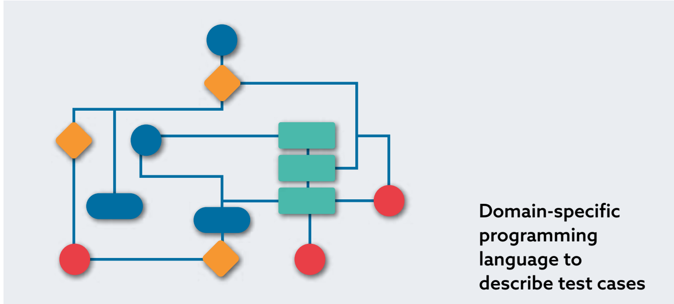
Architectural Overview



Full title High Speed Automation-Access-Protocol for MC Server
Standard type Protocol
Application areas
- MC server
- MC clients

Latest version | Release date
ASAM iLinkRT 3.0.1. | Jun 30, 2022

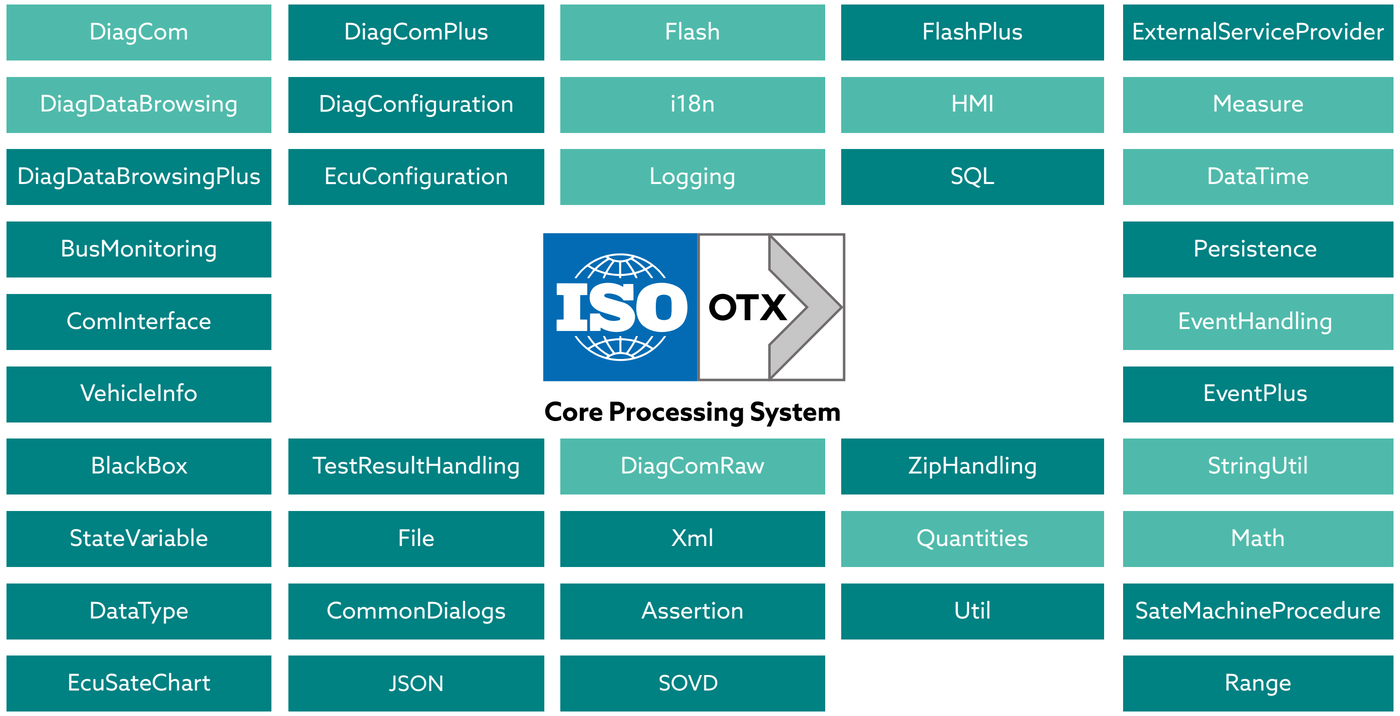
ASAM OTX Extensions



ASAM OTX Extensions in conjunction with ISO 13209 (OTX) can be used in any application area that requires the definition of test procedures for documentation purposes or in an automation system. Typical application areas in the automotive industry are in ECU diagnostics testing, ECU calibration, and EOL testing.

In 2012, ISO published the standard ISO 13209 „Open Test Sequence Exchange" (OTX), part 1 to 3. Its main purpose is to define a language and exchange format for the specification of executable test sequences. Originally, OTX was developed for ECU diagnostics testing but is not limited to this area. Soon after the first OTX-based systems appeared on the market, end users required additional functionality, which was promptly implemented by tool suppliers. Some of the requested functionality, such as file processing or specific complex data types, impeded the exchangeability of OTX files and the interoperability of test systems. Consequently, there was a need to further standardize the additional functionality.

The ASAM OTX Extensions fill those gaps. They extend the core of the ISO 13209 series with a set of additional OTX extensions which are not part of ISO 13209-3. They were developed according to the extension mechanism rules described in ISO 13209-2. ASAM OTX Extensions consists of 25 extensions aiming to expand the range of applications, ensuring exchangeability between different tools and suppliers and improving the OTX code quality and standard acceptance. The ASAM OTX Extensions cover requirements such as XML processing, collection of communicated data and storing arbitrary data at runtime, access to SQL databases and handling of user-defined data types. The standard also includes checker rules for ASAM OTX Extensions which have partly been included in the ASAM Quality Checker Framework (see p. 46 – 47).



Full title Open Test Sequence eXchange Format
Standard typ Domain specific language (DSL)

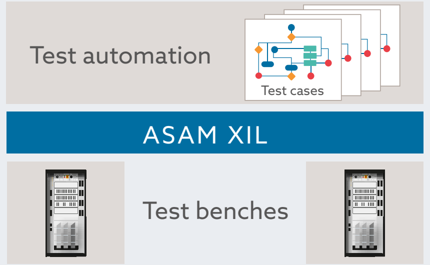
Application areas
- ECU testing, specifically in the areas of diagnostics, calibration and EOL
- Definition, documentation and exchange of ECU tests

Supplementary
UML model, XSD schemata for each extension are part of the standard package.

Latest version | Release date
ASAM OTX Extensions 3.3.0 | Apr 2025

Current projects
ASAM OTX Extensions is one of three ASAM standards to be further developed within the ASAM TestSpecification development project (see p. 44).
Start date: Apr 2025 | Planned release: Apr 2027

ASAM XIL



API between test automation tools and test benches for reuse of test cases

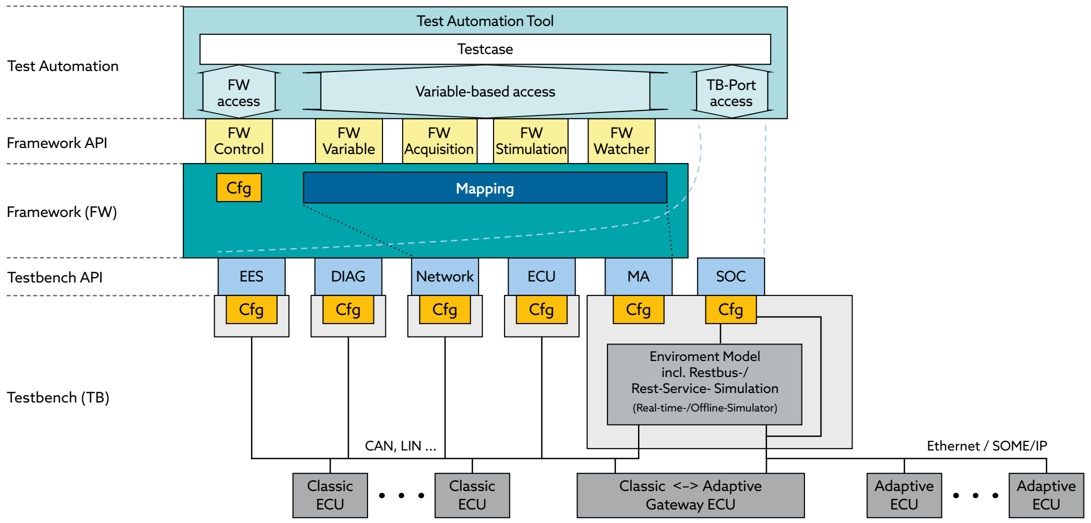
ASAM XIL defines an API for the communication between test automation tools and test benches. The standard supports test benches at all stages of the development and testing process – most prominently in model-in-the-loop (MIL), software-in-the-loop (SIL) and hardware-in-the-loop (HIL) setups. The notation „XIL" indicates that the standard can be used for all „in-the-loop" systems. This has the advantage that it enables users to freely choose testing products according to their requirements and integrate them with little effort. Using ASAM XIL-compliant products allows users of test systems to mix and match the best components from different suppliers.

The standard furthermore decouples test-cases from real and virtual test systems, thus enabling to transfer tests between different test systems with little to no migration effort. Tests can be easily re-used, and know-how is much easier transferred from one test bench to another, resulting in reduced training costs for development and test engineers.

These advantages are the result of two major components of the ASAM XIL standard:

- The framework, which provides data measuring and mapping functionality independent from the used test bench hardware and software.
- The test bench, which provides port-based communication to the simulation model, the ECU, the electrical subsystem and the ECU network.

Test automation applications, which use the ASAM XIL standard, are used in all automotive E/E domains, e.g. drivetrain, steering, electric lighting, and more.



Full title Generic Simulator Interface
Standard type API
Application areas
Test automation using „in-the loop" systems:
- HIL (hardware-in-the-loop)
- SIL (software-in-the-loop)
- MIL (model-in-the-loop)

Supplementary
- C# implementation
- Application examples
- Source code for vendor-independent basic functions and components

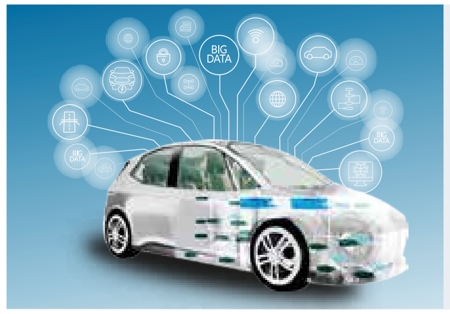
The sample implementations support test case developers and vendors of XIL-compliant products. They may be modified and integrated into products.

Latest version | Release date
ASAM XIL V3.0.0 | Nov 2024

Current project
ASAM XIL is one of three ASAM standards to be further developed within the ASAM TestSpecification development project (see p. 44).
Start date: Apr 2025 | Planned release: Apr 2027

DATA MANAGEMENT & ANALYSIS

ASAM ODS



Storage, exchange and retrieval of test data in an IT-independent architecture

ASAM ODS focuses on the persistent storage and retrieval of testing data. It is primarily used to set up a test data management system on top of test systems that generate measured or calculated data from testing activities.

Tool components of a complex testing system can store and retrieve data as needed for proper operation of tests or for test data post-processing and evaluation. A typical scenario for ASAM ODS in the automotive industry is the use of a central ASAM ODS server, that manages all testing data from vehicle test beds. The major strength of ASAM ODS, as compared to non-standardized data storage solutions, is that data access is independent of the IT architecture and that the data model of the database is highly adaptable yet well-defined for different application scenarios. Despite this flexibility, clients can query data from the database and still correctly interpret the meaning of that data. This is achieved through various mechanisms in the standard:

The standard consists of
- **A base model:** The base model serves as a parent for deriving specific application models. It provides a rough classification of the data in application models by adding semantics thus enabling client tools from different vendors to correctly interpret the data.
- **Application models:** These models cover the data storage needs for specific application areas. ASAM ODS provides pre-defined application models for test object geometry, NVH testing, test stand calibration, bus data, big data analysis, instrumentation components incl. configurations, crash testing and testing workflows.
- **A format for physical storage:** This part of the standard specifies how relational databases should be structured to ensure compliant data storage.
- **APIs:** Clients have access to data on the ASAM ODS server via a web-service API using the Hypertext Transfer Protocol (short: HTTP-API). Data is serialized and transferred in the Google Protocol Buffers format. For legacy reasons, the standard still contains an object-oriented API based on CORBA architecture (short: OO-API) and a remote procedure call API (short: RPC-API).
- **File description formats:** The description formats allow file-based data exchange between tools. ASAM ODS provides a non-XML format (for legacy purposes) as well as an XML-format.
- **External Data API (EXD-API):** A programming interface allows access to mass data stored in external files of any type, provided an EXD-API implementation is available for those file types. This API is also used to reference ASAM MDF files managed by an ASAM ODS mixed mode server or by an ATFX file.

ASAM ODS servers act as data fusion centers integrating data from various test beds and measurement devices from different vendors. Data can be accessed uniformly, regardless of their origin, via the same methods and interfaces. This even extends to mass-data stored in external files (ASAM MDF), where the database only provides descriptive meta data and a pointer to the external storage location. The same API methods are used to access both database-internal measurement data and external mass data, ensuring complete transparency of the data access.

Furthermore, ASAM ODS servers are highly scalable. Users can extend the data models and add more clients to the overall tool chain without having to set up a new server for every extension, making it an efficient and future-proof solution for test data management.

Full title Open Data Services
Standard type Set of standards
Application area
Test data management

Supplementary
- Technology reference RPC API, CORBA-API, HTTP-API
- ATFX schema
- Examples

Latest version | Release date
ASAM ODS 6.2.0 | 31.12.2022

Current project
P_2023_02_ASAM ODS 6.3.0
Start date: Oct 2023 | Planned release: Oct 2025

ASAM ODS is one of three ASAM standards to be further developed within the ASAM TestSpecification development project (see p. 44).
Start date: Apr 2025 | Planned release: Apr 2027

SIMULATION

ASAM OpenCRG

Static road surface description

As the automotive industry advances towards increasingly realistic simulations, precise road surface modelling is essential for accurate vehicle behaviour predictions. The ASAM OpenCRG standard addresses this need by providing a robust file format for describing road surface properties. It was originally developed for storing high-precision elevation data from road surface scans. This data is critical for applications such as tire, vibration, and endurance simulations, as well as in 3D-rendered driving environments.

ASAM OpenCRG efficiently organizes road surface data using a curved regular grid (CRG) that optimizes memory and computation while maintaining accuracy when positioning data onto road networks. The standard supports both ASCII and binary formats, with clear-text headers defining key road parameters like the reference line, longitudinal sections and data sequence formats. External data files can also be referenced for handling multiple parameters in a dataset.

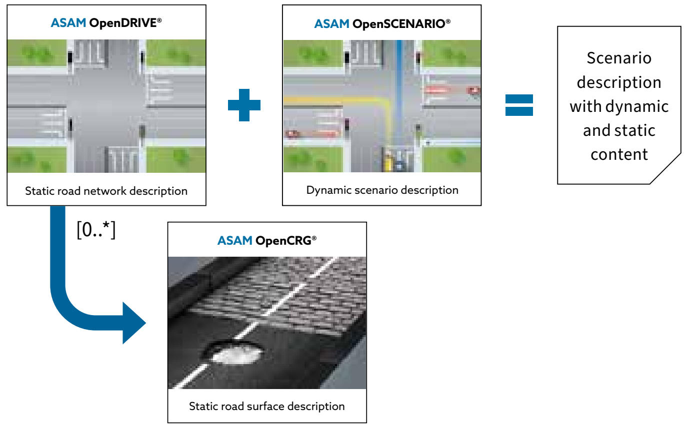
The road surface is divided into a grid aligned with the centerline, with longitudinal (parallel) and lateral (orthogonal) cuts. Each cell stores values like elevation, friction, or grayscale data. The centerline is defined by low-precision headings angles, and the surface data, if interpreted as elevation data, is provided in the z-direction (orthogonal to the grid). To ensure precise placement in a simulation, both the start position and, optionally, a high-precision end position can be provided to prevent drift during data integration.

ASAM OpenCRG plays a critical role in enhancing simulation environments by providing detailed road surface data. It is particularly useful for:

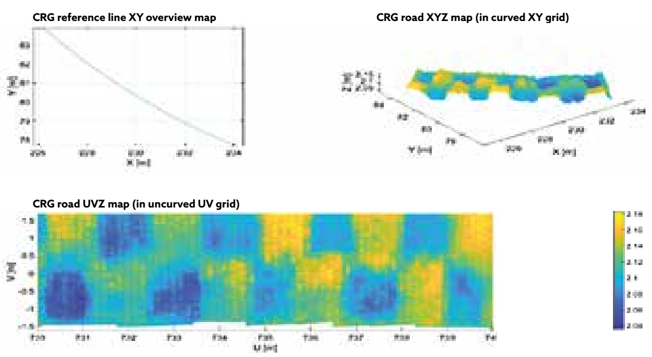
- Tire and vibration simulations that require accurate surface texture and elevation data.
- Driving simulators, where realistic 3D rendering of road surfaces improves the immersion and accuracy of the driving experience.
- Endurance testing of vehicle components or full vehicles, where precise road surface data contributes to accurate wear and performance predictions.

ASAM OpenCRG comes with dedicated APIs for MATLAB/Octave and ANSI-C, allowing users to create, manipulate, visualize, and verify ASAM OpenCRG files. The MATLAB library offers a broader feature set, including data generation and visualization, while the C-API focuses on processing and checking ASAM OpenCRG files.

One of the most powerful aspects of ASAM OpenCRG is its ability to integrate with ASAM OpenDRIVE. This combination allows for the enhancement of road networks by adding detailed surface patches for features like potholes, speed bumps, and manhole covers. ASAM OpenCRG can be used as either a surface layer or friction layer, and its values (e.g., elevation or friction) are interpreted by the simulator based on the context provided by OpenDRIVE.



Relation between ASAM OpenDRIVE, ASAM OpenCRG and ASAM OpenSCENARIO



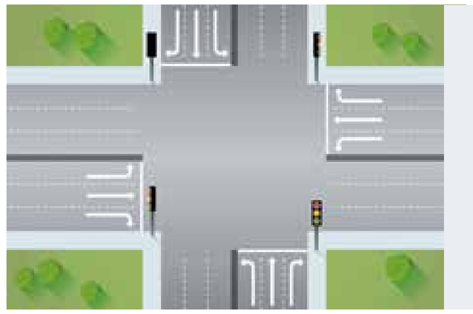
ASAM OpenCRG road surface description using u/v-coordinates and x/y-coordinates

Full title Curved Regular Grid
Standard type File format, API

Application areas
- Description of road surfaces
- Endurance simulation
- Driving simulation
- Traffic simulation

Latest version | Release date
Version 1.2.0 | Sep 30, 2020

ASAM OpenDRIVE



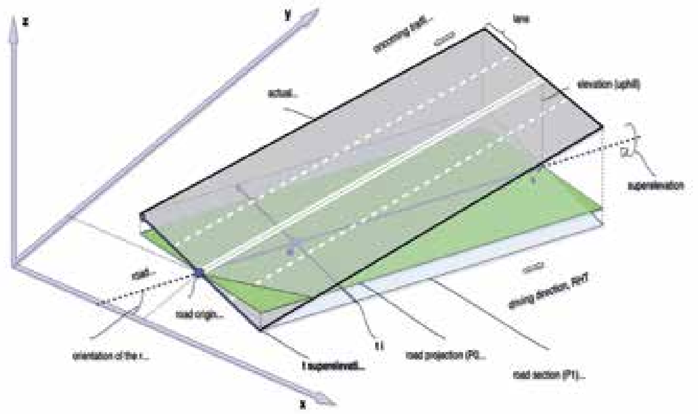
Static road network description

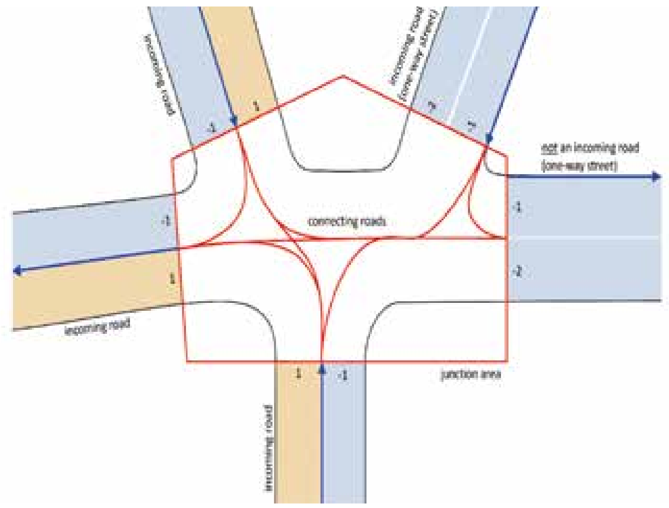
ASAM OpenDRIVE is a widely adopted file format that provides a detailed, XML-based specification for describing static road networks. ASAM OpenDRIVE standardizes critical information such as road geometry, surface properties, signage, lane types, and logical attributes. This unified structure is essential for engineers working on advanced driver assistance systems (ADAS) and autonomous driving (AD) technologies, as it enables precise and consistent road modeling across various simulation environments.

A defining feature of ASAM OpenDRIVE is its hierarchical organization, beginning with a reference line that represents in most cases the center of the road. From this line, other elements – lanes, elevations, junctions, and markings – are systematically attached. Junctions are realized through "connecting roads" that define entry and exit points. This approach ensures that all aspects of the road environment are accurately linked, enabling reliable simulations of both simple roads and complex intersections. As a result, it lays the foundation for realistic traffic flow and vehicle behavior in simulation scenarios.

ASAM OpenDRIVE facilitates seamless data exchange between different simulators and development tools. Through these collaborative solutions, engineers can reduce development costs, avoid the need for extensive data conversion, and focus on refining ADAS and AD features in lifelike simulated environments.

Ultimately, the precision and clarity provided by ASAM OpenDRIVE are vital for advancing autonomous driving and driver assistance systems. By standardizing how road networks are modeled, the format fosters consistent testing procedures, accurate scenario replication, and efficient collaboration among industry stakeholders – all crucial steps in the continued development of safe and reliable automated driving technologies.





Junction representation in ASAM OpenDRIVE

Full title Static Road Network Description
Standard type File format

Application areas
- Driving Simulators
- Traffic Simulation and Management

Latest version | Release date
ASAM OpenDRIVE 1.8.1 | Nov 21, 2024

Current project
P_2024_04_C_ASAM OpenDRIVE Transportation Area Concept
Start date: Jan 2025 | Planned release: Nov 2025

ASAM OpenLABEL

Annotation format and data model for object labeling and scenario tagging

ASAM OpenLABEL defines the annotation format and labeling methods for objects and scenarios. ASAM OpenLABEL provides a guideline on how the labeling methods and definitions should be used.

Significant fragmentation existed in how different organizations categorize and describe driving environment objects. These categorizations are crucial for an autonomous driving system's (ADS) perception stack, enabling it to understand its surroundings.

The lack of a common labeling standard in the industry is the root cause of several issues:

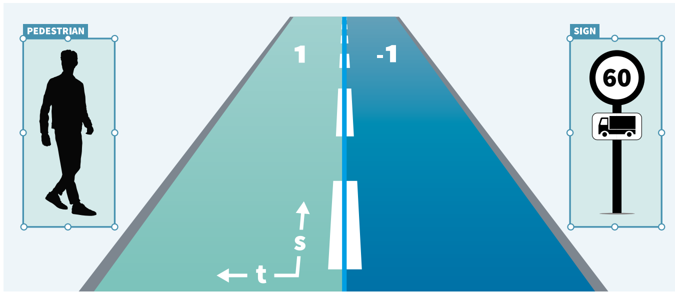
- **Hampered interaction of vehicles:** Different descriptions and understandings of surroundings can lead to casualties in complex situations with multiple ADSs.
- **Precluded sharing:** It is highly difficult if not impossible to share data across organizations that adopted different labeling taxonomies and specifications.
- **Reduced annotation quality:** Each labeling task needs ad-hoc training and custom software, increasing error probability and safety risks.
- **Deprecation of old labels:** Long-term ADS development requires adaptable labels to accommodate evolving driving scenes, new sensors, and scenarios. A flexible descriptive language ensures future extensions and modifications while maintaining backward compatibility.

ASAM OpenLABEL uses JSON format, making it easily parsed by tools and applications. It specifies coordinate systems for labels and provides methods to label objects in single or multiple scenes, including actions, intentions, and relations. The format supports various labeling methods for different data types, such as 2D and 3D bounding boxes, rotations, and semantic segmentation of images and point clouds.

ASAM OpenLABEL defines principles and methods for annotating multi-sensor data streams and tagging test scenarios for automated driving development, validation, and verification. The two main applications are:

- **Multi-sensor data labeling**: Enriching data streams with information on the location and characteristics of labeled objects or scenarios. Labels summarize semantic entities and show their spatio-temporal location using labeling geometries, suitable for computer vision and machine-learning tasks. ASAM OpenLABEL covers:
  - Detailed annotation schema, structure, elements, labeling geometries, coordinate systems, transforms, and other relevant information.
  - Mechanisms for referencing external knowledge repositories, like ontologies, that define label semantics.
  - Supported data types and their representation.

- **Scenario tagging:** Enriching raw data with metadata called tags, which provide high-level information about the scenario. Tags help describe scenarios and act as keywords for searching and filtering within databases. ASAM OpenLABEL tags are categorized into:
  - **Operational Design Domain (ODD) tags**: Describe environmental conditions and road features, aligned with BSI PAS 1883 ODD Taxonomy.
  - **Behavior tags:** Describe road users and their behaviors in a scenario.
  - **Administration tags:** Describe scenario qualities that are not easily derived, such as creation date.



Example for an annotated scene

Full title Data labeling and scenario tagging
Standard type File format (JSON)

Application areas
- Multi-sensor data labeling
- Scenario tagging

Latest version | Release date
ASAM OpenLABEL V1.0.0 | Nov 12, 2021

ASAM OpenMATERIAL 3D

Material properties and 3D model structures

As the automotive industry relies ever more on virtual methods, the demand for realistic simulations of the real world, or „digital twins," is more critical than ever. Accurate sensor simulations require a physically precise representation of the environment, including material properties. ASAM OpenMATERIAL 3D is an open-source initiative that aims to address the need for accurate, standardized 3D assets and material properties to simulate sensor behavior effectively.

The ASAM OpenMATERIAL 3D standard aims to define physical material properties and standardize 3D model structures for more accurate simulations. Instead of simply naming materials like glass, metal, or rubber, it precisely defines characteristics such as refraction index, surface roughness, and permeability. These properties are stored in dedicated material files linked to 3D geometries, ensuring realistic behavior in simulations.

Rather than introducing a new 3D format, the standard establishes a consistent hierarchy for model elements like coordinate systems and movable parts, such as a pedestrian's limbs. This approach enhances compatibility across different simulations and allows existing 3D assets to be seamlessly integrated.

By combining standardized material properties and 3D structures, the standard improves perception sensor simulations, enabling more realistic lidar, radar, and camera outputs. This is essential for generating accurate sensor data, which is critical for testing and training perception algorithms.

The ASAM OpenMATERIAL 3D standard is designed to support key use cases across the entire sensor simulation workflow. It enables the creation of 3D assets and material data, allowing models and material properties to be generated together or separately. These assets and materials can be distributed between organizations through direct exchange or marketplaces, ensuring seamless collaboration.

Once created, they can be imported into simulation platforms, whether they are centralized simulation platforms or decentralized models like functional mock-up units. The standard also supports object part manipulation, allowing 3D models to include movable components within simulations.

GitHub repository

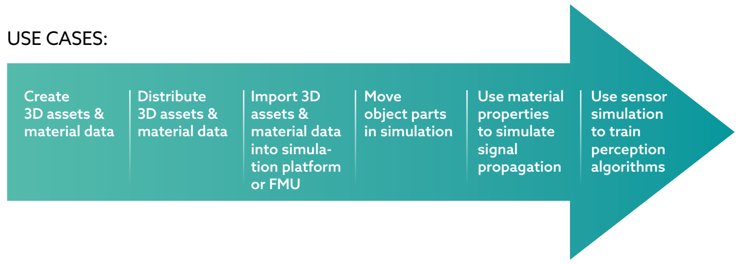
By defining material properties, the standard enhances signal propagation modeling, enabling accurate simulation of how sensors interact with the environment, including energy propagation and signal reflection. Ultimately, this facilitates testing and training of perception algorithms, helping refine autonomous vehicle perception systems.

The standard focuses on the virtual environment and objects that sensors will interact with, including

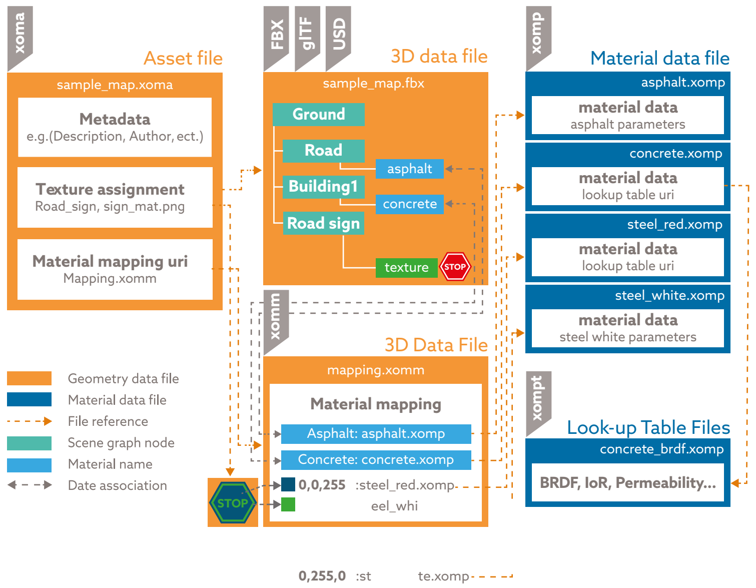
- target objects like vehicles and pedestrians,
- surrounding structures, such as buildings and other fixed elements,
- road surfaces, with physical road characteristics.

However, environmental conditions – such as weather, lighting, and other elements affecting sensors – are outside the scope for now. Similarly, interactions between the sensor housing and the enviroment, such as raindrops or dirt on the sensor, are not included in this standard.

USE CASES:



VISUAL REPRESENTATION:



Full title Material properties and 3D model structure
Standard type File format

Application areas
- Driving environment objects (3D assets)
- Material properties and 3D model exchangeable files
- Scenario simulation, sensor perception

Latest version | Release date
ASAM OpenMATERIAL 3D 1.0.0 | Apr 2025

ASAM OpenODD

Defining the operational design domain for automated vehicles

```
struct odd:
    environmental_conditions : environmental_conditions
    scenery : scenery

struct environmental_conditions:
    weather : weather

struct weather:
    wind : wind_kind
    rainfall : rain_kind
```

Taxonomy definition example

```
import  iso_34503_Taxonomy.osc

extend Environmental_Conditions :
   keep (visibility > 100 meters )

extend Drivable_Area :
   keep(road_type in [motorway, highway] or
      traffic_separation in [one_way_road, physical_barrier])
   keep( not (
         ego_lane.width < 3.5 meters or
         (ego_lane.curvature in [-0.0625 inverse_meters .. 0.0625 inverse_meters] ) or
         ego_lane.split_merge_in_front_present ))
```

ODD example

```
extend weather:
    keep(wind_speed == 26.522 mps)
    keep(wind == storm)
    keep(rainfall == heavy_rain)
```

COD example

ASAM OpenODD specifies a standardized data model to describe the operational domain (OD), current operational domain (COD), and the operational design domain (ODD) for ADAS, DCAS and ADS. It provides a technology-independent data model in UML, defining how taxonomies and related concepts are structured and interconnected, and details how these elements are represented and exchanged.

The standard encompasses instructions for representing ODDs in various machine-readable formats such as YAML, various tabular formats (e.g., CSV, spreadsheets) and ASAM OpenSCENARIO DSL. To provide interoperability, it enables ASAM OpenODD specifications defined in one format, e.g., YAML, to be translated into other formats, e.g., spreadsheet. To support detailed evaluation and compliance, it enables specifying the exact conditions under which an ADAS, DCAS, or ADS is designed to operate.

Key components of the data model include taxonomies to represent ODD concepts and modular rules for inclusion or exclusion of specific environmental conditions. To ensure and correct unambiguous interpretation across languages, it supports multi-language translation. ASAM OpenODD addresses challenges in defining complex ODDs by providing a consistent framework to express conditions modularly, enabling the creation of scalable, machine-readable, and human-readable descriptions.

ASAM OpenODD is designed to directly complement other ASAM standards, particularly from the ASAM OpenX portfolio. The possibility to describe both scenarios and ODDs using the same language offers a lower barrier of entry to using the standard in a founded ODD-based testing workflow.

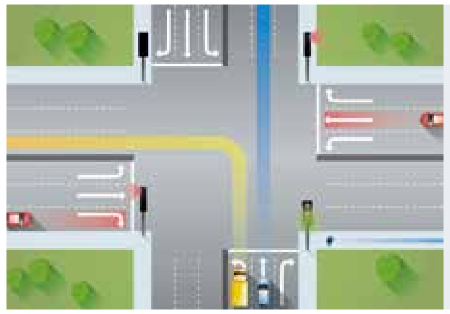
Full title Operational Design Domain
Standard type Data model specification with associated technology mapping references

Application areas
- Development and validation of ADAS, DCAS, and ADS
- Simulation and testing environments
- Safety analysis and homologation processes
- Regulatory compliance documentation

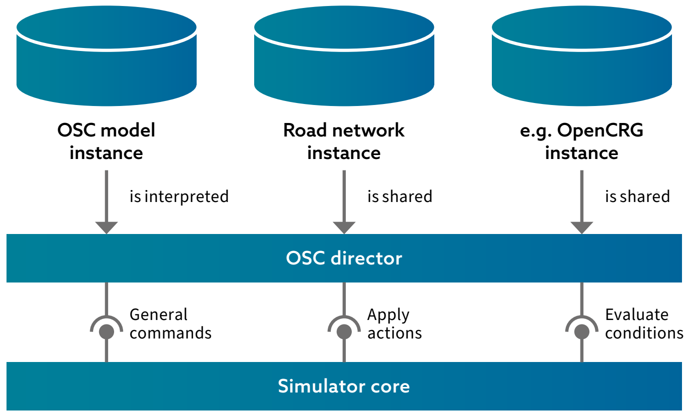
Supplementary
Potential supplementary tools proposed but not yet in development:
- Converter
- Checker bundle for the ASAM Quality Checker Framework

Latest version | Release date
ASAM OpenODD 1.0.0 | Apr 2025

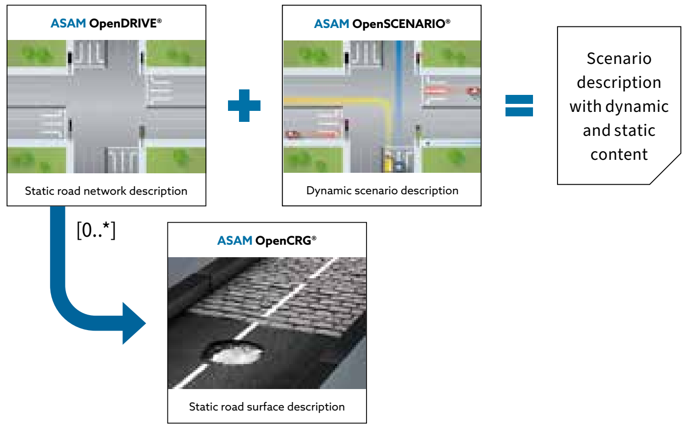
ASAM OpenSCENARIO XML



Dynamic scenario description



ASAM OpenSCENARIO XML provides a structured framework to describe dynamic elements in driving simulation applications. As part of the ASAM OpenX standards family, it complements ASAM OpenDRIVE and ASAM OpenCRG, which define static elements like road layouts and surface features. The main goal of ASAM OpenSCENARIO XML is to support precise scenario descriptions for driving simulations. These scenarios encompass complex maneuvers involving multiple vehicles and dynamic entities, critical for testing automated driving technologies in virtual environments before real-world trials.



Relation between ASAM OpenDRIVE, ASAM OpenCRG and ASAM OpenSCENARIO

To develop and validate autonomous systems, robust simulation mechanisms are essential for dynamic interactions and environmental variations. Before ASAM OpenSCENARIO XML, the absence of a standardized format hindered developers from sharing scenarios across platforms. Additionally, scenarios involving multiple actors, like vehicles, pedestrians, and traffic signals, were challenging and often relied on proprietary solutions, limiting interoperability. ASAM OpenSCENARIO XML addresses these issues with a vendor-neutral, XML-based format that enhances collaboration and facilitates the industry-wide adoption of automated driving technologies.

Using XML, ASAM OpenSCENARIO XML represents data in a hierarchical structure that is readable by both humans and machines. The XML schema defines structure and attributes for different elements, ensuring consistency across scenarios and platforms. Key elements include entities and actors, such as vehicles and pedestrians, with customizable properties like speed and behavior. Scenarios are organized into stories, which break down further into acts, maneuvers, and events, creating a narrative flow that mirrors real-world situations. Triggers and actions define conditions and events, such as a vehicle changing lanes at a certain point. Environmental factors, like weather and lighting, add realism, while catalogs of maneuvers and parameters enable reusability and scenario variation.

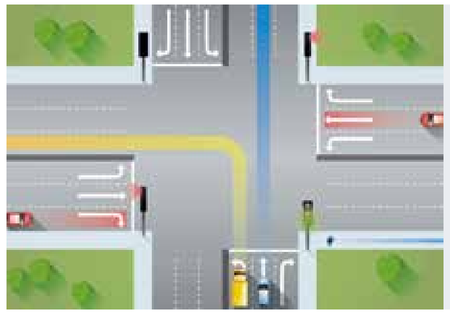
With XML's flexibility, ASAM OpenSCENARIO XML allows simulation tools to parse and validate XML files easily, making it convenient to edit, import, and export scenarios. The XML-based structure also supports scalability, adapting to evolving needs of automated driving systems. This structured approach promotes interoperability, as ASAM OpenSCENARIO XML scenarios can be used across platforms, fostering a consistent approach to testing and validation. Scenario reusability is enhanced through its catalog and parameterization, reducing time spent creating new tests.

Full title Dynamic scenario description
Standard type File Format

Application areas
- Testing of ADAS and ADS
- Reduction of physical testing needs

Latest version | Release date
ASAM OpenSCENARIO XML 1.3.1 | Nov 21, 2024

ASAM OpenSCENARIO DSL



Dynamic scenario description

ASAM OpenSCENARIO DSL is designed to verify the safety and functionality of ADAS, DCAS and ADS by allowing their behavior to be described and observed in dynamic, multi-entity scenarios involving vehicles, pedestrians, and other traffic participants.

ASAM OpenSCENARIO DSL introduces a powerful domain-specific language (DSL) that is both human-readable and machine-readable, making it an ideal tool for large-scale verification and validation (V&V) of ADS, DCAS and ADAS. The standard provides an extendable domain model, representing essential on-road driving concepts, and emphasizes the reuse and composition of scenario descriptions. This allows simple scenarios to serve as foundational elements for building more complex, multi-layered scenarios.

Key benefits include the ability to describe scenarios that are both location-specific and map/ODD-agnostic, offering wide applicability across various environments. ASAM OpenSCENARIO DSL supports a range of scenario types, from concrete and logical to abstract, with a focus on scenarios that involve multiple vehicles, traffic interactions, complex environmental variables, and in-depth analysis of measurement criteria. Of special note is the support of test scenarios (see ISO 34501) and the inclusion of checks, coverage monitors and various configurations.

Version 2.1.0 of ASAM OpenSCENARIO DSL introduces several features that significantly enhance its initial capabilities:

- Namespace Definition and Support: introduces keywords such as namespace, use, and export. This allows users to organize identifiers within namespaces, preventing name conflicts and ensuring backward compatibility.
- Trailer Support: enables modeling of trailers with hitches and couplers, allowing for realistic simulation of vehicle-trailer dynamics. Scenarios can describe both connecting and disconnecting trailers from towing vehicles.
- Traffic Lights Support: allows scenarios to control traffic lights within a map.
- Behavioral Model Interface: gives users the flexibility to define custom behavioral models for any physical object in a scenario. These models can be pre-selected before scenario execution or dynamically switched during execution, allowing for more adaptive and realistic simulations.

Harmonization with ASAM OpenSCENARIO XML

ASAM OpenSCENARIO DSL is developed in parallel with ASAM OpenSCENARIO XML. Although similar in purpose, both standards provide users with different options depending on their specific use cases.

- ASAM OpenSCENARIO XML defines an XML schema for describing scenarios with synchronized manoeuvres of vehicles, pedestrians, and other participants. It is particularly suited for precise trajectory-based testing with well-defined parameters, supporting trigger-action scenarios and optimized for easy machine parsing.
- ASAM OpenSCENARIO DSL, in contrast, provides a high-level, abstract language for describing scenarios and test scenarios. It supports higher-level concepts such as scenario intent, key performance indicators (KPIs), and coverage metrics. Its design enables large-scale verification and validation (V&V) testing and is optimized for composability, facilitating the reuse of scenarios and the automatic generation of tests.

Differentiating use cases

- ASAM OpenSCENARIO XML is ideal for highly precise, predictable scenarios and external test specifications used in V&V workflows.
- ASAM OpenSCENARIO DSL is tailored for large-scale testing of ADS and ADAS safety and functionality, providing the flexibility to explore a broad range of potential driving situations and unknowns.

These two standards complement each other within the automotive testing toolchain, allowing users to select the most appropriate solution for their specific needs while ensuring comprehensive safety testing and functionality validation.

Concrete scenario: All attributes are fully specified for any point in time.

```
scenario my_concrete_scenario:
    map.set_map_file("my_map.xodr")
    my_road: route = map.create_route(get_odr_points(my_file))

    car1: vehicle with:
        keep(car1.color == red)
        keep(car1.model == lincoln_mkz2017)
        keep(car1.category == car)

    do serial:
        car1.drive(duration: 24s) with:
            along(my_road)
            speed(0kph, at:start)
            speed(60kph, at: end)
            lane(3)
            position(distance:50m, at:start)
            position(distance:250m, at:end)
            acceleration(...)
```

Abstract scenario:

```
scenario sut.right_cut_in_by_emergency_vehicle:
    # any road that matches these constraints
    my_road: road with:
        keep(it.min_lanes>=2)

    #object constraints
    my_emergency_car: emergency_vehicle

    do cut_in() with:
        keep(side == right)
        keep(road == my_road)
        keep(car1 == my_emergency_car)
```

Full title Domain-specific language for dynamic scenario description
Standard type Language specification and domain model specification

Application areas
- Simulation
- X-in-the-loop
- Proving grounds

Latest version | Release date
ASAM OpenSCENARIO DSL 2.1.0 | Mar 07, 2024

ASAM OSI

Interface for simulation

ASAM OSI (Open Simulation Interface) provides easy and straightforward compatibility between automated driving functions and the variety of driving simulation frameworks available. It allows users to connect any sensor, via a standardized interface, to any automated driving function and to any driving simulator tooling. It simplifies integration and thus significantly strengthens the accessibility and usefulness of virtual testing.

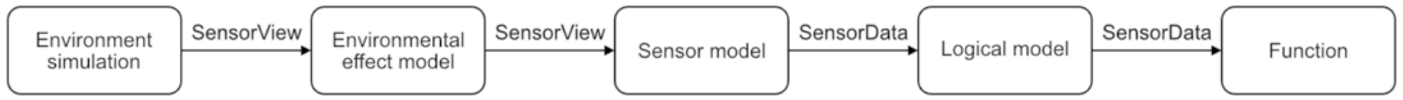
ASAM OSI started as a generic data exchange interface compliant with the ISO 23150 logic interface for the environmental perception of automated driving functions in virtual scenarios. In tandem with packaging specifications, such as the ASAM OSI Sensor Model Packaging (OSMP) specification, the standard provides solutions for simulation model data exchange across different implementations.

ASAM OSI contains an object-based environment description using the message format of the protocol buffer library developed and maintained by Google. It defines top-level messages that are used to exchange data between separate models. Top-level messages define the GroundTruth interface, the SensorData interface, and – since OSI 3.0.0 – the interfaces SensorView and SensorViewConfiguration. Further top-level messages that were added in later versions of ASAM OSI are HostVehicleData, TrafficCommand, TrafficCommandUpdate, TrafficUpdate, MotionRequest, and StreamingUpdate.

The GroundTruth messages describe the simulated environment containing all simulated objects in the global coordinate system at consecutive time instances. They are based on data available to the simulation environment. GroundTruth messages are typically contained in SensorView messages. The sensor view provides the input to ASAM OSI sensor models. SensorView messages are derived from GroundTruth messages. The sensor view is flexibly defined to provide different kinds of sensor models with an appropriate input. The sensor-view configuration defines the configuration of a particular sensor view.

ASAM OSI also defines interfaces for traffic participant models. The TrafficCommand interface makes it possible to send commands to traffic participant models. The TrafficUpdate interface makes it possible to receive the updated state from traffic participant models. The HostVehicleData interface describes the measured internal states of a traffic participant. ASAM OSI currently provides only limited support for data structures that describe measured internal states of traffic participants. One example would be the MotionRequest interface that can be used to communicate the results of the behavior planning to the dynamic model.

The StreamingUpdate message provides an interface to transmit a subset of ground truth and/or vehicle internal data. This interface mainly addresses applications with low latency requirements and no need for highly consistent and complete data, e.g. visualization applications.



Open Simulation Interface overview

Full title Open Simulation Interface
Standard type
- Data layer (Protobuf IDL)
- Packaging layer (OSMP) that defines model types and their packaging as Functional Mock-up Interface (FMI) compliant FMUs, using either FMI 2.0 or FMI 3.0.
- ASAM OSI trace file formats (.osi)

Application areas
- AD simulation
- Simulation visualization
- Sensor model validation

Supplementary
- A python package "open-simulation-interface"
- The ASAM OSI Validator checks the compliance of OSI messages with predefined rules.

GitHub repository

Latest version | Release date
ASAM OSI 3.7.0 | Jul 03, 2024

THE FUTURE OF VEHICLE TESTING USING ASAM STANDARDS

Vehicle testing has become increasingly complex due to the rapid evolution of the mobility industry, driven by advanced technologies and stringent requirements for safety, sustainability, and innovation. ASAM addresses these challenges by providing a standards portfolio that enables efficient and collaborative testing and validation across development teams and organizations. Standards such as ASAM XIL for test automation, ASAM ODS for data management, ASAM OTX Extensions for test logic and ASAM OpenSCENARIO for scenario-based testing foster interoperability, scalability, and consistency in testing workflows. By harmonizing processes and facilitating seamless data exchange, ASAM standards empower the industry to manage complexity effectively while accelerating development cycles and improving product quality. Making automotive testing workflows more efficient continues to be a key part of ASAM's overall technical strategy.

In the following, we introduce to you two initiatives that analyze different test approaches in the mobility industry with the goal of proposing standards that solve the challenges. These projects – the ASAM TestSpecification and ASAM OpenX for Offroad Applications – aim to address the growing complexity of testing autonomous and software-defined vehicle functions. By incorporating multiple ASAM standards, these projects aim to create a coherent framework for the definition, execution and validation of test scenarios. This approach promotes the interoperability and reusability of data, tools and environments across the whole testing and validation process. For that reason, these projects are an integral part of ASAM's effort to drive the standardization of testing, increase safety and foster innovation in the development of autonomous and software-defined vehicles.

ASAM TestSpecification

The increasing complexity of software-defined vehicles and autonomous driving functions calls for advanced testing strategies. To address these challenges ASAM has brought together a network of automotive industry experts in a collaborative approach. This initiative focuses on developing standardized testing methodologies to ensure safety and reliability in autonomous driving.

The project ASAM TestSpecification builds on a prior study and a concept phase:

Study group report
The study group report provides a comprehensive overview of the testing and standardization landscape, developing a test methodology blueprint designed to support the safety validation of autonomous driving functions. The findings of the study group emphasize the need for a multi-pillar approach to testing, laying the groundwork for future standardization.

ASAM OpenTestSpecification concept paper
To address this need, the ASAM OpenTestSpecification concept paper proposes to standardize test specifications and enhance compatibility across automotive testing tools and environments. It aims to streamline testing processes, enhance the reusability of test artifacts, and facilitate validation. The paper includes an in-depth analysis of current test methods, the identification of critical use cases, and the development of a minimum viable product (MVP) to guide future standardization efforts.

ASAM TestSpecification
Both study group report and ASAM OpenTestSpecification concept paper serve as basis for the ASAM TestSpecification project that we launched in early 2025. The concept paper identified the scope, use cases and requirements for a new standard that aims to describe a universal specification of exchangeable tests for the automotive industry. Particular attention is paid to the interaction of various ASAM standards, such as ASAM XIL, ASAM ODS or the ASAM OpenX standards for tests in the field of autonomous driving. Additionally, the project will develop an MVP designed around an adaptive cruise control (ACC) example, based on pseudo code and using ASAM standards. The focus will be to provide a consistent and complete solution that shows a completely functional process of a test specification cycle.
There are no plans to define a new language. Instead, the project group will rely on the interfaces provided by the selected standards. In case any gaps are identified which cannot be addressed by the selected ASAM standards, standardization will be pursued in follow-up activities.

Impacted standards
ASAM ODS, ASAM OTX Extensions, and ASAM XIL.
The development of a new standard is being considered.

Deliverables
The main outcome of the ASAM TestSpecification project will be new versions of ASAM ODS, ASAM XIL and ASAM OTX Extensions. These updates may include extensions to the base standards, new associated standards, guidelines or any other supplementary documents (e.g. user guide).

Current projects
P_2024_05_ASAM TestSpecification Concept Project
Start date: Apr 2025 | Planned release: Apr 2027

ASAM OpenX standards in offroad applications

ASAM's simulation standards have been driven by the automotive industry's need to develop and test ADAS/AD for on-road driving. However, industries like landfill, construction, agriculture, and mining are also leveraging automated driving. These environments have restricted access, controlled conditions, and smaller ODDs, making deployment easier than for on-road applications.

ASAM member companies are exploring the use of ASAM OpenX standards for off-road ADAS/ADS operations. Unique challenges in these environments, such as soil strength characterization and terrain interaction, require standard adaptations. This project seeks to extend ASAM standards to support off-road automation, benefiting both off-road and on-road applications.

The compilation of requirements was based on two major example scenarios:

Scenario A – Moving from point A to point B (Fig.1)

- A mine vehicle follows a pre-defined path from A to B using GPS and onboard sensors, maintaining optimal velocity via a controller. Environmental variations, like soft soil, may cause traction loss and slip. The scenario evaluates the path-following algorithm's performance in such conditions by measuring deviations, speed accuracy, fuel consumption, and traversal time.

Scenario B – Load and haul (Fig.2)

- In construction, earth transport involves navigating rough terrain, including mud and steep slopes. A heavy load affects acceleration, braking, and steering, requiring careful maneuvering and safety measures to prevent tipping or immobilization. The scenario examines how different loads impact vehicle stability, traction, and maneuverability. It also assesses transport efficiency, fuel use, and tire wear while ensuring the vehicle reaches its destination safely.

Requirements cover:

- Representation of terrain, objects & vehicles
- Behaviors for agents in off-road environments
- Interaction between conditions and materials

Figure 1. Moving from point A to point B in uneven terrain

Figure 2. Dirt moving and loading a vehicle to be hauled

Impacted ASAM standards
ASAM OpenCRG, ASAM OpenDRIVE, ASAM OpenLABEL,ASAM OpenMATERIAL 3D, ASAM OpenODD, ASAM OpenSCENARIO, ASAM OSI

Considered external standards

- EMESRT PR-5A Vehicle interaction systems, Landxml 1.2 (specifically infra model 4.0.4)
- NATO AMSP-06 Guidance for standards applicable to the development of the next generation,
- NATO reference mobility models
- ISO/CD 7334 Earth-moving machinery – Taxonomy an vocabulary for automation and autonomy
- ISO 15143-4 Worksite data exchange
- ISO 6165 Earth-moving machinery – Basic types
- ISO 17757 Earth-moving machinery and mining – Autonomous and semiautonomous machine system safety
- ISO 21815 Earth-moving machinery – Collision warning and avoidance
- ISO 23725 Autonomous System and Fleet Management System Interoperability

Application areas
Movement from point A to point B, obstacles, water scenarios, cover, vegetation

Current project
P_2023_03_ASAM OpenX standards in offroad applications

Concept Project
Start date: Nov 2023 | Planned release: Jul 2025

Quality Checker Framework

The ASAM Quality Checker Framework is an innovative open-source tool designed for quality assessment of ASAM standards like ASAM OpenDRIVE, ASAM OpenMATERIAL 3D, ASAM OpenSCENARIO XML, and ASAM OTX Extensions. The framework provides a robust solution for ensuring accuracy and reliability of files used in simulation and automated driving environments.

Besides the framework, ASAM provides official checker libraries for ASAM OpenDRIVE, ASAM Open MATERIAL 3D, and ASAM Open SCENARIO XML, while a representative set of check examples is available for ASAM OTX Extensions. All these libraries and examples will be further expanded in upcoming standardization efforts.

The framework operates through specialized checkers to evaluate different aspects of files, ensuring they meet formal criteria and quality aspects. These checkers are grouped into checker libraries and executed via checker bundles, which can be written in any programming language. Users can extend or customize checks to meet project-specific needs.

All results are consolidated into a single output file, which can be reviewed

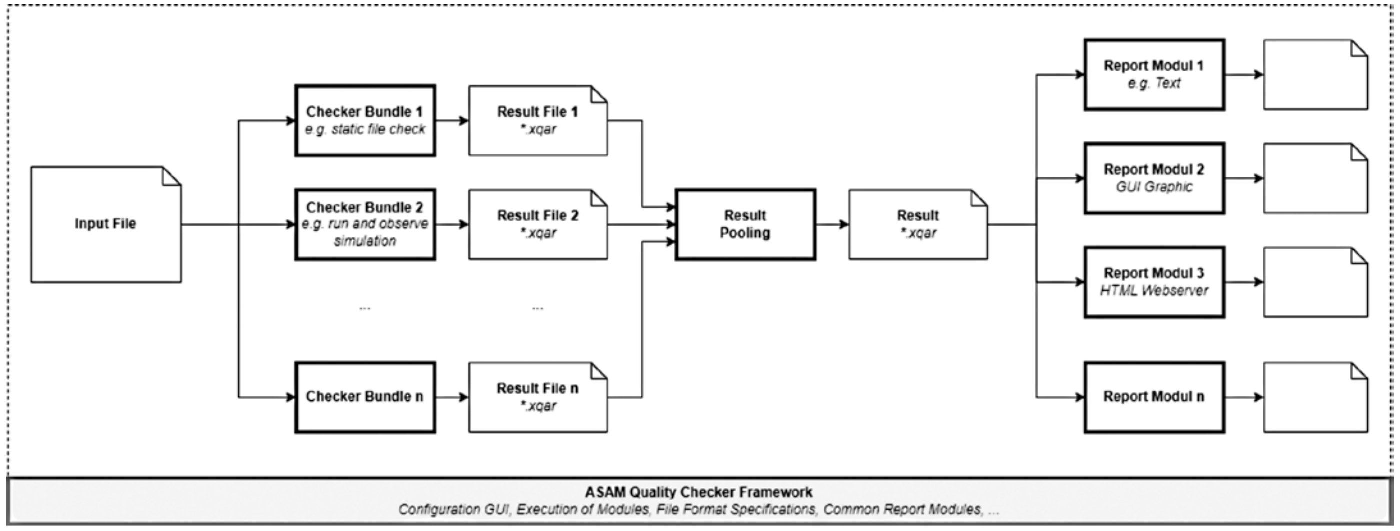
- automatically, by parsing the XML output,
- manually, through text-based output,
- interactively, using the built-in "ReportGUI" module.

This flexibility allows users to choose the method that best fits their workflow for reviewing and interpreting results. Additionally, beyond XML schema validation, users can define custom rule sets for advanced quality metrics.

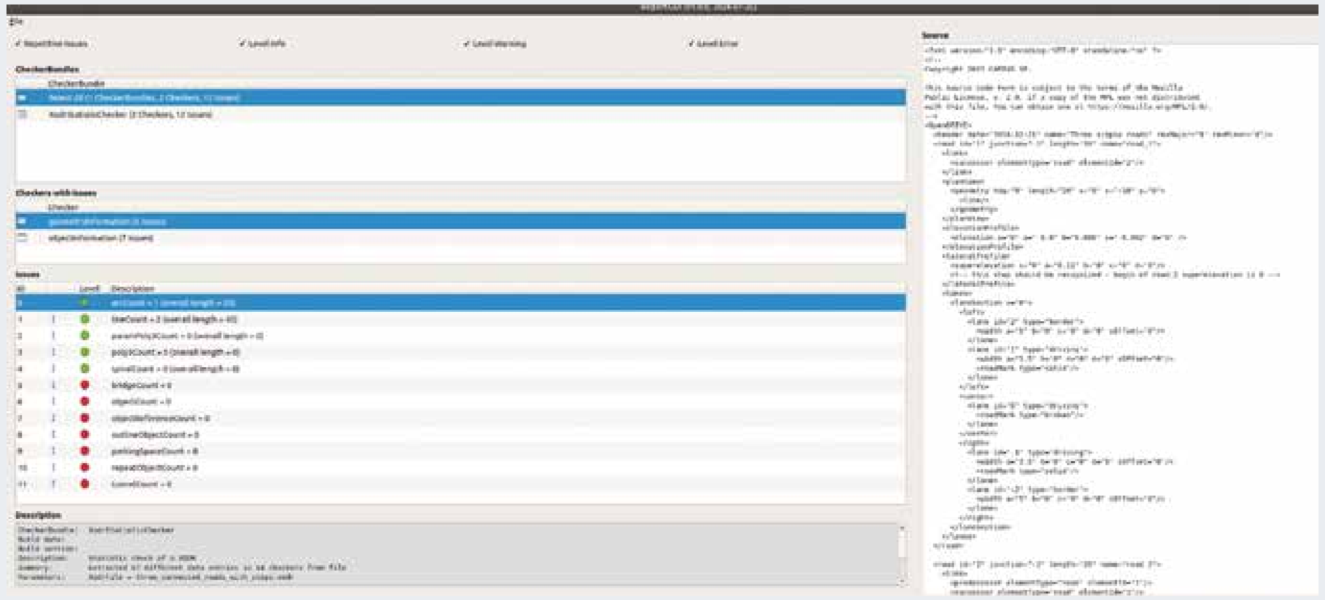
Besides performing static files checks, which read, evaluate and analyze content, it is also possible to create checkers that run an executable, for example a simulation, and analyze the simulation results. By this, non-plausible simulation behaviour may point to problems in the input files.

The following requirement features list was the foundation for the design of the framework:

- Possibility to include a common ASAM rule set, which validates the rules from the specification document.
- Write own rule sets, implemented in any programming language.
- Extract meta information (e.g. if the file contains specific objects and the location of them).
- Configuration sets and parametrization of rules.
- Possibility to include results based on the analysis of simulation runs.
- Text report module to generate a human readable result file.
- Interactive usage or run in an automated workflow.
- Locate the results in the XML source code and in a visualization of the map.
- Runtime to call the checker rule sets and merge all results.
- Report GUI to explore the results in the source code of the input file.
- Plugin system for connecting the Report GUI to any visualization engine to show the results directly in the map.
- Python and C++ base libraries to read/write the configuration and result file format.
- Workflow ASAM Quality Checker Framework:



Using the ReportGUI:
This GUI can be used to filter reported issues. The list of checkers can be used to filter issues from one checker in one CheckerBundle and the window on the bottom left contains all the information about the selected issue.



Additionally, it is possible to link issues that correspond to a 3D error with a viewer application (if the issue contains a valid FileLocation).

GitHub repository

Full title ASAM Quality Checker Framework
Standard type Tool
Application areas
Quality check assessment of ASAM standards
Latest version | Release date
ASAM Quality Checker Framework 1.0.0 | Nov 29, 2024

ASAM'S POSITION IN THE SOFTWARE-DEFINED VEHICLE (SDV)

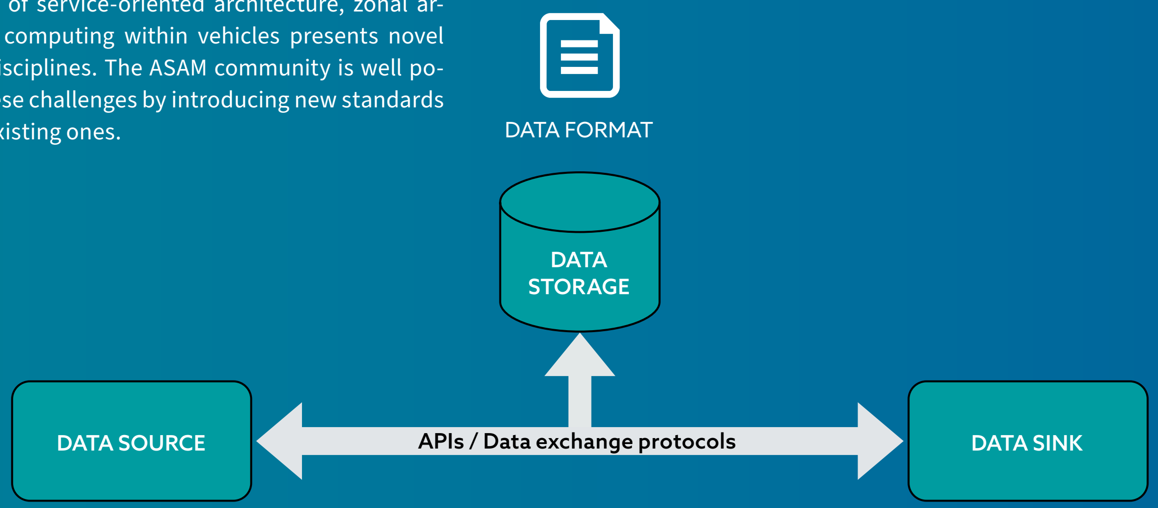
As part of its 2025 strategy, ASAM continues to solidify its position in the dynamic landscape of SDV. The rapid adoption of new vehicle applications, cloud-based services, machine learning, and artificial intelligence within vehicles is driving the SDV trend. Key technological enablers include HPCs, zonal architecture, high-speed connectivity, V2X communication, 5G networks, and OTA updates. However, functional safety, data privacy, and cybersecurity gets more challenging in SDV development.

Moreover, the traditional boundaries between OEMs, Tier-1 suppliers, and technology companies are blurring. Collaborations among these entities are accelerating the deployment of SDVs. Notably, the role of open-source software and standardization is gaining prominence as a solution to the complex SDV puzzle. Various industry consortia and initiatives actively contribute to shaping this transformative landscape.

For years, ASAM standards have been rooted in vehicle software disciplines, including software testing, validation, measurement, calibration, data management, diagnostics, and simulation. However, the emergence of service-oriented architecture, zonal architecture, and cloud computing within vehicles presents novel challenges for these disciplines. The ASAM community is well positioned to address these challenges by introducing new standards as well as expanding existing ones.

ASAM adopts a data-oriented design philosophy, where existing ASAM standards seamlessly interact across the entire toolchain, serving various use cases. ASAM simply visions all use cases from a data point of view, where all software entities are either a data source or a data sink that both need a common understanding of data via a unified data format or a model, and a pre-defined data exchange protocol through APIs. Besides data modelling and exchange protocols, the third pillar is the storage format of the data. Whether these entities are physical or virtual, at the edge or on a cloud, ASAM's focus is the data itself. ASAM's standards shall facilitate the data exchange between different software implementations and at the same time stay architecture-agnostic. By embracing this simple, yet powerful philosophy, ASAM ensures that software-defined vehicle strategies and autonomous driving systems can be realized efficiently and reliably.

The first ASAM standard specifically addressing software-defined vehicles is ASAM SOVD, where the vehicle diagnostics were re-invented to adapt the use of service-oriented architecture, and HPCs. Another running contribution is to improve existing standards such as ASAM MCD-1 XCP to cover new use cases of virtualization of ECUs. ASAM is in collaboration talks with other industry consortia such as the Autoware foundation, AUTOSAR, eSync Alliance and SOAFEE whose outcomes shall guide the industry leaders on going forward in the SDV development.



WHAT IS GOING ON IN THE SDV SPACE?

SDVs pose an engineering challenge that requires collaboration between different industry players. In this section, some of the open consortia are introduced, in-which several companies and research institutes collaborate to define the building blocks for future SDVs:

AUTOSAR

AUTOSAR is a global development partnership of automotive manufacturers, suppliers, and other companies. It aims to create and establish open and standardized software architecture for automotive electronic control units (ECUs). In the realm of software-defined vehicles (SDVs), AUTOSAR plays a pivotal role by providing essential standards and frameworks that ensure safety, security, and interoperability of in-vehicle software systems. Their activities in SDV include developing new standards like the Vehicle API to facilitate interaction between onboard and offboard software and collaborating with other organizations to harmonize technologies and methodologies for the seamless integration and evolution of SDVs.

AUTOWARE FOUNDATION

The Autoware Foundation hosts the Autoware project, an open-source project for autonomous driving. Autoware is a full-stack autonomous driving software built on ROS (Robot Operating System) that covers the main building blocks of an AD stack, including perception, localization, planning, and control, in a modular architecture with well-defined interfaces and APIs. Autoware aims to make AD technology more accessible through open-source software and creating synergies between ecosystem stakeholders. It supports end-to-end autonomy development, starting from sensor drivers until commanding the vehicle actuation.

The Open AD Kit is a collaboration project (the first SOAFEE blueprint) within the Autoware Foundation to make Autoware software-defined. The Open AD Kit Blueprint showcased several generations of containerized Autoware software, running both on the cloud and at the edge, while the cloud and edge are connected via OTA update capability. The Open AD Kit project continues to be developed at the Open AD Kit working group. Its goals are to introduce modern cloud-native development methodologies for the Autoware development, enable validation using virtual prototyping platforms to achieve shift-left, and provide a consistent production environment for deploying Autoware with hardware abstraction technologies, enabling hardware-agnostic solutions.

COVESA

COVESA, which stands for Connected Vehicles Systems Alliance, is a an open and member-driven global technology alliance accelerating the full potential of connected vehicles and the mobility ecosystem. COVESA aims to develop reference software and hardware architectures focused solely on developing common approaches and technologies for connected vehicles. COVESA members launch and contribute to a variety of collaborative groups and projects, such as the Data Expert Group, who are responsible of the Vehicle Signal Specifications (VSS) project, and Automotive Android Open-Source Project (AOSP) App Framework Expert Group, that advance the mobility ecosystem and connected vehicles.

ECLIPSE SDV GROUP

The Eclipse SDV is a working group within the Eclipse foundation that facilitates open-source development of automotive software. The aim is to provide a forum for individuals and organizations to build and promote open-source solutions for worldwide automotive industry markets. Using a "code first" approach, SDV-related projects focus on building open-source software stacks and associated tooling for the core functionality of a new class of automobile. Some of the projects worth mentioning of Eclipse SDV are: uProtocol, eCAL, OpenDUT, Velocitas and Bluechi.

eSync ALLIANCE

The eSync Alliance is a non-profit trade association dedicated to standardizing OTA updates and data gathering in the automotive industry. Formed by a coalition of automotive suppliers, the alliance aims to create a secure, multi-vendor platform that connects every device in a vehicle to the cloud. By providing a standardized yet customizable OTA solution, the eSync Alliance helps automakers and suppliers reduce development time, costs, and risks associated with software updates. Their efforts ensure that vehicles receive continuous updates and improvements throughout their lifecycle, enhancing functionality and safety for end users.

ASAM and eSync Alliance collaborate on integrating ASAM SOVD (Service Oriented Vehicle Diagnostics) with the eSync Alliance OTA specifications. This partnership aims to foster innovation by jointly developing a white paper that will outline use cases for real-world demonstrations as the collaboration progresses.

EU FEDERATE SDV

FEDERATE SDV is a European Union coordination project aims to bring together all relevant stakeholders to accelerate the development of an ecosystem for vehicles of the future, aiming to foster a vibrant community, and supporting accompanying research, development and innovation activities. FEDERATE provides an open forum to the ecosystem at all stages of this initiative. It works towards a common understanding in both software and hardware, while also developing a joint vision for the software-defined vehicles of the future initiative and providing advice for current and future projects in this initiative. The project also aims to coordinate between different EU SDV related projects such as HAL4SDV and SHIFT2SDV, and open consortia working in the SDV such as the SDV Alliance.

SOAFEE

SOAFEE, which stands for "Scalable Open Architecture for Embedded Edge," aims to integrate the cloud-native development paradigm and its extensive ecosystem into the diverse and heterogeneous compute platforms that will drive the next generation of automotive and safety-critical systems. The reference architecture is designed to be scalable across all edge computing applications. The initiative began by refactoring and qualifying cloud computing software components and introducing cloud concepts such as orchestrators, hypervisors, and containerization technologies into the automotive space.

SDV ALLIANCE

The software-defined vehicle Alliance is a collaborative initiative aimed at revolutionizing the automotive industry by integrating advanced software capabilities into vehicles. This alliance brings together key players such as COVESA, Eclipse SDV, AUTOSAR, and SOAFEE to create a coordination framework for developing and deploying software-defined vehicles.

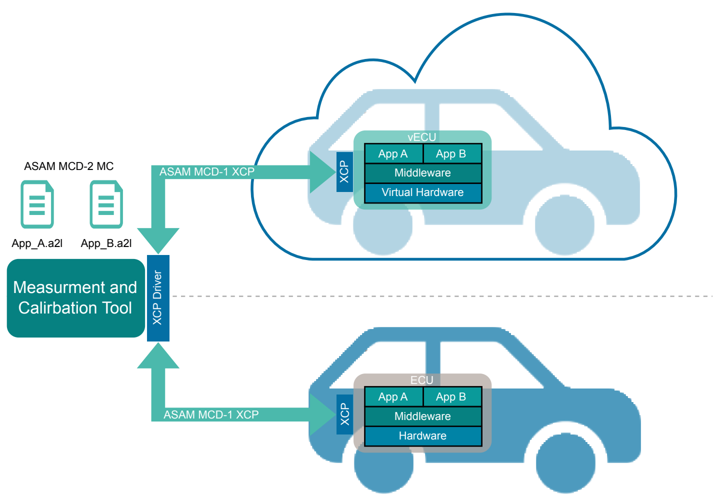
MEASUREMENT, CALIBRATION & DIAGNOSTICS OF SDVs USING ASAM STANDARDS

ASAM is a leader in the areas of measurement, calibration and diagnostics (MCD) standards. Over 80% of the world's vehicles are calibrated today using ASAM standards of this domain. The ASAM community continues to contribute to the respective portfolio either by improving our existing standards with novel use cases or creating completely new standards for them.

Measurements and calibration on virtual ECUs

The ASAM A2L file format and ASAM MCD-1 XCP protocol play an essential role in the measurement and calibration of ECUs. A2L, defined by the ASAM MCD-2 MC standard, provides a detailed description of the internal variables of an ECU, including data types, memory locations, and conversion methods. This information is essential for calibration systems to parameterize and record ECU responses accurately. On the other hand, the ASAM MCD-1 XCP standard describes the communication protocol between the ECU and measurement and calibration tools. ASAM MCD-1 XCP allows for the adjustment of internal parameters and acquisition of real-time data from the ECU. Together, these standards ensure precise and efficient calibration and measurement processes, enhancing the performance and reliability of ECUs.

An important use case for SDVs is the measurement and calibration on virtual ECUs. SDVs will need frequent updates, and virtual testing on the cloud will be an essential part of the development workflow. The vECUs can be part of a full car digital twin, where tests are run virtually on the cloud, and measurement and calibration tools perform the same function on a vECU as on a physical ECU.



Measurement and calibration on physical and virtual ECUs via ASAM MCD-1 XCP

Diagnostics in the cloud

ASAM is currently leading the way in the diagnostics of SDVs by introducing ASAM SOVD to the market. ASAM SOVD provides an API specification that is specifically designed to handle diagnostics on future vehicle architectures. Today's vehicles still depend heavily on the unified diagnostic services (UDS) protocol, which lacks flexibility to be extended to cover diagnostics for HPC, where the software architecture is more modular and could change over time. For backward compatibility, ASAM SOVD specifications map the needed services from UDS, thus enabling the diagnostics of sensors and actuators that still depend on UDS.

ASAM SOVD covers a wide range of diagnostic functions including data access, control of operation and changing the configuration of an ECU. These functions are covered in three use cases which are remote, co-located and in-proximity diagnostics. Therefore, ASAM SOVD can give the OEM the ability to collect various data from the vehicle, as well as to provide a personalization of vehicle services, thus enabling an important aspect of an SDV. Another important feature is the enabling of OTA updates via ASAM SOVD. This is essential to update the user experience of an SDV throughout its lifecycle. The dynamic discovery of an ASAM SOVD capability description makes it easier for maintenance personnel to access car data after software updates. As part of the continuous synergy between ASAM standards, ASAM OTX Extensions will soon provide an extension for ASAM SOVD.

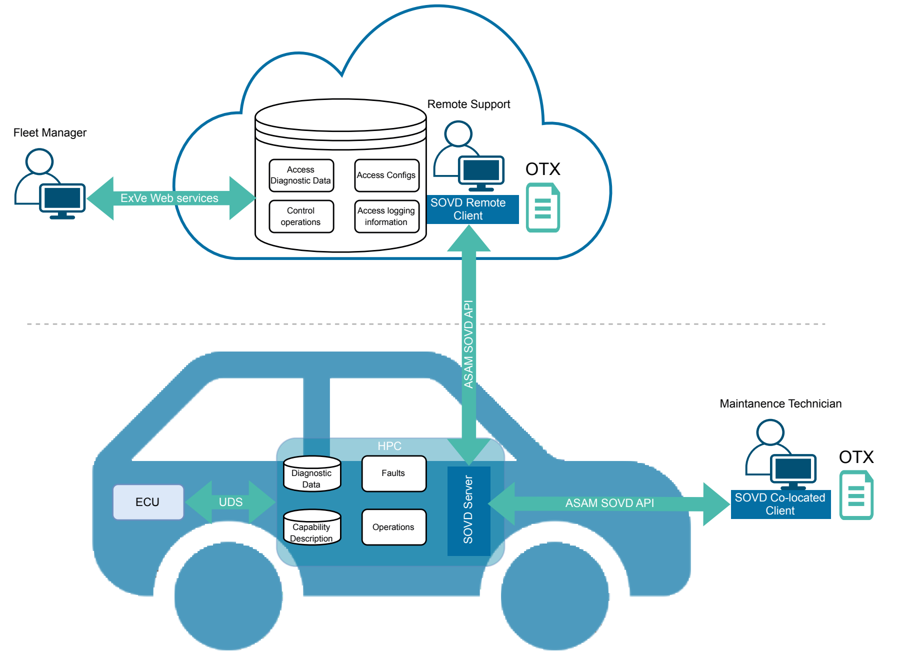
OTA updates with ASAM SOVD

Software updates are vital for ensuring that vehicles perform optimally and meet the changing demands of consumers. The landscape of over-the-air (OTA) software updates is evolving, with new methods and classifications emerging to handle the complexities of modern vehicle systems. The ASAM SOVD API standardizes this process, offering elective, supervised, and safe updates while emphasizing safety, reliability, and user control.

Traditionally, a diagnostic tester outside the vehicle controlled the update process, with the vehicle executing the prescribed steps. In contrast, the ASAM SOVD API shifts control to the vehicle itself, leveraging its OTA capabilities to retrieve and install software updates. This approach supports two main update procedures: stepwise and automated. The stepwise update allows the ASAM SOVD client to control which updates are installed and when, while the automated update gives the ASAM SOVD server full control over the entire update process for the selected package.

Update packages in ASAM SOVD are self-contained, meaning they include all necessary updates for multiple ECUs and are installed in one atomic step. This ensures that if an update involves multiple components, such as the engine and gear shift, all updates are included and installed together. If an error occurs during the update, the process can be rolled back completely to maintain system integrity.

The ASAM SOVD API also supports specific use cases in engineering or production by allowing individual entities to provide the update resources. This flexibility ensures that updates can be tailored to specific needs, whether for individual components or entire systems. Overall, the ASAM SOVD API enhances the efficiency and reliability of software updates, promoting better vehicle performance and user satisfaction.



Remote and co-located diagnostics via ASAM SOVD

APPLICATION

ASAM standards are designed for practical application, and our members are proving how effective they can be. Read how companies are using our standards to streamline processes, improve collaboration and facilitate customer projects.

Hexagon Manufacturing Intelligence

A seamless ADAS / AD testing workflow to accelerate test performance

Featured Standards:

ASAM OpenDRIVE, ASAM OpenSCENARIO XML, ASAM ATX

Author:
David Mear,
Business Development Manager,
Hexagon Manufacturing Intelligence

"We have reached a level of complexity in validating ADAS functions that cannot be solved by a single company alone. Collaboration is key. ADET is an excellent example of how industry-leading partners can leverage open standards to work together, boosting ADAS validation and testing techniques. This collaboration aims to make mobility safer, more comfortable, and more sustainable."

DAVID MEAR,
Business Development Manager,
Hexagon Manufacturing Intelligence

SUMMARY

Challenge: Testing automated vehicles is a challenging task for the automotive industry, facing a fragmented tooling landscape, too many dependencies, long iteration cycles quality risks.

Solution: The ADET initiative (Autonomous Driving End-to-End Testing) composed of Industry leaders like Hexagon, Microsoft, Tracetronic, AVL and Synopsys have come together to propose a seamless ADAS/AD testing workflow through the use of ASAM OpenX Standards enabling ~500x more test runs than similar setups without seamless toolchain. As one fully integrated and aligned holistic solution, it combines state of the art tools, infrastructure and usage of ASAM standards and enables traceability & monitoring, closed data loop, virtual process mapping etc. with a single point of contact, guarantying continuous quality assurance along the development process.

Key Benefits: OEMs and Tier1s can leverage this workflow solution to release high quality ADAS & AD features quickly by scaling up test coverage, turnaround time and enabling interoperability. Its flexibility allows tailoring to meet specific needs by allowing to add, remove, or modify any components or tools as required.

APPLICATION STORY

The ADET initiative (Autonomous Driving End-to-End Testing) composed of Industry leaders like Hexagon, Microsoft, Tracetronic, AVL and Synopsys has proposed a seamless ADAS/AD testing workflow using ASAM OpenX standards enabling ~500x more test runs than similar setups without seamless toolchain, that would actually be a virtual trip to the moon and back 50 times over!

To increase safety and gain market share, OEMs must introduce more and more new ADAS features into their development cycles and integrate them quickly into the vehicle to be in time for the Start of Production. The problem comes from complexity: according to ADET experience, a vehicle has more than 50 embedded systems distributed over more than 20 control units. That leads to millions of tests, to be covered by multiple teams involved at OEMs, Tier1s and Tier2s doing the daily code changes. All that knowing that hardware is often not even available during development.

As of today, there is no single solution that enables fast and seamless iteration loops over the whole ADAS development process. Toolchain and interfaces are often optimized for different testing purposes and there are too many dependencies exist between tools.

But if tools do not fit, workflows do not run, causing delays in software development, too little test coverage, gaps in quality and safety etc.

AVL, Microsoft, Hexagon, Synopsys, and Tracetronic have taken up the challenge and work together on a seamless testing workflow as one fully integrated and aligned holistic solution. It combines state of the art tools, infrastructure and usage of ASAM standards and enables traceability & monitoring, closed data loop, virtual process mapping etc. with a single point of contact, guaranteeing continuous quality assurance along the development process. This integrated digital and automated toolchain facilitates highly efficient and precise simulation of driving functions and their testing in conjunction with various sensors, control elements, and driving environments to bring ADAS features faster into the car.

Through this ADET initiative, these five companies work together to combine their expertise:

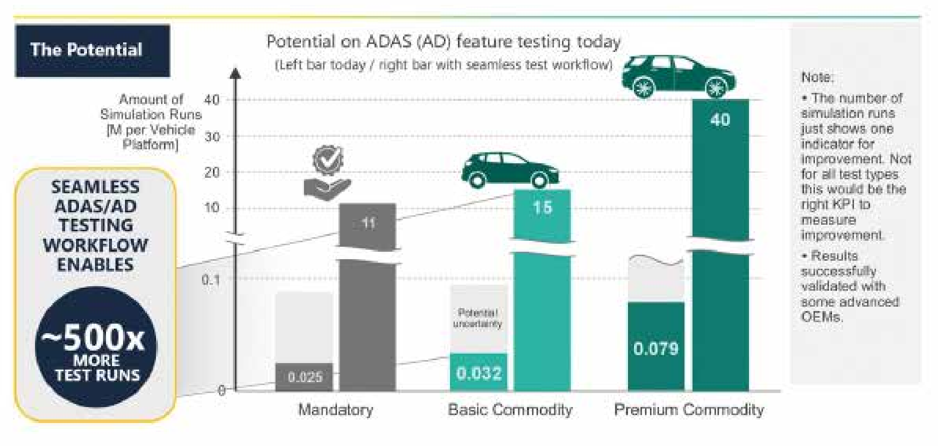
- **Hexagon** provides the environment simulation tool with Virtual Test Drive (VTD) and the Nexus Cloud Platform to connect tools and cloud and enable computational power and collaboration. Hexagon's expertise in standardization (particularly with ASAM) is key to this initiative.
- **Microsoft** provides a secure and scalable cloud infrastructure for AVOps (Autonomous Vehicle Operations) including: DataOps to ingest measurement data, MLOps to train algorithms and automate scenario-based testing at scale, ValOps to validate autonomous driving functions and finally AVOps playing a role of centralized orchestration.
- **Tracetronic** provides platform-independent, standardized test and process automation through test.guide and ecu.test. Numerous tools can be connected and easily integrated in the workflow.
- **AVL** provides SCENIUS™, a groundbreaking solution for scenario-based testing and safety assessment, including strong integration capabilities of testing solutions with an open interface architecture. AVL has the key XIL testing and engineering solution competences necessary for ADET.
- **Synopsys** provides Silver, the market leading SIL technology for virtualization of the electronics architecture, that can compile the virtual ECU as FMU (Functional Mockup Interface).

By leveraging open standards such as ASAM OpenDRIVE, ASAM OpenSCENARIO XML, OpenSceneGraph or ATX, the workflow becomes adaptable, and applicable to any tool landscape or cloud provider.

This in turn enables the consortium to offer a complete but flexible workflow in which users can easily add, remove or modify one or multiple components:

- ASAM OpenDRIVE is used to exchange map data
- ASAM OpenSCENARIO XML is used to exchange scenario data between Scenius and VTD
- OpenSceneGraph is used for 3D models
- ASAM ATX (Automotive Test Exchange) is used for test results
- FMI (Functional Mock-up Interface)

Evaluation of ADAS (AD) Testing Performance Improvement

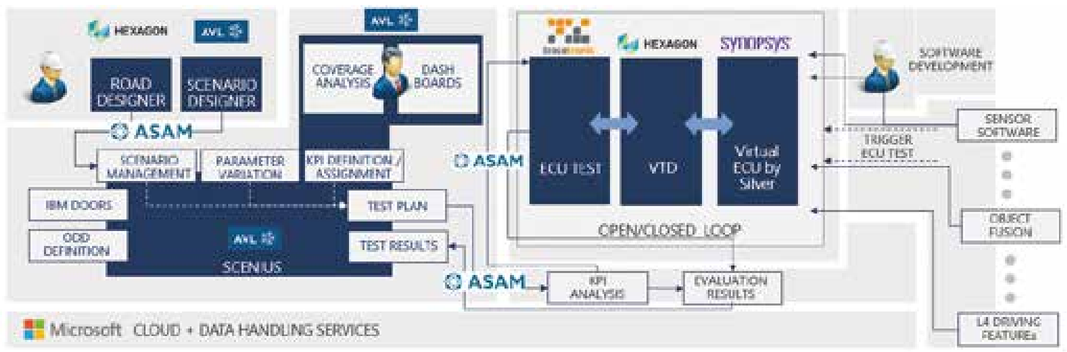


Seamless solution potential: What are OEMs doing now, and what is the potential.

The consortium decided to focus on two use cases initially: The software developer and the tester:

- The software developer creates a new code change, which is automatically built into an executable by the company's CI/CT pipeline as part of the "Software Build". This needs to be tested so that the SW Developer receives feedback on how well the change works, and can ensure that there is no regression, before the change is merged into the main codebase. This feedback should be provided within minutes in order to increase the speed of development. To achieve this, the components are tested in a scalable execution environment, where different instances of an execution container can be created in order to run a large number of tests in parallel by turning logical OpenSCENARIO XMLs in many concrete OpenSCENARIO XMLs. The feedback is generated based on the test plan, as defined by the tester or by a suite of regression tests added from past tests.
- The requirement or validation engineer is responsible for systematically creating the safety validation plan defined in AVL SCENIUS™. New content is then automatically detected in test.guide, and used to distribute the execution across multiple execution environments ("Execution Instances") and to store the test results from these different instances. Finally, the aggregated validation results are looped back into in AVL SCENIUS™, where the requirement or test engineer can get an overview of the validation status and safety performance results. These results are part of the overall safety assessment of the system or vehicle and for the required safety argumentation according to FUSA (ISO 26262) and SOTIF (ISO 21448).

This initiative will enable OEMs and Tier1s to bring ADAS features faster to market, while controlling cost and increasing quality. With the help of ASAM standards, it can be ensured that the workflow is and remains flexible.



RA Consulting GmbH, HighQSoft GmbH

The research project RepliCar – Coverage and interoperability of ASAM standards in an endpoint-2-edge-2-cloud application

Featured Standards:

ASAM ODS,
ASAM MCD-1 XCP,
ASAM XIL,
ASAM MDC-2 D,
ASAM MDF,
ASAM OTX Extensions,
ASAM SOVD,
ASAM iLinkRT

Authors:
Dr. Frank Hantschel,
Director Research & Development,
RA Consulting GmbH
Dr. Ralf Nörenberg,
CEO,
HighQSoft GmbH

“This project shows the potential of the ASAM standards to accelerate engineering for Software-Defined Vehicles and Mobility.”

BOLIN ZHOU,
CATARC

SUMMARY

Challenges: Safe perception of the environment and accurate localization of the ego perspective within the environment are two crucial prerequisites for the virtual validation of automated driving vehicles. The BMWK-funded joint project RepliCar (reference sensor technology for high-precision sensor validation for automated driving) is recording a highly accurate representation of reality as a comparative value for the validation.

Solution: RepliCar aims to integrate sensory ground truth data directly into the simulative validation. This includes data acquisition, data post-processing, feature extraction, and data fusion through to the object list. The project will rely on proven ASAM standards for data artifacts and interfaces and investigate their interoperability within an end-to-end toolchain for homologation. A GAIA-X-related data space enables partners to trustfully exchange information while keeping their intellectual property.

Key Benefits: Replicar is a research project to improve processes of virtual validation of vehicles based on real world data. Explicitly, creating a new level of high-resolution ground truth supports investigating how test procedures must be adapted to validate the sensors‘ reliability. This is a necessity for homologation and avoidance of perception and display errors in the sensors.

APPLICATION STORY

To enable „sensor-in-the-loop“ approaches or simulative validation for the environment detection sensors, it is necessary to capture highly accurate the “ground truth” of the environment to be simulated (other traffic objects, but also the static environment).

To achieve the effective and efficient validation of sensors, the sensors and data processing chains used must be validated to the highest requirements in precision and fidelity.

SOLUTION

To address this challenge the partners of the BMWK-funded joint project RepliCar aim to develop a reference system with integrated high-resolution radar, camera, lidar, GNSS, and inertial sensors. This reference system will be installed into a testing vehicle. By using particularly high-resolution sensors and a particularly powerful sensor data fusion for object recognition, a highly accurate representation of reality is recorded.

The project partner ANavS GmbH will be developing sensor data fusion for environment perception as well as for self-localization of the ego vehicle. The Institute for High-Frequency Technology and Electronics (IHE) at the Karlsruhe Institute of Technology (KIT), Offenburg University of Applied Sciences (HSO), and Freudenberg FST GmbH are developing the high-precision radar system. This essential element in the reference system is validated by the Institute for Regulation and Control Systems (IRS) at KIT. The project partners AKKA Industry Consulting GmbH, the FZI Research Center for Information Technology, IAVF Antriebstechnik GmbH, IPG Automotive GmbH, and GTÜ Gesellschaft für Technische Überwachung mbH will define and implement all steps from simulative validation to the certification of sensors and functions. The driving demonstrator is being realized by Dr. Ing. h.c. F. Porsche AG, Stuttgart. It records initial data and uses it for the release process of an exemplary perception system.

The individual innovations in the validation and testing process are based on ASAM standards. This includes the integration of artificial intelligence methods for analyzing recorded scenarios, a „sensor in the loop“ test bench, integration into existing simulation tools, and modular verification and validation processes. To allow data sharing between partners, HighQSoft GmbH and RA Consulting GmbH will design a GAIA-X-based data space based on ASAM ODS and other descriptive ASAM standards. The targeted endpoint-2-edge-2-cloud architecture includes data capturing in the vehicle (endpoint), data consolidation in a telematics server (edge) and the data space (cloud).

CHALLENGES DURING THE PROJECT

Next to the main challenge of designing a system that records ground truth on an unprecedented scale, the project must provide a solution that enables interoperability and seamless exchange of information across toolchains for research and development in automotive electronics engineering. This task requires the definition and implementation of a reference architecture incorporating the newer simulation standards such as ASAM OpenX with other ASAM standardization domains and applying extensions for interoperability where needed.

One particular focus of the project is on Telematics connectivity, which is one of the essential prerequisites for the efficient and economical performance of driving tests in the Real Driving Validation (RDV) process. The proposed reference architecture (figure 1) shows the standards-based telematics architecture for the communication technology vehicle connection, which combines existing and industry-proven ASAM standards (e.g. ASAM MCD-1 XCP, ASAM XIL, ASAM MDC-2 D, ASAM MDF, ASAM ODS, ASAM OTX Extensions ...) and newer ASAM standards (e.g. ASAM OpenX, ASAM SOVD, ASAM iLinkRT, ...) as well as other established industry standards (e.g. MQTT, ROS), where the project focuses on the industry standards ROS2, which supports real-time applications.

Next to using well established ASAM standards like ASAM MDF or ASAM OpenSCENARIO XML, also recently published standards like ASAM OpenSCENARIO DSL were integrated into the project. Moreover, new developments like the extension of ASAM MDF for camera, radar and lidar data are evaluated and an exchange with the associated standardization groups was established.

Since the research project requires project partners to collaborate and share data artifacts, the methodology of data spaces is introduced alongside the standardization efforts. The key challenge is to establish trust within a technical framework that allows participating partners in a data space to keep their intellectual property while sharing specific information based on transparent contracts. For example, one use case is sharing and executing a scenario extraction service of one partner in the edge node of the partner who owns the recorded rosbag files. This use case requires both, certified and standardized processes and interfaces.

The figure below shows the standard-related ASAM telematics reference architecture, which provides an overview of the necessary interoperability of standards, test data management, and the telematics use case. As part of the RepliCar research project, numerous proofs-of-concept have been implemented to demonstrate the interoperability of ASAM standards.

BUSINESS BENEFITS

The project develops a reference system for ground truth data to improve the whole validation toolchain and the homologation process. Also, based on a reference architecture, the interoperability of ASAM standards and GAIA-X-based data spaces are investigated to provide further details on a standardized digital twin validation process that is interoperable with the domain of automotive electronics engineering.

Such an integrated standard-based architecture will:

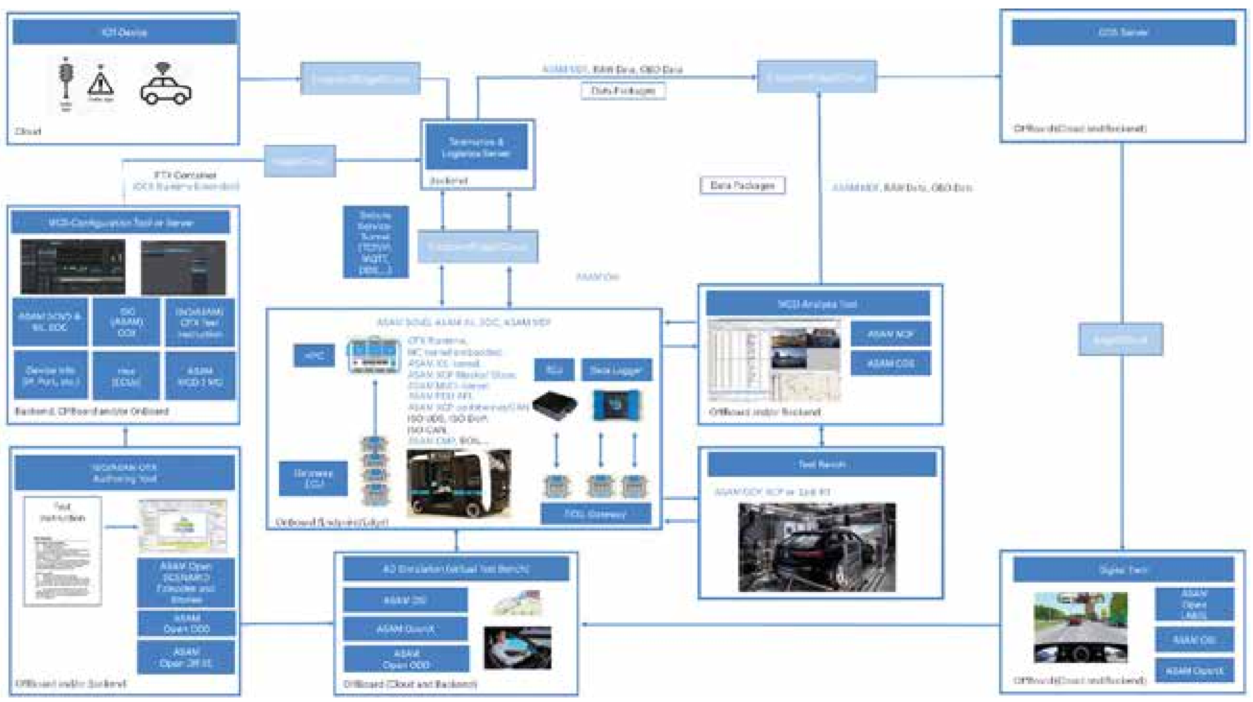
- allow a seamless exchange of information across toolchains,
- accelerate and secure the automotive electronics development processes,
- create tangible results more efficiently and at higher quality,
- allow a seamless exchange of information between all stakeholders and over the product life-cycle,
- reduces the overall costs.

Gefördert durch:

Bundesministerium für Wirtschaft und Klimaschutz

aufgrund eines Beschlusses des Deutschen Bundestages

Real Driving Validation (RDV) is a research project funded by the BMWK on the basis of a decision by the German Bundestag.



Proposed and standard-related ASAM telematics reference architecture.

Vector Informatik GmbH

Democratizing NCAP scenarios for virtual test drives with ASAM OpenX

Featured Standards:

ASAM OpenDRIVE, ASAM OpenSCENARIO XML, ASAM MDF

Author:
Dr. Jakob Kaths,
Senior Product Management Engineer,
Vector Informatik GmbH

"I am pleased to hear Vector publishes the Euro NCAP scenarios in the ASAM OpenSCENARIO XML format free of charge. Such activities foster the community trend for shift left testing with virtual test drives, which ultimately contributes to safer roads."

RICHARD SCHRAM,
Technical Director Euro NCAP

SUMMARY

Euro NCAP provides descriptions of collision scenarios to test active safety systems of vehicles such as AEB. To conduct these tests in simulation, the scenarios must be described in a machine-readable format. This application story sheds light on the capabilities of ASAM OpenSCENARIO XML and ASAM OpenDRIVE to be used to that extent. Given the widespread use of Euro NCAP scenarios, Vector has chosen to implement these scenarios based on ASAM standards and make them available as open source. You can find the implementation at: https://github.com/vectorgrp/OSC-NCAP-scenarios

INTRODUCTION

It is undisputed that the development and validation of complex ADAS functions require scenario-based testing as an essential component of the test strategy. Due to the high resource consumption of real-world test drives and the oftentimes late availability of technology carriers and prototypes in the development process, these test drives are increasingly conducted in a simulated manner. This process already begins in early development phases with model-based function design (MIL), continues through the implementation of functions as control unit code (SIL) and extends to testing with isolated but real target control units (HIL). It is desirable to reuse any test drive scenarios across all development phases and different execution environments as unchanged as possible. By defining input formats to compliant simulators, ASAM OpenSCENARIO and ASAM OpenDRIVE form the basis for this reusability. The relevant scenario catalog content can originate from various sources, including recorded test drives, accident databases, expert knowledge from function developers, or regulatory requirements. Euro NCAP, for example, provides descriptions of collision scenarios to test active safety systems of vehicles. Although these tests are not mandatory, you may as well regard them as regulatory requirements.

MOTIVATION

As the ratings by Euro NCAP are of high importance for OEMs, the scenarios are well-accepted and widely used, both on real test tracks and in simulation. Simulations are not only carried out by the OEMs, but also by their suppliers. Furthermore, numerous simulators exist, many of them with proprietary scenario descriptions. Therefore, it must be suspected that a large number of implementations in various different formats has been created in the past, both by users of simulators and the tool providers alike. This, undoubtedly, has many disadvantages: duplicated efforts, non-reusable scenarios in proprietary formats and potential misinterpretations of the scenario definitions to name just a few. To alleviate these issues, we decided to comprehensively evaluate the suitability of the open standards ASAM OpenDRIVE and ASAM OpenSCENARIO for modeling various scenarios[1]. Specifically, the following aspects were examined:

- The use of ASAM OpenSCENARIO XML parameters to avoid proprietary pre-processing of simulation input data.
- The suitability of the ASAM OpenSCENARIO XML Synchronize Action for generating conflict situations under different initial conditions and parameters.
- The functional capabilities related to logical scenarios in ASAM OpenSCENARIO XML for parameter variations.

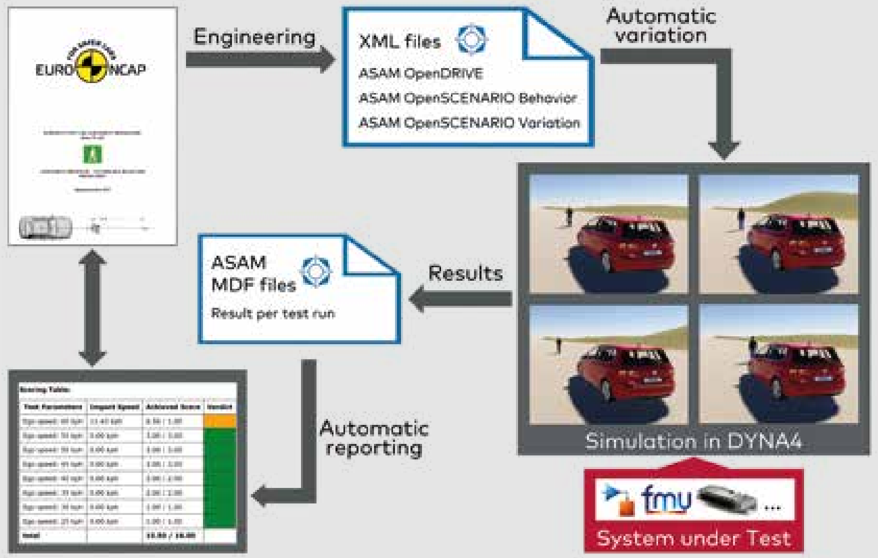
After the proof-of-concept implementation had proven ASAM OpenSCENARIO XML and ASAM OpenDRIVE capable of fulfilling these requirements, Vector decided to make its implementation of these scenarios available open source on Github[2]. You may use this QR code to access the repository.

The goal is not only to avoid duplicate work, but also to foster discussions about the correct interpretation of both the standards and the scenario descriptions by Euro NCAP. It can be expected that this will directly lead to both time savings for the users and an increased quality of the standards.

Implementation using ASAM OpenSCENARIO XML, ASAM OpenDRIVE and ASAM MDF

Euro NCAP provides test protocols free of charge that contain the descriptions of the tests including the scenario definitions. These are made available as textual descriptions and sketches, but also tables with parameters that shall be varied, like the speed of the vehicle under test. Furthermore, assessment protocols are available that describe how to calculate the ratings after the test conduct. The scenarios that were implemented here concern the test of active safety systems, especially AEB systems. The used test protocols include collision scenarios with cars[3] and vulnerable road users[4]. The vehicle and environment simulator Vector DYNA4[5] natively supports both ASAM OpenSCENARIO XML and ASAM OpenDRIVE as simulation input formats. Hence, the implementation and simulation of the scenarios was possible without any intermediate conversion to proprietary input formats. The findings of the implementation can be summarized as follows:

1. **NCAP static parts in ASAM OpenDRIVE**
   - Simple straight roads and symmetrical intersections allow for easy creation of matching ASAM OpenDRIVE descriptions.
2. **NCAP dynamic parts in ASAM Open SCENARIO XML**
   - The ASAM OpenSCENARIO Synchronize Action is used for the behavior descriptions: It synchronizes the target entity's arrival at a target position with the vehicle under test and was of great value to model the desired collision scenarios.
   - Together with this action, the extensive usage of parameters was key to fulfill the goal of avoiding proprietary pre-processing.
   - An apt choice of parameter definitions made it possible to translate the parameter tables from Euro NCAP directly into ASAM OpenSCENARIO XML variation files.
3. **NCAP assessment based on ASAM MDF results**
   - ASAM MDF is used for the recorded data, when simulating the scenarios in DYNA4.
   - A Python-based reporting then automatically calculates the Euro NCAP ratings based on key performance indicators such as impact speed or collision avoidance.



Workflow for creation, simulation and reporting of Euro NCAP scenarios

The entire workflow from creating the scenarios based on the Euro NCAP protocols up to the reporting is summarized in the illustration.

During the implementation, a likely candidate for future standardization has been identified already: For scenarios in which the vehicle under test makes a turn at an intersection, Euro NCAP prescribes concatenated trajectories using straight, clothoid and arc elements. Such trajectories are supported by the latest ASAM OpenSCENARIO XML version 1.3. However, ASAM OpenSCENARIO XML uses the center of the rear axle as the control point for following trajectories, while Euro NCAP specifies the center of the front axle, which is a common reference coordinate system for vehicle dynamics simulation. Until a feature supplement in the standard is possible, a standard-compliant but still proprietary controller property was introduced in DYNA4 to move the control point accordingly.

CONCLUSION

The standards ASAM OpenSCENARIO XML and ASAM OpenDRIVE proved to be capable of modelling the scenarios described by Euro NCAP for the assessment of active safety systems. The open source publishing of this work will likely lead to fruitful discussions regarding the correct interpretation of both the standards and the scenario descriptions by Euro NCAP. In this way, we strive to foster the adoption of the standards within the community and further improve their quality.

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Karakun

Efficiency gains in vehicle development: Function data management using ASAM ODS

Featured Standard:

ASAM ODS

Authors:

Hans-Dirk Walter,
Member of the Board,
Karakun AG

Michael Baumann,
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Karakun AG

SUMMARY

Imagine you want to simulate an elastomeric bushing, a damper, a tire, or some other component. Do you know where to find relevant data to describe stiffness, damping, torque behaviour, or pressure loss, e.g., as input to simulation models? And how can you link development results to requirements? The more effort it takes to answer such questions, the less efficient the development process will be.

The solution lies in the definition of a data standard "FDX" based on ASAM ODS together with the development of software to create and use datasets using this standard. FDX is specifically suited to define data models for the above-mentioned type of data, i.e., so-called function data.

The main benefit is the increase of development efficiency based on faster retrieval of data of known quality, automatic validation of requirements, automatic generation of simulation parameter sets, and automatic computations on data. As this solution relies on established standards (FDX/ASAM ODS), it is future-proof.

APPLICATION STORY

Function or technological data are fundamental for the development process of new vehicles. They describe the behaviour of components, systems, and even whole products. Using function data, engineers can define the required behaviour of components and mix it with 'real' data as measured during simulation runs and tests with prototypes. Depending on the result data, development partners like manufacturers and suppliers exchange function data frequently during the various development iteration cycles. However, it is crucial input for simulation models, e.g., multi-body-simulation.

Whereas most companies involved in developing new vehicles have geometric data for all kinds of components permanently available, function or technological data – if available – are distributed across different departments. They are stored in heterogeneous formats, mostly in files, e.g., Excel, Matlab, and other proprietary tools, leading to expensive and time-consuming disadvantages. Among others, these are:

- It takes a lot of time and effort to spot relevant test result data within the organisation or request them from development partners.
- Data have to be processed manually and adapted to meet the needs of a use case, e.g., for using them as input for simulation models.
- Data providers have to adapt their data to different formats depending on what their customers demand.
- The history and evolution of data along the development process are hard to trace (even if this is possible at all).

The lack of a sound management of function or technological data leads to a longer time-to-market for new products combined with substantially higher costs. The real world shows that, e.g., simulation runs and tests with prototypes have to be repeated because relevant results cannot be found, development results do not behave like expected because of poor quality of data, and the reasons already mentioned above.

SUCCESS STRATEGY

The success strategy to solve the problem consists of the following ingredients:

- VDA initiated (and prostep ivip completed) the definition of a new standard for function or technology data: „FDX Function Data eXchange" on top of ATFX (XML-based format of ASAM ODS). ASAM ODS has been chosen because the physical and technical character of the data suggested it.
- Rich, flexible, and extensible meta-data modelling capabilities that allow component-specific models to cover the technical and process relevant properties of them closely integrated with the data defining or proofing a certain function of a component.
- Being aware that a data standard will only be used if appropriate tooling is available, the prostep ivip working group ensured that a reference implementation for FDX was developed. This tool is called EXOKNOX. A free version of EXOKNOX is available to all interested parties.
- For more ambitious use cases, Karakun developed an enterprise edition of EXOKNOX consisting of a full-fledged data management platform and various tools offering all required functions to cover the complete development cycle of data-driven engineering.

Since the diversity of the required models for the various components that make up a vehicle is very high, additionally openMDM, an Eclipse working group and an associated open-source software project, was chosen to support the easy creation of specific component models. EXOKNOX also provides product data management functions in order to manage the access to data and its state during the development cycle. Furthermore, component models can evolve over time and EXOKNOX ensures the consistency of models and data belonging to these models over time. EXOKNOX guarantees full traceability of all data over the whole lifetime of data.

CHALLENGES DURING THE PROJECT

The magic behind EXOKNOX is its ability to manage multiple diverse models for components. But those models have to be created and evolved. For this, tools had to be created so that both developers and users can perform this task.

Using ASAM ODS together with its generic application model openMDM leads to a high technical complexity of the resulting software one has to cope with – which is possible but requires effort.

When implementing product management principles like status, versioning, object tracing and rights/roles we had to ensure not to create unwanted side effects when extending functionality (especially with a focus on scalability).

One of EXOKNOX's features is the ability to program its own Python scripts and let them execute directly on the ODS meta- and mass-data. This led to the requirement to access the internals of an ODS server. Therefore, we had to develop a specific ODS server component.

We strictly adhered to a data-driven approach when working with component-specific data models, especially ensuring the interchangeability of data between manufacturers and suppliers as they most likely work with different data models. Here, the advantages of self-contained ATFX files play an important role.

BUSINESS BENEFITS

Using the FDX / ASAM ODS standard and EXOKNOX substantially reduces time-to-market because it saves a lot of effort to parameterize complete vehicle models.

FDX / ASAM ODS and EXOKNOX enable organisations to close the process chain for data-driven engineering. That means that the entire development organisation can easily access the latest data at any time and place. Simulation and test campaigns are always executed using quality-checked data. And finally, partners, suppliers, and customers are comprehensively and seamlessly integrated.

The solution is future-proof due to complying with standards (FDX/ASAM ODS). prostep ivip continuously publishes standard models for components. The results of an FDX/ODS-based development are ready for certification. Due to compliance with standards, organisations are not locked into a certain vendor.

The solution enables engineers to automatically validate whether some given function data set matches the requirements. Furthermore, simulation parameter sets can be automatically generated, and engineers can provide scripts that perform specific computations on function data.

Soon after going live with the first version of EXOKNOX in the simulation department of a manufacturer, the team confirmed a substantial gain in efficiency for creating parameter sets for simulation models. In a real-world use case, the development department of a car manufacturer confirmed that using EXOKNOX saved 15 to 20 person days for the development of a specific component.

FEEDBACK BEFORE EXOKNOX WAS AVAILABLE:

"I need to provide functional data. So far there is no database for this."

Testing Engineer (JH), OEM
R&D Department

"An automated process would be a tremendous improvement. "

Simulation Engineer (JB), OEM
R&D Department

FEEDBACK AFTER THE INTRODUCTION OF EXOKNOX:

"I am literally waiting for this tool. I would use it 100%!"

Design Engineer (SK), Manufacturer
R&D Department

"It feels like home. I see everything I need."

Testing Engineer (JH), Car Manufacturer
R&D Department

NorCom Information Technology GmbH & Co. KGaA

Using large language models to analyze measurement data in ASAM ODS format

Featured Standard:

ASAM ODS

Author:
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Data Scientist,
NorCom Information Technology

SUMMARY

In the automotive industry, the rapid evaluation of vast amounts of measurement data facilitates a fast resolution of field and development issues. The integration of the Big Data format ASAM ODS for time series data and the Spark technology enables quick and highly parallelized data processing, facilitating the extraction of necessary information and the execution of AI analyses.

Traditionally, such analyses required expertise in programming and machine learning. However, the growing capabilities of Large Language Models (LLMs), like the popular ChatGPT, empower non-programmers to generate code independently. Our company (NorCom Information Technology GmbH & Co. KGaA) in collaboration with a German car manufacturer, developed a chatbot app capable of translating user queries from natural language into the desired visualizations, along with explanations of the computation process.

Even in its early stages, the app allows engineers without Data Science background to quickly generate custom visualizations, providing insights into one or more measurement channels across plenty of measurement files. The primary benefit of such a tool lies in its accessibility, as it enables personnel without programming expertise to run analyses and generate visualization.

INITIAL SITUATION

The evaluation of large amounts of measurement data, especially in the automotive industry, poses both challenges and significant opportunities, for example, for the fast identification and resolution of problems in the field and in development. The combination of the Big Data format ASAM ODS (standard format proposed by the ASAM Organization for highly parallelized computations) with the Spark technology enables rapid and highly parallelized processing of data to generate the desired results quickly and efficiently and then carry out AI analyses.

Our company (NorCom Information Technology GmbH & Co. KGaA) in collaboration with a German car manufacturer has developed many apps on our DaSense platform, which are able to perform such AI analyses. The focus is mainly on analyzing large amounts of measurement data (time series) with focus on automated anomaly detection and root cause analysis. The goal is to resolve field and development issues more quickly and enable faster reporting.

Our DSL library (an optimized Python library to read and process time series data in ASAM ODS format in a highly parallelized way) facilitates the processing of this kind of data by simply defining measurement channels. The results can then be used to create visualizations or for AI purposes.

However, writing code to perform such analyses on measurement data in ASAM ODS format was only possible for programmers and data scientists and not for automotive engineers.

SOLUTION

Nowadays, Large Language Models (LLM) can generate not only natural language but also code in different programming languages that can be executed in most cases without or with few adjustments. To increase the number of potential users, our company in collaboration with a German car manufacturer has developed a chatbot app (also called AI Assistant) also for measurement data that integrates a Large Language Model (LLM). This LLM can understand the documentation of our DSL library (written in natural language), generate the corresponding Python code, and execute it in the background directly. The results of the interaction with the chatbot are visualizations described in the user query.

CHALLENGES

Although LLMs can generate code quite reliably nowadays and a lot of research effort is put in this direction, developers must face the following challenges:

- **Data sensitivity.** Companies do not want their sensible data to go to an external server as happens for commercial LLM (e.g. ChatGPT). The solution was to send only the user query and the DSL documentation to the LLM in the cloud. The data is processed locally with the code obtained from the LLM as response. Alternatively, it is also possible to create a completely on premises solution with a local GPU.
- **Data security.** The chatbot app must be robust against, for example, prompt injection attacks where malicious people can send dangerous queries to the LLM that can lead to data loss or other harmful actions.
- **Explainability.** One of the greatest challenges of AI in the automotive industry is to explain the generated output. However, state-of-the-art AI models are typically black boxes. Large Language Models (LLMs) are no exception to this, and a lot of effort must be put into ensuring that the output aligns with the user's expectations. At this early stage of our chatbot app, for instance, the user can view the generated code, but more work must be done in this direction.
- **Guiding the user in formulating the question in the proper way.** Every user has a different writing style that may affect the result quality. Therefore, it is important to provide some examples showing how a typical user query should look like.
- **Computation time.** Depending on the size of the measurement data, the number of parameters of the LLM and the computational resources assigned to the Spark cluster, the generation of the visualizations can take from 30 seconds up to a few minutes. The Big Data format ASAM ODS is essential here to achieve a high degree of parallelization and, as a result, the fastest possible response time of the chatbot. The future development for this chatbot app is focused on enhancing its capacity to create increasingly intricate and diverse visualizations and analyses. However, many challenges must be solved on this path, for example, the need to comprehend more and more complex and detailed documentation.

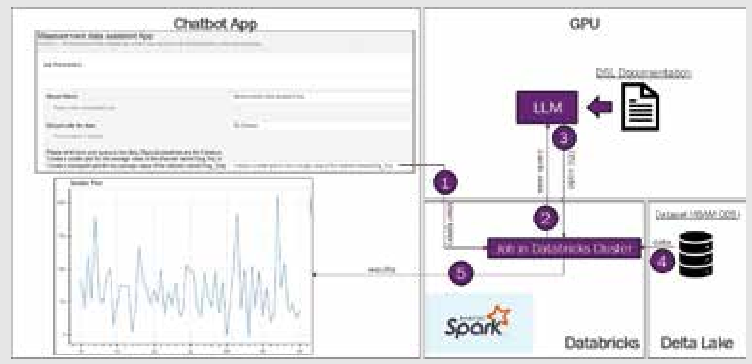
"NorCom is committed to supporting open, standardized formats such as ASAM ODS and constantly strives to assist our customers by implementing innovative AI-based solutions. As part of this initiative, we are pleased to enable engineers to 'talk' to large amounts of measurement data in natural language using the latest LLM technology."

OLEG SKRYPNYUK,
Chief Technology Officer,
NorCom Information Technology

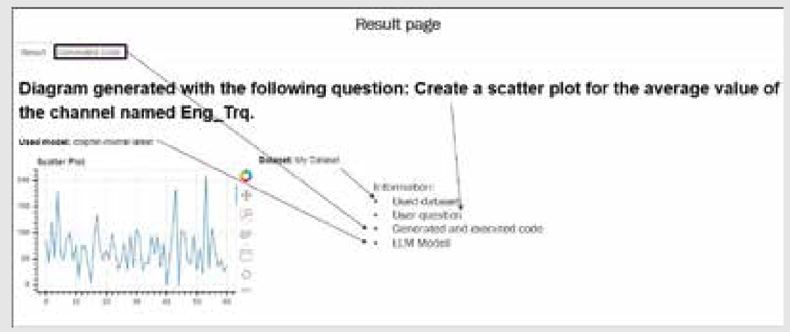
The app incorporates a user-friendly GUI and takes inspiration from the preexisting chatbot app for documents:

The picture below shows the app workflow, which is articulated in the following steps:

1. The user writes and submits a query to the measurement data.
2. The query is received by a Databricks cluster and forwarded to an LLM.
3. The LLM generates the Python code according to the documentation written in natural language.
4. The data in ASAM ODS format are read and the Python code executed.
5. The results are sent back to the app.



The full result page looks like in the following picture:



BUSINESS BENEFITS

Even at this early stage of development, our chatbot app is already able to support the root cause analysis, for example, by visualizing the driving of a vehicle during an endurance test. The simple usability of the chatbot app made this kind of tools accessible to more and more automotive engineers of the customer company, who can now autonomously run AI-based analyses on measurement data in ASAM ODS format without the support of specialized programmers and data scientists saving both time and costs without affecting the quality.

The LLM Models are relatively new technology with big room for improvement. Their rapid and continuous advancement suggests that in the future, generating code for increasingly complex analyses and visualizations will be feasible. This implies additional business benefits, such as a faster and more efficient workflow based on a single chatbot for every type of query on data in ASAM ODS format instead of many highly specialized apps.

Peak Solution GmbH

ASAM ODS data analytics with Python, Notebooks, and AI-Agents

Featured Standard:

ASAM ODS

Author:

Stefan Romainczyk,
Sr. Product Manager,
Peak Solution GmbH

SUMMARY

Keeping up with the latest innovations and technology trends can sometimes be difficult from a standards perspective. In the field of data management (ASAM ODS), Python is the "lingua franca" for data analytics and AI tools, while the existing ASAM ODS HTTP API does not seem very practical from a Python perspective.

With ASAM ODSBox, Peak Solution has introduced a lean Python wrapper on top of the ASAM ODS HTTP API that offers ASAM ODS data in a way that the multitude of existing Python analytics libraries and AI tools can be utilized. A user-friendly query language combined with notebook-based examples lowers the entry barrier for using ASAM ODS. Since all of this is available as open source, AI agents such as Google Gemini or Microsoft Copilot can now also be used to gain data-driven insights - even by non-data scientists.

INITIAL SITUATION

In its daily work with OEMs and solution partners, Peak Solution recognized early on the need to use ASAM ODS data for machine learning (ML) and artificial intelligence (AI). A review of the existing ASAM ODS HTML-API revealed that the current interface was not suitable for this purpose. The weak support for Python – the 'lingua franca' of the data scientist – and the very ASAM ODS specific query language make it difficult for data analysts and data scientists to use ASAM ODS. In addition, the missing public examples makes it even more difficult to get the open-source communities interested in the ASAM ODS standard.

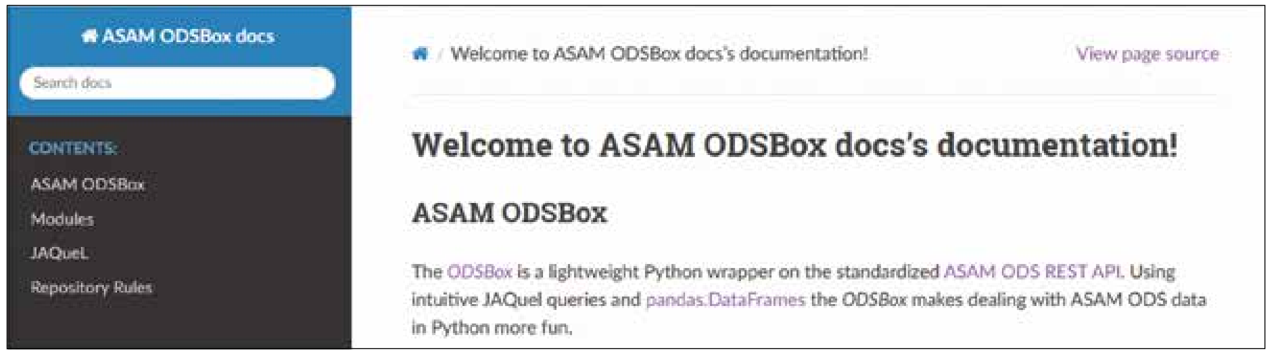
SUCCESS STRATEGY / SOLUTION

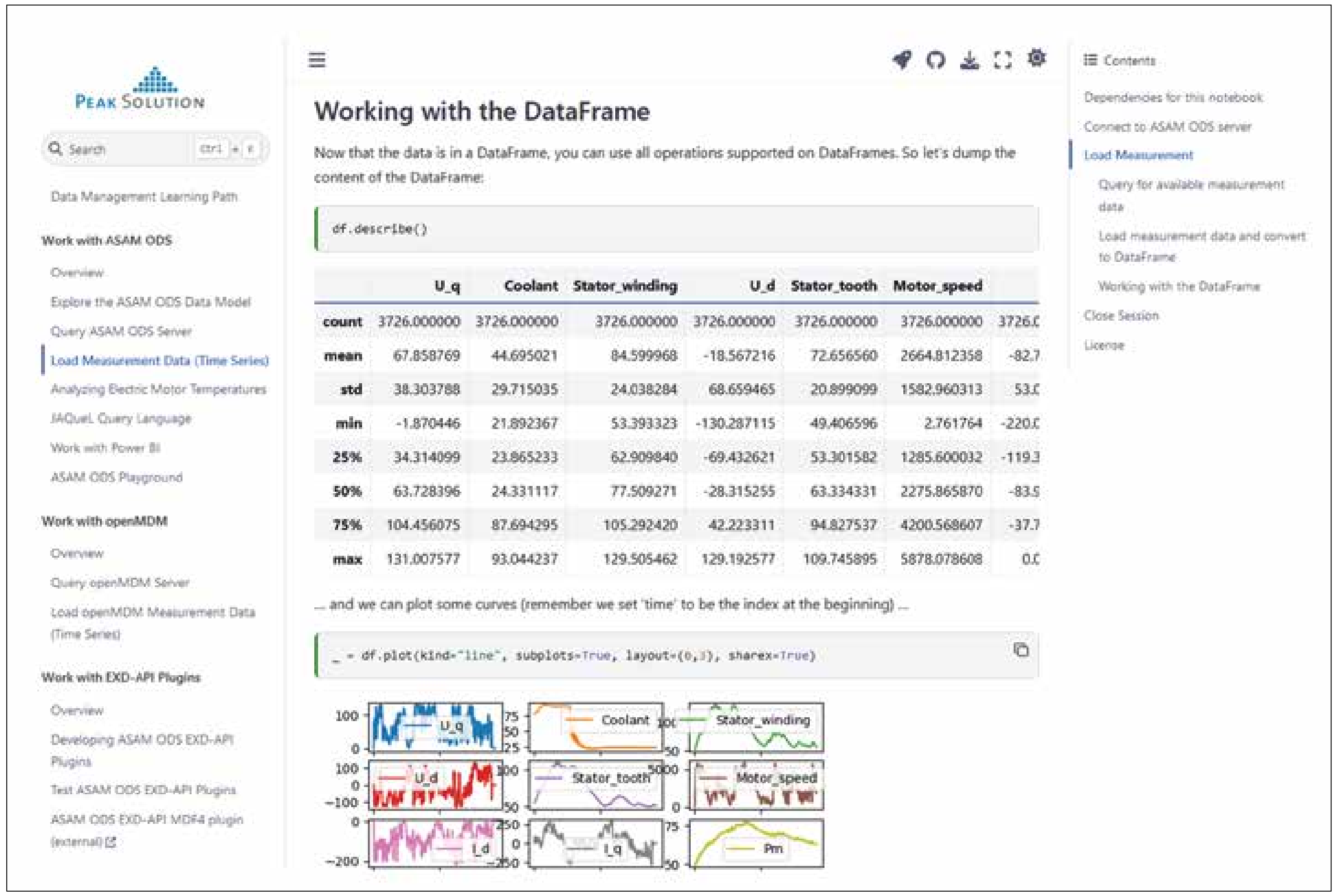
After realizing and analyzing the problem, the three top-most action items were identified:

- Provide ASAM ODS data in way suitable for Python libraries
- Provide an easy-to-learn and "well-known" query language
- Provide examples for using the ASAM ODS-Box

To address the first topic, ASAM ODSBox introduces Pandas.DataFrames as native data type. DataFrames are supported by all relevant Python analysis and machine learning libraries. Furthermore, DataFrames also work in other toolchains such as Apache Spark – a widely adapted technology stack to handle big data. So, mixing and matching technology stacks as well as accessing other data pools is becoming a no-brainer.

The JSON syntax of MongoDB queries is designed to be intuitive and flexible and was used as a blueprint for the „Json ASAM ODS Query Language" –JAQueL for short. It allows the definition of the respective object, the query expression, the attributes to be returned and also aggregates in a JSON format. Furthermore, JSON is also a perfect solution for Python.
To explain the use of ASAM ODSBox we have combined documentation and active (Python) code in form of Jupyter Notebooks and make them available in our open source Github repository "Data Management Learning Path".
With this approach, our sample Notebooks can be easily used in Microsoft Visual Studio Code, GitHub Codespaces and Google Colab – to only name a few.





The combination of open source, established standards and HTML documentation brings an additional benefit: Large Language Models can now be trained in such way that AI Agents such as Microsoft Copilot or Google Gemini can help to create data queries or suggest visualizations for plots of ASAM ODS measurement data.

CHALLENGES DURING THE PROJECT

Introducing the typical build and test pipeline in the open source ASAM ODSBox repository requires that all parts of this pipeline are available as open source. In particular, the data content definition files (Google protobuf files – for the experts) used to decode and convert the data to DataFrames were missing. After the situation was explained to the ASAM organization, the issue was quickly resolved by making these files available in the ASAM Github repository.

BUSINESS BENEFITS

The open source ASAM ODSBox Github project offers the possibility to use Python libraries specifically for data analysis and machine learning in combination with ASAM ODS data. These libraries are often free of charge and also well-known by the data communities which offers a high potential in cost and time savings. The introduction of a simple query language additionally lowers the entry barriers using ASAM ODS and makes it more attractive for data analysts and data scientists, which also lead to better recognition of the ASAM ODS data management standard.

The provision of comprehensive documentation of the ASAM ODSBox in combination with examples lead to the additional positive side effect that AI agents such as Google Gemini or Microsoft Copilot can now also help non-data scientist to gain more insights from the existing ASAM ODS data.

Siemens Digital Industries Software and Peak Solution GmbH

Ready for openness managing NVH test data

Featured Standard:

ASAM ODS

Authors:
Gert Sablon,
Sr. Director physical testing solutions,
Siemens AG
Elena Daniele,
Go-to-market manager physical testing solutions,
Siemens AG
Stefan Romainczyk,
Sr. Product Manager,
Peak Solution GmbH

SUMMARY

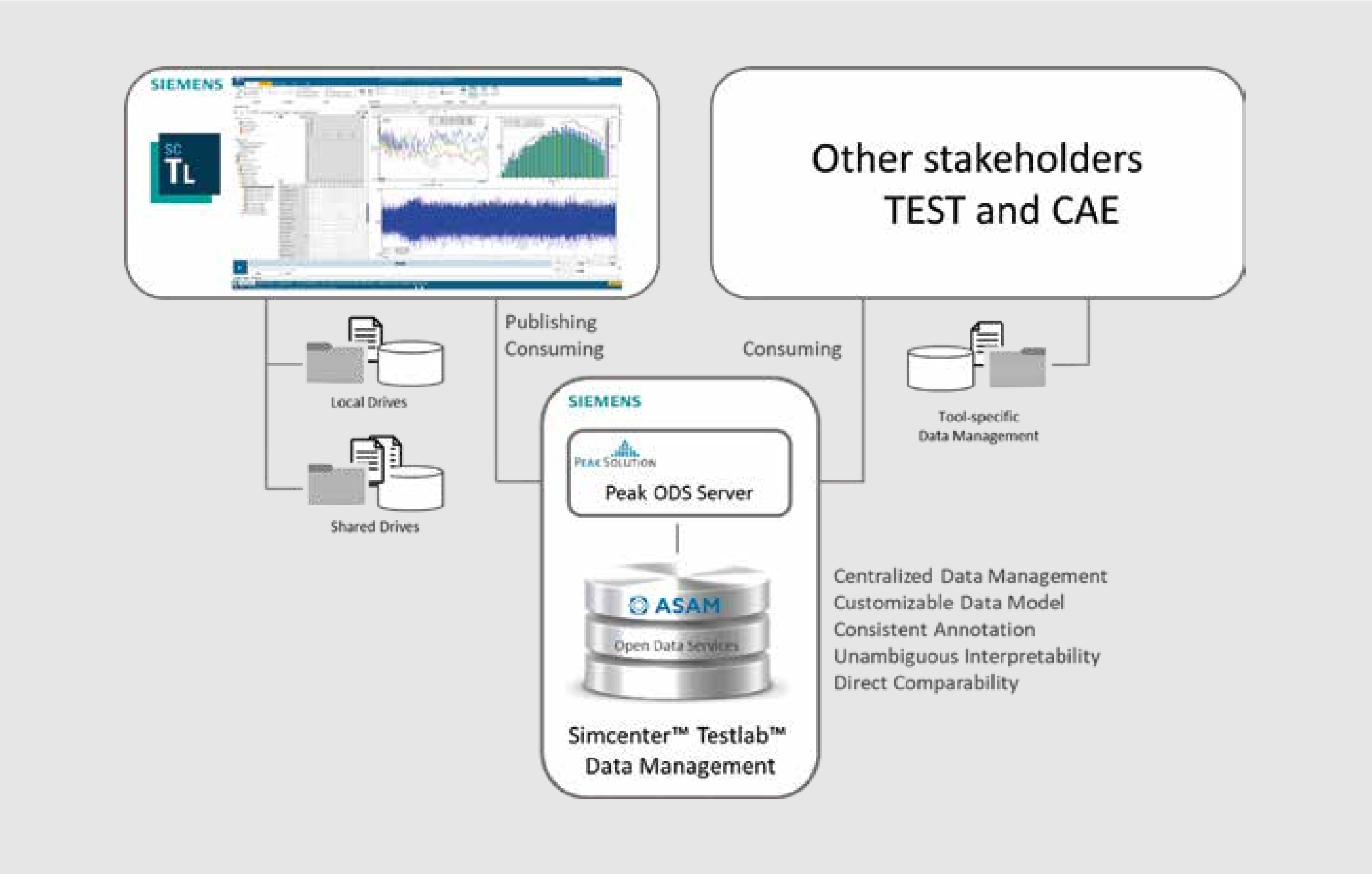
Siemens partners with Peak Solution to help BMW Group move from their established data management solution to a more performant, open, and modern data management solution. Siemens introduces Simcenter Testlab Data Management, based on the ASAM ODS standard and the associated NVH application model to enable access to a central and open server-based database, leveraging the value of annotated data. The key benefit of the solution is that thanks to the openness granted by the ASAM ODS standard, the customers can work with any data source, regardless of the suppliers, as it helps manage and retrieve this data.

INITIAL SITUATION

BMW Group's structural dynamics department sought to transition from a proprietary data management system to an open standard alternative that would grant them independence from any specific supplier. The outdated database solution presented various challenges, necessitating a more modern solution. The Simcenter Testlab Data Management solution, based on the ASAM ODS standard, offered the centralized, open-standard database access BMW Group desired. Additionally, they sought a more efficient solution with robust search and advanced data annotation capabilities. The Simcenter Testlab Data Management solution met all these criteria, offering standardization, openness, and supplier independence.

SUCCESS STRATEGY / SOLUTION

The tight integration of the Simcenter Testlab Data Management solution into the engineering tool of Simcenter Testlab is the first key factor of an industrialized solution.



The Simcenter Testlab Data Management solution is based on the ASAM ODS NVH application model, leveraging ASAM ODS standards for data annotation and management. Both companies closely worked together to implement extensions to Siemens' standard test data management solution, managing to fully meet BMW Group's data management requirements.

The extensibility of the ASAM ODS standard allowed Peak Solution and Siemens to seamlessly work together to implement a background process that would integrate data from different vendors into the same structured and open database without modifying the original data. This process enriched the data with labels to make it compatible with Simcenter Testlab, allowing for further data consumption within the engineering tool.

Key extensions were made in permission management and system openness. Advanced permission management features were implemented to enhance data accessibility and security for individuals or groups, considering the complexity of their internal structure.

The successful implementation of this solution relied on the collaboration between Siemens and Peak Solution.

CHALLENGES DURING THE PROJECT

The migration from BMW Group's proprietary database to the ASAM ODS database presented the biggest challenge of all. Due to huge complexities in data annotation in the old data management solution, a data conversion process was implemented to ensure consistency throughout the entire dataset.

To smoothen the transition, Siemens created tools such as data overviews to understand the scope of the data migration and mapping tables to help BMW Group adjust the database for a 100% consistent outcome. Successful outcomes were achieved through top-down support, tireless collaboration with BMW Group, and with a focus on implementing the desired BMW Group data annotation.

The implementation of the Simcenter Testlab data management solution yielded significant business benefits. These included time savings when searching for and comparing historical data, increased flexibility thanks to the openness of the ASAM ODS standard, and improved project quality.

By capitalizing on the value of NVH data, the solution paved the way for strategic process improvements and future technology integration, such as machine learning and virtual prototype assembly.

Sibros

Sibros' adoption of ASAM SOVD for modern SDV architectures

Featured Standard:
ASAM SOVD

Author:
Steve Schwinke,
Solution Engineering,
VP of Customer Engagement,
Sibros

SUMMARY

Sibros addresses the evolving complexity of vehicle architectures by adopting the ASAM SOVD (Service-Oriented Vehicle Diagnostics) standard. This approach supports OEMs in implementing a unified diagnostics and software update management system that is both scalable and compatible with today's advanced Software-Defined Vehicles (SDVs). Utilizing ASAM SOVD in combination with the Universal Diagnostic Services (UDS) protocol, Sibros has enabled OEMs to streamline communication frameworks, allowing for rapid vehicle development and effective lifecycle management. This solution is tailored for the high-performance, compute-capable zonal architectures now prevalent in SDVs, ensuring they meet the needs of a modern, software-driven vehicle ecosystem.

APPLICATION STORY

The advent of SDVs has transformed traditional vehicle architectures, driving a shift toward zonal designs that integrate higher computing power within key control units to optimize vehicle design and reduce lifecycle costs. These zonal architectures are essential for managing the increasing software and data demands of SDVs, where conventional protocols like UDS alone can no longer support the complex diagnostics required by high-performance computing (HPC) components.

Sibros identified the ASAM SOVD standard as a solution capable of establishing a unified diagnostics and software update framework across varied vehicle architectures. Unlike traditional UDS, ASAM SOVD accommodates the needs of both high-performance and resource-constrained ECUs, making it a holistic, scalable solution that fits into any vehicle's lifecycle, from manufacturing to after-sales support.

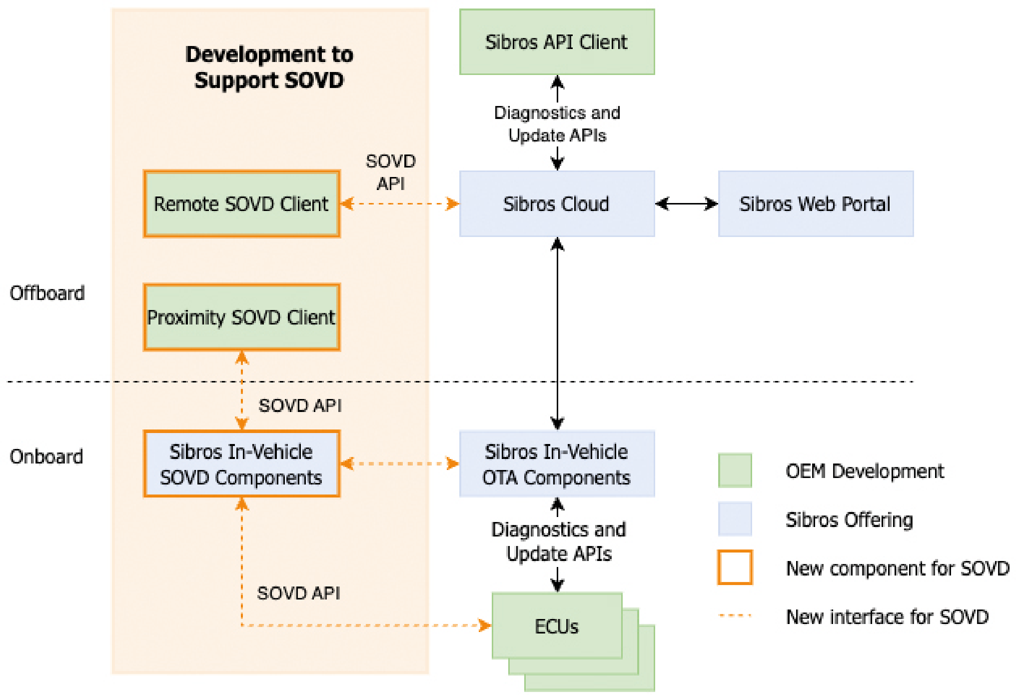


Fig. 1

A diagram (Fig. on the left page) illustrates the Sibros Platform architecture, showcasing how adopting ASAM SOVD enhances its core capabilities. The Sibros Platform empowers OEMs with a comprehensive connected vehicle lifecycle management system that includes OTA updates, diagnostics, data logging, and analytics within a single, integrated interface. The platform is structured as follows:

- In-vehicle components that execute both software updates and diagnostics commands
- A centralized Cloud Platform to manage and monitor fleet operations
- Proprietary APIs enabling enterprise applications to interface with these operations
- A Web Portal offering an intuitive interface for monitoring and command execution

Integrating ASAM SOVD further expands the Sibros Platform's reach beyond OTA, introducing the ability for manufacturing and after-sales teams to interact with vehicles in proximity or offline environments using ASAM SOVD APIs. Key enhancements include:

- In-vehicle SOVD components that use ASAM SOVD APIs for diagnostics and updates
- A proximity client enabling local connections via ASAM SOVD APIs for vehicle diagnostics in offline environments
- A remote client using ASAM SOVD APIs to interface with the Cloud Platform

With ASAM SOVD, OEMs can now develop applications around a standardized framework, reducing the need for complex data descriptions and simplifying software updates across rapidly evolving SDV software ecosystems. This standardization supports parallel development across functions like engineering and manufacturing, enabling smoother transitions from production to in-field operations and ultimately, elevating product quality and operational efficiency.

Additionally, Sibros has strengthened its ecosystem by collaborating with OEMs and technology partners. This network of interoperable solutions enables industry knowledge-sharing, supporting faster innovation and broader adoption of vehicle diagnostics standards. Implementing ASAM SOVD has thus not only optimized Sibros' internal capabilities but also contributed to industry-wide advancements in diagnostics.

"We selected an ASAM-based solution because the standardized framework is critical for managing the complexities of modern vehicle architectures. ASAM standards have been instrumental in advancing our diagnostics and software update capabilities, greatly enhancing efficiency and reliability across all operational touchpoints.

MAYANK SIKARIA,
President and Head of Technology,
Sibros

Softing Automotive Electronics GmbH

Introduction of ASAM SOVD from a development perspective

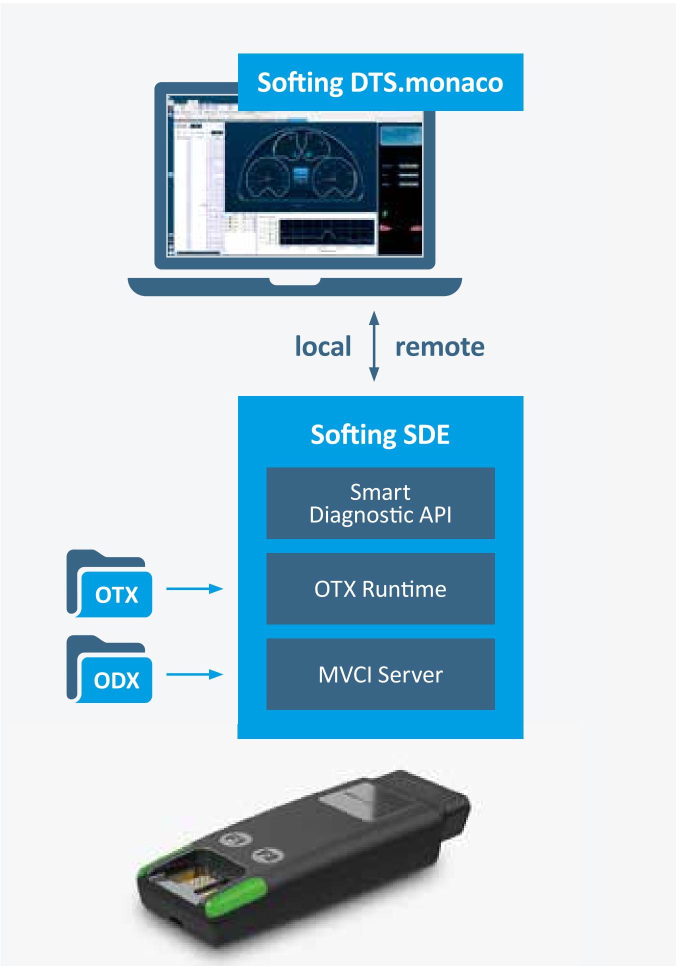
Featured Standards:

ASAM SOVD, ASAM MCD-2 D, ASAM MCD-3 D

Author:
Markus Steffelbauer,
Director Product Management,
Softing Automotive Electronics GmbH

AT A GLANCE

ASAM SOVD (Service Oriented Vehicle Diagnostics) is the first definition of a remote-capable programming interface for accessing a diagnostic system integrated in the vehicle. However, the introduction of a new diagnostic standard must be designed with a view to the producibility and reparability of a vehicle. So when the system is introduced at a German OEM, it is essential to have a powerful safeguarding. The answer is to use an extended engineering tester in which the existing remote capability is extended with ASAM SOVD. All use cases can therefore be covered with reliable processes, and today's ECU diagnostics are available at any time with regard to legacy systems in after-sales, but also as a failsafe.



Current Diagnostic Engineering Tool

CURRENT SITUATION

Current vehicles have up to 150 ECUs, which are addressed directly via the OBD jack and the ISO 14229 (UDS) protocol. Individual information is processed outside the vehicle in the test system. In future, information will be consolidated directly in the vehicle via the integrated diagnostics system (ASAM SOVD server). Vehicle diagnostics are then carried out wirelessly via the cloud. However, the development and release of ECU diagnostics will continue to take place via UDS. Ideally, a multi-stage approach should therefore be taken to the increasing integration of vehicle systems – with established processes for tools and data. Deviations would increase costs enormously over the entire life cycle.

SOLUTION CONCEPT

Today, ECU engineering and release is carried out using a standardized engineering tester (Softing DTS.monaco). The tester is parameterized via ODX data (ASAM MCD-2D, ISO 22901); many tasks that can be automated are implemented via OTX sequences (ISO 13209, ASAM OTX Extensions). A wide variety of display methods allows information to be displayed to suit the specific application. Examples include displays for the error memory, a quick test, flash programming and various ways of displaying measurement values.

The functional basis of the tester is a diagnostic system (Softing SDE) that implements the ASAM MCD-3 standard (ISO 22900) on the one hand, but also OTX sequences and functional diagnostics similar to the ASAM SOVD standard on the other. The solution is remote-capable, with vehicle access usually taking place in the classic way via a VCI (Vehicle Communication Interface).

The ASAM SOVD server is integrated into the system as an additional source of information to enable the customer to diagnose ECUs and entire vehicles in parallel. In principle, four different approaches to diagnosis are possible:

- ECU diagnostics via ODX data, UDS and a VCI: Development and release of ECU or ECU network diagnostics
- Vehicle diagnostics via ODX data, UDS and a VCI: Diagnosis of functions that are not available via ASAM SOVD or if the communication between the ASAM SOVD server and ECUs does not work
- Vehicle diagnostics over ASAM SOVD: Release of vehicle diagnostics and execution of functions required during engineering/development (e.g. flash programming)
- Vehicle diagnostics via the Softing diagnostics system with integrated ASAM SOVD server: Execution of engineering/development functions that are not to be included in the production vehicle via remote access

The data supply for classic diagnostics continues to take place via ODX with this solution. This means that established and proven processes can continue to be used directly. This data can be used accordingly for the parameterization of the ASAM SOVD server in the vehicle. If the engineering tester is to back up the ASAM SOVD server, the diagnostic information provided by the ASAM SOVD server is processed. However, ODX data can also be used to configure test sequences or the tester GUI if required. Otherwise, "pure ASAM SOVD" is possible throughout.

CHALLENGES

Today's diagnostic systems run on a PC and are parameterized via ODX data so that the tester can determine the vehicle, installation status and ECU variants. If the diagnostic system runs as an ASAM SOVD server in the vehicle, parameterization will also make sense because it is impractical to implement the ASAM SOVD server individually for each series and the ECU variants can change during runtime. It makes sense to choose ODX here, also with regard to process consistency from the ECU to the complete vehicle, but this is not mandatory.
Irrespective of this, the mapping of the parameterization data to the ASAM SOVD API must be defined in each project. The standard makes no stipulations here, which is unproblematic for a generic tester. As soon as GUI configurations are to be specified or automatic processes, for example in OTX scripts, are used, a high degree of consistency is required. This is the only way diagnostic services and diagnostic results be clearly assigned.

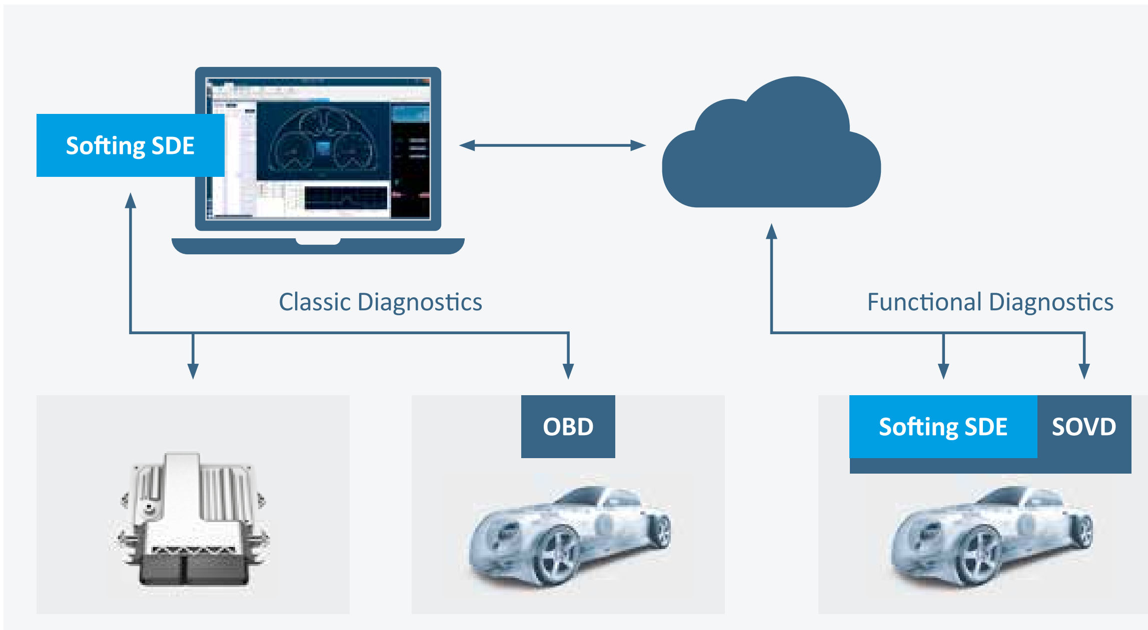
ADVANTAGES

The solution is suitable for bringing high-quality diagnostics to the field. It makes it possible both to test ECU diagnostics in detail and to test and release ASAM SOVD functionality relevant for vehicle diagnostics in the customer's vehicle.

It is of great importance to our customer that this is possible without any great learning effort on the part of the user: Tool operation is familiar and only a few new terms need to be learned. The underlying data processes are also tried, tested and familiar – perhaps the biggest cost advantage. In addition, the solution offers maximum flexibility for the customer to migrate to fully ASAM SOVD-compliant vehicle architectures in the OEM-specific sequence.

"The concept developed by our colleagues for implementing the ASAM SOVD standard in new vehicle developments fulfils all the customer's requirements in both the old and the new world. The migration solution as an extension to the existing Softing DTS.monaco tool is not only extremely attractive in terms of technology, but also in terms of price."

STEFAN BSCHOR,
Key Account Manager,
Softing Automotive Electronics GmbH



One Tool for all Diagnostic Tasks

Tata Consultancy Services Limited (TCS)

Vehicle health solutions using ASAM diagnostic standards

Featured Standards:

ASAM SOVD,
ASAM MCD-2 D (ODX),
ASAM MCD-3 D (D-Server),
ASAM OTX Extensions

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SUMMARY

The latest trends in automotive industry, like increased automation levels, connectivity and service-oriented software requirements have accelerated the evolution of vehicle architectures. Modern architectures involve usage of High-Performance Computers, multiple operating systems and middleware layers that cater to various applications. This increases software complexity and diagnosis of a vehicle does not limit to finding hardware faults. There is a necessity to diagnose High-Performance Compute (HPC) systems and the software applications running on it. To address such needs, ASAM SOVD (Service-Oriented Vehicle Diagnostics) standard defines RESTful APIs for diagnosis of next generation vehicles.

This application story talks about vehicle health solutions comprising of diagnostic server and classic diagnostic adapter developed by TCS, based on various ASAM standards.

INITIAL SITUATION

To enhance diagnostic capabilities of complex modern vehicles,

- A mechanism is required that supports diagnosis of platform and software in addition to diagnosis of classical entities that communicate over CAN (Controller Area Network), DoIP (Diagnostics on Internet Protocol), LIN (Local Interconnect Network), etc.
- The in-vehicle and external applications require access to diagnostic data from vehicle systems to analyze, predict, and detect events and failures.
- To maintain vehicle safety and availability, necessary actions like an update, re-configuration, function inhibition, etc. should be triggered from within the vehicle or by external applications.
- In post purchase scenarios, vehicle owners should be proactively informed of any impending failures.
- Thus, diagnostics and health should be managed throughout the vehicle lifecycle.

SOLUTION

TCS has been working on automotive diagnostics for more than 15 years, providing solutions and services for various automotive customers using ASAM standards.

TCS has developed its own vehicle health solution using ASAM diagnostic standards. The solution comprises software components developed to address various in-vehicle and external diagnostics use-cases.

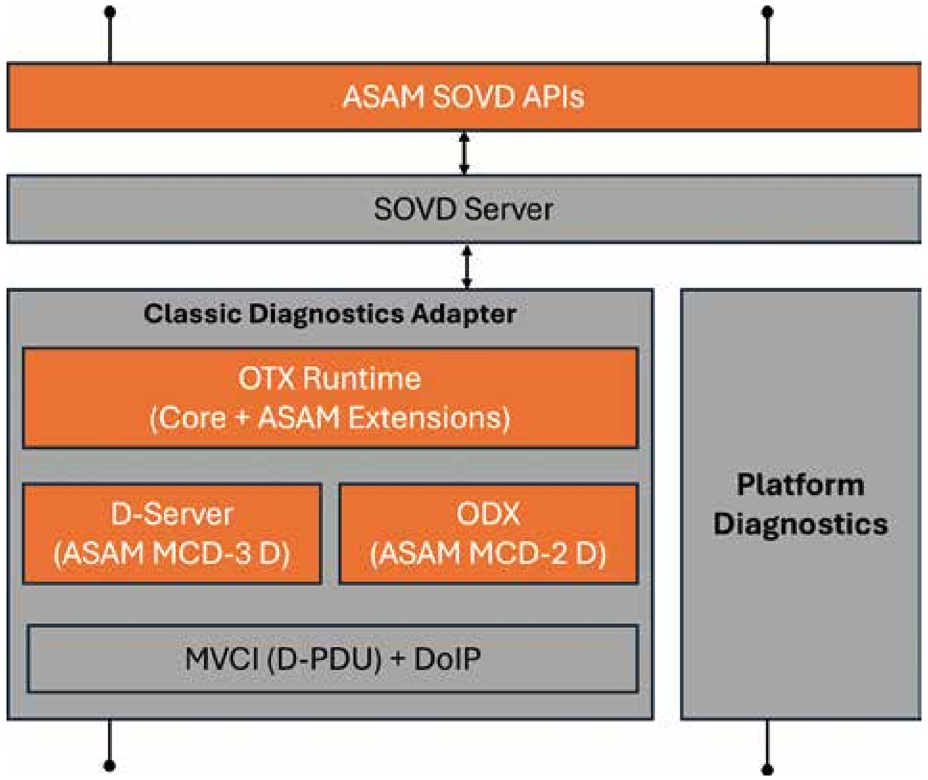
SOVD Server: The HTTPS/REST based server implements ASAM standard and provides ASAM SOVD APIs to interact with classical and HPC diagnostic resources. The server is deployable in-vehicle, on vehicle edge or on cloud, depending on the end use-cases. It abstracts the underlying proprietary implementation and provides uniform access to in-vehicle, remote and co-located clients.

The diagnostic features that can be realized via TCS SOVD server are:

- Read and clear faults
- Read data (vehicle parameters and system information)
- Operations
- Software updates
- Bulk Data transfer
- Logging
- Vehicle Functions
- Custom Script execution
- Application Management

With a roadmap to add new features and architectural improvements, upgrades of this solution will be available in future releases.

Classic Diagnostic Adapter: The current generation vehicles should support UDS communication for extended and legislated diagnostics pertaining to safety and sustainability. Classic diagnostic adaptor manages translation of https/REST protocol into UDS and facilitates diagnostic communication with classical entities. The classic diagnostic adapter leverages ASAM standards such as ASAM MCD-2 D (ODX), ASAM MCD-3 D (D-Server) and ASAM OTX Extensions to make it an industry standard stack that is easy to integrate with target platform and systems.



Source: Tata Consultancy Services Limited (TCS).

TCS Vehicle Health Software Solution with SOVD server, Classic Diagnostic and Platform Adapter

The classic diagnostic adapter can be utilized independently of the SOVD server to develop tools or embed into client applications for in-vehicle and external usage scenarios.

KEY BENEFITS

The key benefits of TCS vehicle health software solution are:

- Multi-purpose caters to engineering, production and service diagnostic needs.
- Caters to in-vehicle and offboard prognostics, diagnostics and update use cases.
- Provides standardized interface for classic and HPC diagnostics.
- Configurable and data driven software components.
- Adaptable for different brands of vehicles and variants.
- Flexible to realize independent use-cases from individual software components.
- Easy to customize and integrate with target systems.
- Flexible deployment as containerized service or as software libraries.
- Supports custom, on-demand diagnostics with script execution engine

BUSINESS BENEFITS

- **Interoperability between software development partners:** Facilitates collaboration across the enterprise and external partners that are part of diagnostics ecosystem. Improves productivity and quality of diagnostics software before deployment.
- **Cost savings:** Uniform and standardized APIs reduce the need of multiple tools for engineering, production and after sales.
- **Legislative and Regulatory Compliance:** Supports government and regulatory diagnostics across geographies.
- **Customer satisfaction:** Facilitates setup of service ecosystem comprising of expert engineers, dealers, independent service workshops, breakdown assistance, fleet owners, insurers, etc.
- **Monetization:** Provides opportunities to set up an App ecosystem for in-vehicle and offboard apps.

"I chose an ASAM SOVD based solution, because SOVD promotes API-first development of diagnostic software and benefits automotive organizations and their partners. It opens a plethora of possibilities to manage vehicle health and not simply diagnose them! This indeed is quintessential for vehicle's reliability, safety and vehicle owner's satisfaction as we enter the era of software-defined vehicles."

REENA PAREKH,
Head of Automotive Diagnostics & Vehicle Health,
Tata Consultancy Services Limited (TCS)

51Sim

AIGC Scenario copilot with ASAM OpenX standards

Featured Standards:
ASAM OpenX,
ASAM OpenSCENARIO

Author:
Zuqiu Mao,
Senior Software Development Manager,
51Sim

SUMMARY

Challenges: In the rapidly evolving field of autonomous driving, the need for extensive and diverse simulation scenarios is paramount. Creating these scenarios requires specialized tools and knowledge, making the process costly and time-consuming.

Solution: The integration of large language models (LLMs) to generate ASAM OpenSCENARIO standard scenarios offers a groundbreaking solution. By utilizing advanced AI technology together with ASAM OpenX standards and quality checker tools, Scenario Copilot enables the creation of detailed and varied simulation scenarios from simple natural language descriptions.

Key Benefits

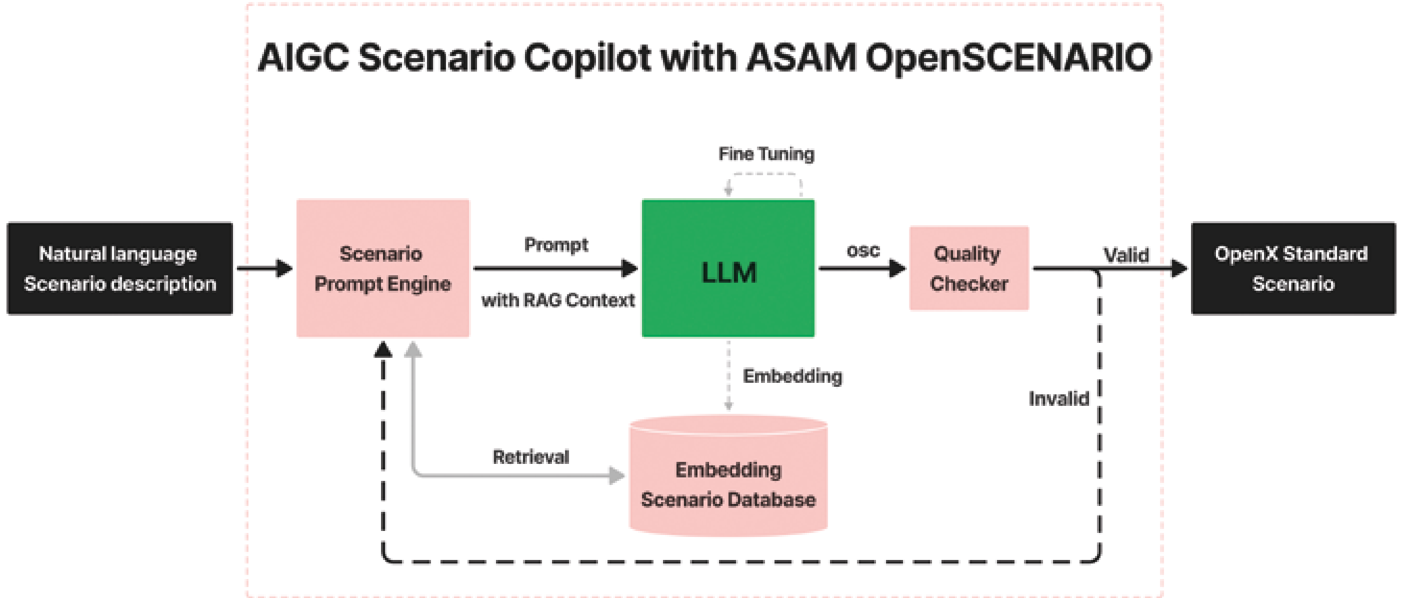
1. Increased Efficiency: Automating the generation of simulation scenarios significantly reduces the time and resources required, allowing for quicker iterations and more comprehensive testing.
2. Enhanced Diversity of OpenX Scenarios: The AI-driven approach facilitates the creation of a wide variety of ASAM OpenX scenarios, essential for robust training and evaluation of autonomous driving systems.

SITUATION

The development of autonomous driving technology necessitates extensive testing across a myriad of scenarios to ensure safety and reliability. However, creating these scenarios poses significant challenges:

- **High demand for scenarios:** Autonomous driving systems require thousands of varied scenarios to be tested rigorously.
- **Cost and resource intensive:** While the OpenX standards, including ASAM Open SCENARIO, provide a unified framework for scenario definition, traditional methods for scenario creation involve substantial investment in specialized tools and skilled personnel.

The motivation behind integrating AI with the scenario creation process stems from the recent advancements in LLM technology, which offer the potential to automate and simplify this process. The goal is to leverage AI to generate diverse, high-quality scenarios at a fraction of the current cost and effort.



Scenario Copilot framework

Scenario Copilot UI and result

SUCCESS STRATEGY

Scenario Copilot addresses these challenges by employing a multi-faceted approach:

- **Fine-tuned large language models:** Scenario Copilot utilizes LLMs that have been specifically fine-tuned to understand and generate ASAM OpenSCENARIO code from natural language descriptions.
- **Scenario prompt engine:** This component translates user inputs into structured prompts that the LLM can interpret accurately, ensuring the generated scenarios meet the required specifications.
- **Scenario library with retrieval-augmented generation (RAG):** By incorporating a comprehensive library of pre-existing scenarios, Scenario Copilot can enhance the generated outputs with relevant examples, improving quality and relevance.
- **ASAM OpenX syntax validation tools:** To ensure the generated scenarios adhere to the ASAM OpenX standards, Scenario Copilot includes quality checker tools.

CHALLENGES

Throughout the development and implementation of the AI-driven scenario generation system, several challenges were encountered:

- **Data quality and quantity:** Ensuring the availability of high-quality data for training the models was a significant challenge. However, thanks to the ASAM OpenX ecosystem, data acquisition and generation were facilitated through the use of standardized tools and resources.
- **Model hallucinations:** Large language models are prone to generating plausible sounding but incorrect or nonsensical outputs, a phenomenon known as „hallucination." The robust tools within the ASAM OpenX ecosystem, such as the Quality-checker, helped mitigate this issue to a significant extent, ensuring the generated scenarios were validated and met the required standards at least.

BUSINESS BENEFITS

Leveraging ASAM OpenX standards and toolchain ecosystem, Scenario Copilot offers substantial commercial benefits:

- **Cost-effective data generation:** The system enables low-cost creation of diverse and high-quality simulation data, which is essential for training and evaluating autonomous driving systems.
- **Enhanced efficiency:** The streamlined workflow facilitated by ASAM OpenX tools significantly boosts the efficiency of scenario generation, allowing for quicker development and testing cycles and ultimately accelerating the deployment of autonomous vehicle technologies.

"We chose an ASAM-based solution because its robust ecosystem integrates seamlessly with AI technology, enabling the effective use of AI to train AI."

SHIQIANG BAO,
CEO, 51Sim

Ansys Inc.

Ansys AVxcelerate utilizes ASAM standards to deliver cloud-based platform for safety and reliability of ADAS / AD systems

Featured Standards:

ASAM OpenDRIVE
ASAM OpenSCENARIO,
ASAM OSI

Author:
Emmanuel Follin,
Senior Manager Product Management,
Ansys

"Leveraging the ASAM standards within AVxcelerate provides a significant competitive edge and efficiency gain for our customers by enabling seamless integration with their existing systems. This standardization also guarantees they can reuse established scenarios, maps and assets across projects. ASAM standards foster an open ecosystem that drives innovation and reduces redundant efforts between OEMs and suppliers. This strategic alignment with ASAM supports our commitment to driving innovation and improving safety standards in the automotive industry."

EMMANUEL FOLLIN,
Sr. Manager,
Product Management,
Ansys

CHALLENGE

The complexity of the Operational Design Domain (ODD) along with the expectation of target system reliability (SAE L3) are the two main reasons that demand a substantially new approach towards development of ADAS/AD systems. This approach ideally should help verification engineers to a) create a safety argument and b) aid simulation-based development and analysis.

One of the key challenges for customers adopting a simulation-based development and assurance platform that meets the complexity, and reliability needs of SAE L3 (and above) systems, is making use of their extensive legacy assets. OEMs and Tier-1s have spent significant time and effort building scenario databases and validating vehicle, tire, road and physics models. Making use of these assets by integrating with their existing simulation infrastructure — whether off-the-shelf or internally-built — can often be a painful and time-consuming process.

SOLUTION

The ASAM OpenDRIVE standard acts like a digital blueprint for describing static elements of a road network. It allows engineers and developers to create a common language for defining these elements in simulations related to Autonomous Vehicles (AVs) and Advanced Driver-Assistance Systems (ADAS). Road network definition, data exchange, common coordinate system and integration with other ASAM standards are all enabled by ASAM OpenDRIVE.

To provide a viable solution using ASAM standards and to foster the development of safe autonomous vehicles, Ansys has partnered with BMW to conceptualize and deliver one of the most modern cloud-based ADAS / AD simulation platforms i.e. Ansys AVxcelerate Autonomy™. This simulation platform has native support for ASAM OpenDRIVE, ASAM OpenSCENARIO and ASAM OSI and is instrumental in verification and validation of ADAS / AD systems.

Additionally, to complement this scenario-based simulation platform, Ansys AVxcelerate Sensors™ offers a powerful suite of physics-based sensors (Camera, LiDAR, Radar, Ultrasonic, Thermal Camera). These physics-based sensors can be used in combination with AVxcelerate Autonomy cloud-based platform.

To help bring this comprehensive solution to market, Ansys AVxcelerate supports:

- a co-simulation model using the ASAM OSI Standard, offering a clean and well-understood interface to an ADAS / AD software stack or host simulator.
- the import and reuse of existing ASAM OpenDRIVE maps and ASAM Open SCENARIO XML scenarios, which ensures that any existing customer content can be reused.
- ASAM OpenSCENARIO variations based on input parameters.
- Environment simulator ensures the creation of ground-truth in ASAM OSI standards by consuming inputs in ASAM OpenSCENARIO and ASAM OpenDRIVE.
- ISO26262 certified toolchains. Soon, AVxcelerate Sensor will have native support for existing and future ASAM standards as well.

Further, Ansys offers another tool to ease this implementation – The Road Logic Suite toolkit for OpenDRIVE maps is an open source and easy-to-use tool that empowers developers to work effectively with OpenDRIVE maps. The Road Logic Suite tool offers functionalities for loading, validating, converting coordinates, and extracting valuable data from the road network descriptions. This is a reference open-source implementation of the ASAM OpenDRIVE standard. OSS reference implementation is key for safety critical validation. Being open-source facilities regulatory authority inspections thereby increase trust in the solution.

KEY BENEFITS

ASAM OpenDRIVE greatly eases the process of integrating with customers – Relieving any woes of vendor lock-in results in reducing a buying hurdle and enabling our customers to feel the benefits of the platform as soon as possible.

Below is a list of key benefits of supporting the ASAM simulation standards in Ansys AVxcelerate.

Standardization Saves Time and Effort:

- **Reduced Development Time:** RoadLogicSuite provides a pre-built solution for reading, writing, and validating OpenDRIVE maps. This saves developers from having to create their own tools from scratch.
- **Consistent Results:** RoadLogicSuite ensures everyone uses the same interpretation of ASAM OpenDRIVE. This eliminates variations in results and compatibility problems.
- **Stronger Supply Chains:** A common tool like RoadLogicSuite facilitates communication and quality control throughout the supply chain. Suppliers and customers can use the same tool for validation, ensuring everyone is on the same page and avoiding disputes about map quality.
- **Standardized Approach:** By providing a common tool based on ASAM OpenDRIVE, RoadLogicSuite ensures consistent implementation across different projects. This reduces the risk of errors and rework, ultimately lowering development costs.

Improved Collaboration and Efficiency:

- **Seamless Data Exchange:** RoadLogicSuite facilitates the use of OpenDRIVE maps across various simulation tools. This promotes collaboration between different teams working on self-driving car projects.
- **Simplified Workflows:** The library streamlines the process of working with OpenDRIVE maps, allowing developers to focus on core designing and implementing simulations.

Enhanced Simulation Quality and Reliability:

- **Error Detection and Prevention:** The validation features of RoadLogicSuite help identify issues within OpenDRIVE maps, preventing errors that could lead to inaccurate simulations.
- **Consistent and Realistic Simulations:** RoadLogicSuite ensures that all parties involved in the development process use the same interpretation of the ASAM OpenDRIVE standard. This contributes to creating more consistent and realistic simulation environments.

Additional Advantages:

- **Open-Source Availability:** Being open-source, RoadLogicSuite offers a free and readily available solution for developers, making it a cost-effective choice.
- **Active Development and Community:** The open-source nature fosters ongoing development and community support, ensuring the library remains up-to-date and adaptable to evolving needs.

Recognizing the importance of interoperability, Ansys simulation tools are developed in alignment with ASAM standards. This allows automotive customers to seamlessly integrate Ansys tools with other simulation platforms within their system under test (SUT) and various models like sensor and vehicle dynamics. Ansys has ASAM standards native support and is committed to contributing to the ASAM open ecosystem, eventually to reduce repetitive maintenance between OEMs and suppliers.

Safety of AD/ADAS systems backed by ISO26262 Certification

In combination with use of safety-oriented scenario database, that usually materializes with ASAM OpenX standards, ISO 26262 certified simulations can greatly improve the efficiency of building an approved safety case and to ultimately make the operation of automated vehicles safe everywhere. ISO 26262 certification of a simulation tool or toolchain allows its use in the validation of safety-relevant automotive functions. It plays a key role in the capability of an OEM to collect and create proofs of system safety regarding the functional safety requirements. AVxcelerate cloud platform is officially approved to be used for car safety systems and can test new car safety features by simulating them in near real-world situations.

Leveraging ASAM OpenDRIVE, ASAM OpenSCENARIO, and ASAM OSI standards offers significant advantages, including enhanced data sharing, standardized test procedures, and a robust ecosystem that facilitates collaboration among OEMs, Tier 1 suppliers, and tool developers. By utilizing the ASAM OpenSCENARIO interface, AVxcelerate platform enables consistent scenario definition for scenario-based simulations. Furthermore, ASAM OSI provides access to a wide range of open-source tools compatible with the AVxcelerate platform. The integration of an OpenDRIVE parser library simplifies the incorporation of road network maps and promotes interoperability among organizations.

Ansys: A Leader in Engineering Simulation for Safety-Critical Systems

Ansys is a recognized leader in engineering simulation, offering a full suite of tools across various disciplines. Ansys has established a strong presence in the automotive industry, promoting safety-centric design and verification approaches to streamline and accelerate the creation of safe and reliable self-driving systems (ADS) for automotive companies and their suppliers.

Applied Intuition

Using ASAM OpenSCENARIO DSL to define abstract scenarios

Featured Standard:

ASAM OpenSCENARIO DSL

Author:
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Engineering Manager Verification & Validation,
Applied Intuition

SUMMARY

A large automotive original equipment manufacturer (OEM) must test its automated driving (AD) functionality across an expansive mapped region to develop a Level 4 AD system. Using ASAM OpenSCENARIO DSL (frequently known as ASAM OpenSCENARIO V2.0), the company can define a small number of high-quality abstract scenarios that test a broad range of realistic simulations. Once the engineering team has developed abstract scenarios, they can run simulations in a continuous integration (CI) system to measure progress continuously against known requirements. This use of abstract scenarios is one of the many validation methods available within Applied Intuition's ADAS and AD development platform. Beyond using ASAM OpenSCENARIO DSL, our customers use other methodologies to validate their L4 systems.

SITUATION

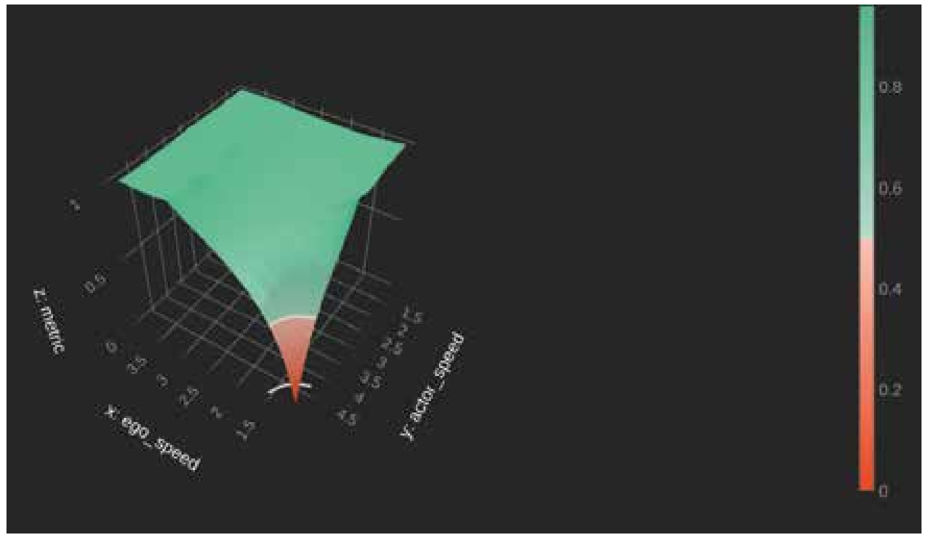
Automated driving (AD) functionality requires extensive software testing beyond what the automotive industry has typically conducted. As the industry strides toward deploying autonomous vehicles, statistical testing methodologies are important to ensure adequate test coverage over possible scenarios. The ASAM OpenSCENARIO DSL standard, an abstract scenario language, provides a powerful tool for conducting comprehensive and scalable simulation tests.

A leading automotive OEM company is developing a Level 4 AD system. Through its verification and validation (V&V) efforts, the team has created a set of requirements that govern the system's AD functionality. The engineering team then creates simulation scenarios to test and validate each individual requirement.

To fully validate all of its requirements, the company needs to define a comprehensive set of tests to validate each version of its AD software in simulation. This can increase the AD system's production timeline, potentially delaying time to market.

SUCCESS STRATEGY

The automotive OEM needs to conduct testing using simulations that cover an expansive mapped region, primarily to reduce its reliance on costly and time-consuming on-road testing. Early on, the team decides to save time and resources by combining tests for requirement validation and validation of behavioral functionality into a single testing methodology.



Predicted pass/fail regions from a parameter space defined in an abstract scenario in Applied Intuition Validation Toolset

To implement this type of dual-use testing, the company turns to Applied Intuition to implement ASAM OpenSCENARIO DSL. Using ASAM OpenSCENARIO DSL, the team writes scenarios in an abstract, high-level language. Writing these abstract scenarios requires the team to specify high-level constraints (e.g., desired actor behaviors, road conditions, and/or generic constraints on the scenarios' map locations). Applied Intuition's ADAS and AD development platform then utilizes these constraints to generate a thorough set of simulations based on the customer's defined scenarios. Validation engineers can then control how many simulations to run for each abstract scenario using an intelligent queuing system provided by Applied Intuition.

After running the simulations, scenario engineers can decide which scenarios across the map are the most relevant for further optimization. The team can also run the same simulations directly in continuous integration (CI), running nightly on new builds of AD software and providing statistical pass/fail results for AD functionality across the mapped region.

CHALLENGES DURING THE PROJECT

The core motivator for this project is to improve the automotive OEM's V&V process by making the act of writing broad sets of scenarios simpler and faster. Most of the company's developers are used to writing scenarios in a concrete or logical manner, where ego and actor maneuvers are declarative and rigid, and the location of a scenario on a given map is fixed. Once the AD simulation team identifies that writing scenarios in an abstract format will significantly improve its workstreams, the team begins to write new and migrate existing scenarios to an abstract language within Applied Intuition's toolchain.

The team faces a key challenge when deciding on the abstract scenario language itself. Applied Intuition implemented its own abstract language prior to the release of ASAM OpenSCENARIO DSL, and the automotive OEM had been using it for two years. This means that key features of abstract languages, including automatically varying the map location and intelligently sampling parameter ranges, are already available within Applied Intuition's toolchain. However, the ecosystem around ASAM OpenSCENARIO DSL is maturing. The OEM's team identifies a few scenario vendors who will be able to provide ASAM OpenSCENARIO DSL scenarios. Applied Intuition then begins to migrate its abstract scenario editor UI, language, and abstract scenario building blocks (such as semantic map querying) to support ASAM OpenSCENARIO DSL.

Thanks to ASAM's clear scenario language spec documentation and example scenarios, the team is able to easily support the ASAM OpenSCENARIO DSL abstract scenario spec while saving time and scenario engineering effort.

BUSINESS BENEFITS

By using the ASAM OpenSCENARIO DSL abstract scenario standard, the automotive OEM is able to generate scenarios affordably across a large map, cover and test a broad range of different parameters in a scenario, and gain confidence in the breadth of its testing on a nightly cadence with CI-based abstract scenarios. Using a concrete scenario language could achieve similar results, but it would require the team to generate and maintain more scenarios by several orders of magnitude. Additionally, the growing ecosystem of vendors around ASAM OpenSCENARIO DSL enables the company to interchangeably purchase solutions that speak the same language, preventing vendor lock-in. Beyond using abstract language, our customers can focus on managing requirements and associating test cases, creating and managing log-based test cases, and robustly triaging failures for safety criticality.

ASAM OpenSCENARIO DSL scenario editor and preview in Applied Intuition Validation Toolset

ASCS e.V.

ENVITED-X: Decentralized data space for ASAM OpenX assets

Featured Standards:

ASAM OpenDRIVE,
ASAM OpenSCENARIO XML

Author:
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Managing Director,
ASCS e.V.

SUMMARY

For the development and analysis of highly automated and self-driving vehicles, precise simulations that replicate realistic traffic and environmental conditions are essential. Manufacturers and suppliers are increasingly using diverse data sources to create digital worlds or digital twins. However, challenges related to the availability, quality, and integration of data assets can limit the effectiveness of these simulations.
The ENVITED-X data space1 is designed to overcome these challenges through community-driven data sharing, quality assessment, and governance. Utilizing the latest Web3 technologies, it builds trust and supports new business models. This robust data ecosystem accelerates and enhances the industrial use of ASAM OpenX assets across various mobility sectors.

APPLICATION STORY

As automated driving functions (ADF) evolve, the need for accurate testing environments becomes critical. Traditional testing methods, reliant on physical prototypes, are increasingly inadequate for modern ADFs. Simulation-based testing offers a safer, scalable, and cost-effective alternative. However, to fully leverage this potential with ASAM OpenX standards, a decentralized simulation data ecosystem is essential. The ENVITED-X data space by the ASCS e.V. community addresses challenges in digital identities, domain-specific metadata, simulation quality, data management, and governance.

Digital Indentities

Digital identities are crucial in a decentralized simulation data ecosystem, ensuring every entity – whether participant, software, hardware, model, or data asset – can be uniquely identified, authenticated, and tracked. This is particularly important in automated driving, where multiple stakeholders must securely collaborate and share data. Digital identities enable traceability, verifying the provenance of data and models, and support trust frameworks for secure data sharing across organizations without compromising intellectual property.
To facilitate this, ASCS developed the Decentralized Member Identity Management (DEMIM), a digital identity verification service that establishes a chain of trust within the community. DEMIM allows organizations to create and manage digital identities, apply for ASCS membership, and securely exchange simulation data on the ENVITED-X data space. The system uses a multi-level onboarding process with various security checks, resulting in digitally signed certificates, or verified credentials, stored in a personal wallet. These credentials are tracked in a blockchain-based registry, ensuring validity, and are cryptographically secure, privacy-preserving, and machine-verifiable.

Domain-Specific Metadata

In a decentralized system where data is spread across multiple platforms, metadata is key to ensuring interoperability and enhancing data usability. ASAM OpenX standards provide the foundation for simulation-based testing of automated driving functions, covering a wide range of virtual development use cases. However, domain-specific metadata is needed to fully utilize these standards and data formats, enabling efficient search and comparison across diverse datasets.

To address this, ASCS and its partners have developed domain-specific metadata, custom ontologies, and associated SHACL shapes for the ENVITED-X data space through the GAIA-X4PLC-AAD research project2. These definitions enable precise, automated asset and service registration, as well as intelligent data search and management. The ASAM OpenX standards support the definition of these attributes and ontologies, ensuring a uniform and standardized data structure.

The development and maintenance of these ontologies and SHACL shapes are managed by ASCS members via the ENVITED Open Source Model & Simulation Library (OpenMSL) on GitHub3, fostering collaboration and knowledge exchange. The following metadata classes are currently supported for registering assets and services in the ENVITED-X data space: HDMap, Environment Model, Scenarios, OSI-trace, Surface Model, CRG, Sensors, Services and Checks. Additional classes can be added via the ENVITED OpenMSL community. Systematic checks ensure that the metadata meets defined standards, maintaining its integrity, consistency, and reliability.

Quantifying Simulation Quality

The effectiveness of simulation-based testing hinges on quantifying simulation quality, which is crucial for the reliability and safety of automated driving functions. In decentralized systems, where assets come from various sources, ensuring consistent quality is challenging. Quality checks and labels offer a standardized way to evaluate and verify asset accuracy and relevance.#

Standardized metrics for assessing simulation quality are essential, enabling users to select suitable data, minimize errors, and ensure effective integration into their development process. In the ENVITED-X data space, systematic checks and labels maintain data quality, with automated checks identifying errors and labels indicating quality levels. The ASAM Quality Checker Framework exemplifies this approach by ensuring compliance with standards like ASAM OpenDRIVE and ASAM OpenSCENARIO XML.

Decentralized Data Management and Governance

Managing large volumes of simulation and AI data in a decentralized ecosystem like ENVITED-X presents both challenges and opportunities. Traditional centralized storage often fails to meet the scale, diversity, and security needs of modern testing. Decentralized approaches, such as blockchain and distributed ledger technologies (DLTs), offer effective alternatives.
Decentralized management provides secure, multi-node data storage, reducing failure risks and enhancing data integrity. It also facilitates seamless data sharing and collaboration across organizations while maintaining strict access controls and data ownership. Additionally, it supports automated data processing, ensuring data is up-to-date and available for analysis.
Robust policies and practices for data access, use, sharing, and retention are crucial. The ASCS plays a key role in developing and enforcing this data governance framework as ecosystem federator through democratic member-driven processes.

Conclusion

The transition to a decentralized data ecosystem for ASAM OpenX assets is not just a technical challenge but a strategic imperative. By addressing the key aspects of digital identities, domain-specific metadata, simulation quality, decentralized data management, and data governance, the industry can create a robust and scalable framework that supports the safe and efficient development of automated driving functions. As we move forward, collaboration among stakeholders will be essential to realize the full potential of the ENVITED-X ecosystem, driving innovation and ensuring the successful deployment of automated driving technologies on a global scale.

"The future of mobility relies heavily on simulation, particularly in vehicle automation. ASAM OpenX standards enhance efficiency and speed in development, but widespread access to high-quality, application-specific assets is crucial. The ENVITED-X data space addresses this need by uniting various data providers for ASAM OpenX assets, creati a forward-looking ecosystem that supports manufacturers and suppliers in becoming data-driven companies and fosters unique synergies."

ALEXANDER F. WALSER,
Managing Director,
ASCS e.V.

Source: AdobeStock (Creative_Bringer)

AVEAS Project

An Open Approach towards the acquisition of safety-critical traffic scenarios for ADAS / AD validation: The AVEAS project

Featured Standards:

ASAM OpenDRIVE, ASAM OpenSCENARIO, ASAM OpenLABEL

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SUMMARY

The AVEAS research project (www.aveas.org), funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK), has developed methods for acquiring real-world data for use in the virtual validation of automated vehicles. Led by understandAI GmbH, it joined the partners dSPACE, Porsche Engineering, Continental, PTV, Allianz, GOTECH, Spiegel Institut, KIT and the three Fraunhofer institutes EMI, IVI and IOSB. Associate partners include ASAM, TÜV Süd, ADAC, ALP.Lab and EDI. Between 2021 and 2024, hundreds of hours of public traffic were collected by road vehicles, airplanes and infrastructure sensors, and simulator studies with hundreds of participants were conducted, to establish data-driven simulations. The outcome: A unified set of files, as a connection of ASAM OpenLABEL, ASAM OpenDRIVE and ASAM OpenSCENARIO, representing the static and dynamic state of the acquired scenarios.

INITIAL SITUATION

With growing complexity and criticality of automated driving (AD) functions and their operational design domains (ODD), there is increasing demand for covering significant proportions of development and validation using virtual environments and simulation models.

If, however, simulations are meant not only to augment real-world experiments but to replace them, quantitative approaches are needed that measure to what degree, and under which preconditions simulations adequately represent reality. There is a significant shortage of real-world data to parameterize and validate simulations – especially with respect to the behavior of human traffic participants and the safety impact of the "open world". Today, "microscopic", agent-based simulation models for human behavior mostly rely on expert-defined models calibrated against aggregated data, while the amount and detail of data are by far insufficient to parameterize or validate detailed simulation models for quantitative safety tests.

This is even though several large and well-known international campaigns to acquire such data have been conducted, including datasets from the US NGSIM and SHRP2 NDS projects, the computer vision datasets KITTI, Cityscapes, BDD100K, nuScenes, ACDC and A2D2, or the highD dataset, as well as subsequent datasets. Similarly, many test areas acquire comparable data continuously, but this data is often not stored or distributed, partly for privacy reasons. While each of these data sources can contribute to an extensive body of real-world driving scenarios, they are not only based on different acquisition methods, but also follow different acquisition and processing principles and formats. Hence, their joint consideration is difficult, and no research efforts are known that leverage a larger proportion of these datasets cumulatively. Furthermore, most of these datasets originate from temporary project enterprises. No systematic large-scale acquisition effort is known that aims to provide significant data for the given use case.

SUCCESS STRATEGY

The AVEAS project focused on developing a systematic approach to acquire real-world data under "relevant conditions" and transforming these into simulation models for the virtual validation of AD functions.

First, the results comprise a considerable range of methods for acquiring and processing real-world data with a focus on economically viable, systematic, long-term data acquisition. These include methods for deriving OpenDRIVE maps from lightweight vehicle sensors, the robust, privacy-safe detection and tracking of objects to achieve consistent OpenSCENARIO and OpenLABEL scenario data, and the derivation of data-driven models. All methods have been evaluated exhaustively to establish best practices, and published in open, peer-reviewed papers. Real-world acquisitions at accident hotspots in Germany have been conducted in the Dresden area via stationary thermal infrared cameras by Fraunhofer IVI, in Paderborn via road vehicles by dSPACE and UnderstandAI, as well as in the Karlsruhe area via road vehicles by Porsche Engineering and KIT, via static LiDAR sensors by KIT, and via light aircraft-mounted cameras by Fraunhofer IOSB.

Second, a joint metadata standard based on ASAM OpenLABEL has been developed as part of DIN SAE SPEC 91518, which combines the flexibility of OpenLABEL with detailed specifications developed by an international consortium that harmonizes parameters, principles and units of measurement, criticality metrics and uncertainty measures across the heterogeneous acquisition methods and heterogeneous applications. This format is intended to unify and consolidate the international efforts towards the establishment of a consistent and compatible body of data.

Third, the project has acquired extensive data as an initial dataset to support the newly developed data format, part of which will be provided as open data as part of the project deliverables. This dataset will enable organizations to familiarize themselves with the format, as well as developing data-driven methods based on the data and evaluating their own methods' performances.

CHALLENGES DURING THE PROJECT

During its three-year period, the project faced challenges ranging from technology over regulation up to force majeure. But a principal challenge, already foreseen during preparation, was the unification of risk concepts, data and simulation purposes and eventual testing applications.

Most AD-related datasets introduce custom data formats and schemes tailored to the specific use case. Instead, when joining a wide range of methods and use cases, harmonization needs span all steps of the processing pipeline, from a basic definition of how the "position" and "dimensions" of an object can be determined uniformly, how it is filtered and matched to the road network, to a definition of concepts like "lane change" or "time to collision". Resolving such challenges posed a key project focus throughout.

BUSINESS BENEFITS

The AVEAS project results contribute to streamlined processes in traffic safety and the virtual / data-driven validation of automated driving primarily in the three dimensions outlined priorly.

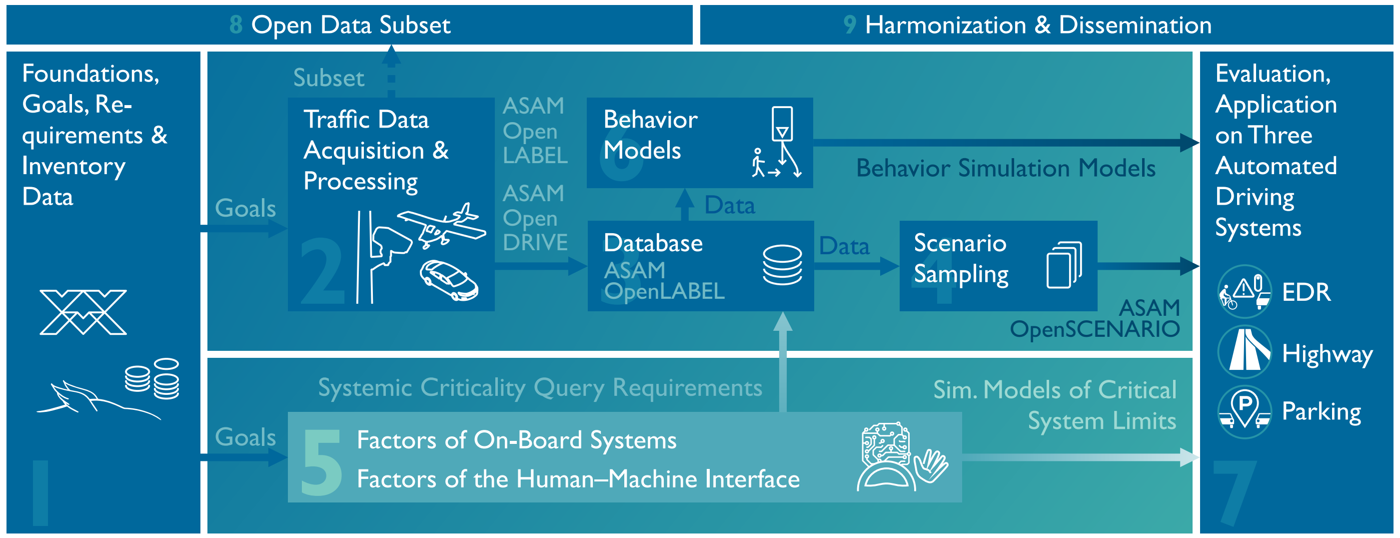
First, the developed methods for acquiring real-world data share a focus on economically viable, systematic, long-term data acquisition. They were evaluated exhaustively, and published as peer-reviewed open-access papers and, in part, open source.

Second, the joint metadata standard specified in DIN SAE SPEC 91518, in conjunction with ASAM OpenLABEL and ASAM OpenDRIVE, is expected to minimize efforts for assuring consistency and data quality across heterogeneous sources. Due to the already wide adoption of the underlying ASAM OpenX standards, the SPEC can be immediately applied and utilized by a wide range of parties.

Third, the AVEAS dataset is intended to enable organizations to familiarize themselves with the format, as well as developing data-driven methods based on the data and evaluating their own methods' performances.

"The establishment and further development of standardized formats is crucial to ensure sufficient interchangeability and reusability of input data across different simulation frameworks that serve as the basis for XiL test benches and/or driving simulators in the development and validation process."

TILLE KAROLINE RUPP,
Head of Simulation,
Porsche Engineering



Overview of the tasks within the AVEAS project, aligned around the development of a scenario database as the central element

CARIZON (Beijing) Technology Company Ltd.

Shared scenario library as key to engineering success of ADAS and AD System: Consistent, transparent and interoperable

Featured Standards:

ASAM OpenDRIVE,
ASAM OpenCRG,
ASAM OpenSCENARIO XML,
ASAM OpenSCENARIO DSL,
ASAM OpenLABEL

Author:
Estha Li,
System Architecture Solution Engineer,
CARIZON (Beijing) Technology Company Ltd.

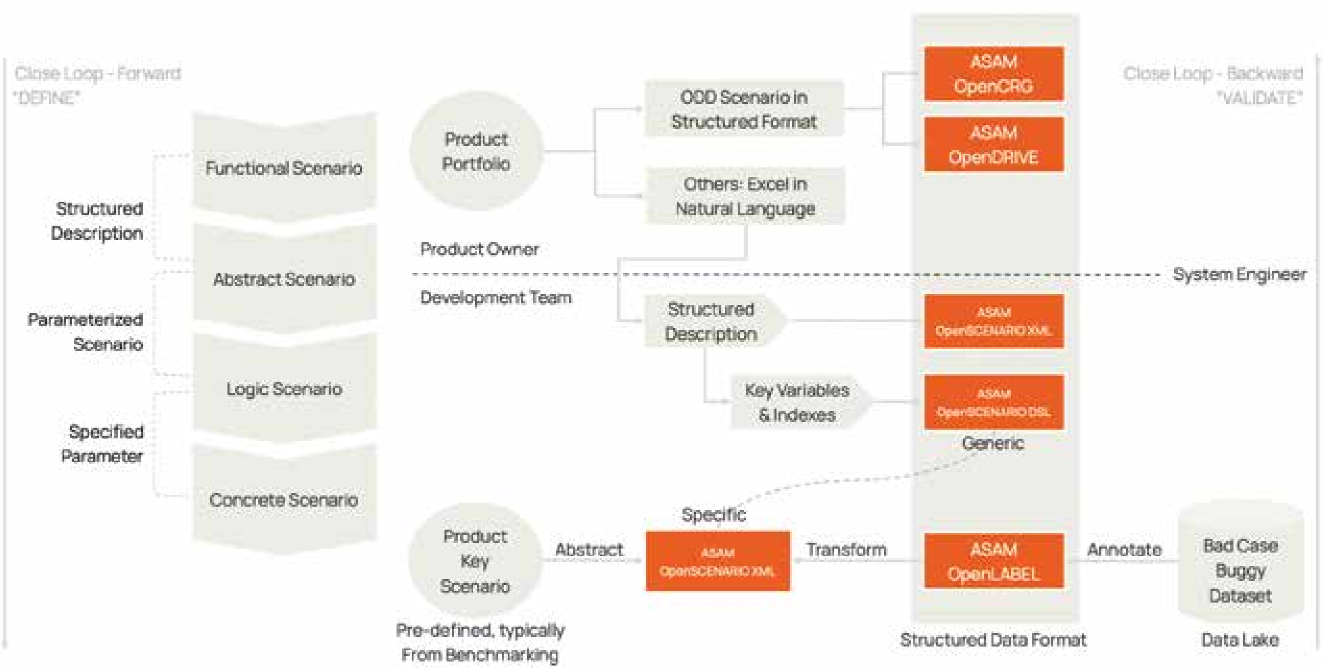
SUMMARY

Background: As newly founded Joint Venture, CARIZON's key business is to provide highly intelligent ADAS systems to Volkswagen Group in China on multiple carlines with rich variance. New business places high demand on a digital framework that facilitates scenario data exchange and interoperation. Further, a more intelligent and efficient solution that can bridge data- and knowledge-driven approaches is needed to accelerate product iteration from both directions. Therefore, we initialized this research project.

Solution: Functional scenarios defined by a product owner help as starting point. Logic scenarios are then derived by system engineers and used to generate simulation data sets. On the other side, the testing team applies reverse mechanism to real world sensor data collected from test fleets, from which concrete SCENARIO is extracted and described in a standardized format. In the same data base, scenarios from both ends of the V-Model are analyzed, aggregated and linked. Based on these scenarios, simulated data and collected real-world data are annotated, sorted, enhanced and clustered in a data lake, used for algorithm training, evaluation, and end-to-end system validation. The accepted new software release is then deployed back into the test infrastructure to close the loop. Iteration by iteration, flowing cross teams, scenarios and data sets are shared and properly used in all development activities to shorten the development lifecycle and enhance the product performance.

INITIAL SITUATION

Complexity of ADAS/AD systems is increasing, and at the same time the pressure to reduce costs is increasing. To deliver products faster than competitors with better quality and cheaper quotes, an advanced engineering level is essential. CARIZON has both strengths and weaknesses: the data lake infrastructure and simulation platform are productive, but the data sets are not yet managed in scenario context; scenarios on different layers have been well-documented, however they are maintained as data islands in different teams and lack consistency; similarly, we do have acceptance criteria for some modules, nevertheless a retrievable evaluation index system is missing. As a result, huge effort was wasted in communication, especially while switching from one product line to another, to share and/or re-use these data.



CHALLENGES DURING THE PROJECT

Scenario and tags should be described with standardized and machine-understandable language that is extensible, continuously updated along with ADAS/AD technology evolution, commonly accepted in the industry. To share scenario library and data set, a user-friendly graphic UI for sorting, filtering, preview, editing and exporting should be provided. Not just function-related evaluation index, but also non-functional index e.g. Run-time performance, CPU, memory utilization should be considered as edge case and corner case candidates. The same functional scenario might derive several logic scenarios with a variety of parameter sets, thus scenario lineage should be described and tracked.

SUCCESS STRATEGY

The solution can be divided into the following steps:

STEP 1: Based on product portfolio, functional scenarios are extracted and described in ASAM OpenDRIVE, ASAM OpenCRG and ASAM OpenSCENARIO. The Product team uses these scenarios for system requirement specification, based on which the engineering team conducts initial solution architecture design. Sensor simulation is carefully implemented as proof of concept for perception sub-systems. Furthermore, sensor technical specification and installation layout are used to analyze edge cases of perception.

STEP 2: Scenarios are reviewed and updated referring to public accident libraries, international and national standards. Legacy projects' valuable scenarios are also counted. Based on functional scenarios, product line specific system evaluation indexes are added to logic scenarios. The first stable version is then distributed to development and testing teams.

STEP 3: Based on logic scenarios for the whole system, module-based evaluation indexes in individual scenarios are inferred. Some variables are used as touchstones to explore system functional behavior in certain scenarios, e.g. ego-car speed and acceleration, while others are used to check non-functional performance e.g. a system module's worst case processing time in an intersection with heavy traffic. These are critical inputs for system design, implementation and validation on every layer in the V-Model.

STEP 4: Starting the evaluation of system components before the system is integrated with edge cases generated from both, real and simulated data. Validating the overall system end-to-end performance in real vehicles. Analyzing evaluation reports, adjusting scenarios and evaluation indexes whenever necessary.

STEP 5: Annotating selected test fleet data sets, typically bad cases and bugs with the help of ASAM OpenLABEL. These valuable cases are analyzed and described in ASAM OpenSCENARIO XML as concrete scenarios, from which logic scenario with corresponding parameter sets and evaluation indexes is extracted and stored in form of ASAM OpenScenario DSL. Such scenarios are more generic and easy to customize due to their Python-wise grammar, widely used for cross-system simulation, evaluation and validation, while results could be traced back to referred scenarios on all layers.

KEY BENEFITS

The project has proven that data-driven and knowledge-driven methods work together perfectly. Driven by knowledge, from top to bottom, we go through functional, abstract, logic and concrete scenarios, while driven by data, from the bottom up, we recognize logic scenarios from concrete scenarios and link them to the corresponding functional scenario based on a well-maintained scenario tree. Furthermore, the experience of this project helps validate the idea of „Lean Management" against individual system modules. Since evaluation indexes and variable ranges are broken-down to module-level, 6σ index e.g. upper/lower control limit can be applied to lower system level. Now, featured product configuration management is much easier: centrally managed scenarios with evaluation indexes are transparent to engineering teams, changes could take effect without delay or misunderstanding.

OUTLOOK

This is not a single success story of ASAM OpenX standards. As machine-readable language, OpenX standards have digitalized important project data assets into a structured data format, making it possible to involve new automation and artificial intelligence technology in the picture. As a next step, we will record and analyze distribution and usage statistics of scenarios and data sets, so that data quality, scenario library, development process and workflow, eventually the overall product performance can be continuously improved.

"We chose ASAM OpenX standards not just because of their well-defined data structure but also because of the existing ASAM OpenX community. Familiar simulation platforms and tool-chains can be enrolled immediately, time and effort are saved. We are looking forward to working closely with other partners and making active contributions to the ASAM OpenX standards development."

YANLE ZHANG,
Head of System & Architect
CARIZON (Beijing) Technology Company Ltd.

CATARC Intelligent and Connected Technology Co., Ltd.

ADGenerator: An AD / ADAS simulation testing scenario generation and management platform

Featured Standards:

ASAM OpenDRIVE,
ASAM OpenSCENARIO DSL

Authors:
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ADGenerator

SUMMARY

The current simulation of autonomous driving scenarios faces problems such as difficulty in applying road data collection, inconsistent scenario data formats, low scenario generation efficiency, small scenario coverage, and incomplete scenario data management system. An integrated solution and tool are needed to overcome a series of difficulties in scenario data before the simulation application.

The ADGenerator of CATARC Intelligent and Connected Technology Co., Ltd. automatically converts road acquisition data containing sensors such as cameras, LiDAR, and inertial navigation into ASAM OpenDRIVE and ASAM OpenSCENARIO DSL format AD/ADAS simulation testing scenario files in bulk, thereby solving the problems of difficult application of road acquisition data, inconsistent scenario data formats, and low scenario generation efficiency; To solve the problem of low scenario coverage, ADGenerator uses the ASAM OpenSCENARIO DSL standard to generate simulation scenario generalization of road acquisition data by changing parameter values such as vehicle speed, vehicle action start time, and vehicle action duration, and selects more dangerous simulation testing scenarios through TTC and THW indicators to improve the efficiency of scenario simulation testing; In addition, ADGenerator provides a powerful data management system (label based scenarios management system) that can automatically classify, quickly filter, and retrieve ASAM OpenSCENARIO DSL scenarios.

APPLICATION STORY

CATARC Intelligent and Connected Technology Co., Ltd. has 1 million kilometers of road acquisition data including camera, LiDAR, inertial navigation, and other sensor data. To apply road acquisition data with real environmental information and real dynamic scenario information to AD/ADAS system testing, and achieve effective management and rapid retrieval of AD/ADAS system testing scenarios, CATARC Intelligent and Connected Technology Co., Ltd. has launched the research and development work of the ADGenerator project, And based on the ASAM OpenDRIVE and ASAM OpenSCENARIO DSL standards, automatic batch generation generalization from data collection to simulation scenarios has been successfully achieved, greatly improving the efficiency of scenario generation and AD/ADAS testing verification.

During the ADGenerator project, we encountered four challenging issues: how to automatically convert the collected static road information into a simulated usable map? How to automatically convert dynamic scenario information into simulated dynamic scenarios and effectively combine it with simulation map files? How to achieve automatic batch generalization generation of data collection to simulation scenarios? How can the simulation scenarios generated by generalization be effectively classified, managed, and quickly retrieved?

Road information is mainly obtained by fusing camera data and LiDAR data, including parameters such as number of lanes, type of lane lines, and curvature of lane lines. How to convert road information into a high-precision map that can be used for simulation is an urgent problem that needs to be solved. We have studied the simulation map construction logic of multiple domestic and foreign commercial software for autonomous driving simulation testing, including Carmaker, PreScan, 51sim one, etc. We can use the collected road information to convert it into a map unique file format that can be run by any commercial software for autonomous driving simulation testing, but we cannot achieve cross-simulator use of scenarios. We found that the high-precision maps defined by the ASAM OpenDRIVE standard can be compatible with multiple commercial software for autonomous driving simulation testing. Due to the good compatibility of ASAM OpenDRIVE maps and the strong logical construction and easy conversion of ASAM OpenDRIVE maps, we chose the ASAM OpenDRIVE standard as the basis for converting simulation map files.

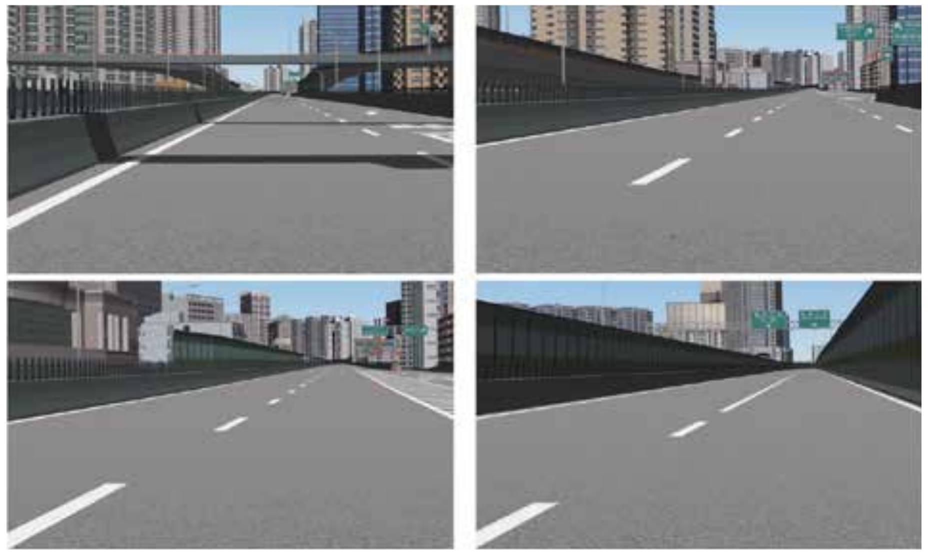
The collected dynamic scenario information is obtained by fusing data from cameras, LiDAR, millimeter-wave radar, and other sensors, including parameters such as traffic participant types, traffic participant actions, and weather. To convert the collected dynamic scenario information into dynamic simulation files, it is necessary to solve the compatibility problem of scenario files in multiple simulators, At the same time, it is also necessary to solve the problem of association between dynamic simulation files and simulation map files, as well as the problem of automatic batch generalization generation of simulation scenarios. We found that the ASAM OpenSCENARIO DSL standard can completely solve all the above problems, so we used the ASAM OpenSCENARIO DSL as the conversion basis for dynamic simulation files in ADGenerator.

To solve the problem of effective classification and fast retrieval of simulation scenarios, ADGenerator provides a label-based scenario data management system. ADGenerator refers to ISO 34503 and ISO 34504 standards to provide a label library and a mapping relationship between the labels in the label library and the parameter fields of ASAM OpenDRIVE and ASAM OpenSCENARIO DSL. When an external OpenX simulation scenario is uploaded to ADGenerator or when ADGenerator generalizes to generate a simulation file, ADGenerator will traverse the parameter fields within the simulation file and automatically classify the simulation file into appropriate categories based on the mapping relationship. Users can also quickly filter and retrieve simulation files through tags.

At present, ADGenerator has approximately 50000 scenarios and is compatible with VTD, Carmaker, dSPACE, CARLA, and SCANeR5 commercial software for autonomous driving simulation testing. ADGenerator has already served many universities and car companies in China. For example, NIO Inc. uses ADGenerator to transform simulation scenarios of RosBag format road data, and verifies its self-developed ADAS algorithm with Carmaker software; China Automotive Innovation Corporation uses ADGenerator to classify and manage simulation scenarios, including CIDAS accident scenarios, standard regulatory scenarios, expert experience scenarios, and so on.

“In the development of the autonomous vehicle, the ASAM OpenX standards play an important role, providing a unified data interface specification for the entire industry, promoting the seamless flow of simulation data between autonomous vehicle simulators, and greatly reducing the complexity and cost in the development process of the auto drive system.”

SHUAI ZHAO,
Chief expert,
CATARC



ADGenerator conversion scenario (a section of road in Shanghai, China)

IAV China

AI-powered ADAS scenario generation and management

Featured Standards:

ASAM OpenSCENARIO, ASAM OpenDRIVE, ASAM OpenLABEL

Authors:
Yuxin Xuan,
ADAS System Engineer,
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Kangkang Zhou,
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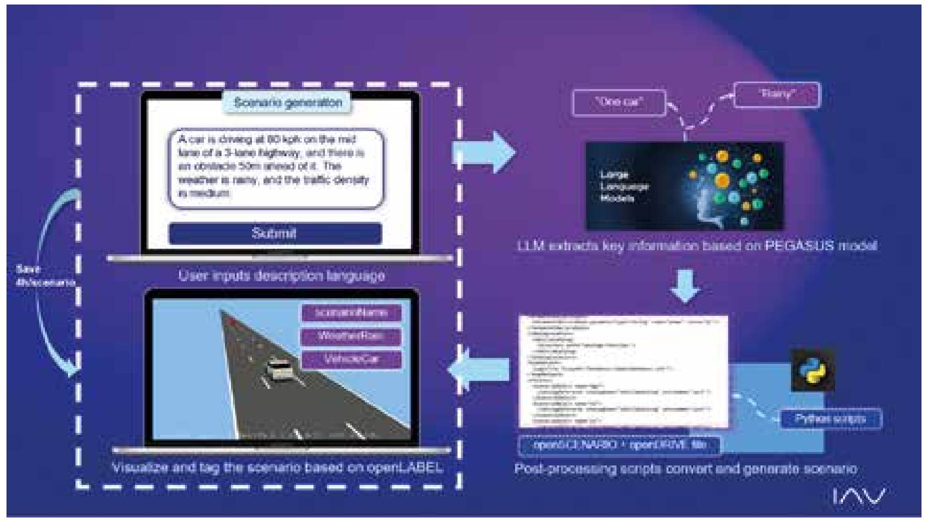
IAV China

SUMMARY

Clients in the automotive industry face the challenge of creating and testing an infinite number of scenarios with limited resources and time, a problem that exaggerates if they are using different standards and simulation platforms. IAV Automotive Engineering leverages cutting-edge AI technology to streamline the creation and management of ASAM standard-based scenarios and overcomes the constraints of traditional scenario generation.

By integrating customer-facing Large Language Models (LLMs) with rigorous data processing procedures, we transform diverse test case specifications and scenario descriptions into highly modifiable and parameterizable scenarios that are compatible with clients' simulation and testing toolchains.



AI-powered ADAS Scenario Generation and Management Pipeline.
Source: IAV Automotive Engineering (Shanghai) Co., Ltd.

This automated approach, supported by ASAM standards, has significantly enhanced our clients' efficiency, reduced costs, and improved the quality and flexibility of scenario management and test automation processes.

INITIAL SITUATION

Before the project, our clients faced significant challenges in the manual creation of scenarios, which was both time-consuming and prone to human error. This complexity was further compounded when the clients' input and output requirements pole apart. The input sources may range from expert knowledge, crash reports, regulations, to internal function requirements. In addition, while companies need realistic scene setups for ADAS function validation, the input map might originate from multiple sources. The output formats supported by different simulation software were also incompatible, thus hampering our ability to quickly respond to new requirements and feed the output forward to testing processes. Therefore, the motivation was clear: we need a more efficient, accurate, and compatible solution.

SOLUTION

Understanding the need for transformation, we integrated the text understanding capability of Large Language Models (LLMs) to automate the generation of these scenarios. The LLMs, combined with a pre-processing and post-processing techniques, enabled us to convert various test case specifications or text descriptions into scenarios that could be easily modified and derived. Moreover, this new solution harmonized with our internal scenario database management and analysis tool chain. Specifically, users can perform scenario generation, select the algorithms for finding critical scenarios, conduct scenario-based simulations to validate ADAS functions and carry out SOTIF analyses. By referencing the ASAM OpenLABEL standard, we ensured that our scenario database store relevant scenarios in a highly organized and generic format, with data collection methods, assets, parameters, tags and KPIs carefully defined to fulfill clients' need.

CHALLENGES DURING THE PROJECT

Throughout the project, we encountered several challenges, notably the integration of sophisticated AI with our existing tools and aligning it with ASAM standards.

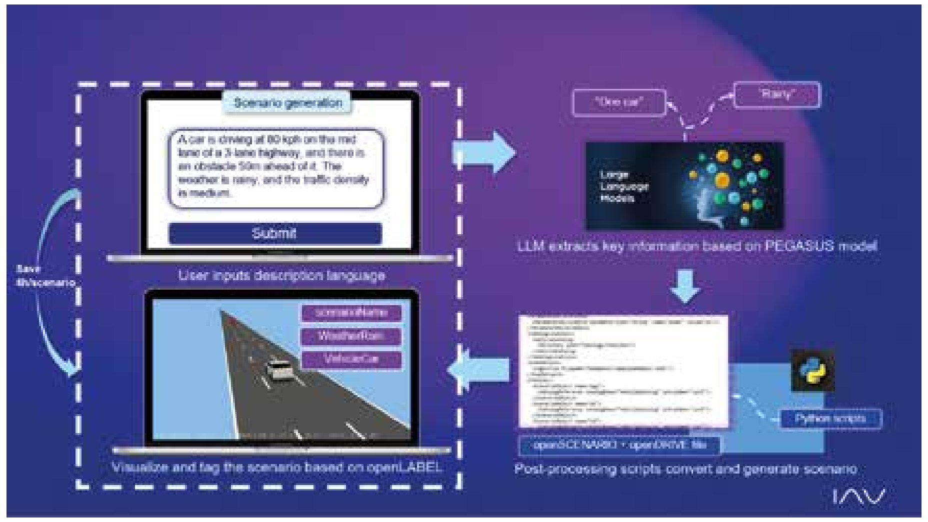
Ensuring accuracy and reliability of the scenario generation pipeline posed a significant hurdle, requiring continuous refinement of our data processing steps. We tested multiple data sources and scenario categories to better hone the multimodal AI service for understanding and tagging different inputs. We conducted extensive research and statistical testing to ensure that LLM service is deployed in a safe, economic and stable way. We were transparent with users about how their data would be protected and provided options for deploying the pipeline in their internal environment. By using access control and authentication protocols, we verified that only allowed users could access the database and upload or download scenario data.

At the same time, since clients need scenarios during different phases of the V-model, we faced challenges when the scenarios became domain specific, necessitating precise filtering and organization. As a result, we studied how ASAM OpenSCENARIO, ASAM OpenDRIVE and ASAM OpenLABEL components can be used and combined to adapt to regulation scenarios, accident scenarios, and the concrete scenarios designed for functional purposes including autonomous driving, parking and guard. We found out that the ASAM OpenX standards could be applied throughout the validation and verification of autonomous driving systems. Therefore, this standard had the potential to serve as a bridging language across different sections of ADAS development in the long term.

Moreover, we iterated on the post-processing and visualization components. We studied possible use cases and designed the UI/UX layer for users to interact with the AI tool in a clear and intuitive manner. We also ensured that the tool supports common types of simulation software integration, both locally and via cloud deployment. IAV engineers collaborated extensively during the releasing, productionizing and monitoring phase to seamlessly embed the AI tool into target systems.

BUSINESS BENEFITS

The transition to this innovative, AI-driven approach brought substantial business benefits. We witnessed time and cost savings by significantly reducing the time required to manually generate and organize scenarios. Additionally, the new process offered a gain in flexibility, allowing us to quickly adapt scenarios to new data sources, requirements and parameter variations. Most importantly, the quality and compatibility of our scenarios are guaranteed, ensuring outcomes that can be further built upon in mainstream simulation software and validation tools.



AI-powered ADAS Scenario Generation Web Interface.
Source: IAV Automotive Engineering (Shanghai) Co., Ltd.

CONCLUSION

By leveraging LLM and ASAM standards, we not only addressed our customers' immediate challenges but also enhanced the effectiveness and scalability of our ADAS simulation tool chain. We believe that embracing AI technology would position ourselves for long-term success, maintaining a high standard of industry excellence.

"The ASAM standards have provided us with a robust foundation for scenario generation and tool integration, which is crucial for advancing our work in ADAS validation. This alignment with industry standards not only streamlines our processes but also ensures that we remain at the forefront of technological innovation."

TIANYI LIAN,
Automated Driving System Department Head,
IAV China

IVEX NV

Traffic behavior and scenario extraction from fixed sensors

Featured Standards:

ASAM OpenDRIVE,
ASAM OpenSCENARIO XML

Author:

Victor Vaquero,
Product & Innovation Manager,
IVEX

“Powered by ASAM standards, IVEX is transforming testing and validation for our customers. By unlocking the full potential of data, we‘re not just meeting their needs; we‘re exceeding expectations, lowering time to market and driving innovation at every turn.”

MARIO TORRES,
CEO,
IVEX

SUMMARY

This project involved a Truck OEM aiming to obtain traffic behavior and relevant driving scenarios to test their automated driving functions.

IVEX’s solution consists of a personalized data processing pipeline flexible enough to process data from fixed sensors on highways and intersections. From this data, we extract driving behaviors and relevant driving scenarios from each different vehicle passing by and we automatically generate standardized ASAM OpenSCENARIO XML and ASAM OpenDRIVE files, enabling the IVEX customer to test their system in a simulation environment.

Key benefits:

1. Save time & valuable resources on data collection campaigns
2. Avoid complex infrastructure devops with real scalability and customization
3. Easily access and interact with richer data, boosting teams’ efficiency and collaboration

INITIAL SITUATION

OEMs and Tier 1’s spend huge amounts of time and money to test and validate their ADAS functions. Usually, part of these tests are done by collecting real-world driving data during long driving campaigns for hundreds and thousands of kilometers with one or two engineers in the vehicle. The collected data is usually to test one specific function or issue, no additional value is extracted. This is far from optimal and does not allow further discoveries. Additionally, accessing and analyzing the data is often reserved to high technical people and developers, which compartmentalize the learnings from it as well as its communication.

Another way of obtaining valuable driving information is via traffic behavior analysis, extracting vehicle maneuvers from sensors mounted on the road infrastructure. This approach multiplies the chances of finding interesting driving scenarios to test vehicles, as every vehicle passing is a possible candidate. It also allows closing the loop from real-world to simulation.

With high quality digital twins extracted using ASAM OpenSCENARIO XML and ASAM OpenDRIVE, we can simulate the ego vehicle and ADAS feature from the perspective of any captured vehicle. This in fact multiplies the value of the recorded information.

In this use case, we will review how IVEX helped a Truck OEM to obtain naturalistic driving behaviors from intersections, analyze the data and automatically generate standardized digital twins to be used across different simulators.

SUCCESS STRATEGY / SOLUTION

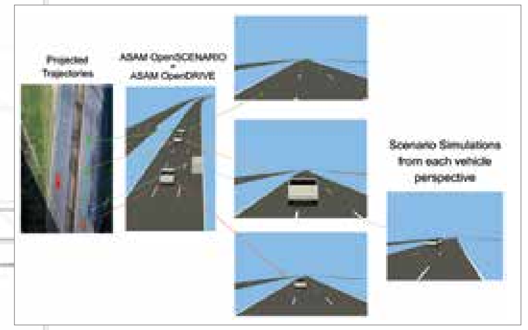
IVEX software helps OEMs and Tier-1s in obtaining the maximum of their data collected from static sensors installed on road infrastructures. IVEX‘ customer starts by ingesting camera and LiDAR recorded data from selected intersections. The ingested data can be formatted in ASAM OpenLABEL or any other format.

The tailored data processing pipeline automatically analyzes the recordings using IVEX’s own developed algorithms and /or customer algorithms in docker modules. The pipeline applied here includes computer vision models to detect and extract the vehicles in 3D, tracking algorithms, homography calculations, measurements, KPIs computations and IVEX’s own scenario extraction algorithms to find and extract interesting known and unknown relevant driving behaviors.

The analyzed data and results are available in IVEX Data Analytics Platform for easy visualization, inspection and interaction of the different scenarios. It is also accessible to people without specific technical knowledge, which brings teams together, helps engineers to get insights from the data fast, and supports the management to take smarter data-based decisions with the help of interactive reports.

Finally, the IVEX customer gets to choose which scenarios to download for re-simulation, and the tool automatically generates the corresponding ASAM OpenSCENARIO XML and ASAM OpenDRIVE files that create the digital twin of the scenario.

Traffic Monitoring



Multiple Simulation

CHALLENGES DURING THE PROJECT

IVEX overcame a few challenges during this project.

First, building a proper processing pipeline to serve the purpose of extracting relevant driving scenarios from fixed sensors. For that, IVEX integrated its own perception and tracking algorithms with the outputs from perception algorithms that the customer had dockerized (no IP leak), which were also incorporated into the new generated processing pipelines.

Second, IVEX had to continuously iterate to be able to quickly show the data in IVEX cloud software to the customer and allow them to access the platform for internal inspection. It really alleviated the communication during the project and the decision making. Sharing simple links to data points with relevant findings made the engineers life easier, and they were very responsive.

Another challenge arose when generating shareable digital twins, knowing that the customer works with different simulators. With IVEX‘s expertise in ASAM standards, generating the ASAM OpenSCENARIO XML and ASAM OpenDRIVE files was the perfect solution to be consumed by any simulator.

BUSINESS BENEFITS

The business benefits for IVEX customers were many:

- **Time and effort saving on expensive data recording driving campaigns:**
  Data recording campaigns run sensorized vehicles usually with a couple of engineers in it for several days, only for searching specific points of interest at the time. After that, the data is commonly not used anymore. Also, as this data collection is done from the ego perspective only, the number of scenarios found is limited and not enough for obtaining proper driving behaviors. IVEX solution enables customers to save time and effort in terms of data collection campaigns. They also multiply by several times the number of scenarios found, as each vehicle in the scene is a potential candidate.
- **Flexibility and reusability of processing algorithms:**
  IVEX is able to quickly configure new pipelines, using existing algorithms and combining them with new ones. The flexibility of these pipelines allows IVEX customers to reuse the collected data and search for new, now “unknown” scenarios in the future.
- **Improve team collaboration, communication, efficiency and quality:**
  By enabling different users to easily access the data, check the findings without coding burden, and share links to specific data points with colleagues, IVEX improves customers’ internal team communication and efficiency, as well as project communication between IVEX & customer. This enables faster iterations with adequate feedback and increases the results quality. It also allows IVEX customers to really learn and understand from the data while gaining trust in the full process.

“With ASAM standards, we are closing the loop from the real world to the simulation, which simplifies testing relevant scenarios for our customers. We‘re making their data work harder, so they can work smarter.”

VICTOR VAQUERO,
Product & Innovation Manager,
IVEX

The MathWorks Inc.

The role of ASAM standards in scenario-based testing: Insights from BMW and Aptiv

Featured Standards:

ASAM OpenDRIVE, ASAM OpenSCENARIO, ASAM OSI

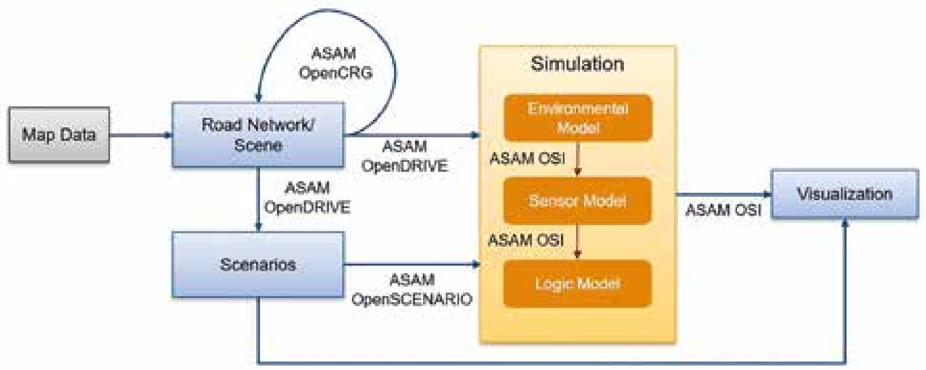
Author:
Naga Pemmaraju,
Principal Product Manager,
Autonomous Systems,
The MathWorks Inc.

SUMMARY

ASAM OpenX standards improve interoperability and efficiency for the simulation and testing of automated driving systems. OpenX standards, such as ASAM OpenDRIVE, ASAM OpenCRG, ASAM OpenSCENARIO, and ASAM OSI (Open Simulation Interface), are instrumental for scenario-based testing. This article will discuss how leading automotive organizations adopt these standards for simulating virtual worlds, recreating scenarios from real-world data, and validating ADAS ECUs.

What is scenario-based testing? How does ASAM support it?

Scenario-based testing involves creating specific situations or scenarios that one might encounter while operating advanced driver assistance systems (ADAS)/autonomous driving (AD) systems. ASAM standards play an important role in scenario-based testing by facilitating interoperability, data exchange, and toolchain integration. ASAM OpenDRIVE and ASAM OpenCRG are used to describe and exchange road networks between simulators. ASAM OpenDRIVE is used to describe elements of a scene such as roads, lanes, junctions, traffic signs, etc. ASAM OpenCRG helps in describing road surfaces that are used for testing vehicle dynamics. Scenarios involve dynamic elements, such as the ego vehicle (the vehicle equipped with ADAS/AD systems) and other traffic participants moving within the scene. ASAM OpenSCENARIO is used as a file format to describe the dynamic content of the driving and traffic simulators. ASAM OSI provides compatibility between automated driving functions and driving simulation frameworks.



Workflow for scenario-based simulation and testing.

ASAM OpenDRIVE visualization in the RoadRunner tool.

MathWorks supports ASAM standards in its software for automated driving, including RoadRunner and Automated Driving Toolbox. This support has helped its customers address specific challenges in the development, testing, and validation of ADAS/AD technologies. Each section below represents an example project where ASAM standards were a critical part of the workflow.

Virtual world generation for BMW driving simulation

BMW's advanced driving simulation center, featuring 14 distinct simulators, is at the forefront of testing and validating new vehicle functionalities, with a particular focus on ADAS and UI/UX concepts. The center creates large, accurate road networks for simulation studios, using software tools such as Spider, Unreal Engine, and RoadRunner. ASAM standards, such as ASAM OpenDRIVE and ASAM OpenCRG, are used to provide consistency, accuracy, and interoperability across different simulation setups.

One challenge BMW faced was to ensure that the 3D models of roads and environments accurately matched the logical descriptions provided by its simulation software, Spider. By leveraging ASAM OpenDRIVE, BMW could ensure a seamless match between the 3D visual content and the logical road network data. BMW used RoadRunner to import ASAM OpenDRIVE files and then generate corresponding 3D models for a consistent and accurate representation of virtual environments.

Another challenge for BMW was to accurately recreate various road surfaces for use in simulating and testing vehicle dynamics with high precision. ASAM OpenCRG, an open standard that describes road surfaces in detail, enabled BMW to simulate real and synthetic road conditions with accuracy. BMW used RoadRunner to edit ASAM OpenCRG files and adjust road surfaces in its scenarios. By using ASAM standards, such as ASAM OpenDRIVE and ASAM OpenCRG, BMW ensured consistency between simulation logic and 3D visualization, preventing discrepancies in virtual environment. BMW has presented this work at the MathWorks Automotive Conference, Germany in 2023.

Harvesting driving scenarios from recorded sensor data

Aptiv wanted to perform regression testing of its AD/ADAS algorithms by harvesting driving scenarios from recorded sensor data. Data from GPS, IMU, camera, radar, and lidar sensors were fused to accurately reconstruct driving scenarios such as lane changes, vehicle cut-ins, and more. This involved steps such as ego and non-ego vehicle trajectory reconstruction, scenario generation, and validation.

One challenge Aptiv faced was to export these scenarios for use in other simulators and ensure the behavior remains the same. Aptiv used RoadRunner to export scenarios to the ASAM OpenSCENARIO XML format and test them in the esmini tool. ASAM OpenSCENARIO played a crucial role in ensuring the generated scenarios could be exported and run across various simulation tools for AD/ADAS software testing. Aptiv has presented this work at the 2023 MathWorks Automotive Conference, Novi, Michigan in 2023.

Leveraging ASAM OSI for ADAS ECU validation

Aptiv wanted to efficiently validate and test its ADAS/AD systems without the extensive need for real-world road tests. Its approach was to create a virtual simulation environment that replicates real-world conditions, which is then used to simulate and test vehicle dynamics, controls, and sensor accuracy. Creating the virtual environment involved extracting and processing various objects, such as moving and stationary objects, traffic signs, and environmental information, and transforming these from world coordinates to sensor coordinates for detailed analysis.

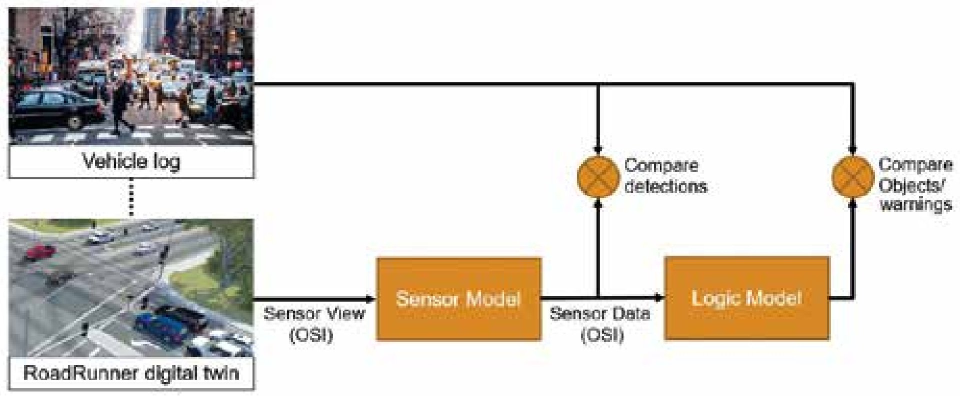
Scenario simulation in RoadRunner and the esmini tool using ASAM OpenSCENARIO.

ASAM OSI plays a crucial role in Aptiv's simulation ecosystem by serving as a standardized middleware that facilitates the exchange of information between environmental simulators and its sensor and logic models. This standard helps in improving interoperability between automated driving functions and driving simulation frameworks.

RoadRunner was used for creating Aptiv's virtual simulation environments. RoadRunner Scenario along with MATLAB were used to simulate and export ground truth sensor data into the ASAM OSI file format. These files were used to validate Aptiv's sensor and logic models. ASAM OSI ensured integration and interoperability between different environmental simulators and models without requiring changes to the interface. Aptiv's work on ASAM OSI using RoadRunner for ADAS ECU validation was presented at the MathWorks Automotive Conference held in Chennai, India in 2023.

CONCLUSION

ASAM standards have emerged as key enablers in the area of autonomous driving, offering a unified framework for simulation and testing. MathWorks worked with leading automotive companies such as BMW and Aptiv in the adoption of these standards by significantly improving their simulation capabilities. This standardization not only promotes interoperability but also accelerates the development and validation of safer, more efficient ADAS/AD systems.



Aptiv's framework for the virtual simulation and testing of its sensor and logic models.

Persival GmbH

Co-simulation of high-fidelity perception sensors

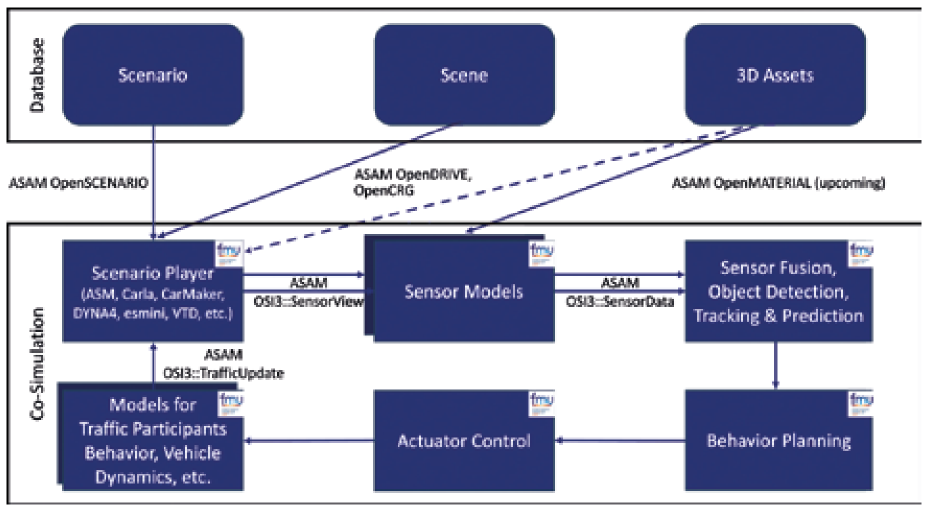
Featured Standards:

ASAM OpenDRIVE,
ASAM OpenSCENARIO,
ASAM OSI,
ASAM OpenMATERIAL

Author:
Dr. Clemens Linnhoff,
CTO,
Persival GmbH

“The ASAM OpenX standards enable us to create high-fidelity sensor models that perform advanced ray tracing in physically accurate 3D environments – all neatly packaged into one FMU. The seamless integration with all standard-compliant simulators significantly enhances the usability of validated high-fidelity perception sensor models.”

DR.-ING. CLEMENS LINNHOFF,
CTO,
Persival GmbH



Source: Persival GmbH

Fig. 1: Generic co-simulation architecture using ASAM OpenX standards

SUMMARY

High-fidelity sensor models require a sophisticated rendering engine and highly detailed 3D environment models. To achieve the highest accuracy, it's essential for companies developing real-world sensors to be involved in the modeling process. However, they are reluctant to implement their models within the custom frameworks and interfaces of the various simulation tools available.

The ASAM OpenX standards, namely ASAM OpenDRIVE, ASAM OpenSCENARIO, ASAM OpenMATERIAL, and ASAM OSI (Open Simulation Interface), provide an effective solution to this challenge. ASAM OpenDRIVE defines where to drive in a map format, ASAM OpenSCENARIO specifies the dynamic elements of test cases, ASAM OpenMATERIAL details the appearance of objects to different perception sensors, and ASAM OSI facilitates the transfer of information between simulation models in a co-simulation. The main advantage is that sensor manufacturers can model their sensors and validate the models just once, then connect them to any simulation tool using the ASAM standards. Additionally, ASAM OpenMATERIAL allows for using complex 3D environments and performing detailed ray tracing, moving beyond simple object-based models.

CHALLENGE

In the rapidly advancing field of autonomous driving, creating high-fidelity sensor simulation models is crucial for developing and testing reliable vehicle systems. Sensor manufacturers developing digital twins of their real-world sensors often face the challenge of integrating their models into various simulation tools, each with its own unique framework and interfaces. While ASAM OSI has enabled the connection of object-based sensor models to different simulators for some time enabling a lot of testing use cases, these models lack the necessary fidelity for high-accuracy testing and validation. Additionally, because they primarily output object lists, they are unsuitable for low-level fusion architectures.

SOLUTION

With the addition of ASAM OpenMATERIAL to the ASAM OpenX family, standard-compliant perception sensor co-simulation is taken to an entirely new level. The combination of ASAM OpenDRIVE, ASAM OpenSCENARIO, ASAM OpenMATERIAL, and ASAM OSI allows for packaging sensor models with advanced ray tracing into a functional mockup unit (FMU), ensuring seamless integration and superior model fidelity. This all-in-one custom sensor simulation package also streamlines model validation, as sensor models no longer need to be validated alongside a specific simulation tool but can be validated independently.

Fig. 1 illustrates a generic co-simulation architecture using the ASAM OpenX standards. Every simulation requires a comprehensive database of what is to be simulated, comprising three key components:

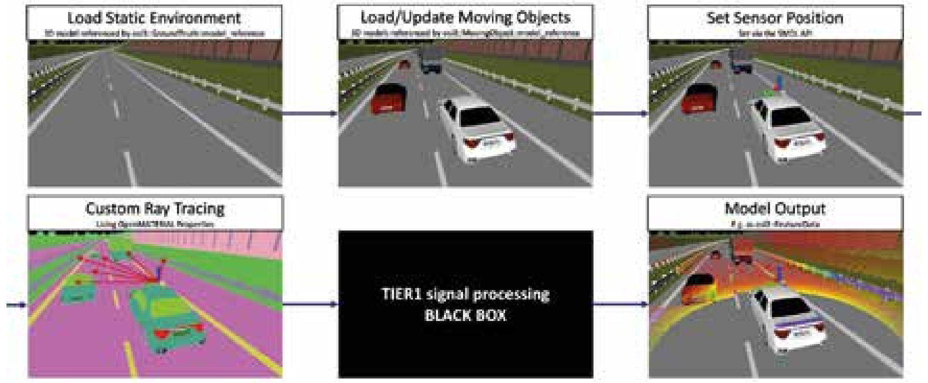
- **Scenario:** Description of the moving entities of a test case in ASAM OpenSCENARIO format.
- **Scene:** Description of the road on which the dynamic entities move in ASAM OpenDRIVE format, optionally enhanced with ASAM OpenCRG for detailed road surface characteristics.
- **3D Assets:** 3D geometry of the stationary environment and moving objects, with assigned physical material properties for different sensor modalities.

A scenario player reads the ASAM OpenSCENARIO and ASAM OpenDRIVE files to playback the scenario. At each simulation time step, it sends an ASAM OSI SensorView message to the sensor model(s). The sensor models then send an ASAM OSI SensorData message to the downstream algorithms, such as sensor fusion and object tracking. Optionally, the simulation loop can be closed with further modules for behavior planning, actuator control, and vehicle dynamics simulation.

Let's delve deeper into the inner workings of the sensor model and explore how ASAM OSI and ASAM OpenMATERIAL seamlessly integrate. Fig. 2 illustrates the process of constructing the 3D environment, casting rays into the virtual scene, and determining the virtual sensor output. First, the stationary environment is loaded. The input OSI message contains a so-called model reference in the ground truth data pointing to a 3D model file of the static environment. Moving objects in the ASAM OSI input also include individual model references, pointing to 3D model files in ASAM OpenMATERIAL format. These objects are positioned according to the position and orientation data provided in the OSI ground truth. The model references for both the environment and the moving objects can be defined in ASAM OpenSCENARIO to have one single source of truth. Additionally, the OSI data can specify a sensor mounting position on the ego vehicle. From this point, a custom ray tracing process is initiated, utilizing wavelength-dependent reflection properties stored in ASAM OpenMATERIAL files. This approach enables the simulation of various sensor technologies, including radar, lidar, camera, and ultrasonic sensors. Sensor-specific signal processing then calculates the actual sensor detections from the ray tracing results and outputs them in an ASAM OSI SensorData message.

The level of detail in the environment can be further enhanced by utilizing additional information from the ASAM OSI ground truth data, such as wheel angles and wheel rotation, to dynamically adjust the wheel positions and orientation of the simulated vehicles. Furthermore, the skeleton structure of pedestrians can be used to animate their movements within the scene, adding another layer of realism to the simulation.

Fig. 3 depicts the co-simulation of the open-source scenario player esmini with a Persival lidar model, utilizing the ASAM OpenX standards. The visualization on the right shows the 3D environment that is built up in the model using ASAM OSI and ASAM OpenMATERIAL.



Source: Persival GmbH

Fig. 2: Example sensor simulation process using ASAM OpenX standards

KEY BENEFITS

1. Seamless Integration

The ASAM OpenX standards enable co-simulation of all kinds of models. For sensor simulation, they enable the use of detailed 3D environments and advanced ray tracing within a single functional mockup unit (FMU). This allows for seamless integration across various simulation tools without the need for custom frameworks or interfaces.

2. Reduced Effort for Sensor Modeling and Model Validation

With the potential to plug the sensor models into any standard-compliant co-simulation tool chain, combining it with all available simulation tools, the effort for modeling and model validation only must be performed once. This saves a lot of time and costs, as only one API needs to be used. Integration effort is eliminated almost completely.

3. Superior Model Fidelity

Because sensor models can be individually packaged and be connected with standardized interfaces, they can be validated independently from the rest of the tools. Saving time for developing the models against several APIs and validating them for each of them enables superior model fidelity and facilitates efficient development and testing processes, while keeping development efforts small.

4. Versatility in Sensor Technology Simulation:

The combination of ASAM OSI and ASAM OpenMATERIAL enables the simulation of various sensor technologies, including radar, lidar, camera, and ultrasonic sensors. ASAM OSI SensorData can incorporate the output of these different sensor technologies, while ASAM OpenMATERIAL provides wavelength-dependent material properties to ensure accurate simulation.

Fig. 3: Co-simulation of esmini and a Persival lidar model using ASAM OSI and ASAM OpenMATERIAL

PMSF IT Consulting

ASAM OSI and ASAM MDF as measurement data exchange formats for data-driven sensor model development and validation

Featured Standards:

ASAM OSI, ASAM MDF

Authors:
Thomas Sedlmayer,
System Architect Sensor Simulation,
PMSF IT Consulting
Pierre R. Mai,
CEO,
PMSF IT Consulting

SUMMARY

Increasing complexity of automotive software and hardware solutions, collaboration and traceability along growing supply chains make efficient data exchange between stakeholders and subsequent tool integration increasingly challenging, yet they are substantial requirements for comprehensive validation of automated driving functions.

Development and validation of sensors and sensor models used for systems such as ALKS (Automated Lane-Keeping Systems) involve acquisition, inspection, annotation, exchange, and processing of real and synthetic sensor data: For simulation-based testing the similarity between real sensor output and sensor model output needs to be assessed. Hence, the availability of measurement data of the device-under-test and corresponding aligned ground truth reference data is essential for a data-driven validation method.

Even where the contents of sensor data are comparable across sensor technologies and manufacturers, the diversity of sensor interfaces, measurement setups and corresponding measurement data formats restrains efficient workflows in multi-stakeholder environments. ASAM OSI and ASAM MDF provide standardized links between simulation and real measurement data for use cases like sensor model validation. Simulation tool compatibility, data reusability and test case replication are only a few benefits that come along with using ASAM OSI as a measurement data exchange format for sensor data. This can be combined with ASAM MDF for more encompassing initial raw data capture, and as a container for combined data streams.

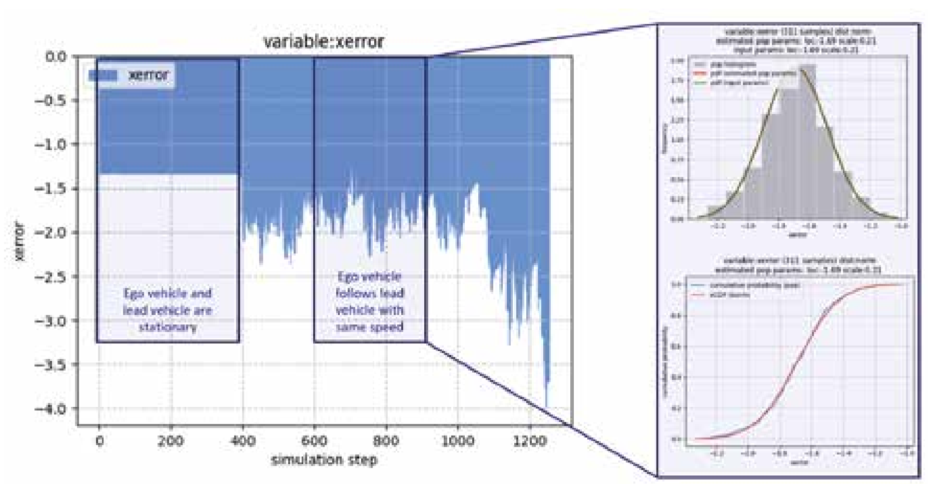
APPLICATION STORY

As part of ALKS testing and validation, the development of a data-driven sensor model of a Continental long-range radar sensor aims to move a major share of testing activities into the virtual world without the need for complex and in-depth modeling of the underlying technology. The use of such sensor models for virtual testing requires constructive development and validation approaches.

The specification of common scenarios for the respective use case defines the scope of the sensor model and forms the basis for data acquisition. Situations like lane change or brake maneuvers on multi-lane roads like the German Autobahn pose an exemplary selection of scenarios for the ALKS use case. Test vehicles equipped with the sensor-under-test capture the specified scenarios under real-world conditions.

"Development activities in the area of Automated Driving (AD) require the most seamless and efficient collaboration between the stakeholders involved. Standardization makes a fundamental contribution to creating a suitable ecosystem. ASAM OSI supports us as Tier-1 in collaborating with our customers and development partners."

RAINER AUE,
System Architect,
ADC Automotive Distance Systems GmbH



Section-based analysis of measurement data (e.g. target vehicle dimension error) for sensor model development.

The determination of measurement errors and deviations requires corresponding ground truth information. Vehicle-mounted reference sensors record the surrounding environment, while on-board systems and equipped GNSS receivers capture the behavior of the test vehicle. Reference data acquisition can also be supported by resources such as test bed infrastructure, drones, or meteorological stations. However, this variety of data sources entails a corresponding variety of setup- and manufacturer-specific interfaces and data formats. The adaptation of tools to specific data sources is time-consuming and not scalable to larger and wider validation landscapes.

ASAM OSI provides interfaces for both ground truth and sensor data for distributed simulation of automated driving functions. We found that these interfaces can also be used as a standardized exchange format for real measurement data between stakeholders like data providers, sensor model developers and sensor model consumers for development and validation purposes.

Data-driven sensor model development: The availability of suitable sensor data and ground truth traces is the starting point for a data-driven sensor modeling approach. To get an understanding of the actual sensor behavior, a subset of the collected sensor output is statistically compared to the reference data. Besides technological fundamentals and partial insights into the sensor's hardware and software design (grey box approach), statistical findings provide the basis for sensor model development and tuning. Homogeneous sections of scenario sequences (e.g., containing consistent behavior or explicit actions) are isolated and analyzed separately. Section-dependent parameters (e.g., distance or alignment between ego and target vehicle, vehicle speed, vehicle acceleration or deceleration, weather conditions) and corresponding extracted error distributions establish a sensor model with well-defined scope of application. Due to the data-driven approach the model is inherently reflecting a specified range of the modeled sensor's behavior.

Sensor model validation: To meet quality requirements, validation of the similarity between sensor model output and another subset of collected real sensor output (not used in the modeling process) is necessary. Defining and computing appropriate KPIs (Key Performance Indicators) formalizes the required level of similarity of target detection properties between sensor and sensor model. The choice of KPIs depends on the intended simulation use case. An example is the Kolmogorov-Smirnov test, which quantifies the distance between a model CDF (cumulative distribution function) and an empirical CDF. Depending on the variety of observed true sensor behavior for apparently equivalent situations, the acceptance range of such KPIs can vary accordingly: Widely varying sensor behavior entails broader acceptable KPI ranges as an automated driving function must take such variations into account in its design.
The exchange of sensor models entails further validation steps to ensure that the model still behaves appropriately after customer integration. Using ASAM OSI trace files generated by the sensor model provider as a baseline, the customer can re-validate proper functionality of the sensor model in their own simulation environment. Similarly, use-in-range validation allows a customer to validate that the use of a model in a closed-loop simulation is kept within its intended range of operation. Finally, sensor model trace files generated from a closed-loop simulation can be compared against real sensor data to ensure that the testing activities cover the range of realistic data.

Challenges and contributions: ASAM OSI provides the basis for cost-effective multi-stakeholder validation processes by enabling data exchange and smooth processing of measurement and simulation data. As ASAM OSI was not initially oriented towards measurement data, we encountered the need for certain metadata definitions to document measurement data information such as content description, sensor configuration or software details, localization data, or corresponding reference or raw data. We started to tackle these challenges by identifying necessary metadata for storing and exchanging ASAM OSI measurement trace files. Also, a new field describing a global system time was introduced to ASAM OSI SensorData as an outcome of our work. The timestamp can be used to transmit or store an internal time of the source component of the respective sensor data which is also suitable for other use cases.

The use of ASAM OSI in combination with ASAM MDF helps in maintaining consistency between raw data streams, multiple derived OSI traces, and related metadata. In future, a best practice guide for the combined use of ASAM OSI and ASAM MDF should enable streamlined broader use of these two ASAM standards.

Ground truth generation with PMSF DroneTracker from aerial drone footage.

Integration of real measurement data in PMSF OSI viewer using ASAM OSI trace files.

University of Warwick

Enhancing scenario searchability with ASAM OpenLABEL

Featured Standards:

ASAM OpenSCENARIO XML, ASAM OpenDRIVE, ASAM OpenLABEL

Author:
Prof. Siddartha Khastgir's Safe Autonomy Team, University of Warwick

SUMMARY

Safety Pool™ maintains a large database of scenarios in various formats including ASAM OpenSCENARIO XML, ASAM OpenDRIVE, and BSI Flex 1889. The challenge lies in efficiently searching this diverse database for relevant scenarios. To address this, we adopted the ASAM OpenLABEL standard to label our scenarios. It's features, such as tag boundaries and support for multiple ontologies, enable users of Safety Pool™ to create custom labels according to their requirements and apply these labels to scenarios. Additionally, we implemented an automation to analyse scenarios and automatically generate scenario Operational Design Domain (ODD) and behaviour tags using this labelling standard. The structured and standardized approach provided by ASAM OpenLABEL has made our database more organized and searchable, significantly improving workflow efficiency for Safety Pool™.

APPLICATION STORY

Safety Pool™, a repository of diverse scenarios (including ASAM OpenSCENARIO XML, ASAM OpenDRIVE, and BSI Flex 1889 formats), faces the critical challenge of efficiently searching this extensive database. The motivation stems from the need to promptly locate relevant scenarios for a variety of stakeholder. The database's size can make it difficult to quickly locate and utilize the scenarios needed by users of Safety Pool™.

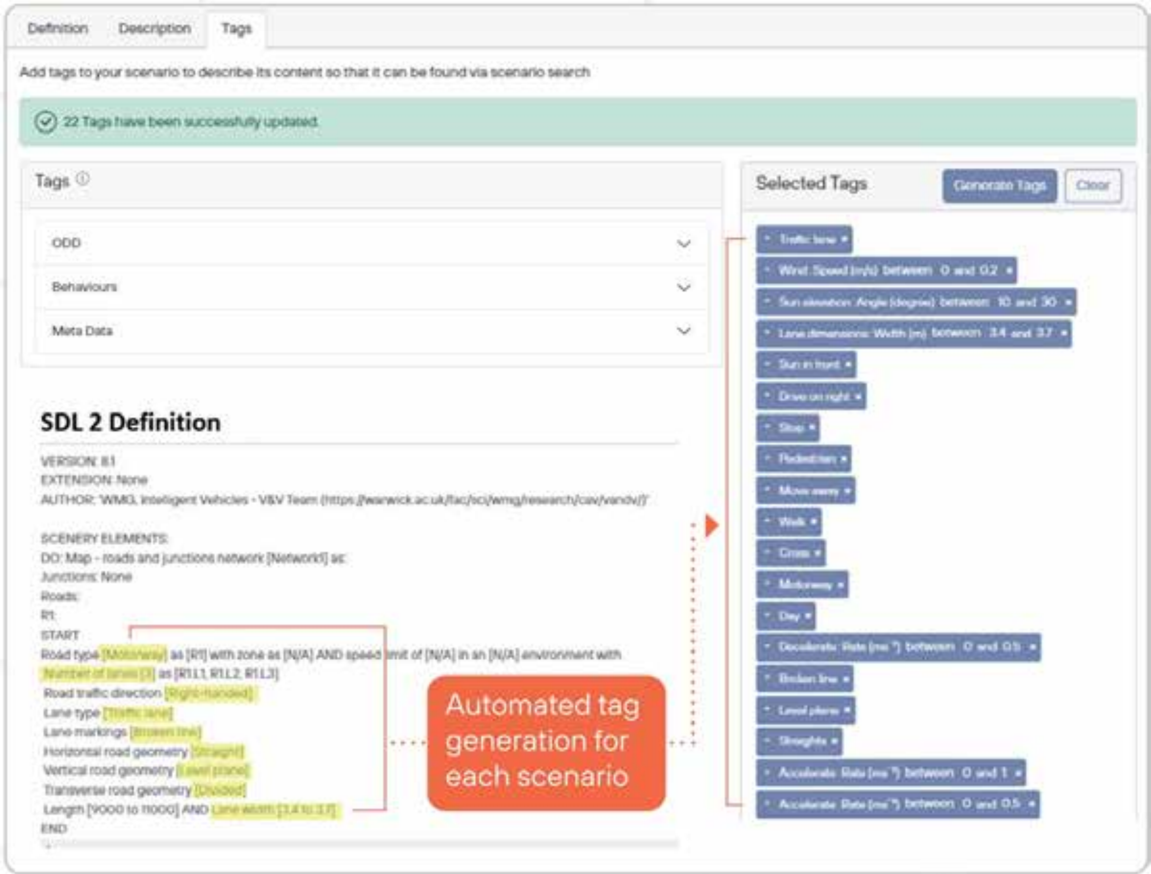
To address this challenge, we adopted the ASAM OpenLABEL standard. The focus is on leveraging existing standards and initiatives, particularly addressing the database operational mechanism for scenarios. This strategic move allowed for structured scenario labelling, making the database more organized and searchable. Here's how it worked:

- **Automation for ODD and Behaviour Tags:** Safety Pool™ implemented an automation process. It analysed scenarios and automatically generated Operational Design Domain (ODD) and behaviour tags based on the ASAM OpenLABEL standard. This streamlined the tagging process and ensured consistent labelling across scenarios.
- **Use of ASAM OpenLABEL Features:** The standard's features, including tag boundaries and support for multiple ontologies, played a pivotal role.

  – **Tag Boundaries:** These boundaries define the relevant domain of tags for scenario labelling. By explicitly indicating which tags label a scenario (and implicitly which tags are absent), Safety Pool™ achieved clarity in scenario representation.

  – **Multiple Ontology Support:** The ability to extend the tag vocabulary to multiple ontologies enabled users to create custom labels tailored to their requirements. The support for multiple ontologies enabled users of Safety Pool™ to create custom labels in accordance with their requirements and use these labels to label scenarios.

One of the core challenges encountered during implementation was the ability to support custom ontologies. As the number of scenarios increases, collaboration among industrial and research stakeholders drives demand for an efficient scenario cataloguing and sharing mechanism. Organizations often need to associate custom metadata with scenarios that don't fit existing standard domain models (e.g., the ASAM OpenLABEL Ontology). However, using non-standard extensions can limit other users' ability to interpret associated metadata. Enabling the use of multiple ontologies demanded adaptability. Adopting the ASAM Open LABEL tagging standard facilitated this, enabling labels belonging to multiple ontologies to be used consistently across scenarios.



Furthermore, the language-agnostic nature of ASAM OpenLABEL enabled us to support using the same framework for labelling across multiple scenario languages.

The adoption of ASAM OpenLABEL yielded substantial benefits. Efficient scenario searches improved productivity. Safety Pool™ could swiftly identify relevant scenarios, saving time and effort. The structured approach enhanced scenario organization. Safety Pool™ showcased expertise in applying ASAM standards. And finally, the solution's flexibility allowed for future extensions and support for new labelling ontologies. Overall, the use of ASAM standards not only streamlined our processes but also showcased our expertise in the application of these standards.

University of Warwick

Harnessing the power of ASAM OpenSCENARIO and ASAM OpenDRIVE for enhanced scenario simulation

Featured Standards:

ASAM OpenSCENARIO XML, ASAM OpenDRIVE

Author:

Prof. Siddartha Khastgir's Safe Autonomy Team, University of Warwick

SUMMARY

At Safety Pool™, we are entrusted with a diverse collection of scenarios that we aim to simulate for testing and validation purposes. Scenarios describe the situations an Automated Driving System (ADS) may encounter during its operation. ASAM scenario format standards, ASAM OpenSCENARIO XML and ASAM OpenDRIVE formats, became the cornerstones of off-the-shelf simulation tools, such as esmini. These ASAM standards form a universal language for describing intricate details of road junction networks, dynamics of road actors, and environmental conditions.

APPLICATION STORY

Safety Pool™ manages a diverse collection of scenarios intended for testing and validation. These scenarios need simulation, but they exist in various formats. Scenarios describe the situations an Automated Driving System (ADS) may encounter during its operation. The specification of a scenario includes specifying scenery elements (road/junction layout), the environmental elements (weather and lighting) and dynamic elements (other agents and their activities). Unambiguous specification of a scenario requires the use of formal languages. ASAM scenario format standards—specifically, ASAM OpenSCENARIO XML and ASAM OpenDRIVE—are scenario description languages. They serve as a universal language set for describing intricate details of road networks, actor dynamics, and environmental conditions.

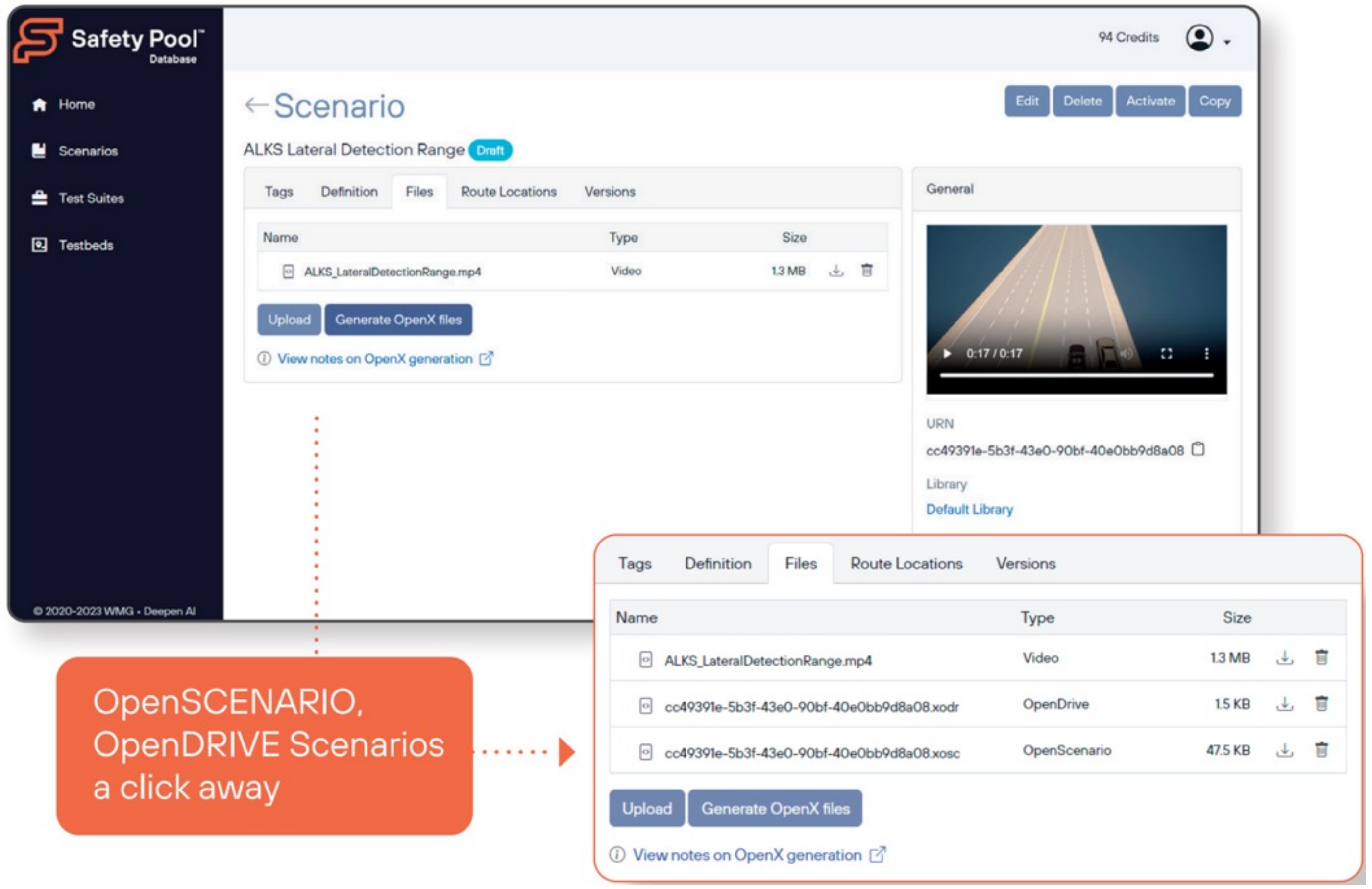
To bridge this compatibility gap, we embarked on a journey to translate our scenarios, that were in our open logical scenario format WMG SDL Level 2 (WMG-SDL), into ASAM OpenSCENARIO XML and ASAM OpenDRIVE formats. The ASAM standards were not just tools; they were the catalysts that streamlined our translation process. They offered a clear, standardized format that ensured our translated scenarios retained their original complexity and intent.

Translating WMG-SDL scenarios into ASAM OpenSCENARIO and ASAM OpenDRIVE formats posed several challenges, which we systematically addressed. First, while WMG-SDL combines the specification of all scenario elements (scenery, dynamics and environment), these are separated as follows: with scenery specified in ASAM OpenDRIVE and dynamics and environment specified in ASAM OpenSCENARIO. Converting WMG-SDL scenery into ASAM OpenDRIVE involves a geometrical transformation. While WMG-SDL specifies scenery in relative declarative terms, functional terms (e.g., road segments with varying lengths and curvature), this had to be transformed into concrete coordinates (x-y-z and heading angles) for each road segment and junction in ASAM OpenDRIVE.

Algorithmically, we encountered three core challenges in translating WMG-SDL to ASAM OpenSCENARIO. First, handling synchronous and asynchronous actions required overcoming differences in specification structures. Second, abstract manoeuvres in WMG-SDL needed translation into sub-manoeuvres in ASAM OpenSCENARIO. Third, indexing roads and lanes posed challenges for implementing vehicle turning manoeuvres.

Our translation strategies varied. Where possible, we provided exact translations. However, for complex components (such as scenery and dynamics), lacking a one-to-one mapping between syntactic elements, we used semantic translations. This approach involved using ASAM OpenSCENARIO / ASAM OpenDRIVE syntax components to build manoeuvre dynamics and roads/junctions, ensuring uniform scenario translation.

In summary, our approach ensures consistency, overcomes challenges, and facilitates the translation of WMG-SDL scenarios into ASAM OpenSCENARIO and ASAM OpenDRIVE formats.



The standards ASAM OpenSCENARIO and ASAM OpenDRIVE served as a common language, enabling us to create a seamless bridge between our original scenarios and the simulation environment. This was a critical step as it unlocked the potential to use off-the-shelf simulators, which only accepted scenarios in specific formats.

It's worth noting that ASAM standards are the cornerstone of scenarios at Safety Pool™. Our scenarios are not just compatible with a wide array of tools and systems supporting these standards, but they also contribute to a larger ecosystem of ASAM-compliant scenarios, thereby enhancing their interoperability and usability.

The adoption of ASAM standards transformed our simulation capabilities. The translated scenarios could now be simulated using esmini and other simulation platforms that support ASAM standards. This not only amplified our ability to test and validate our scenarios but also revolutionized our overall workflow. The use of ASAM standards in this process helped us surmount the challenge of scenario simulation, and it underscored our company's expertise in applying these standards.

VIRTUAL VEHICLE Research GmbH

Simulation of material-dependent LIDAR reflection intensities within Carla based on ASAM OpenDRIVE and ASAM OpenSCENARIO

Featured Standards:

ASAM OpenDRIVE, ASAM OpenSCENARIO, ASAM OpenMATERIAL

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SUMMARY

Challenge: With the AI4CSM project consortium, Virtual Vehicle is working on a prototype for an autonomous robotaxi to pick up customers and drive them to a selected destination to enable smart connected shared mobility for urban areas. To test and train the software components – our perception and intelligence modules – we use a simulator (Carla) with a self-built digital twin of the city of Amberg (Bavaria). One of the main goals is to generate synthetic annotation data to train our AI-based perception methods.

Description: State-of-the-art LIDAR sensors provide high resolution 3D and reflectivity data. The latter is very powerful for lane and object detection (reflecting car plates or traffic signs). In order to simulate the reflection data of a LIDAR sensor it is essential to incorporate material properties in the object structure. After first attempts to assess material properties in Carla, we joined the ASAM OpenMATERIAL project to bring material standards in perception sensor simulation to the next level.

Key benefits: With a standardized material and standardized 3D model structure, it is possible to collect and share material information, suitable for sensor simulation especially in the field of autonomous driving.

With a large and detailed database, it would be possible to find the proper material (or limit to a few possible ones) with a few surface material properties.

INITIAL SITUATION

Within our project we need a digital twin of perception sensors in order to test and train our AD functions. For the creation of the digital twin of Amberg we received ASAM OpenDRIVE files of the local street network from OTH (Ostbayrische Technische Hochschule Amberg-Weiden) and designed different scenarios with ASAM OpenSCENARIO to fulfill the project goals of testing critical urban scenarios like overtaking vulnerable road users or stopping in from of a crosswalk.

Especially for training our perception algorithms we need labelled and accurate LIDAR sensor data, a so called semantic pointcloud. The Carla simulator enables the creation of such sensor data synthetically by using a semantic LIDAR sensor with approximately 28 semantic categories.

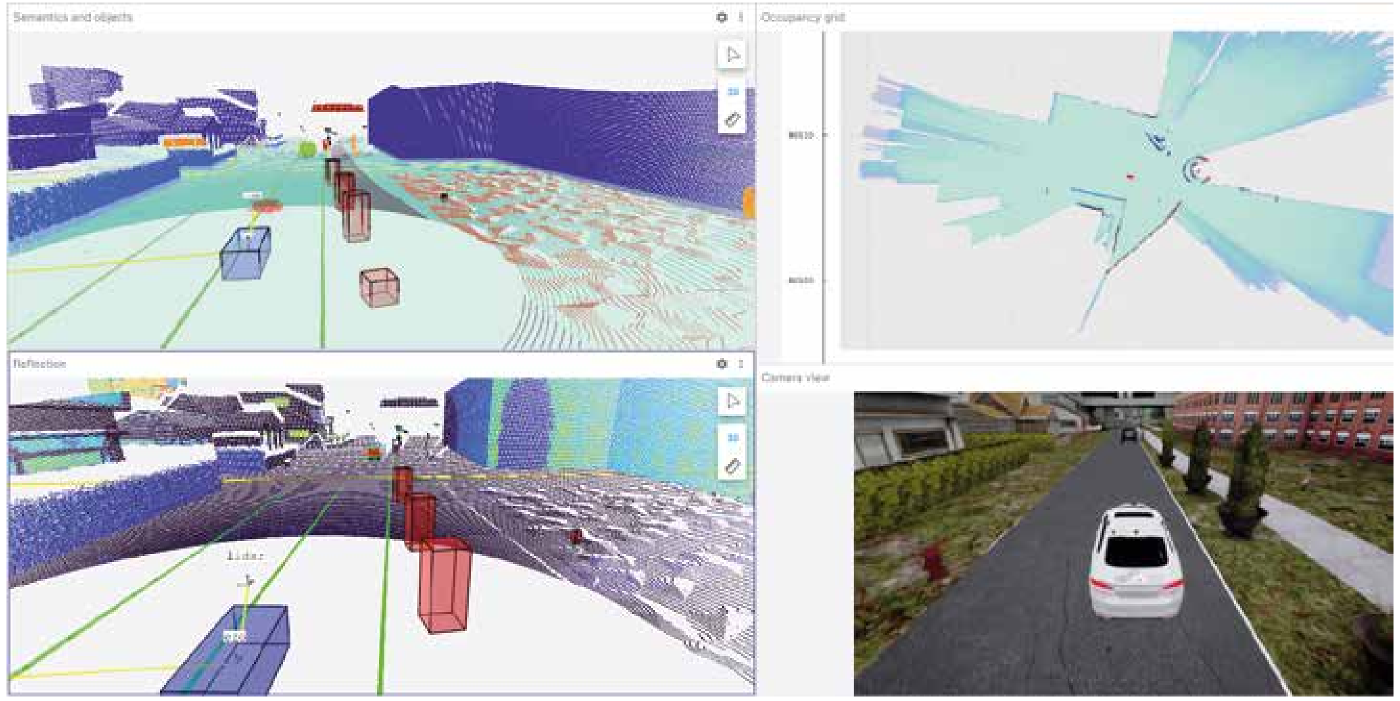
Currently, the semantic LIDAR sensor includes

- X: position in meter
- Y: position in meter
- Z: position in meter
- cosine of the incident angle
- Unsigned int containing the instance index of the object hit
- Unsigned int containing the semantic tag of the object hit

In version 0.9.14 of Carla, the camera sensor got a new function to collect metallic, specular, and roughness values for each pixel of the camera picture. This material function could be used to enhance the synthetic pointcloud by the reflectivity which is a very valuable channel for semantic segmentation and object detection. Unfortunately, this pipeline broke in newer versions of Carla.

Recognizing the need to properly simulate sensor data, we joined the initiative ASAM OpenMATERIAL to work on a future standard, that will on the one hand form the foundation of physical sensor simulation by providing the relevant material properties and on the other hand an easy interface for 3D artists to assign the right material class to 3D objects.

We truly hope that this material standard will boost also the implementation within 3D simulation tools to enable high fidelity physical perception sensor simulation.



Carla Simulation based on ASAM OpenDRIVE and ASAM OpenSCENARIO including material dependent LIDAR reflection intensities

The standard focusses on physical material properties and on the other hand on geometric assignment to objects compatible with different file formats.

BUSINESS BENEFITS

Currently there are only a few good solutions for sensor simulations that incorporate the physical material properties of objects. Especially for autonomous driving there is huge potential for perception tasks to have more realistic sensor models for training and testing perception algorithms.
A standard for materials and their physical description properly linked with 3D objects would enhance simulation development significantly.

The material data in a simulation is not only important to simulate LIDAR or perception sensor data, but also for several kind of applications (for example, calculating wireless data transmission range).

"ASAM standards will be the common language to make autonomous driving possible."

GERHARD DORN,
Senior Scientist,
VIRTUAL VEHICLE Research GmbH

Reference: https://www.ai4csm.eu

emotive GmbH & Co. KG

Better together:
How OTX connects standards

Featured Standard:
ASAM OTX Extensions

Author:
Dr. Jörg Supke,
emotive GmbH & Co. KG

SUMMARY

OTX is a domain-specific programming language (DSL) for the process-safe description of exchangeable and executable test logic within the automotive industry. OTX has established itself as a platform-independent description of diagnostic test logic in the automotive industry. Thanks to its standard-compliant expandability to include any number of functions, OTX is able to connect different, previously separate standards from a wide range of varying areas. This article shows the potential of OTX in connecting various ASAM standards, e.g. ASAM XIL, ASAM ODS and the ASAM OpenX standards for testing in the field of autonomous driving.

1. Introduction

We are experiencing a radical change today – nothing is as constant as change. The increasingly demanding customer requirements and the increasing global competition are leading to growing complexity and thus to permanent pressure on all operational procedures and processes. Therefore, mastering complexity is one of the key challenges of today. In the long term, this is not a task for one person. It affects everyone. When it comes to collaboration between many people, standardization is unavoidable. To be successful in the long term, standardized processes are needed. This results in greater efficiency, reduced costs and improved product quality, which ultimately increases competitiveness and market opportunities.

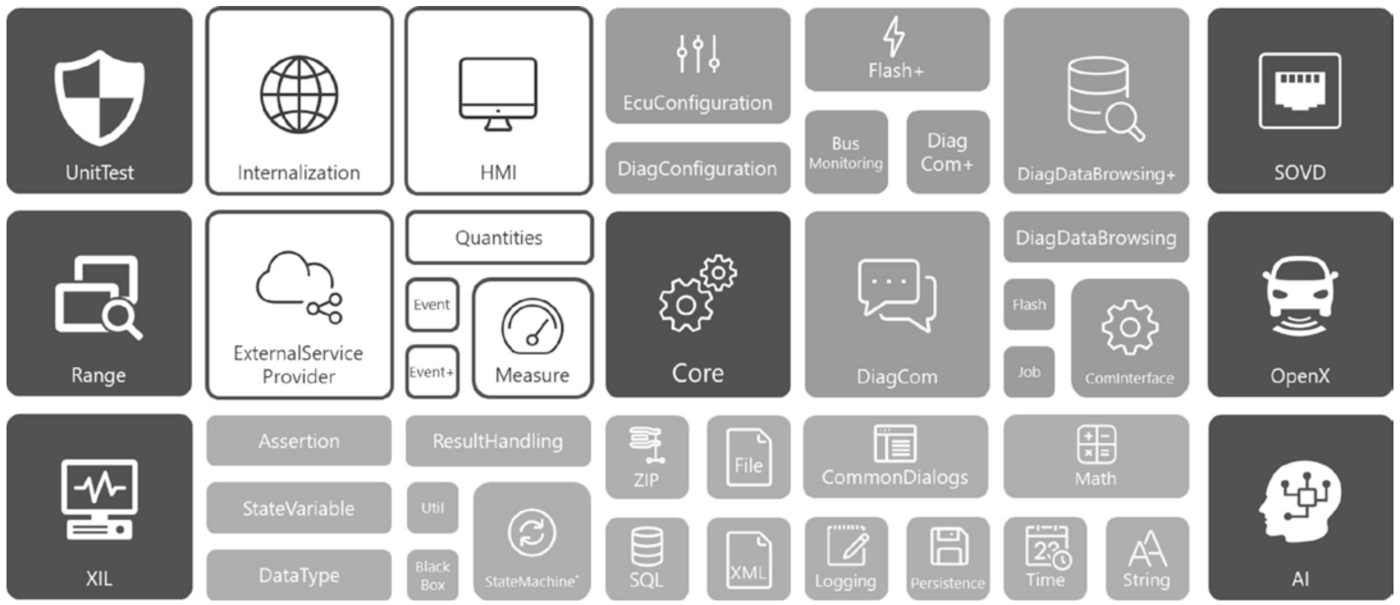
To achieve this goal, the OTX standard has been established in vehicle diagnostics at automobile manufacturers in recent years. The practical introduction has shown that OTX is primarily a process and integration issue. OTX enables consistently standardized processes from specification to execution of test logic on any target system.

2. What is OTX?

OTX according to ISO 13209 stands for „Open Test sequence eXchange" and is a domain-specific programming language (DSL) for the process-safe description of exchangeable and executable test logic. Test sequences can be created graphically or using a code editor and at the same time described in such detail that the same test logic can be executed barrier-free in any different target environment. The standard has the necessary maturity and is comprehensive enough to replace existing solutions in development, production and the workshop. The possible uses of OTX range from the description of simple functional tests in development to commissioning processes in production to completely generic tester applications with guided troubleshooting in customer service. OTX is open, stable, platform and technology neutral. It is continuously further developed under the roof of ASAM. In summary, it can be said that OTX can ensure that the same unchanged test logic can be executed in any target system at any time and always produces the same results.

OTX is Turing-complete. This means it can calculate any computable function. It consists of a stand-alone executable core, see Fig. 1. The data model of the programming language and all extension points are defined within the core. Each OTX extension extends the core with new domain-specific functions. First for the area of vehicle diagnostics, then for communication with external systems and for many other functions that are required for a complete programming language.

Fig. 1: OTX Extensions



3. OTX Extensibility

OTX can be extended with new OTX extensions in accordance with the standard. Eleven extension points are defined in the core data model for this purpose. These extension points can extend OTX with any new language elements. This ranges from new activities, data types and declarations to new types of procedures or structural elements. This means that OTX can bring together different, previously separate standards under one roof like hardly any other standard. For example, to use the ASAM SOVD standard within OTX, one can simply standardize a new OTX extension for ASAM SOVD. A current, practical example of this is the new planned standard ASAM TestSpecification.

4. OTX and ASAM TestSpecification

The ASAM TestSpecification project aims to develop a standard for the general specification of interchangeable tests. Focus is placed on the interaction of various ASAM standards such as ASAM XIL, ASAM ODS or the ASAM OpenX standards for testing in the field of autonomous driving. To connect these standards, OTX was evaluated and selected as the basic standard. For ASAM TestSpecification, OTX is being expanded to include new extensions for test description and access to ASAM XIL. Likewise, this could be done for ASAM OpenSCENARIO as well.

Code example for ASAM TestSpecification:

```
/// Imports
import OtsPackage1.OTS_Requirements as Req1;

/// Global Declarations

[Requirements({Req1::Req_A})]
[TestCase(buttonState = ButtonStates.Pressed, expected systemState =
OTS.System.States.ActiveControl)]
[TestCase(buttonState = ButtonStates.Hover, expected systemState =
OTS.System.States.ActiveControl)]
TestStepProcedure Test1(in OTS.ButtonState buttonState, out OTS.System.State systemState)
{
  /// Local Declarations

  // The PreCondition must be met before the TestSteps are executed
  precondition
  {
    /// Flow
  }
  // The expectation is a BooleanTerm
  expectation
  (
    /// Condition as BooleanTerm
  )
  // An arbitrary number of observers (watchdog) can be started
  observer : Observer1
  {
    /// Flow
  }
  // The test steps contains the logic of the test
  teststeps
  {
    teststep TestStep1
    {
      /// Flow
    }
    teststep TestStep2
    {
      /// Flow
    }
  }
  postcondition
  {
    /// Flow
  }
  // The expectation is a BooleanTerm
  expectation
  (
    /// Condition as BooleanTerm
  )
}
```

5. Benchmarking OTX

When considering the significant effort required to develop a new programming language, one might reasonably ask: Why do we need a new language? Aren't there already enough existing solutions? We have explored these questions and aim to derive the answer by comparing OTX and C++ in terms of performance, memory usage, integrability, and process acceptance. To give a clear answer upfront: yes, we do need this new programming language! Instead of C++, one could fundamentally choose another language like .NET C# or Python. However, the results would be comparable. We are using C++ because we expect the best results in terms of performance and memory usage for deployment in embedded systems. For the examination of OTX, the EMOTIVE OTX Runtime is used.

5.1 Process Acceptance

OTX was developed as an XML format for cross-domain integration into existing processes. OTX supports the entire development process of diagnostic test logic, starting from the specification level by component managers without programming knowledge, to execution on various target systems. The specification is created in OTX and transported with the test logic as a single source. Afterward, an OTX programmer implements the test logic graphically or in the OTL code editor, without altering the specification. At this stage, the test logic should be secured through unit and integration tests using the OTX UnitTest exemotive GmbH & Co. KG

tension, as shown in Fig. 4. The next step is to adapt the platform-independent test logic to a specific target environment and distribute it, for example, through OTX mapping. The final step is execution on any target system. Results can be logged and returned, and runtime behavior can be analyzed directly on the target system through OTX profiling.

From a user's perspective, OTX integrates very well into the existing processes of an automotive manufacturer. This is also fundamentally possible with C++; all necessary tools are available, but the required interfaces would need to be defined and implemented. This is precisely what OTX already provides as an ISO standard. Therefore, I would rate the process acceptance of C++ as satisfactory.

5.2 Integrability

In this context, integrability refers to the ability to integrate into various technical systems without side effects and with minimal effort. The EMOTIVE OTX Runtime was specifically designed for this purpose. The OTX Runtime itself is written in native C++ and is available for Windows and various Linux distributions in both 32- and 64-bit versions. It offers APIs for C++, .NET, and Java, facilitating integration into existing applications. The execution of OTX test logic can occur either within the application's process or encapsulated in a separate process. For communication with external systems, the OTX Runtime provides various interfaces, known as CustomImplementations, through which any function within a proprietary test system can be called directly from OTX, such as turning the ignition on or off. This makes the OTX Runtime highly integrable.

While the same is technically possible with C++, the effort required is disproportionately higher compared to OTX. Therefore, I would rate the integrability, like the process acceptance, as satisfactory.

5.3 Performance and Memory Usage

o make valid statements about performance and memory usage, a typical OTX application was implemented natively in C++ directly on an MVCI server and once in OTX. The chosen typical application was the generic reading of vehicle identification (FAP = Vehicle Analysis Protocol). Two functionally identical routines were programmed, one in OTX and one in C++.

The process parses ODX data through database access to an MVCI server and reads information from the ECU using several diagnostic services. The data retrieval occurs over a fixed number of services simultaneously for five ECUs in parallel, and the collected information is then structured and written into a file. Communication is established via CAN and a simulated D-PDU API. It should be noted that the objective here is to perform a quick performance comparison, not to fully determine a vehicle analysis protocol.

For measurement purposes, the process is executed multiple times. The execution duration, average CPU load during execution, and average memory usage during execution are measured. Fig. 2 compares the measurement results for native C++ and OTX. Lower values indicate better performance.

The measurements show that native C++ achieves better results in all evaluated metrics. This aligns with the expected performance for C++. There is virtually no room for further optimization; in other words, C++ serves as the performance benchmark. Although the OTX Runtime itself is written in C++, it incurs some overhead to ensure process acceptance and integrability. In terms of execution duration, the OTX Runtime is 20% slower; CPU load with OTX is about 30%, and memory usage with OTX is about 50 MB higher. In my view, the CPU load and memory usage values are within an

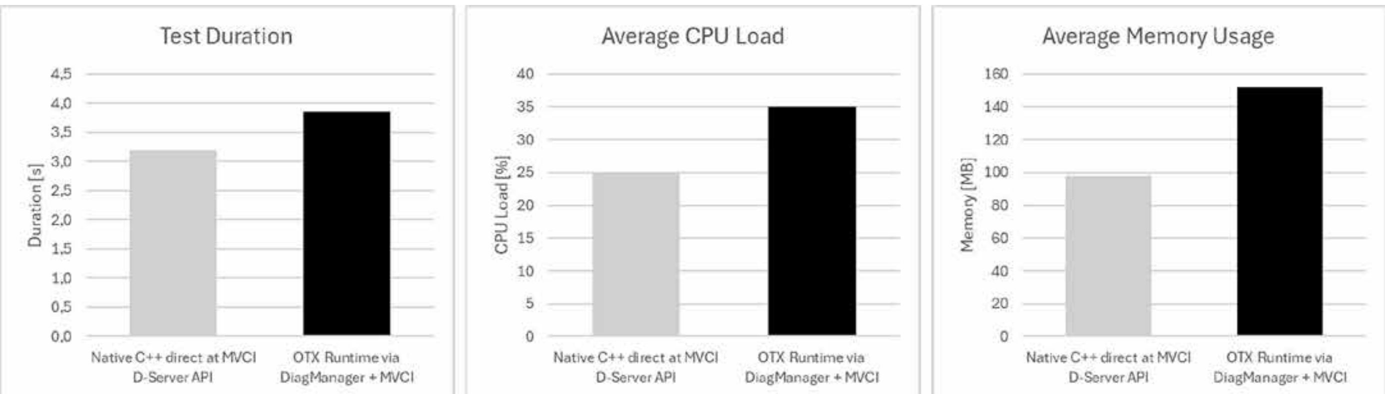


Fig. 2: Measurements for execution duration, CPU load, and memory usage

	Native C++	OTX Runtime
Process Acceptance	Satisfactory	Very Good
Integrability	Satisfactory	Very Good
Performance	Excellent	Very Good

Fig. 3: Comparison between Native C++ and the EMOTIVE OTX Runtime

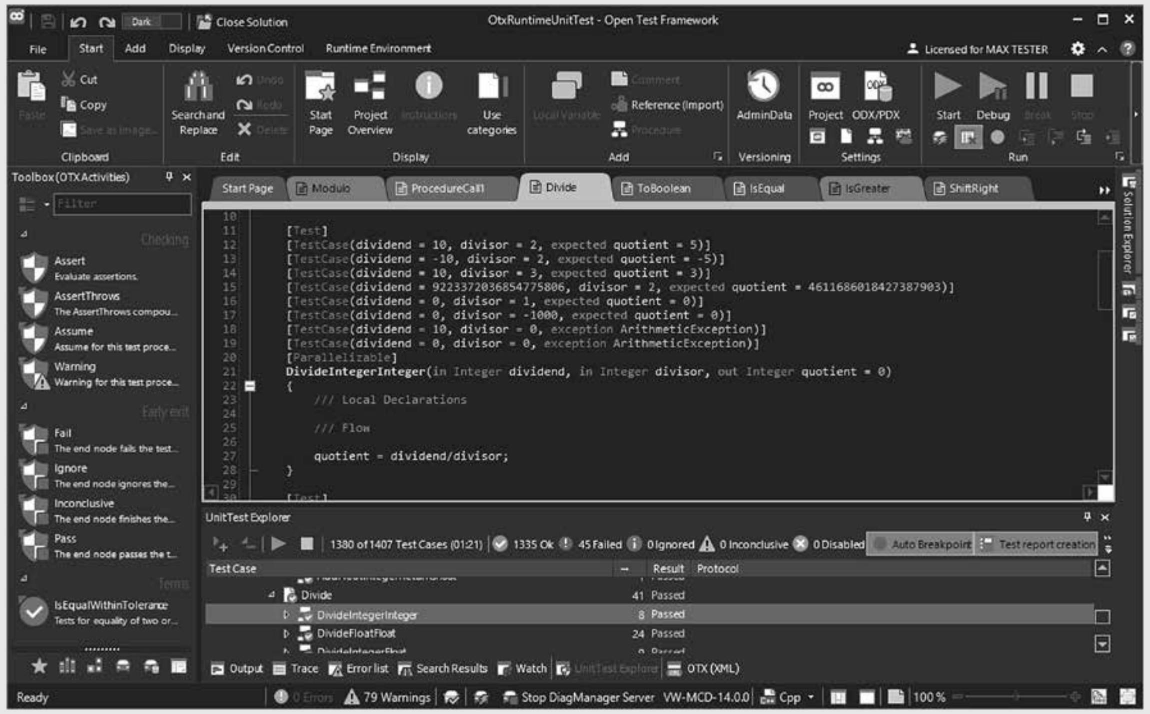


Fig. 4: Example OTX development environment (IDE) with Unit-Test Explorer

acceptable range, making execution duration the primary relevant metric for performance assessment. Thus, one could say that the EMOTIVE OTX Runtime is approximately 20% slower than native C++. I believe this is a very good result for OTX. Therefore, I would rate the performance of C++ as excellent and the performance of OTX as very good.

5.4 Comparison

As expected, C++ excels in performance. The OTX Runtime, however, shines in process acceptance and integrability across various target systems, while still being performant enough to support all vehicle diagnostics use cases, including those for embedded systems (see Fig. 3).

6. OTX Tool Support

Standards also offer numerous advantages to tool manufacturers, as they provide tool support required to tap the full potential of standards. For tool manufacturers, standards make market access easier and increase customer satisfaction. Tools based on standards are easier to scale to new customers. Existing resources can be invested in increasing product quality instead of supporting proprietary interfaces. This leads to greater innovation and investment security.

In recent years, a broad tool landscape has been established for the OTX standard. Through practical use by vehicle manufacturers, the tools have been tested and show to have the necessary maturity. Fig. 4 shows an example development environment for creating, editing, testing and executing OTX procedures, like a Visual Studio for OTX.

7. Conclusion

With consistent standards compliance from creation to execution, OTX is more capable than almost any other standard in the automotive environment of exchanging quality-assured test knowledge across process and tool boundaries and executing it under a wide range of environmental conditions. The harmonizing and integrative effect makes OTX a platform for connecting different, previously separate standards, even outside of vehicle diagnostics. OTX is used as the basic technology in the upcoming standard ASAM TestSpecification. OTX is powerful enough to map all use cases in the area of vehicle diagnostics, even in embedded systems.

MEMBERS

ASAM thrives on the collaboration of its members. These members not only bring additional expertise to standards development, but also expand the user base of the standards. Major tools on the market already rely on the use of ASAM standards.

ASAM MEMBERS

OEMs

- Audi
- BMW
- BRP
- CEER
- DAIMLER TRUCK
- JOHN DEERE
- Ford
- GEELY
- gm
- HINO
- HONDA The Power of Dreams
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- SUBARU
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- Volkswagen
- VOLVO – VOLVO Car Corporation
- VOLVO – Volvo Technology AB
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- YAMAHA

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- DENSO
- HATZ DIESEL
- FORVIA HELLA
- HEXAGON
- HUAWEI
- MARQUARDT
- NIRA DYNAMICS
- Qualcomm
- RIMAC TECHNOLOGY
- mtu A Rolls-Royce solution
- SCHAEFFLER
- SONY
- thyssenkrupp
- TTDC
- TRIUMPH
- VAIVA Safe Mobility
- ZF

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Ansys
ANTEMOTION
ANYVERSE
Apex.AI
Apicom
Applied Intuition
aptpod
areus
天安星控 Astrocontrol
astc
auto-com
AutoCore
AAI
中汽中心 数据
AVENYR
AVESREALITY
AVIN SYSTEMS
AVL
AVSIMULATION
AXER
b-plus
BeamNG
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cognata
ComfortUni
CSC
CRYSTAL INSTRUMENTS
CSM
deepen
DEMICON
德赛西威 DESAY SV AUTOMOTIVE
DEWESoft
diconium auto
digitalwerk
DNV
DSA
DSO
dSPACE
DTS INSIGHT
DUNASYS
e-SYNC
ESR LABS
eGLUE
embeddeers
emotive
eSoL
ESTECH
ETAS
EUtech Scientific Engineering
excelfore
excelfore
exida
FIVE
fka
foretellix
FunctionBay
FUTAVIS
GAFS
GAiLOGIC
GAIO TECHNOLOGY
GEMS
GLIWA
世冠科技
GRYFTEC Embedded Systems
fiedlerMPS
HBK
HEAD acoustics
HGL Dynamics
HighQSoft
HOERBIGER
HORIBA
HORIBA FuelCon
HYUNDAI AutoEver
I.C.M. Inc.

iAE
ASYS
iaV automotive engineering
imbus
imc
INCHRON

md
INNOSIMULATION
INTEMPORA
intive
INTREPID CONTROL SYSTEMS
IP Camp

IPETRONIK
IPG
ISYST
itimotor
itk ENGINEERING
IVEX

iVH
Ixxat
KAN Engineering
Karakun
KÜBRICH
KENOTOM

KEYSIGHT TECHNOLOGIES
KISTLER
Kithara
KLARIC
KOGNIC
KPIT

KS
KUNYI
KVASER Advancing connectivity
LAUTERBACH
LibroDuct
RT LINKS 灵思创奇

LIPOWSKY INDUSTRIE-ELEKTRONIK
Luxoft
m+p international
M2M craft
MAHA
MathWorks

McLaren Applied
measX Measurement System Experts
Mechanical Simulation
MEIDEN
Micro Technology
MicroNova Software and Systems

ModelingTech
MORAI
MOTEON
MXNAVI
MÜLLER-BBM VibroAkustik Systeme

南金研
NEXTY Electronics
NorCom
NTT DATA
OPAL-RT TECHNOLOGIES

OPVengineering
OTSL
PEAK SOLUTION
PEAK System
Persival

pico Technology
PIKETEC
PILOT Automotive
PLC2
plexim
pls Development Tools

PMSF IT Consulting
Polytec
technvil
PTV GROUP part of Umovity
RA CONSULTING
瑞风协同 RAINFE

RAWLAB
Razorcat
rd
Rhf REILHOFER KG
ReliaTec
rFpro

RIDECELL
roboGaze
SAIMO
H.-J. Schleißheimer
SCSK

Secondmind
SGE
SGS
SIBROS
SICOR ENGINEERING
SIEMENS

SIERRA CP ENGINEERING
SKYTECHNOLOGY
SODIUS WILLERT
optimized softing
Software Testing Solutions
SONATUS

Sontheim
SPARKS
speedgoat
STAR COOPERATION
STARMATA
STELVIO

ACADEMICS

PRODUCT OVERVIEW

The following overview highlights the widespread adoption of ASAM standards in the industry. Here, you can find products that seamlessly integrate into your tool chain.

For more information on ASAM-compliant products visit:
www.asam.net/members/product-directory

The information on the following pages is based on data provided by our members. ASAM assumes no responsibility for the correctness or completeness of this information.

MEASUREMENT & CALIBRATION

Company	Product	Tool / Service	ARTI	CDF	CMP	CPX	HMS	MCD-1 CCP	MCD-1 POD	MCD-1 XCP	MCD-2 CERP	MCD-2 MC	MDF	Others
A&D Company, Ltd.	A&D ORION	Tool						x		x				
	A&D Real-Time Platforms	Service						x		x				
	A&D Real-Time Software Development Environment	Tool										x		
Accurate Technologies Inc.	CANLab™ Network Analysis Software	Tool						x						
	CANary Interface Module	Tool						x		x				
	DLX Datalogger Module	Tool						x		x		x		
	VISION Network Hub	Tool						x		x				
	VISION™ Calibration & Data Acquisition Software	Tool		x				x		x		x		
ACTIA IME GmbH	D-PDU-API	Tool										x		
aiMotive Kft.	aiData	Tool											x	x
	aiSim	Tool											x	x
Akkodis Germany Consulting GmbH	PROVEtech:RE - Runtime Environment	Tool								x				
	PROVEtech:TA - Test automation	Tool						x		x		x	x	x
Areus GmbH	TurboLab	Tool						x		x			x	
Avin Systems Private Limited	Diagnostics Stack	Tool										x		x
	XCP Stack	Tool								x				
AVL LIST GMBH	AVL CAMEO™	Tool						x		x		x	x	x
	AVL CRETA™ Calibration Data Browser	Tool										x		
	AVL CRETA™ Calibration Data Management	Tool										x		
	AVL PUMA™	Tool										x		x
b-plus GmbH	CANTucan	Tool						x		x				
	MDILink	Tool			x									
	UNIBoot	Tool								x				
CSM Computer-Systeme-Messtechnik GmbH	INCA AddOn	Tool										x		
	MiniModules	Tool								x				
	UniCAN 2	Tool						x		x				
	UniCAN 3 ETH	Tool						x		x				
	XCP-Gateway	Tool								x				
demicon GmbH	DiTics-Architecture	Tool											x	x
DENSO Corporation	ASAM MCD-2 MC compliant ECU	Tool										x		
	Meister	Tool										x		x
Dewesoft d.o.o	CAN Interfaces	Tool						x		x				
	Dewesoft CAN devices	Tool						x		x				
	Rugged CAN	Tool						x		x				
Digitalwerk GmbH	ADTF Calibration Toolbox	Tool								x		x	x	
	ADTF Device Toolbox	Tool											x	x
dSPACE GmbH	AutomationDesk	Tool											x	x
	ControlDesk	Tool		x				x		x		x	x	x
	Platform API Package	Tool											x	x
	RTI Bypass Blockset	Tool						x		x		x		
	SystemDesk	Tool								x		x		x
	TargetLink	Tool						x		x		x		
	VEOS	Tool								x		x		x
	Variable Editor	Tool										x		
	dSPACE ECU Flash Programming Tool	Tool								x				
	dSPACE XCP Service	Service								x				
DTS INSIGHT CORPORATION	RAMScope-EXG (GT170 series)	Tool								x				
	RAMScopeVP	Tool										x	x	x
ETAS GmbH	ETAS ASCET	Tool										x		x
	ETAS ASCMO	Tool		x									x	
	ETAS EHANDBOOK	Tool		x								x		x
	ETAS EHOOKS	Tool										x		x
	ETAS INCA	Tool		x				x		x		x	x	x
	ETAS INCA-FLOW	Tool		x						x		x	x	x
	ETAS INTECRIO	Tool										x		x
	ETAS INTECRIO-RLINK	Tool										x		x
	ETAS VECU-BUILDER	Tool								x		x		
	ETAS XETK/ETK	Tool								x		x		
Excelfore (China) Information Technology Co., Ltd	eSync OTA Platform	Service						x		x				x

MEASUREMENT & CALIBRATION

Company	Product	Tool / Service	ARTI	CDF	CMP	CPX	HMS	MCD-1 CCP	MCD-1 POD	MCD-1 XCP	MCD-2 CERP	MCD-2 MC	MDF	Others
Gailogic Corporation	IPEmotion	Tool						x		x		x	x	x
	M-LOG, IPElog, FLEETlog2	Tool						x		x				x
	M-Series Modules, X-Modules	Tool								x				x
General Engine Management Systems Ltd.	DA3 Data Logger	Tool						x		x				
	GEMS Data Analysis Pro	Tool						x		x				
	GWv4	Tool								x				
	Implementation of XCP support	Service								x				
GRYFTEC Embedded Systems Sp. z o.o.	A2L, AML generator	Service										x		
	MF4 generator	Service											x	
HighQSoft GmbH	AReS Libertas ODS6 Server	Tool											x	x
	AReS ODS Gateway	Tool											x	x
	ASAM ODS Proof-of-Concepts	Service											x	x
	ASAM ODS Toolbox for Matlab®	Tool											x	x
	ASAMCommander	Tool											x	x
	HQL	Tool											x	x
	Merlin Analysis Server	Tool											x	x
HMS Technology Center Ravensburg GmbH	EtherCat extension	Tool								x		x		x
	FRC-EP190 / -EP170	Tool								x		x		x
	FRC-Mobile	Tool								x		x		x
	IXXAT ACT Data Logger bundle	Tool								x		x		x
	IXXAT ACT Data Visualization bundle	Tool								x		x		x
	IXXAT ACT Gateway bundle	Tool								x		x		x
	IXXAT ACT RBS bundle	Tool								x		x		x
HORIBA FuelCon GmbH	TestWork	Tool											x	x
Hottinger Bruel & Kjaer UK Ltd HBK	nCode GlyphWorks	Tool											x	x
	nCode VibeSys	Tool											x	x
iASYS	BRIX Distributed ODS	Tool										x	x	x
	BRIX Lab	Tool										x	x	x
	BRIX ODS server	Tool											x	x
	BRIX PVM	Tool										x	x	x
	Fuel Cell & Electrolyser Testing System	Tool										x		x
	Orbit test automation platform	Tool										x		x
imc Test & Measurement GmbH	On-Road, off-road measurement equipment, software & solutions	Tool						x		x				x
	Test stand, measurement equipment, software & solutions	Tool						x		x				x
INCHRON AG	chronSIM	Tool	x											
	chronVIEW	Tool	x											
INTEMPORA	Dataloggers	Tool								x		x	x	x
	IVS	Tool											x	x
	RTMaps	Tool								x		x	x	x
Intrepid Control Systems GmbH	ValueCAN	Tool						x		x		x		x
	Vehicle Spy Professional	Tool						x		x		x		x
	neoVI FIRE / neoVI RED	Tool						x		x		x		x
	neoVI PLASMA	Tool						x		x		x		x
IPETRONIK GmbH & Co. KG	IPEmotion	Tool						x		x		x	x	x
	M-LOG	Tool						x		x				x
IPETRONIK GmbH & Co. KG	Mx-SENS, Sx-STG	Tool								x				
IPG Automotive GmbH	CarMaker	Tool						x		x			x	x
	MotorcycleMaker	Tool						x		x			x	x
IPG Automotive GmbH	TruckMaker	Tool						x		x			x	x
iSyst Intelligente Systeme GmbH	iTestStudio	Tool						x		x				x
IVEX NV	IVEX Vehicle Dynamics Information Generator (VDIG)	Tool						x	x	x				x
Keysight Technologies Deutschland GmbH	Energy Storage Discover	Tool											x	
Kistler Chemnitz GmbH	MaDaM	Tool											x	x
Kithara Software GmbH	Kithara RealTime Automotive	Tool											x	
	Real-Time Automation	Tool		x		x		x	x	x		x	x	x
KPIT Technologies GmbH	K-DCP Aftersales Suite	Tool								x				x
	K-DCP Engineering Toolchain	Tool								x				x
Kristl, Seibt & Co GmbH	Tornado Software Suite	Tool								x			x	x
Kvaser AB	CanKing 7	Tool											x	

MEASUREMENT & CALIBRATION

Company	Product	Tool / Service	ARTI	CDF	CMP	CPX	HMS	MCD-1 CCP	MCD-1 POD	MCD-1 XCP	MCD-2 CERP	MCD-2 MC	MDF	Others
Kvaser AB	Kvaser Memorator Pro 2xHS v2	Tool											x	
	Kvaser Memorator Pro 5xHS	Tool											x	
Lauterbach GmbH	TRACE32	Tool	x											
Lauterbach GmbH	TRACE32	Tool								x				
MathWorks	Simulink Real-Time	Tool								x				x
	Vehicle Network Toolbox	Tool								x			x	
measX GmbH & Co. KG	X-Crash	Tool											x	x
MicroNova AG	EXAM	Tool											x	x
	NovaCarts	Tool											x	x
Mindmotiv GmbH	Arttest	Tool											x	x
NI (formerly National Instruments)	DIAdem	Tool						x		x		x	x	x
	ECU Measurement and Calibration Toolkit	Tool						x		x		x		
	LabWindows™/CVI	Tool						x		x		x		x
	SystemLink - DataFinder, Analysis Server	Tool											x	x
	VeriStand	Tool						x		x		x		x
Peak Solution GmbH	ODSBox Python Library	Tool											x	x
	Peak Data Transfer Tool	Tool											x	x
	Peak ODS Server	Tool											x	x
	Peak ODS Spark Adapter	Tool											x	x
	Peak Test Data Manager	Tool											x	x
	Peak Test Data Manager - File Focus	Tool											x	x
PEAK-System Technik GmbH	PCAN-CCP API	Tool						x						
	PCAN-XCP API	Tool								x				
PHINIA Delphi	High Voltage Controllers	Tool						x		x				x
	Motor Generator With Integrated Electronics (MGI)	Tool						x				x		x
	Powertrain ECU	Tool						x		x		x		
PikeTec GmbH	TPT	Tool											x	x
PLS Programmierbare Logik & Systeme GmbH	UDE® Universal Debug Engine	Tool	x							x			x	
PMSF IT Consulting Pierre R. Mai	PMSF FMI Bench	Tool								x		x	x	x
	PMSF RFMI Server	Tool								x		x		x
RA Consulting GmbH	A2L Parser	Tool										x		
	DiagRA® D	Tool										x		x
	DiagRA® LE	Tool										x		x
	DiagRA® X	Tool						x		x		x	x	x
	DiagRA® X Viewer Pro	Tool											x	
	MA API	Tool											x	
	MC Server	Tool						x		x			x	x
RAWLAB GmbH	RL[b]	Tool											x	x
rd electronic GmbH	UBAT	Tool										x		x
ReliaTec GmbH	ReliaFX Access	Tool										x		x
Schleißheimer Soft- u. Hardwareentwicklung GmbH	AFDB	Tool										x		x
	AFE	Tool										x		x
	CanEasy	Tool						x		x			x	
SCSK Corporation	QINeS-BSW	Tool								x				
SGE GmbH	CompareArtist	Tool		x										
SGE GmbH	DataArtist	Tool											x	
	MapArtist	Tool		x								x	x	
	ModelArtist	Tool		x									x	
	SGE Circus	Tool		x								x	x	
Shanghai TOSUN Technology Ltd.	1014-TC1014-4 channels CANFD interface	Tool						x		x				
	TSMaster	Tool						x		x				
Shanghai Vehinfo Technologies Co., Ltd.	LABCAR	Tool					x	x					x	x
	LCO	Tool					x	x		x			x	x
Sierra CP Engineering Ltd.	CADET Automation System	Tool						x						
Softing Automotive Electronics GmbH	Softing DTS.venice	Tool										x		x
Software and Testing Solutions SAS	MORPHEE®	Tool						x		x		x		x
	xMOD®	Tool								x		x		x
STAR ELECTRONICS GmbH & Co. KG	FlexConfig RBS	Tool								x				x
	FlexDevice	Tool								x				x
STIEGELE Datensysteme GmbH	MLab	Tool						x		x				x

MEASUREMENT & CALIBRATION

Company	Product	Tool / Service	ARTI	CDF	CMP	CPX	HMS	MCD-1 CCP	MCD-1 POD	MCD-1 XCP	MCD-2 CERP	MCD-2 MC	MDF	Others
Synopsys GmbH	Silver	Tool		x						x		x	x	x
	Virtualizer and Automotive VDKs	Tool								x		x	x	
Technica Engineering GmbH	ANDi	Tool											x	x
Techways Co., Ltd.	DTS Venice	Tool										x		
	IPEmotion	Tool						x		x		x	x	x
TOYO Corporation	CRONOS-compact/-flex	Tool						x				x		
tracetronic GmbH	ecu.test	Tool										x	x	x
	trace.check	Tool											x	x
T-Systems International GmbH	MDF4 Transcoder	Tool											x	
U.chain Vehicle Network Technology Co., Ltd.	MDF Viewer	Tool											x	
	VehicleCAN	Tool						x		x			x	x
	VehicleFlex	Tool											x	x
Vector Informatik GmbH	ASAP2 Tool-Set	Tool										x		
	CANalyzer	Tool											x	x
	CANape	Tool						x		x		x	x	x
	CANoe	Tool						x		x		x	x	x
	CANoe Server Editions	Tool						x		x		x	x	x
	DYNA4	Tool											x	x
	DaVinci Configurator Classic	Tool										x		x
	GL Logger Family	Tool						x		x				x
	MDF4 Lib	Tool											x	
	MDF4 Validator	Tool											x	
	MICROSAR Classic	Tool								x				
	VX1000	Tool								x		x		
	XCP Professional	Tool								x				
	vAnonymize	Tool											x	
	vCDM	Tool		x								x		
	vCDM Tool-Set	Tool		x								x		
	vCDMstudio	Tool		x								x		
	vMeasure	Tool						x		x		x	x	x
	vSignalyzer	Tool											x	x
	vVIRTUALtarget	Tool								x				
ViGEM GmbH	Basic solution: CCA 9003	Tool								x				
	CCA CS1-10G	Tool		x		x		x		x		x	x	x
Visu-IT! GmbH	ASAM MCD-2MC File Parser	Tool										x		
	ASAP2 Library (A2Lib)	Tool										x		
	ASAP2Toolkit	Tool										x		
	Data Declaration System (DDS)	Tool										x		x
	FunDoc	Tool		x										x
XI-Works	AXE ATX Workbench	Tool						x						
	Advanced XML Editor (Axe) for Eclipse Generic XML Editor	Tool		x									x	x
	AxeEcuDoc Ecu Documentation Suite Editing solution for functional specification based on MSRSW, E-FSX, AE-MDX, MSRREP, AE-CC and AE-ATX	Tool		x										x
	EcuDoc-Publisher PDF publishing for functional specification.	Tool		x										x
	EcuDoc-Publisher Server Web application server for server based PDF publishing and continuous integration of functional specification	Tool		x										x
	XIDiff Generic XML differ	Tool		x										
	XMetal-Kit for MSRSW, MDX, Container Catalog, MSRREP and MSRSYS	Tool		x										
Xylon d.o.o.	logiRECORDER Automotive Data Logger	Tool											x	x
	logiRECORDER Dashboard	Tool											x	x
	logiRECORDER SDK	Tool											x	x
Yokogawa Test & Measurement Corporation	DL950	Tool											x	
ZD Automotive GmbH	ZD Datalogger 3 Series	Tool			x									

DIAGNOSTICS

Company	Product	Tool / Service	MCD-2 D	MCD-3 D	SOVD	Others
ACTIA IME GmbH	D-PDU-API	Service	x	x		x
	D-Server	Tool	x	x		
	SOVD-Server	Tool		x	x	x
Akkodis Germany Consulting GmbH	PROVEtech:IVIY	Tool	x			
	PROVEtech:TA - Test automation	Tool	x	x		x
Avin Systems Private Limited	Diagnostics Stack	Tool	x			
BlueBinaries Engineering and Solutions Pvt. Ltd.	Diagnostics Stack	Tool	x	x		x
	ECU Diagnostics Validator	Tool	x	x		x
	ECU Simulator	Tool	x	x		
	ODX Author | OTX Author	Tool	x	x		x
	Quick Flash	Tool		x		x
	Smart Engineering	Tool	x	x		x
DSA Daten- und Systemtechnik GmbH	Authoring Guidelines & Process Setup	Service	x	x		
	Firmware Update over-the-Air (FOTA)	Tool		x		
	PRODIS.Authoring	Tool	x			x
	PRODIS.Automation	Tool	x	x		x
	PRODIS.MCD	Tool		x		x
	PRODIS.MVCI (Modular Vehicle Communication Interface)	Tool	x	x		x
	PRODIS.RTS	Tool	x	x		x
	PRODIS.SOVD	Tool	x	x	x	
	PRODIS.Share	Tool	x			
	PRODIS.WTS	Tool		x		x
	Remote Diagnosis and Telematics	Tool		x		
	SOVD Consulting	Service	x	x	x	x
dSPACE GmbH	AutomationDesk	Tool		x		x
	ControlDesk	Tool	x	x		x
	RTI CAN MultiMessage Blockset	Tool	x			
E.S.R. Labs GmbH	E.S.R. ODX Tools	Tool	x			
emotive GmbH & Co. KG	OTX Consulting	Service	x	x		x
	OTX IDE – Open Test Framework (OTF)	Tool	x	x		x
	OTX Runtime	Tool	x	x		x
	OTX User Training	Service	x	x		x
	Open Test Player (OTP)	Tool	x	x		x
ETAS GmbH	ETAS EHANDBOOK	Tool	x			x
	ETAS INCA	Tool	x			x
	ETAS ISOLAR-A	Tool	x			x
Excelfore (China) Information Technology Co., Ltd	Adaptive autosar COM Software	Tool	x		x	
	eSync OTA Platform	Service	x		x	x
Gailogic Corporation	DTS-Monaco (Diagnostic Tool Set)	Tool	x	x		
	OTX Studio	Tool	x	x		
GRYFTEC Embedded Systems Sp. z o.o.	ODX, PDX generator	Service	x			
I-Chin Motor Technology Co., Ltd.	OBD Trace	Tool	x			
Intrepid Control Systems GmbH	ValueCAN	Tool	x			x
	Vehicle Spy Professional	Tool	x			x
	neoVI FIRE / neoVI RED	Tool	x			x
	neoVI PLASMA	Tool	x			x
Kithara Software GmbH	Real-Time Automation	Tool	x	x		x
KPIT Technologies GmbH	K-DCP Aftersales Suite	Tool	x	x		x
	K-DCP Engineering Toolchain	Tool	x	x		x
Meidensha Corporation	MEIDACS-DY6000P	Tool		x		x
Motorenfabrik Hatz GmbH u. Co. KG	Prototype CR - engine	Tool		x		x
PHINIA Delphi	High Voltage Controllers	Tool	x			x
PROTECHNVIL SYSTEMS PRIVATE LIMITED	D-VS	Tool	x			
	DB Exchange	Tool	x			
	DIACOM Framework	Tool	x	x	x	x
	ODX Builder	Tool	x			
	ODX/OTX Data Authoring & Consultancy Services	Service	x			x
	OTX Builder	Tool	x	x		x
	SOVD Consultancy	Service	x	x	x	x

DIAGNOSTICS

Company	Product	Tool / Service	MCD-2 D	MCD-3 D	SOVD	Others
PROTECHNVIL SYSTEMS PRIVATE LIMITED	Service Studio	Tool	x	x	x	x
	i-RED Tester	Tool	x	x	x	x
RA Consulting GmbH	DiagRA® D	Tool	x			x
	DiagRA® LE	Tool	x			x
	DiagRA® S	Tool	x			
	ODX API	Tool	x			
	RA® ODX Viewer	Tool	x			
ReliaTec GmbH	ReliaFX Access	Tool	x			x
Schleißheimer Soft- und Hardwareentwicklung GmbH	AFDB	Tool	x			x
	AFE	Tool	x			x
Siemens AG	SIDIS Authoring	Tool	x	x		x
	SIDIS MCD-3 D Server	Tool	x	x		
	SIDIS MVCI	Tool		x		
	SIDIS Runtime	Tool	x	x		x
SodiusWillert	MagicDraw Publishers	Tool	x			
	Migration Toolkit for DOORS	Tool	x			
	OSLC Connect for Jira	Tool	x			
	OSLC Connect for Windchill	Tool	x			
	RXF Autosar Classic Edition	Tool	x			
	SECOLLAB	Tool	x			
Softing Automotive Electronics GmbH	ODX/OTX/MCD-3 training	Service	x	x		x
	Softing DTS.monaco	Tool	x	x	x	x
	Softing DTS.venice	Tool	x			x
	Softing OTX.studio	Tool	x	x		x
	Softing SDE	Tool	x	x	x	x
	Softing TCS	Tool	x			
	Softing TDX	Tool	x	x	x	x
Sontheim Industrie Elektronik GmbH	CANUSB	Tool	x			
	CANexplorer 4	Tool	x			
	CANfox	Tool	x			
	CLCM 2.0 – Communication Lifecycle Manager	Tool	x	x		x
	COMfalcon	Tool	x	x		x
	COMhawk xt	Tool	x	x		x
	M.D.T. 2.0 – Modular Diagnostic Tool	Tool	x	x		x
	ODX-Editor	Tool	x			
Techways Co., Ltd.	OTX Studio	Tool		x		
tracetronic GmbH	ecu.test	Tool	x	x		x
T-Systems International GmbH	OTX2SOVD	Tool			x	x
	SOVD Vehicle Gateway	Tool			x	
U.chain Vehicle Network Technology Co., Ltd.	VehicleCAN	Tool	x			x
Vector Informatik GmbH	CANalyzer	Tool	x			x
	CANape	Tool	x	x		x
	CANdelaStudio	Tool	x		x	
Vector Informatik GmbH	CANoe	Tool	x			x
	CANoe Server Editions	Tool	x			x
	CANoe.DiVa	Tool	x		x	
	Consulting & Engineering Services for ODX	Tool	x			
	D-PDU API	Tool	x			
	DaVinci Configurator Classic	Tool	x			x
	GL Logger Family	Tool	x			x
	Indigo	Tool	x			
	ODXStudio	Tool	x			
	Solutions for SOVD	Service			x	
	Training for ODX	Service	x			
	vFlash	Tool	x			
	vMeasure	Tool	x			x
ViGEM GmbH	CCA CS1-10G	Tool	x	x		x
Visu-IT! GmbH	Data Declaration System (DDS)	Tool	x			x
XI-Works	XIDiff Generic XML differ	Tool	x			x

ECU NETWORKS

Company	Product	Tool / Service	MCD-2 NET	Others
Digitalwerk GmbH	ADTF Device Toolbox	Tool	x	x
dSPACE GmbH	Bus Manager	Tool	x	
	ControlDesk	Tool	x	x
	RTI LIN MultiMessage Blockset	Tool	x	
	SystemDesk	Tool	x	x
	dSPACE Ethernet Configuration Package	Tool	x	
	dSPACE FlexRay Configuration Package	Tool	x	
E.S.R. Labs GmbH	E.S.R. FIBEX Tools	Tool	x	
ETAS GmbH	ETAS INCA	Tool	x	x
	ETAS INTECRIO	Tool	x	x
	ETAS INTECRIO-RLINK	Tool	x	x
	ETAS ISOLAR-A	Tool	x	x
Gailogic Corporation	IPEmotion	Tool	x	x
HMS Technology Center Ravensburg GmbH	EtherCat extension	Tool	x	x
	FRC-EP190 / -EP170	Tool	x	x
	FRC-Mobile	Tool	x	x
	IXXAT ACT Data Logger bundle	Tool	x	x
	IXXAT ACT Data Visualization bundle	Tool	x	x
	IXXAT ACT Gateway bundle	Tool	x	x
	IXXAT ACT RBS bundle	Tool	x	x
Intrepid Control Systems GmbH	ValueCAN	Tool	x	x
	Vehicle Spy Professional	Tool	x	x
	neoVI FIRE / neoVI RED	Tool	x	x
Intrepid Control Systems GmbH	neoVI PLASMA	Tool	x	x
IPETRONIK GmbH & Co. KG	IPEmotion	Tool	x	x
IPG Automotive GmbH	CarMaker	Tool	x	x
	MotorcycleMaker	Tool	x	x
	TruckMaker	Tool	x	x
IVEX NV	IVEX Vehicle Dynamics Information Generator (VDIG)	Tool	x	x
Kithara Software GmbH	Real-Time Automation	Tool	x	x
NI (formerly National Instruments)	DIAdem	Tool	x	x
	LabWindows™/CVI	Tool	x	x
	NI-XNET	Tool	x	
	VeriStand	Tool	x	x
RA Consulting GmbH	DiagRA® D	Tool	x	x
ReliaTec GmbH	ReliaFX Access	Tool	x	x
Shanghai Vehinfo Technologies Co., Ltd.	LCO	Tool	x	x
Software and Testing Solutions SAS	MORPHEE®	Tool	x	x
STAR ELECTRONICS GmbH & Co. KG	CHI Generator RBS	Tool	x	
	FlexConfig Developer	Tool	x	
	FlexConfig RBS	Tool	x	x
	FlexDevice	Tool	x	x
STIEGELE Datensysteme GmbH	MLab	Tool	x	x
Synopsys GmbH	Silver	Tool	x	x
Technica Engineering GmbH	ADELa	Tool	x	x
	ANDi	Tool	x	x
Technische Hochschule Köln	Consulting	Service	x	x
	Contract research/development	Service	x	x
	Student internships	Service	x	x
	Student projects	Service	x	x
Techways Co., Ltd.	IPEmotion	Tool	x	x
tracetronic GmbH	ecu.test	Tool	x	x
	trace.check	Tool	x	x
TTTech Auto Gemany GmbH	TTX-Disturbance Node	Tool	x	
	TTX-Optical Link	Tool	x	
Vector Informatik GmbH	CANalyzer	Tool	x	x
	CANape	Tool	x	x
	CANoe	Tool	x	x
	CANoe Server Editions	Tool	x	x
	DaVinci Configurator Classic	Tool	x	x

ECU NETWORKS

Company	Product	Tool / Service	MCD-2 NET	Others
Vector Informatik GmbH	GL Logger Family	Tool	x	x
	vMeasure	Tool	x	x
ViGEM GmbH	CCA CS1-10G	Tool	x	x
XI-Works	XIDiff Generic XML differ	Tool	x	x
Xylon d.o.o.	logiRECORDER Automotive Data Logger	Tool	x	x
	logiRECORDER Dashboard	Tool	x	x
	logiRECORDER SDK	Tool	x	x

SOFTWARE DEVELOPMENT

Company	Product	Tool / Service	CC	FSX	ISSUE	LXF	MBFS	MDX	SDCL	Others
ETAS GmbH	ETAS ASCET	Tool						x		x
	ETAS EHANDBOOK	Tool	x	x				x		x
	ETAS EHOOKS	Tool					x			x
GRYFTEC Embedded Systems Sp. z o.o.	MLX, MDX, XML generator	Service						x		
Intrepid Control Systems GmbH	ValueCAN	Tool						x		x
	Vehicle Spy Professional	Tool						x		x
Intrepid Control Systems GmbH	neoVI FIRE / neoVI RED	Tool						x		x
	neoVI PLASMA	Tool						x		x
Kithara Software GmbH	Real-Time Automation	Tool	x		x	x	x	x		x
PHINIA Delphi	Motor Generator With Integrated Electronics (MGI)	Tool	x							x
ViGEM GmbH	CCA CS1-10G	Tool		x	x	x	x	x		x
Visu-IT! GmbH	Automotive Data Dictionary (ADD)	Tool						x		
	Data Declaration System (DDS)	Tool						x		x
	FunDoc	Tool	x	x				x		
	PACES	Tool						x		
XI-Works Profile	Advanced XML Editor (Axe) for Eclipse Generic XML Editor	Tool	x	x						x
	AxeEcuDoc Ecu Documentation Suite Editing solution for functional specification based on MSRSW, AE-FSX, AE-MDX, MSRREP, AE-CC and AE-ATX	Tool	x	x				x		x
	EcuDoc-Publisher PDF publishing for functional specification.	Tool	x	x				x		x
	EcuDoc-Publisher Server Web application server for server based PDF publishing and continuous integration of functional specification	Tool	x	x				x		x
	XIDiff Generic XML differ	Tool	x	x	x			x		x
	XMetal-Kit for MSRSW, MDX, Container Catalog, MSRREP and MSRSYS	Tool	x	x				x		x

TEST AUTOMATION

Company	Product	Tool / Service	ACI	ASAP 3	ATX	GDI	iLinkRT	MCD-3 MC	OTX Extensions	XIL/XIL-MA	Others
A&D Company, Ltd.	A&D Data Acquisition Products	Tool	x								
	A&D VirtualConsole	Tool		x							x
ACTIA IME GmbH	D-PDU-API	Service							x		x
	SOVD-Server	Tool							x		x
Akkodis Germany Consulting GmbH	AI-Core Test AId	Tool								x	
	PROVEtech:TA – Test automation	Tool								x	x
ALIARO Group	Aliaro Signal Configurator	Tool								x	
	xMove Configurator	Tool								x	
Applied Intuition Inc.	Simian	Tool								x	x
AVL LIST GMBH	AVL CAMEO™	Tool	x	x			x	x		x	x
	AVL PUMA™	Tool	x			x	x				x
	AVL vega.creator	Tool							x		
BlueBinaries Engineering and Solutions Pvt. Ltd.	Diagnostics Stack	Tool							x		x
	ECU Diagnostics Validator	Tool							x		x
	ODX Author | OTX Author	Tool							x		x
	Quick Flash	Tool							x		x
	Smart Engineering	Tool							x		
DENSO Corporation	Meister	Tool						x			x
DSA Daten- und Systemtechnik GmbH	PRODIS.Authoring	Tool				x					x
	PRODIS.Automation	Tool				x					x
	PRODIS.MCD	Tool						x			x
	PRODIS.MVCI (Modular Vehicle Communication Interface)	Tool						x			x
	PRODIS.RTS	Tool				x		x			x
	PRODIS.WTS	Tool						x			x
	SOVD Consulting	Service							x		x
dSPACE GmbH	AutomationDesk	Tool						x		x	x
	ControlDesk	Tool						x		x	x
	Failure Simulation Package	Tool								x	
	Platform API Package	Tool								x	x
dSPACE GmbH	VEOS	Tool								x	x
DTS INSIGHT CORPORATION	RAMScopeVP	Tool		x							x
emotive GmbH & Co. KG	OTX Consulting	Service							x		x
	OTX IDE – Open Test Framework (OTF)	Tool							x		x
	OTX Runtime	Tool							x		x
	OTX User Training	Service							x		x
	Open Test Player (OTP)	Tool							x		x
ETAS GmbH	ETAS INCA	Tool		x			x	x			x
	ETAS INCA-FLOW	Tool		x			x				x
Excelfore (China) Information Technology Co., Ltd	eSync OTA Platform	Service							x		x
Gailogic Corporation	M-LOG, IPElog, FLEETlog2	Tool				x					x
	M-Series Modules, X-Modules	Tool				x					x
HORIBA FuelCon GmbH	TestWork	Tool		x							x
HORIBA	STARS Automation	Tool	x	x				x			x
	STARS VETS	Tool	x	x				x			x
Hyundai AutoEver Corp.	mobilgene X Studio	Tool								x	
iASYS	Fuel Cell & Electrolyser Testing System	Tool	x			x		x			x
	Orbit test automation platform	Tool	x			x		x			x
INTEMPORA	Dataloggers	Tool								x	x
	IVS	Tool								x	
	RTMaps	Tool								x	x
IPETRONIK GmbH & Co. KG	M-LOG	Tool				x					x
	M-Series Modules	Tool				x					
IPG Automotive GmbH	CarMaker	Tool								x	x
	MotorcycleMaker	Tool								x	x
	TruckMaker	Tool								x	x
iSyst Intelligente Systeme GmbH	iTestStudio	Tool								x	x
Kithara Software GmbH	Real-Time Automation	Tool	x	x	x	x		x	x	x	x
KPIT Technologies GmbH	K-DCP Aftersales Suite	Tool							x	x	x
	K-DCP Engineering Toolchain	Tool							x	x	x
Kristl, Seibt & Co GmbH	Tornado Software Suite	Tool	x	x			x			x	x

TEST AUTOMATION

Company	Product	Tool / Service	ACI	ASAP 3	ATX	GDI	iLinkRT	MCD-3 MC	OTX Extensions	XIL/XIL-MA	Others
MathWorks	Simulink Real-Time	Tool								x	x
	Simulink Test™	Tool								x	x
Meidensha Corporation	MEIDACS-DY6000P	Tool	x					x			x
MicroNova AG	EXAM	Tool			x					x	x
	NovaCarts	Tool								x	x
Mindmotiv GmbH	Arttest	Tool								x	x
Motorenfabrik Hatz GmbH u. Co. KG	Prototype CR - engine	Tool						x			x
NI (formerly National Instruments)	TestStand	Tool								x	
	VeriStand	Tool		x						x	x
PikeTec GmbH	TPT	Tool						x		x	x
PROTECHNVIL SYSTEMS PRIVATE LIMITED	DIACOM Framework	Tool							x		x
	ODX/OTX Data Authoring & Consultancy Services	Service							x		x
	OTX Builder	Tool							x		x
	SOVD Consultancy	Service							x		x
	Service Studio	Tool							x		x
	i-RED Tester	Tool							x		x
RA Consulting GmbH	DiagRA® D	Tool		x							x
	DiagRA® X	Tool		x				x			x
	MC Server	Tool						x			x
RAWLAB GmbH	RL[b]	Tool			x						x
rd electronic GmbH	FLG	Tool				x					
	GDI Framework	Tool				x					
rd electronic GmbH	Services	Tool				x					x
	UBAT	Tool				x					
RWTH Aachen University, Teaching and Research Area Mechatronics in Mobile Propulsion	LExCI 2	Tool		x							
Schleißheimer Soft- und Hardwareentwicklung GmbH	Micro HiL Ecosystem	Service								x	
SGS CyberMetrix Inc.	CyFlex	Tool		x							
Shanghai Vehinfo Technologies Co., Ltd.	LABCAR	Tool		x						x	x
	LCO	Tool								x	x
Siemens AG	SIDIS Authoring	Tool				x					x
	SIDIS GDI	Tool				x					
	SIDIS Runtime	Tool				x					x
Softing Automotive Electronics GmbH	ODX/OTX/MCD-3 training	Service							x		x
	Softing DTS.monaco	Tool							x		x
	Softing OTX.studio	Tool							x		x
	Softing SDE	Tool							x		x
	Softing TDX	Tool							x		x
Software and Testing Solutions SAS	MORPHEE®	Tool						x			x
	OSIRIS™	Tool						x			
	xMOD®	Tool						x		x	x
Sontheim Industrie Elektronik GmbH	CLCM 2.0 – Communication Lifecycle Manager	Tool							x		x
	COMfalcon	Tool							x		x
	COMhawk xt	Tool							x		x
	M.D.T. 2.0– Modular Diagnostic Tool	Tool							x		x
Synopsys GmbH	Silver	Tool								x	x
Technica Engineering GmbH	ADELa	Tool	x								x
Technische Hochschule Köln	Consulting	Service	x			x					x
	Contract research/development	Service	x			x					x
	Student internships	Service	x			x					x
	Student projects	Service	x			x					x
tracetronic GmbH	ecu.test	Tool	x		x		x	x		x	x
	test.guide	Tool			x						
T-Systems International GmbH	OTX2SOVD	Tool							x		x
Typhoon HIL, Inc.	BMS HIL Testbed	Tool								x	
	HIL404	Tool								x	
	HIL606	Tool								x	
	Typhoon HIL Control Center (THCC)	Tool								x	
	TyphoonTest	Tool								x	
	e-Drive HIL Testbed	Service								x	

TEST AUTOMATION

Company	Product	Tool / Service	ACI	ASAP 3	ATX	GDI	iLinkRT	MCD-3 MC	OTX Extensions	XIL/XIL-MA	Others
Vector Informatik GmbH	CANape	Tool		x			x	x			x
	CANoe	Tool								x	x
	CANoe Server Editions	Tool								x	x
	DYNA4	Tool								x	x
ViGEM GmbH	CCA CS1-10G	Tool	x	x	x	x		x		x	x

DATA MANAGEMENT & ANALYSIS

Company	Product	Tool / Service	CEA	ODS	Others
Apicom S.p.A.	Horus SE	Tool		x	
AVL LIST GMBH	AVL CONCERTO™	Tool		x	
	AVL PUMA™	Tool	x	x	x
	AVL data.CONNECT™	Tool		x	
	AVL iGEM™ Offline	Tool		x	
Beijing Rainfe Technology Ltd.	tdm3000	Tool		x	
BETA CAE Systems International AG	ANSA/META suite	Tool		x	
CAETEC GmbH	ARCOS	Tool		x	x
	µCROS	Tool		x	x
Crystal Instruments	CI Data File Reader	Tool		x	
demicon GmbH	DiTics-Architecture	Tool		x	x
DSO Infomation Technology	Q-Vision	Tool		x	
Gailogic Corporation	M-LOG, IPElog, FLEETlog2	Tool		x	x
HEAD acoustics GmbH	ArtemiS SUITE	Tool		x	
HighQSoft GmbH	AReS Libertas ODS6 Server	Tool		x	x
	AReS ODS Gateway	Tool		x	x
	ASAM ODS Proof-of-Concepts	Service		x	x
	ASAM ODS Toolbox for Matlab®	Tool		x	x
	ASAMCommander	Tool		x	x
	HQL	Tool		x	x
	Merlin Analysis Server	Tool		x	x
HORIBA FuelCon GmbH	TestWork	Tool		x	x
HORIBA	STARS Automation	Tool		x	x
	STARS Enterprise	Tool		x	
	STARS VETS	Tool		x	x
Hottinger Bruel & Kjaer UK Ltd HBK	ASAM ODS Connectivity	Tool		x	
	nCode GlyphWorks	Tool		x	x
	nCode VibeSys	Tool		x	x
iASYS	BRIX Distributed ODS	Tool		x	x
	BRIX Lab	Tool		x	x
	BRIX ODS server	Tool		x	x
	BRIX PVM	Tool		x	x
	EV Testing	Tool		x	
	Fuel Cell & Electrolyser Testing System	Tool		x	x
	Orbit test automation platform	Tool		x	x
imc Test & Measurement GmbH	On-Road, off-road measurement equipment, software & solutions	Tool		x	x
	Test stand, measurement equipment, software & solutions	Tool		x	x
IPETRONIK GmbH & Co. KG	M-LOG	Tool		x	x
Karakun AG	ASAM ODS Consulting and Software Engineering	Service		x	
	EXO:FDM	Tool		x	
	EXO:FDX	Tool		x	

DATA MANAGEMENT & ANALYSIS

Company	Product	Tool / Service	CEA	ODS	Others
Karakun AG	EXO:RDM	Tool		x	
	EXOKNOX	Tool		x	
Kistler Chemnitz GmbH	AMS-ATF Importer/Konverter	Tool		x	
	MaDaM	Tool	x	x	x
	jBEAM	Tool	x	x	
Kithara Software GmbH	Real-Time Automation	Tool	x	x	x
Kristl, Seibt & Co GmbH	Tornado Software Suite	Tool		x	x
measX GmbH & Co. KG	MVA-PC	Tool		x	
	X-Crash	Tool		x	x
	X-Frame	Tool		x	
Mecalc Technologies Inc.	QuantusSeries	Tool		x	x
Müller-BBM VibroAkustik Systeme GmbH	PAK 6.x	Tool		x	
	PAK capture	Tool		x	
	PAK cloud	Tool		x	
	PAK pass-by	Tool		x	
NI (formerly National Instruments)	DIAdem	Tool		x	x
	SystemLink - DataFinder, Analysis Server	Tool		x	x
NorCom Information Technology GmbH & Co. KGaA	DaSense	Tool		x	
Peak Solution GmbH	ODSBox Python Library	Tool		x	x
	Peak BigODS Exporter	Tool		x	
	Peak Data Transfer Tool	Tool		x	x
	Peak ODS Permission Manager	Tool		x	
	Peak ODS Server	Tool		x	x
	Peak ODS Spark Adapter	Tool		x	x
	Peak Test Data Manager	Tool		x	x
Peak Solution GmbH	Peak Test Data Manager - File Focus	Tool		x	x
Pico Technology Ltd.	PicoDiagnostics NVH Kit	Tool		x	
Polytec GmbH	PSV-500 Scanning vibrometer	Tool		x	
	PSV-500-3D-H 3D Scanning Vibrometer	Tool		x	
	RoboVib Structural Test Station	Tool		x	
RAWLAB GmbH	RL[b]	Tool		x	x
rd electronic GmbH	Lexikon	Service		x	
	SP Host	Tool	x	x	
	Services	Tool	x	x	x
Reilhofer KG	delta-ANALYSER	Tool		x	
	eol-ANALYSER	Tool		x	
SGS CyberMetrix Inc.	Mach	Tool		x	
Shanghai Vehinfo Technologies Co., Ltd.	LABCAR	Tool		x	x
	LCO	Tool		x	x
Siemens Digital Industries Software	Simcenter Testlab	Tool		x	
	Simcenter Testlab Data Management	Tool		x	
Sky Technology Inc.	Engine Analysis System	Tool		x	
Software and Testing Solutions SAS	FLEX™	Tool		x	
	MORPHEE®	Tool		x	x
STIEGELE Datensysteme GmbH	MGraph	Tool		x	
Technische Hochschule Köln	Consulting	Service		x	x
	Contract research/development	Service		x	x
	Student internships	Service		x	x
	Student projects	Service		x	x
TOYO Corporation	PAK/PAK cloud	Tool		x	
	Peak ODS Server - ASAM-ODS tools	Tool		x	
	imc-FAMOS	Tool		x	
U.chain Vehicle Network Technology Co., Ltd.	VehicleFlex	Tool		x	x
Vector Informatik GmbH	vSignalyzer	Tool		x	x
Vibes Technology B.V.	VIBES Toolbox for MATLAB	Tool		x	
ViGEM GmbH	CCA CS1-10G	Tool	x	x	x

SIMULATION

Company	Product	Tool / Service	OpenCRG	OpenDRIVE	OpenLABEL	OpenMATERIAL 3D	OpenODD	OpenSCENARIO	OpenSCENARIO XML	OpenSCENARIO DSL	OSI	Others
51Sim Computer Systems Co.,Ltd.	51SimOne	Tool		x				x	x	x		
aiMotive Kft.	aiData	Tool						x	x		x	x
	aiSim	Tool	x	x		x		x			x	
Akkodis Germany Consulting GmbH	osc-language-server	Tool								x		
Ansys, Inc.	Ansys VRXPERIENCE Driving Simulator powered by SCANeR™	Tool		x							x	
Applied Intuition Inc.	Simian	Tool		x					x			
Automotive Artificial Intelligence (AAI) GmbH	Real2Sim	Service		x			x					
	Scenario Generation	Tool		x			x					
	Versatile	Service		x								
Automotive Data of China (Tianjin) Co., Ltd	ADChauffeur	Tool		x				x			x	
AVL LIST GMBH	AVL SCENIUS™	Tool		x				x				
BeamNG GmbH	BeamNG.tech	Service		x								
BIPROGY Inc.	DIVP simulator	Tool		x		x		x			x	
Change Vision Inc.	Astah	Tool		x				x				
Cognata Ltd.	Cognata simulation platform	Tool		x				x				
	Synthetic Datasets	Tool		x				x				
dSPACE GmbH	Automotive Simulation Models (ASM)	Tool		x				x			x	
	ModelDesk	Tool	x	x				x			x	
	Scenario Generation Service	Service		x				x			x	
Five	The Five Platform	Tool		x				x			x	
fka GmbH	levelXdata	Service		x				x				
Foretellix Ltd.	Foretify™	Tool		x			x	x		x		
	Foretify V-Suite™	Tool		x			x	x		x		
	Foretify™ LogIQ	Tool		x			x	x		x		
	Foretify™ Manager	Tool		x			x	x		x		
Hexagon Manufacturing Intelligence GmbH -Vires	Road Designer (ROD)	Tool	x	x								
	VTD Scale	Service	x	x				x				
	Virtual Test Drive (VTD)	Tool	x	x				x			x	
iASYS	BRIX Ontology	Tool						x				
	Brix Label	Tool						x				
	Brix Scenario	Tool						x				
Institute DIGITAL of JOANNEUM RESEARCH Forschungsgesellschaft mbH	Highly Automated Driving Laboratory	Service	x	x			x					
	UHD Mapping, UHD Maps, Mobile Mapping	Service	x	x								
IPG Automotive GmbH	CarMaker	Tool						x				x
	MotorcycleMaker	Tool	x	x				x				x
	TruckMaker	Tool	x	x				x				x
	VIRTO	Tool	x	x				x				
ITK Engineering GmbH	Individual Virtual Environment and Sensor Simulation (iVESS)	Tool		x	x			x			x	
IVEX NV	Euro NCAP On-road Evaluator	Tool		x	x		x	x				
	IVEX Data Analytics Platform	Tool	x	x	x		x	x				
	IVEX Trajectory Checker	Tool	x	x	x		x	x				
iVH	iSuite52	Tool									x	
Luxoft GmbH	scenARI.Lux	Tool		x			x	x	x	x		
MathWorks	Automated Driving Toolbox	Tool		x				x			x	
	RoadRunner	Tool	x	x								
	RoadRunner Scenario	Tool						x				
MORAI Inc.	MORAI SIM	Tool						x				
NTT DATA Automobiligence Research Center, Ltd.	ZIPC GARDEN	Tool		x				x				
Persival GmbH	Custom Perception Sensor Model Development	Service	x	x		x		x	x		x	
	Perception Sensor Performance Measurements	Service	x	x	x	x	x	x	x		x	
	Persival Avelon	Tool		x		x		x	x		x	
	Persival Simspector	Tool		x		x		x	x		x	
	Specification of Perception Sensor Simulation	Service	x	x	x	x	x	x	x		x	
PMSF IT Consulting Pierre R. Mai	PMSF FMI Bench	Tool									x	x
	PMSF OSI3Test Framework	Tool		x					x		x	
	PMSF RFMI Server	Tool									x	x
PTV Planung Transport Verkehr GmbH	PTV Vissim	Tool		x								
RA Consulting GmbH	OpenSCENARIO API	Tool							x			

SIMULATION

Company	Product	Tool / Service	OpenCRG	OpenDRIVE	OpenLABEL	OpenMATERIAL 3D	OpenODD	OpenSCENARIO	OpenSCENARIO XML	OpenSCENARIO DSL	OSI	Others
Shanghai Vehinfo Technologies Co., Ltd.	LABCAR	Tool		x								x
Shanghai Yoocar Network Technology Co., Ltd.	YooDriveCloud Solution for Autonomous Driving	Tool			x							
Siemens Digital Industries Software	Simcenter Prescan	Tool		x				x				
	Simcenter Prescan360	Tool		x				x				
TNO	TNO StreetWise	Tool		x					x			
tracetronic GmbH	ecu.test	Tool		x				x			x	x
	scenario.architect	Tool		x				x			x	
	trace.check	Tool									x	x
Vector Informatik GmbH	CANoe	Tool									x	x
	CANoe Server Editions	Tool									x	x
	DYNA4	Tool	x	x				x	x		x	x
Xi´an Forecast Data Technology Co., Ltd.	Cognata	Tool		x				x				

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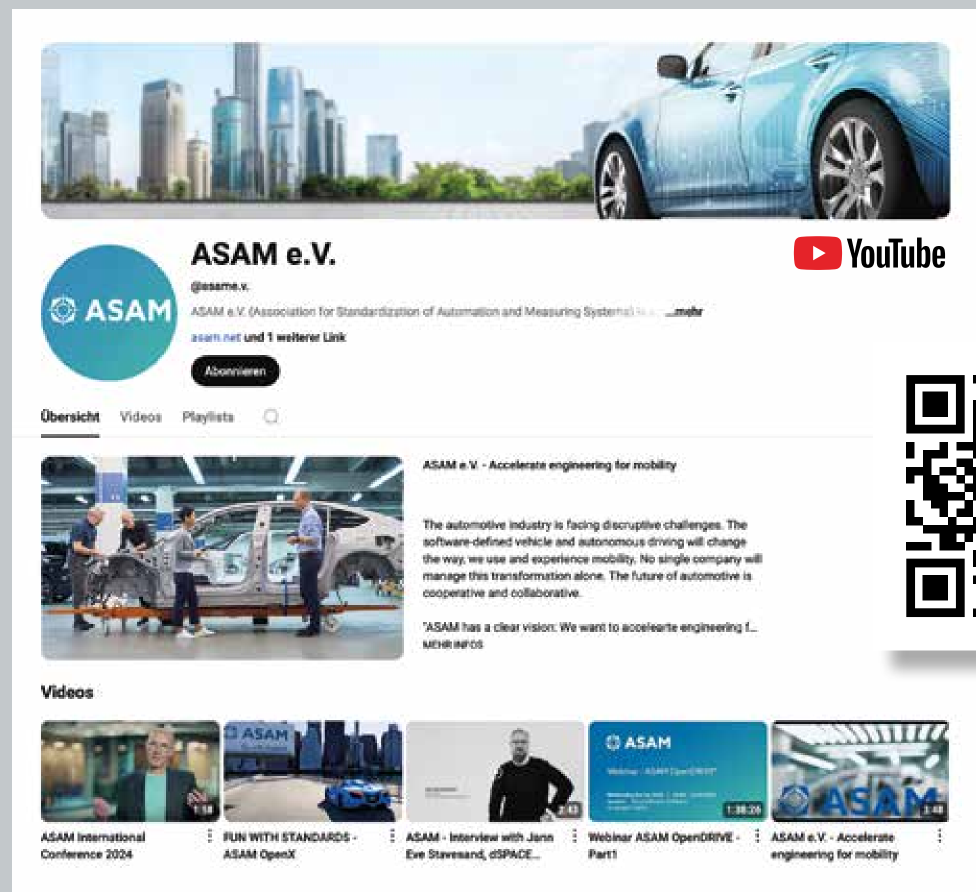

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(C-ASAM)

ABBREVIATIONS

ACS	Automated calibration systems
AD	Autonomous driving
ADAS	Advanced driver assistance systems
ADS	Autonomous driving system
AI	Artificial intelligence
AUSY	Automation systems
BoD	Board of Directors
BOM	Byte order mark
DAQ	Data acquisition
DCAS	Driver contol assistance systems
ECU	Electronic control unit
HPC	High-performance computer
MC	Measurement and calibration
OEM	Original equipment manufacturer (vehicle manufacturers)
SDV	Software-defined vehicle
TSC	Technical Steering Committee
V&V	Verification and validation

IMPRINT

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