AVL Global Engineering Competence – A Network of Technical Centers



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PA4025E, Classification Public

AVL is serious about serial development.

RELIABLE PARTNERSHIP AND A TRUE ADDED VALUE FOR AVL'S CUSTOMERS.

Vehicle manufacturers not only have to manage the complexity of more and more variants and the challenges of global legislation. Their resources are also increasingly tied up with electrification and autonomous driving. That's why they sometimes need reliable external development partners for the serial development of lead and derivative powertrains to support them.

Over the last years, AVL has successfully taken on projects in the area of Serial Development – and not only calibration projects. A very experienced global Serial Development team has been put in place – from all AVL skill areas and different locations. Highly commited people, who are fully dedicated to the customers, their projects and their final products. They are skilled in listening to the customer, talking to them on eye level and truly understand their specific needs and problems. This AVL team is determined to prevent problems in order to ensure the stipulated quality, timeline and cost. With this, AVL offers their customers a reliable partnership and a true added value in the AVL services.

The following guide is meant to show AVL's Serial Development capabilities in detail and to prove the excellent credentials AVL already has in this field.

The 10 Key Targets in Serial Development

Serial Development projects are highly complex because of the many conflicting goals that need to be reconciled. It is about development and engineering, yes, but it's also about finding the best technical and commercial trade-offs in a global production context.



The complex and conflicting challenges in Serial Development projects.



SERIAL DEVELOPMENT: THE ART OF THE TRADE-OFF

Serial development has to ensure that not only the technical goals – emissions, fuel economy, performance, etc. – are met, but that all other issues affecting industrialization and production of the component have been considered and the trade-offs have been made.

AVL development and engineering for serial projects is carried out by well-known and enhanced expert teams in PTE. Besides the technical know-how, further skills like supplier management, cost engineering and quality management according to APQP have been developed to excellence to bring powertrain sub-systems to production maturity.





AVL SERIAL DEVELOPMENT PROJECT SCOPE

AVL offers Serial Development for electric, hybrid and internal combustion-powered vehicles. We cover the following sub-systems:

- IC Engine
- E-Motor & Power Electronics
- HV-Battery
- Transmission and Hybrid Modules
- Electronic Controls and Software
- Entire powertrain system
- Vehicle Systems (Thermal, HVAC...)

10 Essential Capabilities for Serial Development Projects

AVL CAPABILITY 1: TECHNICAL GOALS & INTEGRATION

What is meant by technical goals & integration?

The technical development goals refer to the vehicle targets in regard to parameters such as emissions, fuel economy, performance, durability, range, drivability and acoustics. Integration refers to the integration of the sub-system into the complete vehicle. The design of the powertrain and its sub-systems makes a significant contribution to attaining these goals. In Serial Development, key guestions are:

- How can the technical development goals of the vehicle be achieved while taking all of the constraints of production into account?
- How can the optimum between conflicting goals be achieved from the perspective of the final vehicle and, furthermore, the end-user?

What does AVL do?

AVL offers a complete range of skills and services to develop powertrains and powertrain sub-systems for electric, hybrid and conventionally-powered vehicles, taking all technical and legal parameters into consideration. These services include:

- Target and specification setting and alignment
- Concept development
- Desian
- Hardware and software development
- Simulation
- Mechanical development and testing
- Calibration
- Validation

Furthermore, AVL is able to derive and write complete supplier specifications for the systems or components in question.

How do we add value

- Powertrain development and engineering is the core competence of AVL, with over 70 years of experience
- We have teams of world-renowned development experts in both "new" and "traditional" propulsion systems
- We support all industries with a global network of development and test facilities



AVL CAPABILITY 2: ENSURING MANUFACTURABILITY

How does AVL understand manufacturability?

However technically brilliant the design of the component or sub-system may be, in Serial Development the key questions are:

- Can the component be manufactured with suitable processes and technologies?
- Does it allow stable and robust processes?
- Can our design allow the use of mostly existing equipment?

That means, for example:

- Can the designed geometry actually be cast / forged / sintered easily?
- Are the tolerances feasible and can they be measured easily?
- Does the design take the production process into consideration?
- Can existing production tools, manufacturing and assembly equipment be used?
- Are specified materials available globally in a consistent quality?

What does AVL do?

AVL's task in this area is, ideally, to design the component in such a way as to ensure its manufacturability from the outset. Alternatively, AVL is responsible for adapting a pre-series design in such a way as to ensure that all producability criteria are taken into consideration.

How do we add value

AVL's powertrain development expertise and facilities allow us to develop component and system designs that are not only producible, but also do not compromise the technical objectives of the vehicle such as emissions, performance and drivability. In other words, we find the ideal trade-off at the best production cost.

AVL CAPABILITY 3: ENSURING SERIAL QUALITY



What is serial quality?

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Quality is of the utmost importance in Serial Development projects and requires systematic processes, discipline and great care. The key questions are:

- Is the component or system robust and safe and does it meet all specifications?
- Can the component be manufactured in the required quality and does the production meet all requirements?
- Will the component or system be satisfying and reliable from the end-user perspective?

What does AVL do to ensure serial quality?

AVL supports the OEM's quality assurance team in the following areas:

- Checking the robustness of the design to make sure that interference factors will have no effect on the functionality of the system
- Align the design with the planned manufacturing methods
- Checking the functional safety of the system
- Design validation, in particular planning and reporting
- Analysis of OEM field data to check for quality issues and derive preventive actions
- Inspection of components on delivery
- Recommendations on which components need testing to which tolerances
- Documenting particular, safety-critical features that may influence the production process and must be monitored with narrower statistical tolerances.

How do we add value

- In addition to rigorously implementing quality management methods such as APQP, FMEA and DVP&R, AVL has developed a proprietary tool, the AVL Load Matrix, that systematically cross-references all specifications with measured field data from the customer
- AVL's long experience and our spectrum of customers and applications allow us to really understand and influence the impact of critical features and dimensions on customer relevant functions
- The combination of AVL's technical expertise with our industrialization competence enables us to find the most cost-effective design for sufficient quality

AVL CAPABILITY 4: PRODUCTION COST MANAGEMENT

What is meant by production cost management?

Production cost management is all about taking a smart approach to how a system or component has to be designed, and planning in advance which production tools and processes should be implemented to ensure minimal total cost. Central to this are the following questions:

- How can we contribute during system development to meet or even underrun the planned product costs?
- How can we design a system or component in the most cost-efficient way?
- How can we find the optimal solution for our customer by balancing piece and tooling cost?

What does AVL do?

Some of the considerations that AVL makes:

• To ensure that the choice of production technology used in the system is appropriate to the number of units being produced



- Minimization of the volume of waste material from the cutting or stamping process
- Minimization of the number of times the machines have to be re-tooled or changed during production
- Optimization of the tooling strategy

How do we add value

- The AVL focus is to optimize production cost in the first "Serial Design Intent" generation (Gen. 1) together with customer and AVL industrialization experts as cost reduction in later development phases would generate high maturity risks
- AVL can provide our customers a broad spectrum of competences and tools such as "Should Cost Analysis", Benchmarking and systematical Value Analysis
- We manage the "Simultaneous Engineering" process on behalf of the customer, meaning
- the joint development of product and production processes
- the permanent synchronization between Engineering, Production, Suppliers, Quality and Aftersales
- the joint optimization of the product cost and quality already in early development phases, including alignment with serial suppliers

AVL CAPABILITY 5: TIMING DISCIPLINE - KEEPING TO DEADLINES

What is the significance of timing discipline in Serial Development?

Working within an agreed time frame is absolutely essential in Serial Development. Any slight delay can potentially cause major problems and expense and can endanger start of production.

There is no key question here. The deadlines simply must be met.

What does AVL do?

For the components within AVL's responsibility, our tasks include:

- Planning and monitoring progress and milestones proactively
- Carrying out quality gates
- Function-based release planning, which ensures that all electronic control units are tested and synchronized with each other by a certain date
- Integration planning
- Planning and monitoring supplier progress and deadlines
- Planning and monitoring of components releases

How do we add value

- AVL uses the closed-loop principle, in which any actual or potential deviations from the agreed time plan are immediately spotted and reported internally. Corrective action has to be implemented to recover the schedule
- Externally, the customer is provided with full transparency of the timing status. This gives the customer teams the chance to immediately escalate within their own organization and to get the decisions needed



AVL CAPABILITY 6: SUPPLIER MANAGEMENT

What is supplier management?

Once the powertrain components and sub-systems have been designed and specified, supplier management deals with these questions:

- Which supplier can deliver innovative solutions and ensure their successful industrialization?
- Who can produce and deliver these parts to the exact specifications and at the best quality and cost?
- How to manage and coordinate the selected component suppliers up to SOP on behalf of the OEM – on time and in accordance with all targets?
- How to cope with the daily challenges caused by permanent cost pressure such as global supplier landscape, change management, delivery issues...

What does AVL do?

OEMs have highly professional purchasing departments who handle the commercial and contractual details of supplier sourcing. These responsibilities remain in the domain of the OEM even when a Serial Development project is outsourced.

The role of AVL in supplier management may be as a first step to help set up the supplier candidates long-list and to carry out technical evaluations of their capabilities. On the basis of these technical audits, AVL can make supplier recommendations, assist with quality and cost planning and support the claim management towards the suppliers. AVL knows and masters all necessary methodologies (APQP, PPAP, PVR,...).

Once the suppliers have been selected, AVL takes charge of supplier management for the specified components or sub-systems, including planning and monitoring of technical development, industrialization maturity and final release recommendation of the parts, and of serial production preparation.

Powertrain Development Process





How do we add value

- We work with a tried and tested collaboration model that streamlines cooperation between OEM, AVL and suppliers
- AVL's deep technical knowledge enables us to evaluate the expertise of suppliers and to anticipate, or later to solve technical problems
- AVL's industrialization competence and experienced staff allow us to handle the supplier interaction (technical alignment, alignment with OEM manufacturing, time management...) on behalf of the OEM

AVL CAPABILITY 7: DESIGN FOR ASSEMBLY

What does assembly have to do with Serial Development?

How easy the vehicle or sub-system is to assemble on the production line can have a significant effect on production time, cost and quality. So it is crucial to take assembly into consideration when designing the system. The central questions are:

- How can the system be designed to make it easy to assemble?
- How can the mix-up of similar parts be avoided by design?
- How can we minimize the demand for expensive special assembly tooling and fixtures?

What does AVL do?

AVL's tasks regarding assembly include:

- Defining the logical order in which parts are assembled, while ensuring accessibility of each part to its mounting position
- Documenting the order of assembly in an understandable way
- Ensuring that assembly is as simple, cheap and flexible as possible
- Ensuring that there is enough space either for manual assembly or for the movements of tools
- Ensuring that parts cannot be mistaken for one another – either by using the same parts or ensuring that all parts are recognizably different ("Poka Yoke")
- Avoiding by design damage of parts or subsystems during assembly or handling
- Defining end-of-line testing of the assembled components

How do we add value

- AVL's team of Serial Development experts is recruited from the field of serial production to monitor all issues relating to assembly
- AVL has experience in the industrialized production of measurement equipment to the highest quality standards
- Our long lasting experience with different concepts for various customers allows us to define assembly optimized design solutions



AVL CAPABILITY 8: ENSURING SERVICEABILITY

What is Serviceability?

When developing for serial production, engineers are obliged to think ahead to when the vehicle is in service long after production date. The key questions are:

- Can the component or system be easily serviced, once the vehicle is in the field?
- Can the maintenance be done with globally existing OEM service tools, or are specific tailored tools required in each and every garage worldwide?
- Are the "Lifecycle Costs" of the vehicle, including maintenance and spare parts, competitive?

What does AVL do?

AVL is careful to take serviceability in the after-market into consideration in a very early phase of development work. Detailed discussion of the hardware and software concept take place with the OEM service department during the "Serial Design Intent" Phase (Gen. 1) - so before the first real prototypes are built.

The aim is to make the component or sub-system as easy to repair or replace as possible. The following factors are carefully considered:

- How easy is it to mount spare parts for aftermarket service staff?
- How can we ensure that standard garage workshop tools can be used instead of needing specialized tools – when servicing this component in the vehicle?
- How easily can you access the part with tooling?
- How can we maximize safety and minimize the risk of injury to mechanics?
- For hybrid and electric vehicles, has high-voltage safety during repairs been adequately addressed?
- Can faults be diagnosed guickly and accurately?



How do we add value

- AVL's work on vehicle projects has given us a large amount of insight and experience in terms of how easy a vehicle must be serviced
- AVL's broad spectrum of customers and applications enables us to ensure "best practice" serviceability
- AVL's affiliate company, AVL DiTest, is specialized in diagnosis and testing equipment for the after-market. These same specialists are involved in software development for Serial Development projects and advise on serviceability aspects



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AVL CAPABILITY 9: LOGISTICS & PACKAGING

What is the significance of logistics & packaging?

The requirements in packaging and transportation of components and sub-systems have an effect on both quality and cost. They need to be considered from an early stage in the Serial Development process. The key questions are:

- Does the design drive complexity from documentation to packaging and require expensive logistical paths?
- How can the manufactured system or component be packaged and transported to avoid corrosion or damage at minimal cost?

What does AVL do?

During the design and engineering of the components AVL is responsible for, we work closely with planners and specialist departments at the OEM or supplier to ensure the following factors are taken into consideration:

- Optimization of volume and shape to minimize air pockets and packaging materials
- Reduction of complexity and variants, use of common parts/ modules/ systems whenever possible
- Considering the minimization of transportation distances and distribution costs already in the design
- Protection from physical damage, corrosion, incompatibility of lubricants and conservation as well as dust damage
- Global optimization of packaging, damage and rust protection for different climates and terrains
- Easy and clear identification of parts and systems

How do we add value

- As a producer and global shipper of highly sensitive measurement technology, AVL has a very high level of packaging and logistical know-how and is sensitive to the problems of particular climatic conditions around the world
- Again, AVL's broad spectrum of global customers provides extraordinary experience on "best practice" cleanliness requirements and conservation methods

AVL CAPABILITY 10: CHANGE, CONCERN & RELEASE MANAGEMENT

What is change, concern and release management?

In the course of a Serial Development project, even the best preventive action and proper planning cannot avoid frequent technical changes, necessary optimization loops for systems and components or even changes in specifications. The key questions are:

- How can we organize the flood of changes in the most professional and efficient way, especially on the interfaces with customer and suppliers?
- How can we solve problems in the best systematic and effective way – and permanently learn more about how to avoid similar problems?
- How can we ensure absolute precision and discipline in change and concern management?
- How can we finally release the components and systems in a way that fulfils the customer requirements AND limits legal and commercial risks for AVL?

What does AVL do?

- AVL is responsible for defining release criteria for components and last-minute changes in coordination with all project stakeholders
- AVL will organize the change management process either in the customer's or AVL systems, professionally make recommendations with regard to the changes and ensure the official decision is made
- Once the changes have been officially implemented and released, AVL is responsible for appropriate documentation of the changes





How do we add value

- In order to manage changes, concerns and releases as efficiently as possible, AVL ideally works within the OEM's systems and is already certified by many OEMs to do so. This eliminates interfaces to other systems and the AVL team can work with the OEM team in a highly integrated way
- If such a system is not accessible, AVL uses its own system in a highly secure environment – certified according to ISO 27001 – regularly providing all relevant documentation
- AVL has the technical and methodical expertise and the broad experience to define release criteria and to analyze and solve problems at state-of-the-art level



AVL Serial Project References

WHOM ARE WE WORKING FOR?

Some of AVL's successfully completed Serial Development projects:

V8 Diesel T2B5	Complete engine development on-site at OEM up to SOP within joint development team (US OEM)
V8/V6 NA/TC GDI, EU5	Engine topwork development up to SOP off-site at AVL in close cooperation with OEM (European OEM)
V6 Twin Turbo, ULEV	Development of downsized engine variant up to SOP off-site at AVL within joint development team (US OEM)
I4 TC GDI, EU6c, CH6	Development of new high performance derivate up to SOP off-site at AVL considering different vehicle applications (European OEM)
I3 GDI engine, EU6c	Development of new engine periphery for modified engine installation up to SOP off-site at AVL (European OEM)
V6 NA GDI – ULEV 70	Development of engine periphery for integration into new vehicle variants (Japanese OEM)
P2 PHEV Module (83kW) & 7-speed DCT	Development up to SOP off-site at AVL (Chinese OEM)
P2 HEV Module	Development up to SOP off-site at AVL (Chinese OEM)
High voltage Battery for BEV (70kWh)	Development up to C-sample (Chinese OEM)
High voltage Battery for BEV (23kWh)	Development up to B-sample (Chinese OEM)
l4 Diesel engine, EU5 & EU6	Combustion development and calibration (emissions, driveability, OBD) up to SOP (European OEM)
V6 Diesel engine, EU6	Calibration (base calibration, emissions, OBD) up to SOP (European OEM)
V6 TC GDI, EU6	Calibration (base calibration, emissions, driveability, OBD) up to SOP (European OEM)