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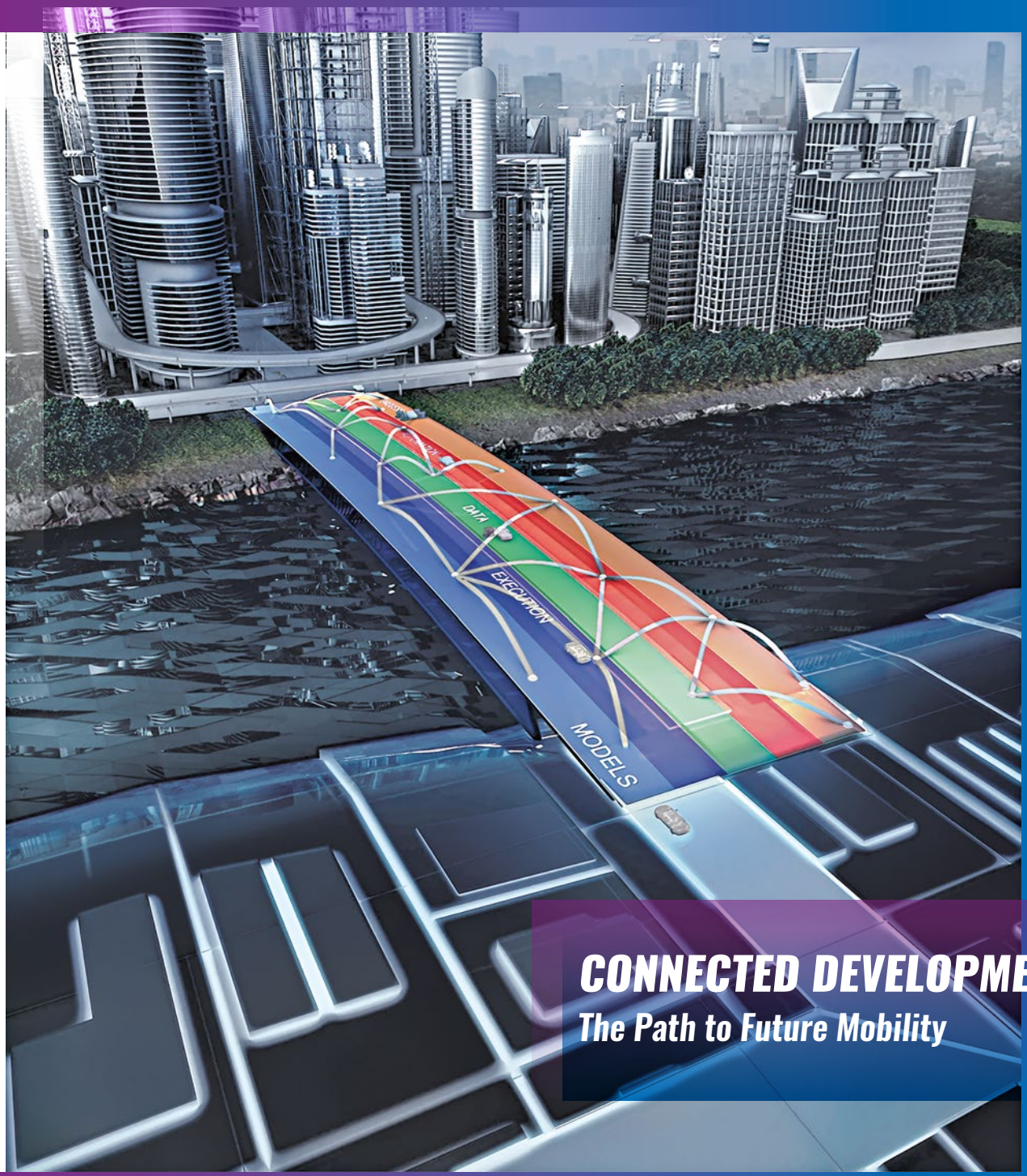

CONNECTED DEVELOPMENT

The Path to Future Mobility

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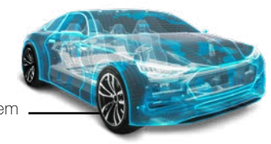
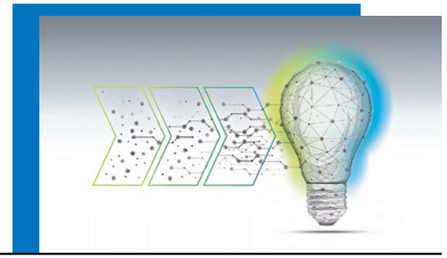




Editor and media owner:
AVL List GmbH
Hans-List-Platz 1, 8020 Graz
Tel.: +43 316 787-0
www.avl.com

Publisher and producer:
SCOOP & SPOON GmbH
Kirchberggase 10, 1070 Wien
Tel.: +43 1 523 4088 150
www.scoopandspoon.com

EDITORIAL

KATRIN MOSER
Marketing Manager
AVL

Can you envision a future worth getting excited for? A world based on sustainable energy, e-mobility and next-generation vehicles?

To make this vision a reality, automotive development will change significantly in the coming years and decades. Digitalization and the adoption of a more software-centric approach to development will enable OEMs, Tier1 suppliers and new market entrants to take full advantage of connected and augmented development:

- Model-based development and frontloading will ***speed up*** the development process.
- Innovative and adaptive methodologies complemented by scalable technologies will ***future-proof*** your development activities. This ensures that you remain flexible and versatile.
- Expanding the use of virtual and hybrid prototypes (part virtual, part real) will ***reduce costs*** and deliver reusable and reproducible test results.
- The ***openness*** of tools and systems will allow you to seamlessly integrate new and third-party tools or solutions into your existing development ecosystem.

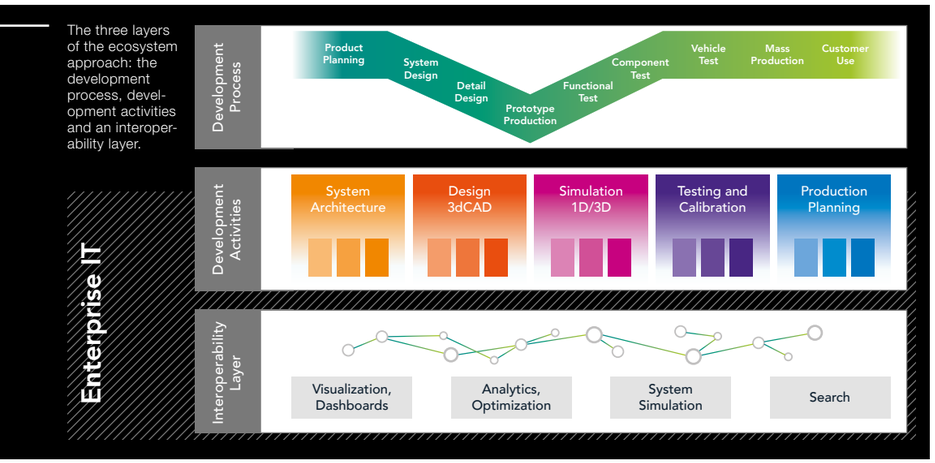
When you look at the many possible paths ahead, are you excited about the possibilities, or do you feel trapped by market expectations? I propose a third option: be bold and stay curious!

Albert Einstein once said, "I have no special talent, I'm passionately curious." Adopting a radically curious mindset, creates a willingness to explore many different paths. It pushes you to keep asking questions and discover a future worth getting excited about.

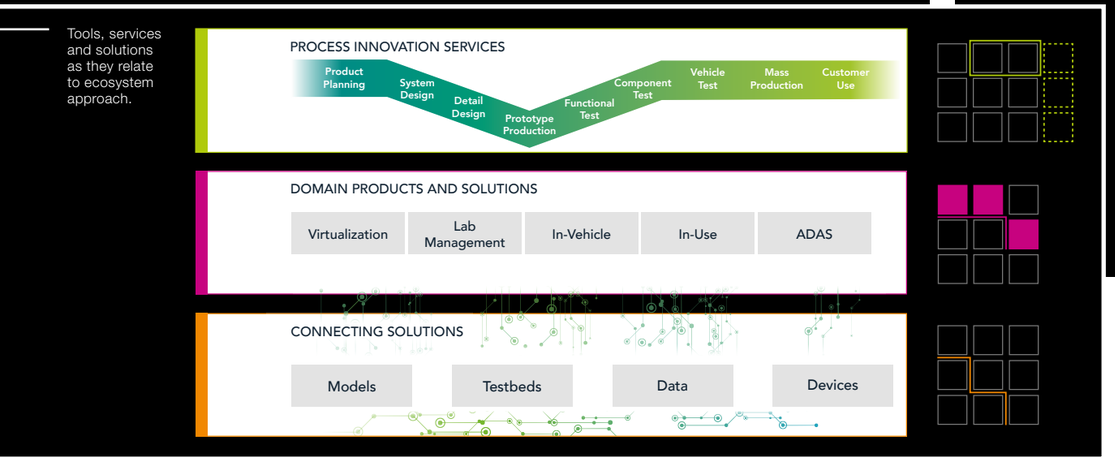
At AVL, we are re-committing ourselves to a bold new future. We're investing in our individual and combined skills and our ferocious reliance on curiosity. To help create a world that is carbon neutral and one that makes safe, comfortable, green mobility a reality for everyone on this beautiful planet.

Augmented Development and the Ecosystem

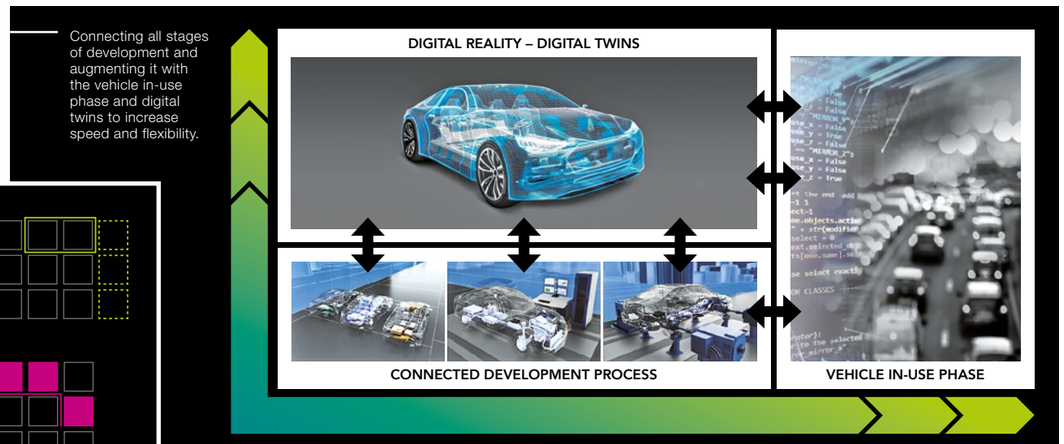
A new era of automotive technology calls for revolutionary development thinking. And that is just what AVL is offering with the development ecosystem



The three layers of the ecosystem approach: the development process, development activities and an interoperability layer.



Tools, services and solutions as they relate to ecosystem approach.



Connecting all stages of development and augmenting it with the vehicle in-use phase and digital twins to increase speed and flexibility.

— For more than seven decades AVL has been creating products and solutions for every aspect of powertrain development. From combustion sensors to emission measurement systems, NVH solutions, thermal management and beyond. A broad product portfolio of tools which address every inch of the vehicle and every individual development phase, backed up with the know-how of a global network of highly skilled experts.

The conventional vehicle as we know it has been developed over more than a hundred years. But as new, highly complex electrified powertrain configurations and autonomous driving technologies represent the future of mobility, OEMs don't have the next century to bring mature products to market.

The answer to these challenges is not simply individual tools, solutions and areas of expertise. Instead it's about bringing all of these things together to realize a revolutionary new vision of what the development process should look like. And that's exactly what we're doing at AVL.

A HOLISTIC, ECOSYSTEM APPROACH

Typical vehicle development involves different teams working on individual domains and parts of the vehicle. One team might be working on thermal management for example, another on NVH characteristic design, and another on the transmission system.

While all of these teams and disciplines work towards a shared goal of the complete vehicle, they also have individual goals to meet. And it's not until systems and components are integrated – on the testbed or in costly prototypes – that the cross influences can be thoroughly investigated, and synergies understood.

This conventional approach is expensive, time consuming, and results in unwanted development loops. And in this period of automotive transformation and growing vehicle system complexity, where efficiencies must be found in every part of the development process, it is becoming increasingly impractical to develop vehicles this way.

And so, at AVL we have brought our years of expertise, our tools and methodologies together in a single, unified approach, that revolutionizes the way we approach vehicle development.

Using digitalization, simulated digital twins and an end-to-end development philosophy that extends to the in-use phase, we are helping OEMs and Tier1 suppliers break out of this siloed thinking. Our approach allows teams to easily share their work and progression, right across the project. Furthermore, it utilizes the power of data intelligence to share goals and drive optimization all the while significantly reducing the need for prototypes. This diminishes time to market, saves money and accelerates innovation.

CONNECTED TOOLS AND LAYERS

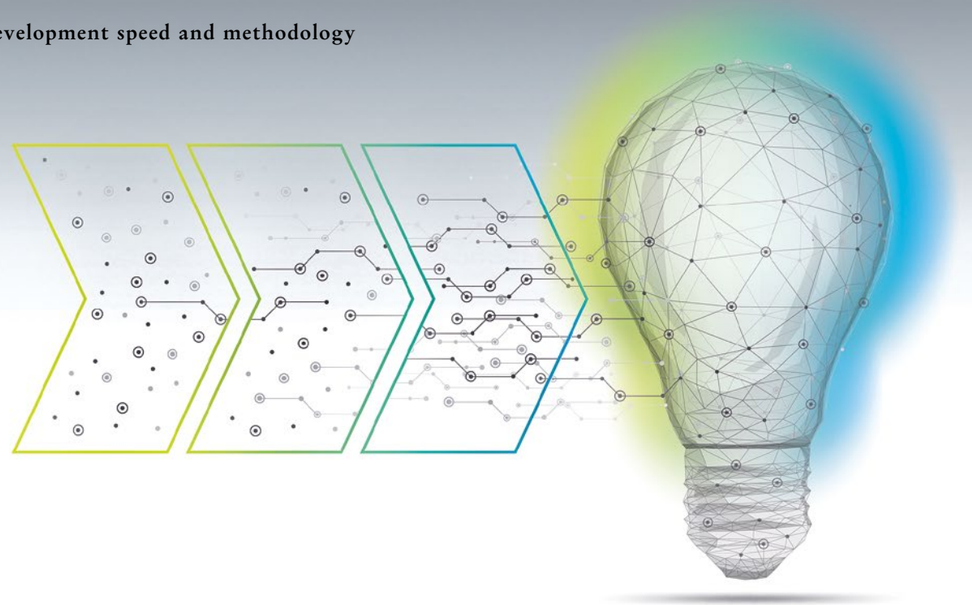
By harnessing our cross-domain know-how and our Open and Integrated Development Platform (IODP), the development ecosystem allows the rapid realization of project goals on both micro and macro levels. This ecosystem approach can be used to create new development workflows, or to augment existing architectures. It is organized into three layers: the development process, development activities and an interoperability layer. In accordance with this, AVL provides services and tools that match this ecosystem.

The first layer, Process Innovation Services, is designed to optimize each step of the process, from product planning to functional design and component testing, right through to mass production and customer use.

The second layer, Domain Products and Solutions, provides tools for specific domains / applications. It covers virtualization, lab management, in-vehicle testing, the in-use phase and ADAS system development.

The final layer is the Connecting Solutions layer. This allows the best use and sharing of data from all activities across the development process - independent of tools or suppliers. It includes our IODP solutions, Model.CONNECT™, Testbed.CONNECT™, Device.CONNECT™ and Data.CONNECT™.

These layers allow every domain, every process and every activity to be conducted with the bigger picture in mind. And, crucially, given the vast amounts of testing that are currently required for ADAS and autonomous systems, it extends into the in-use phase. This allows real world usage data from the latest connected vehicles to inform the development of the next vehicles coming off the production line.



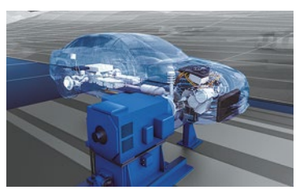
AVL Process Innovation Services help you realize your potential

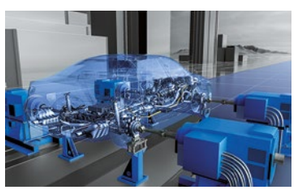
MANAGING CHANGE FOR THE BETTER

— The automotive industry is no stranger to change. But today the pace of change is accelerating, and this poses almost as many obstacles as opportunities.

There is a gap between what is possible within current development processes and the increasing testing effort required to meet emission legislation and manage the complexity of producing more vehicle variants. Hardware-centric approaches lead to time-consuming and expensive development cycles which can take traditional OEMs up to five years, when a goal of two years is what OEMs are trying to achieve. Our Process Innovation Services are designed to tackle this problem.

"Our goal is to improve the customer's development processes," say Engelbert Loibner, Global Business Development Manager for IODP and Rainer Schantl, Chief Engineer Process Innovation and Implementation at AVL. "The main considerations are time, money and quality, so the typical KPIs our customers come to us with are in terms of earlier, faster, cheaper and better."





TECHNOLOGICAL PROWESS

Process Innovation Services, consisting of a comprehensive consulting service and its implementation, covers everything from analysis of our customer's current situation all the way through to creating a quantifiable business impact. It forms the top layer of the Development Ecosystem approach and follows a six-step process. It helps you see how modern connected methodologies can optimize your development process, manage the evolving demands of efficient vehicle development and make the right decisions for the future.

At AVL we actively invest 10 % of our turnover in R&D and engage with steep learning curves to find solutions to challenging problems. We have done the work – learned the difficult lessons, and gained the knowledge – so you can benefit from our experience.

Our process is based on your goals and boundary conditions, such as your product portfolio, existing tools and methods, competences and strategies. Our aim is to improve either your entire process or just introduce minor changes in key areas.

"NOBODY KNOWS THEIR BUSINESS AND PROCESSES BETTER THAN THE CUSTOMER THEMSELVES."

Rainer Schantl
Chief Engineer Process Innovation and Implementation at AVL

A FOUNDATION OF COMMUNICATION

Change isn't always easy. Besides the investment, cultural acceptance within an organization can also be challenging. Because our completely customizable Development Ecosystem offering reflects your unique needs, goals and ways of working, it also takes into account your culture and your people.

We know decisions are made at management level, and we support this with relevant success examples, data and strategic information. But we also consider the engineers who'll be impacted by the changes at ground level. With pilot projects, training programs and conversations with experts from the relevant domains across our business, we ensure that everyone is brought on board to embrace the changes you will be implementing. Offering confidence and reassurance, we help you make the most of your existing expertise, and ours.

"Nobody knows their business and processes better than the customer themselves," says Rainer Schantl. "By combining their knowledge with our decades of project experience – as well as our industry-leading expertise in future technologies – we offer an expanded perspective that can help them realize their global potential."

PROVEN EFFECTIVENESS

Our approach is already helping OEMs and suppliers around the world. In some cases, manual tasks conducted on the road or test track are now done virtually, removing any need for hardware. In other cases, tasks such as vehicle calibration with prototypes on the road have been shifted to testbeds as much as six months earlier. We do this by combining any available hardware with simulated components and automation tools, long before complete prototypes are available.

For example, we helped a major automotive brand to ensure that powertrains and vehicles on a testbed behave in the same way as the vehicle on the road. In doing so, we were able to perform the maneuvers on the testbed six times faster than on the road. Similar results have been seen in integrations with other globally recognized OEMs, and also Tier1 suppliers, who are increasingly tasked with producing complete systems, such as e-axles, and integrating them into the vehicle, rather than simply supplying individual components.

The key benefit of our Process Innovation Services is that we optimize what you already do well, helping you keep pace and lead the way in a rapidly evolving automotive landscape.

Virtualization
in the Connected Development Ecosystem

With rapidly increasing system complexity, traditional development methods are quickly becoming outdated. AVL's new augmented ecosystem approach offers a wide array of solutions and methodologies that revolutionize the development workflow. One such solution is the application of virtualization.

— Virtualization is the change process that transforms a physical and hardware-centric development process with a more extensive use of simulation technologies and methodologies. Virtualization can be applied in varying degrees which are tailored to your needs. We call this the virtualization ladder.

FOUR STEPS TO VIRTUALIZATION

The virtualization ladder starts at step one, with a development workflow that includes only physical testing in the lab and on the proving ground, prior to SoP. In this scenario, data is shared manually between the lab and the office, and there is a heavy reliance on costly prototypes. The whole process is slow and expensive, and bringing products to market takes much longer than is ideal.

In circumstances like this, where there is no virtualization competence, our role is to introduce the customer to its benefits in the most accessible way possible, taking them to step two in the process. We achieve this by recommending application-related packages that begin to streamline the relationship between the office and test environments, and reduce reliance on prototype hardware.

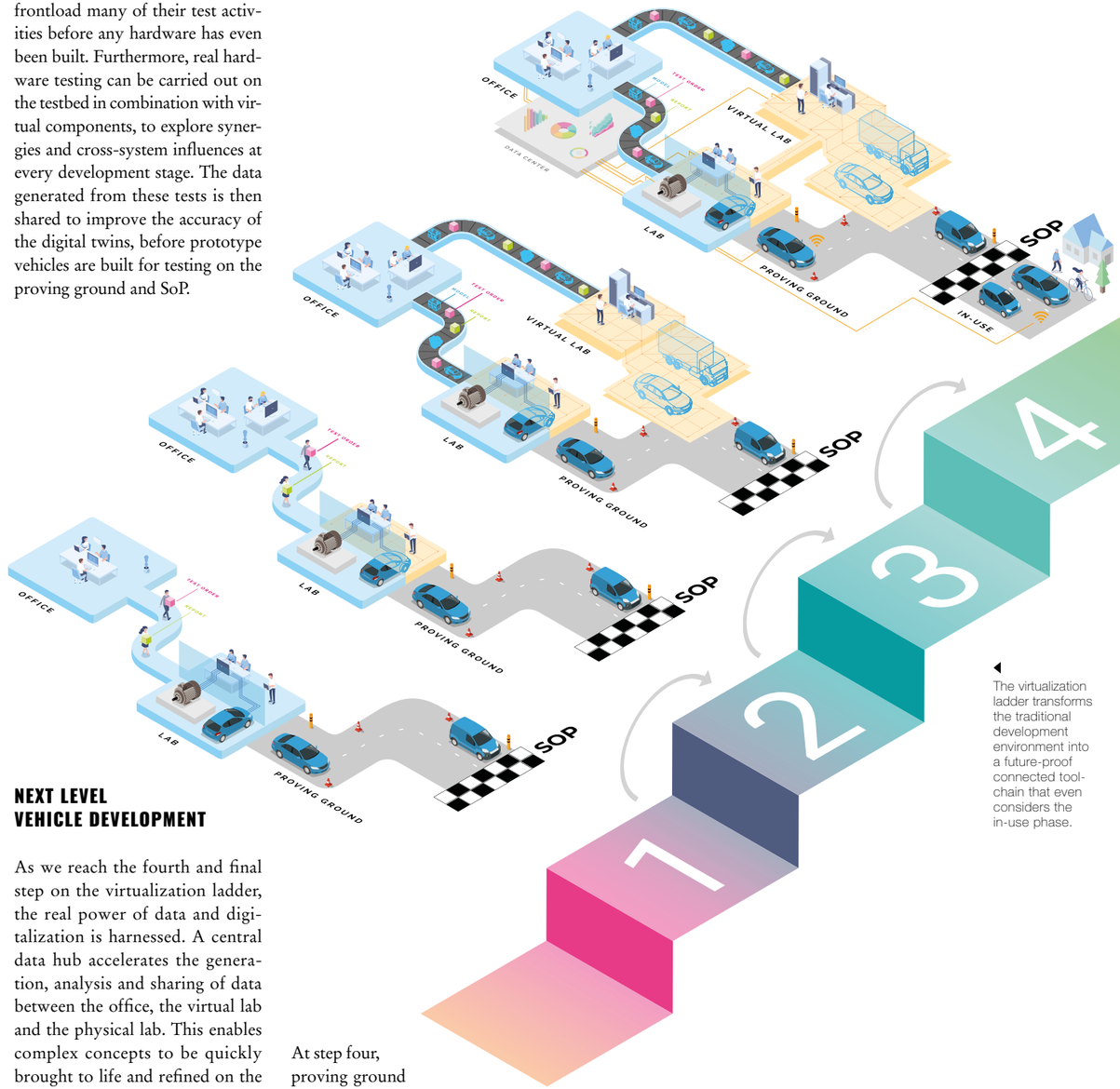
The packages we recommend are implemented locally at critical points in the toolchain. Test preparation is improved both in the lab and on the proving ground with the application of our AVL Smart Mobile Solutions™ simulation package. Complete vehicle modelling is powered by AVL ISAC™ and AVL VSM™ and test analysis is provided by AVL CONCERTO™. Crucially, at this second step of the ladder no simulation expertise is required on the part of our customer, and we offer full integration support and training to ensure the transition occurs as painlessly as possible. Integrating our tools and methodologies into a development environment where there were previously none is a simple and effective way of demonstrating the powerful impact of virtualization.

CONNECTING THE VIRTUALIZATION EXPERIENCE

At level two, most departments are still working relatively independently with test orders and test results being shared manually, and only partial system modelling happening. There is still a large requirement for hardware and proving ground testing. However, as we progress up the ladder to level three, bridged applications with more simulation tools are connected to enable data to flow more freely.

Virtual testing is facilitated with AVL Virtual Testbed™, which is supported by our complete vehicle modelling solutions to create a virtual lab where simulated systems or a complete virtual vehicle (a digital twin) can be built and tested. Testbed.CONNECT™ links the tools together in order to make the most of the data, and feed the results of the testbed activities back into the vehicle models.

With the further addition of our market-leading solutions for test preparation, optimization and results analysis, our customers can frontload many of their test activities before any hardware has even been built. Furthermore, real hardware testing can be carried out on the testbed in combination with virtual components, to explore synergies and cross-system influences at every development stage. The data generated from these tests is then shared to improve the accuracy of the digital twins, before prototype vehicles are built for testing on the proving ground and SoP.



The virtualization ladder transforms the traditional development environment into a future-proof connected toolchain that even considers the in-use phase.

NEXT LEVEL VEHICLE DEVELOPMENT

As we reach the fourth and final step on the virtualization ladder, the real power of data and digitalization is harnessed. A central data hub accelerates the generation, analysis and sharing of data between the office, the virtual lab and the physical lab. This enables complex concepts to be quickly brought to life and refined on the virtual testbed in order to meet targets at system and complete vehicle level. As hardware is rigorously tested and validated in the lab, the results are quickly fed back to the office and the virtual lab, and further refinements and trade-offs can be quickly introduced to the vehicle model, which then further informs more hardware testing.

At step four, proving ground testing can now feed directly back into the workflow, further validating the simulated models, and enabling thorough testing under real conditions. Crucially, with the advent of connected vehicles, development can now be extended to the in-use phase. Real drivers become part of the development team, and their behavior, maneuvers, and fleet-wide data that is simply impossible to collect during formal testing can now be fed back into the development loop.

This in-use data can inform the next generation of vehicles, and can be used to create firmware updates to improve vehicles already on the road.

Virtualization is a key tool in the acceleration of complex vehicle development, and at AVL we are already employing it to help OEMs shape the future of mobility.

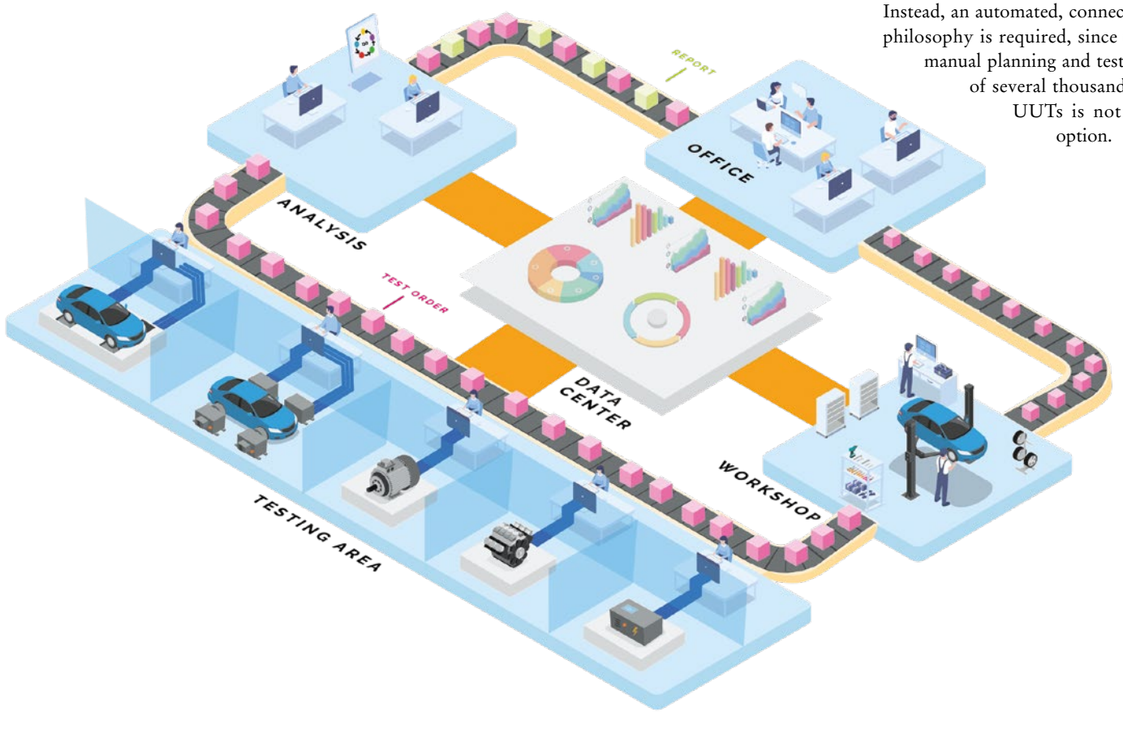
Realizing the Potential of Your Test Field

AVL Lab Management™ helps you get the most out of your test environment

— Vehicle development is vastly complex and expensive. To ensure the products that get to market meet the requirements of the end-user, legislation and cost of ownership, every aspect of development and validation must be optimized for the best performance and productivity, and maximum overall equipment effectiveness (OEE).

Yet even in modern testing labs, it's not uncommon for OEE to be just 30 % of its capability. From downtime losses due to maintenance, for example, to productivity losses due to idle and empty channels in cell testing, quality losses due to data issues and test repetition due to unclear test requests, most development environments are not working to their full potential.

It is precisely because these environments are so complex that these losses occur. Simply put, vehicle development and testing are too complicated to be done manually. Instead, an automated, connected philosophy is required, since the manual planning and testing of several thousand of UUTs is not an option.



INTRODUCING AVL LAB MANAGEMENT™

Productivity must therefore be optimized, data must deliver maximum value, energy and resources must be managed, and maintenance, bottlenecks and other downtime must be avoided or carefully scheduled.

At AVL, drawing on our decades of experience and deep understanding of our customers' needs, we have developed AVL Lab Management™ to make this a reality. It includes three extendable and customizable base configurations:

- AVL Lab Management™ for Battery
- AVL Lab Management™ for Propulsion
- AVL Lab Management™ for Vehicle

Each addresses specific customer needs, and each is designed to maximize OEE and deliver high quality data for your Design Validation Plan (DVP).

SIMPLE SOLUTIONS FOR COMPLEX CHALLENGES

AVL Lab Management is designed to deskill your development or test environment. Rather than requiring an engineer for every lab-based task, it automates nearly everything that can be standardized, and allows flexibility where required, leaving the engineers to focus their efforts where they are most useful.

Whether it's the management of test orders, the planning and scheduling of test activities, the linking of required data such as data sheets or test documentation, or even the management of test resources and UUTs, AVL Lab Management does it all.

The concept is modular and open, allowing it to be tailored to your unique needs. And it supports both AVL and 3rd party systems with modern, easy-to-use container and web-based software.

FROM LAB TO DATA, AND EVERYTHING IN BETWEEN

To understand how comprehensive this solution is, let's take Lab Management for Battery as an example. Modern battery test labs can include thousands of test channels in hundreds of climatic chambers, each accommodating hundreds of cells. As some tests can run for over a year, it's vital that each chamber is optimally filled, and the only way to do this is to combine test activities and programs. But in a facility that might be testing tens of thousands of cells at any one time, it's impossible to do this manually. This is where our solution steps in.

Optimizing schedules, channel availability, resources and throughput, and then making the resulting data available for analysis, it takes the heavy lifting out of testing. But there's more to it than just throughput.

Battery testing requires cells to be charged and discharged repeatedly. When this happens at scale, electrical power requirements can be staggering. Exceed the maximum connection line and all tests will shut down, requiring costly and time-consuming resumption. Lab Management for Battery manages your energy use, by planning according to the capabilities of test systems in order to balance charge and discharge tests at the same time, using the electricity discharged from some cells to charge others. This protects your operations and increases lab efficiency.

SELF-SERVICE DATA FOR SUPERIOR ANALYTICS

Whether you're using our Battery, Propulsion or Vehicle reference solutions, Lab Management also offers advanced contextual data management. You can choose your own best approach for analysis of data from the data lake, using your preferred tools such as Python. Or alternatively, to save time, data can be interrogated using standardized evaluations that require no programming.

Whatever your needs, AVL Lab Management is here to help you realize your development goals by maximizing OEE.

THE WORLD AT YOUR FINGERTIPS

Digitalizing the in-vehicle calibration, validation and certification process for the entire test fleet

— To meet emission legislations and customer demands, vehicle development is becoming more challenging than ever. Prototype vehicles are spiraling in cost, and the testing effort for different vehicle models in different locations – such as the heat of South Africa or the cold of Scandinavia – is immense.

At AVL we are experts in the application of cutting-edge simulation solutions to frontload development. Our products and services streamline development and testing processes, reducing effort and the need for prototypes, therefore cutting costs and saving time. However, there will always be a need for real-world prototype testing.

In-vehicle testing, though, with its need for multiple drivers and exhaustive requirements, is logistically difficult, expensive and extremely time-consuming. And now, with calibration engineers unable to travel due to global Covid-19 restrictions, alternative ways of working are required. This is where our in-vehicle testing solutions can help.

SIMPLE TO INSTALL AND USE, THE SYSTEM SAFELY AND QUICKLY ENSURES THAT YOU GET THE DATA YOU NEED.

IMPROVING THE PROCESS – STEP BY STEP

Conventional testing, whether on the road or proving ground – or overseas in different climatic environments – is normally a manual process. A driver and calibration engineer in a vehicle conduct a series of maneuvers and then return the data to the office for analysis. If more data is required, the vehicle goes back onto the road, and the process is repeated.

This is slow and costly, typically with data siloes hindering data processing and increasing effort. To streamline the process we offer solutions that join the dots, in varying degrees of connectedness. Our simplest offering focuses on central data storage and management, which speeds up the analysis of the data, offers traceability and reuse, and is a great improvement on conventional methods.

Building on this foundation we can also introduce in-vehicle testing solutions that do away with the need for the calibration engineer to be in the car. Instead the driver is guided to complete predetermined maneuvers until the required data has been successfully collected. Simple to install and use, the system safely and quickly ensures that you get the data you need. This approach is well suited to applications such as ADAS fleet validation activities, vehicle validation and certification, and BEV function testing.

Reducing data siloes, testing time and manpower, this approach also increases quality with reliable and repeatable results that support calibration and certification. This ensures the targets achieved in simulations and on the testbed are also met in the real world.

One of the added values of this method comes with the ability to conduct real-world testing remotely. With travel greatly restricted due to the pandemic, and the increasing pressure to reduce costs in all areas, in-vehicle testing can now occur with the calibration engineer in the office and the test driver on the track – even if they're on opposite sides of the world.

Once the tests are prepared and uploaded to a data center, the driver simply downloads them with a click of a button – anytime, anywhere – to the vehicle. If the maneuvers in the vehicle don't meet the preselected test criteria, the system guides the driver to repeat them until they have all been completed.

It is fully integrable – and open to AVL and non-AVL hardware and software with open interfaces – allowing for consistent testing processes and guaranteeing revision safety. Integrated planning, testing and data handling produce an automated testing process with strong data intelligence.

Our connected approach offers huge benefits, from simple logistics management or data handling, right through to a completely digitalized, connected approach of the entire in-vehicle testing process. And whether it is cost and time-saving you're seeking, reduction of complexity, or an increase in quality and compliance, it offers all these benefits in an open package that can be integrated with minimal disruption.

BUILDING A CONNECTED FUTURE

Harnessing the power of connected workflows to promote interoperability

— Trends in the automotive industry and global emission legislation are driving complexity in the vehicle and the development process, with new features and functions increasingly becoming an issue of software and not just hardware. This places pressure on manufacturers in terms of balancing this complexity with time-to-market and cost, without sacrificing quality.

The development process must therefore be optimized, from concept through to the in-use phase. Frontloading as much development in early stages as possible is an obvious solution, as is a holistic view of vehicle development, with data shared throughout to ensure continuous validation and verification (V&V). Enabling a much closer interaction between domains in this way cuts time-to-market, saves money, and promotes continuous V&V across all competencies.

However, in most development workflows this approach exists in only a limited way. Instead, experts in each domain use the tools that are right for their specific needs, but which don't necessarily suit such a holistic approach. This heterogenous landscape of simulation tools, databases and test equipment becomes an obstacle to rapid, high-quality development. We call it the Interoperability Gap.

CLOSING THE GAP

"This is where AVL's Connecting Solutions come in," says Josef Zehetner, Chief Engineer System Architecture, AVL. "They connect the domain-specific tools and activities throughout your entire development process – or just part of it, depending on your needs – and build up your Integrated and Open Development Platform (IODP). Offering lifecycle management of relevant information objects, such as simulation models and parameters, testbed configurations and Units-Under-Test, it enables you to link your CAD-driven product development process and your continuous V&V activities, from early simulation to on-road testing. You can create a complete virtual prototype in the computer, and then as hardware becomes available, continue development with a mixed virtual/real prototype. Ultimately development moves into a complete real prototype, with data continuing to be gathered and fed back into the process. And it's with the application of our Connecting Solutions that your data can really deliver its full value.

ADDING MASSIVE CONTEXT FOR MASSIVE VALUE

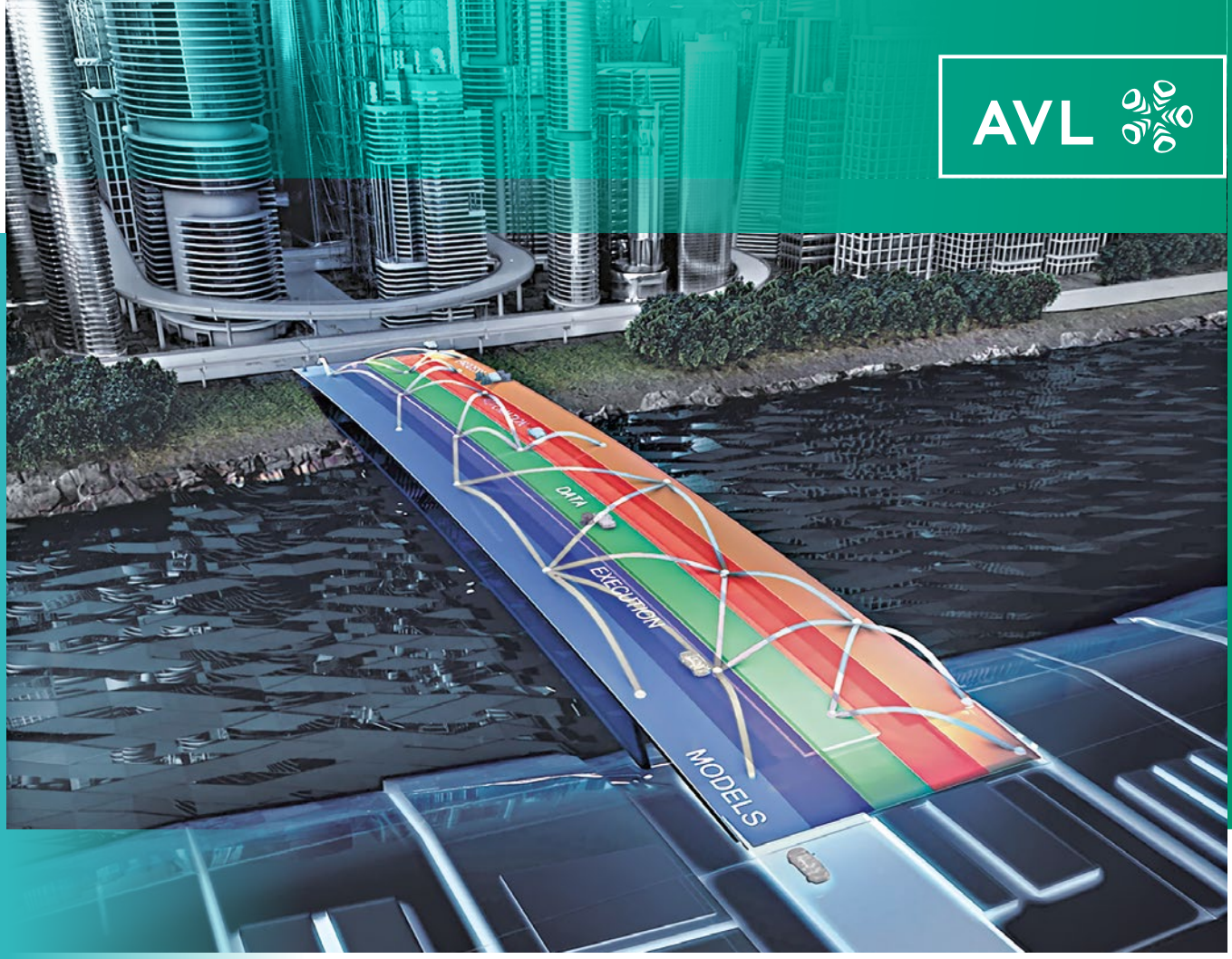
Vehicle development produces vast amounts of data. But much of this is underused because of data siloes, or because it lacks context. Our connecting solutions undertake to bridge the gap between silos, and structure your data, with full context and a focus on re-use for all phases of development.

Crucially, this enables transparency and traceability for your V&V activities, delivering continuous results and consistency. And it enables us to leverage your existing data and expertise to increase efficiency and agility in your entire development process.

This vision of interoperability is made possible with the Integrated and Open Development Platform and our tools, Model.CONNECT™, Testbed.CONNECT™, Device.CONNECT™ and Data.CONNECT™. Each one addresses a different function within the development workflow, and then they join together to support the bigger picture. The different modelling tools, for example, can now talk to each other, or to your testbeds, or the devices you operate in your test cells, on the proving ground, or during the in-use phase. Data now offers much more value. Data from your proving ground devices can now inform your modelling practices, your models can inform your testbed activities and so on. Quickly, easily, and securely.

Establishing a link between your product-structure-driven systems, such as Bill of Materials and Product Data Management, and the functional representation of the product as well as your development competencies, our Connecting Solutions offer a new way for you to meet your goals and manage your time and budget.

With our expertise in product development and our deep understanding of your needs, we can tailor these solutions to your existing processes, system architecture and tool landscape. Supporting your digitalization process, and building on your strengths, it helps you do what you do best – only better.



Boosting Your Development Speed and Methodology

Bridging the gap between the virtual and real worlds

How do you handle the increasing complexity of your development projects? How do you speed up your time-to-market? How do you not just keep pace with rapidly changing market conditions but actually pave the way forward? And how can you make the most of your existing diverse tool landscape and, at the same time, foster a holistic system development through extensive integration?

Current development topics demand one thing above all else: interdisciplinary cooperation with a consistent focus on the overall product. The goal is clear: to achieve greater agility and speed in the development process by introducing new methodologies and making development more software centric.

We provide services, tools and solutions perfectly tailored to your company-specific development ecosystem. The foundation for this is the interconnection of all elements of the vehicle development process – step by step and independent of tools and suppliers. Neutral connectors integrate simulation models, testbeds, devices and data across your process.

Together, we define measures to increase development efficiency, which we achieve by optimizing your productivity within existing environments and by shifting workloads to earlier process phases.

www.avl.com/iodp