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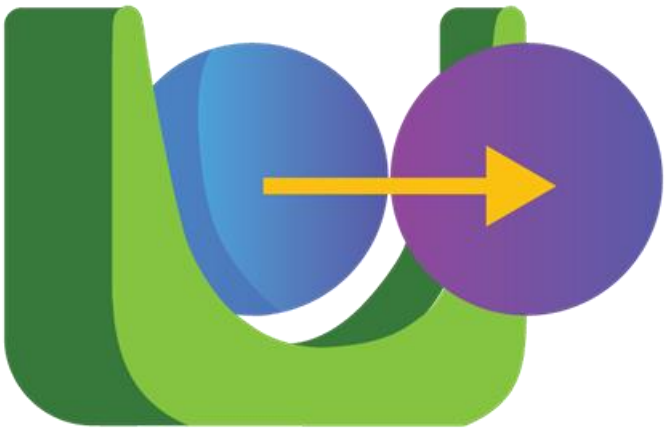

ARCHIMEDES

Trusted lifetime in operation for a circular economy

Deliverable	Standardization State-of-the-Art and Analysis of Gaps		
Deliverable File	D7.8		
Project	Archimedes	**Grant Agreement Number**	101112295
Lead Beneficiary	ST-SA (ST-GNB + ST-ROU)	**Dissemination Level**	PU - Public
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1 Contents

2 Executive summary

This document is intended to give an overview of the State-of-the-Art in existing or evolving standards related to all essential ARCHIMEDES activities, by providing best practices, raising awareness, and increasing knowledge and use of these standards.

From requirements defined by WP1 and outcomes from supply chains and other WPs, a first analysis of gaps is provided, too, by determining at this step of the project which technologies or innovations enabled by the project are not yet covered or not fully covered by State-of-the-Art standards.

Based on appropriate results, experiences and gaps identified, in some cases with direct contribution to industry consortiums, additional standards or extensions of existing standards will be propose in the future deliveries of task 7.4 in order to ensure uptake of ARCHIMEDES solutions in different industrial sectors.

3 Publishable summary

Section 2 Executive summary is publishable.

4 Non publishable information

Section 9 Gap Analysis should not be published until the end of the project. Then the full document is publishable (Dissemination Level: PU – Public).

5 Introduction & Scope

5.1 Purpose of this document

A number of sectors, including the semiconductor industry, rely heavily on global standards to ensure interoperability between hardware and software connected devices. International standards also facilitate the diffusion of technology and innovation and are becoming increasingly important given the complexity of emerging technologies. The considerable benefits of using international standards are recognized by many governments around the world and any deviation from international standards can have a serious effect on trade.

Mobility is one of the industry sectors that strongly relies on standards linked to reliability, availability, maintainability, durability, functional safety and cybersecurity, all of these domains being regrouped under the term dependability. Many examples can be given from the ISO Technical Committee TC22 that deals with road vehicles, or from IEC Technical Committee TC56 that deals with dependability. Standards for Quality and Reliability testing methodologies are also crucial to enable adoption of new semiconductor materials like SiC and GaN to the industry. Indeed, there is no interest in differentiation in that domain, the objective is to get the highest confidence level of these technologies based on a general industrial and academic shared understanding of failure mechanisms and unique behaviours to agree on a common stress test qualification strategy.

Defining and precising the requirements of the different applications, especially for that domain in term of mission profile, is an essential way to shape the development of these technologies and components in a standardized and optimized way, avoiding over design, overuse of resources and energy, while covering long operational lifetime requirements.

While reporting in this document the State-Of-The-Art of existing or evolving standards linked to these ARCHIMEDES activities, an overview of State-Of-The-Art EU regulations, certifications and EU homologation process is also provided. Some standards referenced in section 7 Standards in link with ARCHIMEDES activities derives from continental or governmental regulations of other parts of the world. Those regulations are intentionally not referenced in this section. See reports in References for complemental information.

- **EU Regulations**: The European Commission or governments issue regulations, which are typically derived from international regulations issued by e.g. UNECE (United Nations Economic Commission for Europe) and adapted or extended by the European Commission. The OEM must prove to a technical service provider that the product – i.e. the car – complies to these regulations. Slightly oversimplifying, such regulatory framework describes the 'what' of system certification, i.e. they specify which properties and capabilities the system (i.e., vehicles, aircrafts, infrastructures, …) need to have and what proof of respective test obligations are set in place in order to demonstrate these. Regulations often deliberately don't describe the 'how', i.e. the technical means or methods that OEMs and their Tiers manufacturers can or must use to fulfil these obligations. The reasoning behind this distinction is that regulations are a kind of law, which need to be technology neutral to leave enough room for innovations and technological advancement and to not promote certain companies and manufacturers. Nevertheless, while remaining essentially independent of the 'what', the EU regulatory framework uses standards as a tool to support EU policy and legislation through the process of 'Harmonized Standards' (see normative standards below) dedicated to European industry market. While the relation between regulations and standards is mostly not made explicit, the concrete wording used in regulations often 'points in the right direction'. Regulations covering the homologation of cars, for example, often use the term 'functional safety', thereby pointing towards the main standard used for demonstrating functional safety in Automotive, namely ISO 26262, whereas 'safety of the intended functionality' hints at the SOTIF standard (ISO 21448).
- **Standards**: The role of describing the 'how' is left to the appropriate standards.
    - **Technical standards**. Developed by Standards Developing Organization (SDOs), also called Standard-Setting Organizations (SSOs), these are written by technical experts, harmonized on a consensus between stakeholders that include firms, academics, research institutes, interest groups …, quality checked, and maintained, independently of legislative progress. Technical standards help in maximizing compatibility, interoperability, safety, repeatability, quality. Technical standards might become mandatory (normative) if adopted by a legislation.
    - **Normative standards (=norms).** "Normative" applies to a document or element "that provides rules, guidelines or characteristics for activities or their results" which are mandatory. The two international 'standards developing organizations' ISO and IEC, and the three European 'standards developing organizations' CEN, CENELEC and ETSI are in charge of normative standards ('harmonized standards' in case of the three

European 'standards developing organizations'). Contributions from technical experts to these international or European SSOs are made through their recognized National Standards Bodies (NSBs).

- **Certification and homologation**: In many application domains, products need to be certified, before they can be sold in the market. Whether a certain product needs to be certified typically depends on the type of product and sometimes on the region in which these products are sold. As a rule, so called *safety-critical* products, i.e. products whose operation or usage can cause harm to their operators, other humans, or the environment, generally need some sort of certification almost anywhere. For other properties of a system, especially for the dependability properties described above, sometimes certification is mandatory, sometimes optional. In the latter case, manufacturers of these product undergo certification in order to show high product quality.

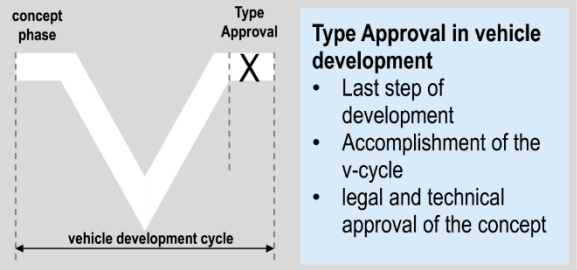


FIGURE 1: HOMOLOGATION / TYPE APPROVAL IS THE LAST STEP OF (CLASSICAL) SYSTEM DEVLOPMENT

Homologation is a term used mostly in the automotive domain, whereas **type approval** is the more common expression in most other application domains. Homologation (or type approval) refers to a certification process of a product – i.e., a car, a vehicle – demonstrating that it complies with all regulations applicable to this product, such as safety and environmental regulations. Homologation is the last step of the (classical) system development process (c.f. Figure 1[1]). Successful homologation requires not only that the system was developed correctly, but also that it was validated thoroughly and that all the necessary documentation – especially test and validation results – was generated.

Third party homologation vs. self-certification. For homologation – or indeed any type of certification – two approaches are followed throughout the world, namely self-certification and third-party certification (cf. Figure 2[2]): with self-certification, the manufacturer is responsible itself for testing the car against all applicable regulation provided by the legislator; it issues the certificate for its own products itself. It is typically not required to provide this certificate to anyone else; however, in case of damage incurred by the product resp. by the operation of the product, the manufacturer is liable if the damage is a direct result of a property of the product that does not conform to regulations.

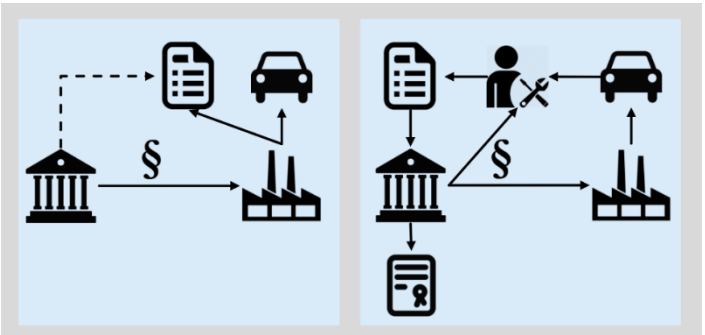


FIGURE 2: SCHEMATIC OVERVIEW OF SELF-CERTIFICATION (LEFT) AND 3RD PARTY CERTIFICATION (RIGHT)

[1] Figure 1 taken from: Dr. Houssem Abdellatif, Global Head Autonomous Driving & ADAS, TÜV SÜD Auto Service. Virtual Homologation of Software-Intensive Safety Systems: From ESC to Automated Driving. Presentation given on the Workshop 'Challenges for Highly Automated Road Transportation Systems in Germany and the US: Diversities and Synergy Potentials', Washington, DC, USA, October 2018

[2] Figure 2: Schematic Overview of Self-Certification (Left) and 3rd party Certification (Right) taken from the same source as Figure 1, see 1.

With third-party certification, public authorities instruct a third party for checking the certification evidence. In the automotive domain, this third party is called 'Technical Service Provider' (TSP). The legislator provides the regulations both for the conformance of the product as well as the requirements for testing this compliance. The manufacturer provides the product together with documentation about the applied tests and validation methods and their results. The TSP may require additional information and, in addition, may test structural and organisational properties of the manufacturer (i.e., suitability of design and test procedures, etc.). Finally, after the TSP has been satisfied that the product indeed does comply all necessary regulations, it issues a report to the legislator / governmental organisation, which in turn issues the certificate.

In automotive, third-party certification is used in the EU and many other regions, whereas self-certification is done e.g., in the United States. In Avionics, third-party certification is done world-wide, with organisations like EASA in Europe or FAA in the US being typical examples for TSPs.

From the above it becomes immediately clear, that certification – i.e., homologation or type approval – covers an extremely broad range of system features and properties, even when one restricts oneself to 'only' those properties that are influenced by the electrical and electronic system of the products. In addition, given (a) the increase in functionality of today's and future products – i.e., highly automated or even autonomous vehicles, AI-based features and functions, and many more – (b) the increased restrictions and constraints for producing and operating them – i.e., considering sustainability, longevity, 'greenness' – and (c) the advances in processes and methods for development and validation of such systems – i.e., continuous development processes, agile processes, AI based development methods – it becomes clear that both regulations and corresponding standards are in constant change. Any large-scale research project like Archimedes must, by necessity, stemming from finite time and finite resources, focus its correspondent activities and results to a manageable subset of this vast space. To ensure, that our standardisation activities are consistent with those undergone in other projects, we will use the so-called Reference Homologation Process as a means to include our results in a 'global map' of similar activities (c.f. Figure 4).

The Reference Homologation Process (also more commonly called the 'Reference Lifecycle Process', or RLP for short), is a detailed description of the process flow for designing, testing, building, operating, maintaining and decommissioning safety critical products. Starting from a general reference description of the classical development and test processes, it has been extended to include process and method advancements from many projects during the last years (i.e. the Joint Undertaking projects ENABLE-S3, ArchitectECA2030, national projects like the PEGASUS project series in Germany, and similar). The advantage of the RLP is that it allows a complete view of the state of the art for the whole process, thereby giving new and running processes the possibility to focus on those parts of the process that are relevant for them. Figure 4 gives a very high-level overview of the process. We will use it in Year 2 to map the technologies and

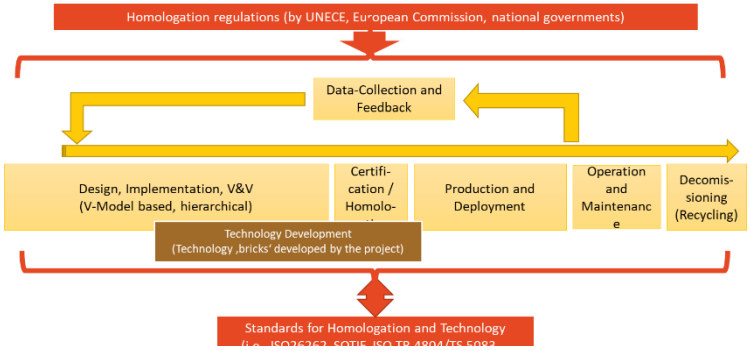


FIGURE 3: HIGH LEVEL VIEW OF THE RLP (REFERENCE LIFECYCLE PROCESS)

standardisation results of Archimedes to the process, which will enable us to (a) check their compatibility to regulations for homologation and (b) include the results of our gap analysis into the 'overall picture' of gaps existing with current standards.

Given the above explanations, Figure 4 gives an overview about the content of this deliverable ant the two follow-ups that will be issued in Year 2 and Year 3 of the project, respectively.

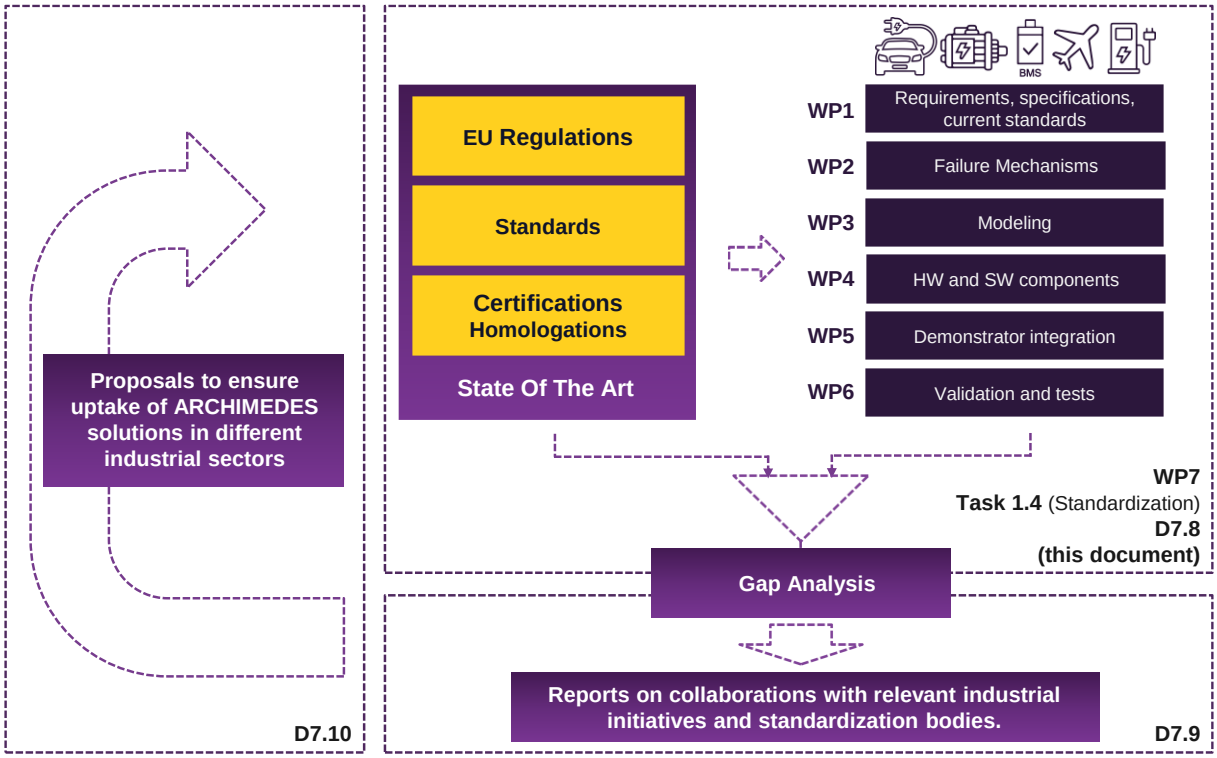


FIGURE 4: TASK 7.4 PROCESS FLOW

5.2 Contributions of partners

Each ARCHIMEDES partners, in particular contributing in WP1 to the referencing of the current standards in use, are directly or indirectly contributing to build this State-Of-The-Art of existing or evolving industry standards:

TABLE 1: ARCHIMEDES DIRECT CONTRIBUTORS TO THIS DOCUMENT

Chapter	Partner	Contribution
all	ST-GNB ST-ROU ST-Catania	Document setup and core filling Updates and maintenance from contributions
all	ST-Toulouse	WBG-related standards
all	IRT	Test to pass / test to fail definition JC70 description and gap analysis Aero/Auto (SC4 /SC2) gap analysis

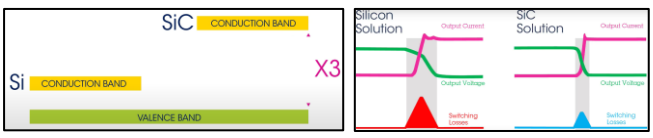
		FIDES inputs
all	SAFETRANS	Complement introduction about Standards, Regulations and Homologations ASAM OpenX ISO/IEC standards related to system validation/certification/homologation
all	STELLANTIS	GB/T standards
IEC TC56	IFAT	IEC TC56 WG4 work description
all	W&W - Eunice	SC5 directives and standards

5.3 Concept and Acronyms definition

TABLE 2: CONCEPT AND ACRONYMS DEFINITION

CBM	Condition Based Maintenance. "Condition-based maintenance (CBM) is a strategy that monitors the actual condition of an asset to decide what maintenance needs to be done. CBM dictates that maintenance should only be performed when specific indicators show decreasing performance or upcoming failure. Checking a machine for these indicators may include non-invasive measurements, visual inspection, performance data, and scheduled tests. Condition data can then be gathered at specific intervals or continuously (as is done when a machine has internal sensors). Condition-based maintenance can be applied to mission-critical and non-mission-critical assets." [3]
EMP	Extended Mission Profile. Electronic component mission profile indicates all the expected environmental and functional conditions that the component will face during its service life. In ARCHIMEDES context, Extended Mission Profile refers to the extension of the operating lifetime of the mission profile, compared to the operating lifetime used in traditional combustion engine-based cars which is about 8000 to 12000 hours.
EV	Electric Vehicle. • MHEV (Mild Hybrid) - the electric motor assists the petrol/diesel engine only during (regenerative) deceleration/brake or (boosted) start/acceleration, to save C02 emission, from a 48V/~1 kWh battery. • FHEV (Full Hybrid) - the electric motor can drive the car for very short distance (urban usage, few kms) from a 200-300V/few kWh battery. • PHEV (Plug-in Hybrid) - the electric motor can drive the car for short distance (urban usage, ~60 kms) from a 400V/<10 kWh battery. • BEV (Battery) - pure electric vehicle with 400V-800V/40-80 kWh battery. • FCEV (Fuel Cell) - single motor powered by fuel (hydrogen) cell
FRAME	Failure Risk Assessment Methodology. See IEC TR 62240-2 - Electronic components capability in operation.
IC	Integrated Circuits
ICT	Information and Communication Technologies
LSI	Large Scale Integration
MPFo	Mission Profile Format. The Mission Profile Format (MPFo) represents a XML based formal description of specific mission profiles of a mechanical, electronic or electromechanical component. While the format was initially developed for the design of automotive electronic components, its use is not limited to the automotive domain only. An MPFo has been primarily developed within the German publicly-funded research project autoSWIFT (2015-2018). IEC TC56 WG4 works on standardizing MPFo.
PHM	Prognostics and Health Management

[3] Source: https://fiixsoftware.com/maintenance-strategies/condition-based-maintenance/#:~:text=Condition%2Dbased%20maintenance%20(CBM),decreasing%20performance%20or%20upcoming%20failure.

RPA / PoF	Reliability Physics Analysis / Physics of Failure RPA is an engineering discipline that implements the principles of PoF within specific applications.
RUL	Remaining Useful Lifetime
SC	Supply Chain
TC	Technical Committee
Test-to-pass Test-to-fail	In qualification tests, stress conditions are chosen to represent the most stringent mission profile for the device reliability; key electrical parameters (threshold voltage, leakage current, etc.) are monitored throughout the test to check its health status. A component is considered as failed when, during the test, a certain parameter drift more than a certain value. In this type of test, conditions are not chosen to stress until wearout, and it is expected that there will be no failures within the test timeframe. In a qualification test, if no failures are observed, the component is considered as qualified. In this document, we will refer to this type of test as "test-to-pass". Qualification tests are described in several standards such as JEDEC, AQG, etc, where test conditions (voltage, current, temperature, duration, failure criteria etc) are precisely described. These qualification standards have been conceived for silicon, so when evaluating WBG (Wide Band Gap) components reliability, one fundamental question arises: are these qualification standards adaptable to WBG? Indeed, the technologies of SiC and GaN are fundamentally different from silicon, thus implying that the underlying physics of failure may also differ, necessitating adaptations of the qualification protocols or introducing new one (e.g. GSS for SiC). To understand the physics of failure of a given technology, it is necessary to observe failures and study the influence of different usage parameters such as voltage, current, temperature, etc. Specific tests need to be carried out for this purpose. In this document, we will refer to this type of test as "test-to-fail." **Test-to-fail** • **Objective**: observing drifts compatible with product's operativity • **Stress level**: high, even more than maximum rating • **Duration:** till failure/drift • **Output**: Acceleration factors and stressors **Test-to-pass** • **Objective**: qualify a technology • **Stress level**: medium → most stringent mission profile conditions but never exceeding maximum rating • **Duration**: fixed • **Output**: pass/fail *Test to fail permits to properly determine the test conditions (stressors and duration) of the test-to-pass* In a test-to-fail, testing conditions are chosen to observe wearout failures within the test timeframe. Failures are necessary to allow the plotting of failure distributions (e.g., Weibull, lognormal, etc.) and to understand the physics of failure. Wearout models are then obtained using these distributions, allowing for the calculation of device lifetime under application-use conditions. These tests are also fundamental inputs for the design of qualification tests, as they aid in determining the most stringent test conditions (for example, high vs. low temperature).
WBG	Wide-BandGap semiconductors like Silicon Carbide (SiC) or Gallium Nitride (GaN) are semiconductor materials which have a larger band gap than conventional semiconductors like silicon. That permit devices to operate at much higher voltages, frequencies, and temperatures. 
WLR / TQ	Wafer Level Reliability / Technology Qualification Reliability is defined as the ability of a device to conform to its electrical specifications over a specified period under specified conditions at a specified confidence level. Once a new technology platform has been developed and the first silicon comes out, Technology Qualification Reliability tests are performed on active and passive devices, metallizations and dielectrics to accelerate new IC designs and processes verification by assessing the

	reliability characteristics of the technology process. The results of these tests will be a measurement of the "rate of degradation" of the basic circuit elements caused by a standard stress. Technology qualification is often linked to WLR even if a huge number of trials are done at package level (HTRB/HTGS, TDDB, EM).
WP	Work Package

5.4 Relation to other activities in the project

This document relates to all WPs activities, see Figure 4: Task 7.4 process flow.

6 EU Regulations in link with ARCHIMEDES activities

6.1 EU Regulations overview

TABLE 3: EU REGULATIONS OVERVIEW

	All SCs	SC1 – SC2 – SC3	SC4	SC5
System Quality Management (Requirements)	See normative standards same raw of Table 4: Standards overview			
Electromagnetic Compatibility (EMC)	EMC Directive 2014/30/EU			
Lifetime		EU ECWVTA		
Energy conversion Efficiency	EPSMA	NEDC (EU) => WLTP (UNECE) for range of EV		
Safety		EU GSR 2019/2144 Euro NCAP ETSC	EASA	LVD 2014/35/EU RoHS 2011/65/EU
Security	ENISA	UNECE R155 UNECE R156		
Circular Economy	European Green Deal Euro 7 European Chips Act EU 2023/1542 (DBP) ESPR (DPP)	ELV Directive ELV Directive (new)		

Colour code: Under definition – Defined, not yet in effect – In effect - Other organisms in link with EU regulation

6.2 UNECE (United Nations Economic Commission for Europe)

6.2.1 WLTP (Worldwide harmonised Light vehicles Test Procedure)

WLTP is a standard for determining the range of fully electric vehicles, after having been in charge of determining the levels of pollutants, CO_2 emissions and fuel consumption of traditional and hybrid cars. The standard is accepted by China, Japan, the United States, and the European Union, among others. It aims to replace the previous and regional New European Driving Cycle (NEDC) as the European vehicle homologation procedure.

6.2.2 UNECE R155 - Cyber security and cyber security management system

Vehicle manufacturers are required to establish a Cyber Security Management System (CSMS) and to prove that this CSMS works for the type approval of a new vehicle type. Processes for vehicle development are defined for a CSMS so that risks from cyber-attacks are systematically collated and assessed.

The requirements in the member states have been in force for the approval of new vehicle types since July 2022. The requirements will be applied to all vehicles produced starting from July 2024.

ISO/SAE 21434 engineering standard must be followed by all the actors in automotive supply chain. By supporting ISO/SAE 21434, the car marker satisfies the duties imposed by the UN regulation.

6.2.3 UNECE R156 - Software update and software update management system

Proof of a functioning Software Update Management System (SUMS) is required from manufacturers if they want to update the software in their vehicles. The regulation requires that the manufacturer can prove this to the licensing authority, or to a testing institute accredited by the licensing authority. ISO 24089 "Road vehicles - Software update engineering" is the standard currently being developed to describe suitable measures for the industry.

The requirements in the member states have been in force for the approval of new vehicle types since July 2022. The requirements will be applied to all vehicles produced starting from July 2024.

6.3 European Commision

6.3.1 EU ECWVTA (European Community Whole Vehicle Type Approval)

6.3.2 Directive 2000/53/EC on end-of-life vehicles ('ELV Directive')

This EU regulation 2000/53/EC was adopted in order to minimise the impact of end-of-life vehicles on the environment and to improve the environmental performance of the economic operators involved in the life cycle of vehicles. The Directive sets out provisions on waste prevention, collection, and treatment (including depollution) of end-of-life vehicles, and reuse or recovery of components. It restricts the use of some hazardous substances (cadmium, hexavalent chromium, lead and mercury) in vehicles sold after July 1st 2003 (with some possible exemptions). Member States have to ensure that all end-of-life vehicles are stored and treated in accordance with the waste hierarchy.

Vehicle and equipment manufacturers must factor in the dismantling, reuse and recovery of the vehicles when designing and producing their products. They have to ensure that new vehicles are:

- reusable and/or recyclable to a minimum of 85% by weight per vehicle

- reusable and/or recoverable to a minimum of 95% by weight per vehicle.

6.3.3 2023/0284 – new ELV directive

This new end-of-life vehicles EU regulation 2023/0284 intends to improve ‘design circular’, ‘use recycled content’, ‘treat better’, ‘collect more’, ‘Extended Producer Responsibility (EPR) schemes‘, ‘cover more vehicles’ from EU regulations already in effect.

6.3.4 European Green Deal

The European Green Deal, approved in 2020, is a set of policy initiatives by the European Commission with the overarching aim of making the European Union climate neutral in 2050. The plan is to review each existing law on its climate merits, and introduce new legislation on the circular economy, building renovation, biodiversity, farming and innovation.

6.3.5 Euro 7

The European emission standards are vehicle emission standards for pollution from the use of new land surface vehicles sold in the European Union, European Economic Area member states and the United Kingdom. The standards are defined in a series of European Union directives staging the progressive introduction of increasingly stringent standards.

In December 2023, Euro 7 was provisionally agreed to include non-exhaust emissions such as particulates from tyres and brakes.

6.3.6 European Chips Act

The European Chips Act will reinforce the semiconductor ecosystem in the EU, ensure the resilience of supply chains and reduce external dependencies. It is a key step for the EU's technological sovereignty.

One important link with Archimedes activities is the CENELEC TC47X initiative derived from this regulation.

6.3.7 EU 2023/1542 – 'Battery Mandate'

Scope: EU Regulation on batteries and waste batteries.

This regulation has been published on July 28th 2023, and entered into force on August 17th 2023.

6.3.7.1 European Digital Battery Passport (DBP)

From February 1st2027, all EVs and industrial batteries over 2 kWh sold into the EU market will require a unique battery passport retrievable using a unique product identifier, as ex in the form of a QR code. It will be the responsibility of the party placing the battery on the market, to ensure that all data required is entered in the digital record and that the information is correct and up to date. Battery passports requires input from:

- Mining and refining companies
- Cell and battery producer
- Vehicle brands
- Battery servicing, refurbishing, and recycling companies

6.3.8 ESPR (Eco-design for Sustainable Products Regulation)

Scope: environmental sustainability, promote circularity, support legal compliance. Digital Product Passport (DPP) is the tool to support three policy objectives.

By February 2027, Digital Battery Passport (DBP) will be the first DPP to be operational.

6.3.9 EU GSR 2019/2144 (General Safety Regulation)

Date class B (2022 for EU type-approval, 2024 for all vehicle registrations) main features:

- Driver Drowsiness monitoring
- Tire pressure monitoring system
- Emergency stop signal
- Reversing information System
- Intelligent speed assistance
- Blind spot information system
- Moving off information system

Date class C (2024 for EU type-approval, 2026 for all vehicle registrations) main features:

- Distraction recognition and prevention
- Improved direct vision from driver's position

Date class D (2026 for EU type-approval, 2029 for all vehicle registrations) main features:

- Event (accident) data recorder

In discussion:

- IID (Ignition Interlock Device)

6.3.10 LVD (Low Voltage Directive) 2014/35/EU

The low voltage directive (LVD) (2014/35/EU) ensures that electrical equipment on the market fulfils the requirements providing for a high level of protection of health and safety of persons and of domestic animals and property, while guaranteeing the functioning of the internal market.

This Directive shall apply to electrical equipment designed for use with a voltage rating of between 50 and 1 000 V for alternating current and between 75 and 1 500 V for direct current.

It has been applicable since April 20th 2016.

6.3.11 RoHS (Restriction of Hazardous Substances) Directive 2011/65/EU

This directive lays down rules on the restriction of the use of hazardous substances in Electrical and Electronic Equipment (EEE) with a view to contributing to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE.

6.3.12 EMC (Electromagnetic Compatibility) Directive 2014/30/EU

This directive aims to ensure that any Electrical and Electronic Equipment minimizes the emission of electromagnetic interference that may influence other equipment. The directive also requires equipment to be able to resist the disturbance of other equipment.

6.3.13 EU CRA (Cyber Resilience Act)

The European Cyber Resilience Act is a legal framework that describes the cybersecurity requirements for hardware and software products with digital elements placed on the market of the European Union. Manufactures are now obliged to take security seriously throughout a product's life cycle.

6.3.14 EASA (European Union Aviation Safety Agency)

The European Union Aviation Safety Agency (EASA) is an agency of the European Commission with responsibility for civil aviation safety in the European Union. It carries out certification, regulation and standardisation, performs investigation and monitoring, collects and analyses safety data, drafts and advises on safety legislation and co-ordinates with similar organisations in other parts of the world, in particular the Federal Aviation Administration (FAA) which regulates civil aviation in the United States.

6.4 Other organisms in link with EU regulation

6.4.1 Euro NCAP

The European New Car Assessment Programme (Euro NCAP) is not a regulation program but a European voluntary car safety performance assessment programme. Their slogan is "For Safer Cars".

Examples of voluntary assessment- based features with their date of application:

- 2023: Child Presence Detection (indirect sensing)
- 2024: V2X
- 2025: Child Presence Detection (direct sensing)

- Vision 2030: Driver impairment (driving under the influence and sudden sickness), seatbelt load limiter adapted to occupant (posture monitoring), advanced airbag deployment and deactivation, reliable occupancy information for advanced emergency call.

6.4.2 ETSC (European Transport Safety Council)

The European Transport Safety Council (ETSC) is a non-profit organization that works to reduce the number of deaths and injuries in traffic collisions that occur in Europe. It publishes an annual Road Safety Performance Index Report, measuring progress in reducing road deaths in Europe.

6.4.3 ENISA (The European Union Agency for Cybersecurity)

The European Union Agency for Cybersecurity (ENISA) is the Union's agency dedicated to achieving a high common level of cybersecurity across Europe. ENISA contributes to EU cyber policy, enhances the trustworthiness of ICT products, services, and processes with cybersecurity certification schemes, cooperates with Member States and EU bodies, and helps Europe prepare for the cyber challenges of tomorrow.

6.4.4 EPSMA (European Power Supplies Manufacturers' Association)

The EPSMA was formed to provide a much-needed forum for discussing and progressing issues of common concern to the power supply industry, for the benefit of power supply manufacturers, users and component suppliers alike. Regulatory and standards issues are of particular importance. The EPSMA aims to provide members with information regarding the provisions and proposals of the European Commission and the US Department of Energy with reference to the harmonisation of laws, and other regulatory issues and standards affecting the power supply industry. It also aims to be an effective lobbying group during the formation and introduction of new legislation within the EU.

The EPSMA is currently active in a number of key areas like:

- Safety - guidance papers on safety in hazardous, medical, railway, telecom power supplies applications
- Energy Efficiency - tracks what is happening regarding efficiency standards, regulations and incentives around the world for external power supplies and battery chargers
- Emerging Technologies – watching brief on emerging technologies in the power electronics area such as electric vehicles and new semiconductor SiC and GaN technologies.

7 Standards in link with ARCHIMEDES activities

7.1 Standards overview

TABLE 4: STANDARDS OVERVIEW

	All SCs	SC1 – SC2 – SC3	SC4	SC5
System Quality Management (Requirements)	ISO9001	ISO/TS16949	EN9100	ISO/TS16949
Mission profile definition	JEDEC JESD94A ISO 16750 IEC TC56 WG4 VDE DKE/K 132 IEC 63287-2:2023	ZVEI Mission Profile questionnaire VDE ITG MN5.7 WG		
Qualification methods	JEDEC JESD22 JEDEC JESD47 IPC/JEDEC-9702 JEITA EDR-4708C MIL-STD-883,750 MIL-PRF-38535 IEC TC47 WG2 IEC TC47 WG5	AEC Q10x	IEC TS 62686-1, IEC TR 62240-2 IEC60749- IEC/EN60068 DO-160G IEC TS 62564-1 (AQEC)	
WBG qualification methods	JEDEC JC70 IEC TC47 WG8	AEC WBG TG ECPE AQG-324		
Extended Lifetime qualification		AEC Q10x §A7.3 ZVEI RV Handbook SAE J1879		
Failure Mechanisms Failure Modes	JEDEC JEP122 JEDEC JEP148 JEITA EIAJ ED-4704 JEDEC JESD91 EDR4708 ANADEF	ZVEI Knowledge Matrix	IEC 60270 ASTM D1868-20	
Failure Rates	IEC 61709 IEC 62380 SN 29500 MIL-HDBK-217F FIDES			
WBG Failure Mechanisms	IEC TC47 WG8			
Reliability / dependability mitigation techniques	IEEE P2851 IEC TC56 WG1-2-3 IEEE 1856	IEC60664/747 SAE J3168		
Electromagnetic Compatibility (EMC)			DO-160G	IEC 61851-21-2 IEC 61000-6-2 IEC 61000-6-3
Safety	IEC 61508	ISO 26262 ISO/AWI TS 5083 ASAM OpenX IEC61851-1, IEC 62368	DO-178C DO-254	IEC61851-1 IEC 61851-23:2018
Security	CLC/TC47X	ISO/SAE 21434 SAE J3101 ISO 24089 ISO 15118		
Circular Economy	CLC/TC47X CEN-CLC/JTC 24 (DPP)			

Colour code: Has active WGs without any published document yet – Has active WGs with some documents already published – All documents published, no more WG activity

Note about access to standards documents: from a legal point of view, standards documents given here in reference cannot be populated in an ARCHIMEDES repository. Partners that need to get access to these documents shall proceed based on the different cases:

- Some documents can be downloadable from the corresponding organization website without restrictions (as example from AEC, ZVEI, …). Links are given in that document for these cases.
- Some documents can be downloadable when the partner is member of the organization, through a registration (as ex from JEDEC). Partners can proceed in that way if they are member of the given organization.
- For fee-based documents (as ex from ISO, IEC, CEN-CLC, …), partners have to refer to their internal standards documentation policy (individual nominative purchase or licence-based services offered by standards information platforms).

7.2 AEC (Automotive Electronics Council) AEC

The Automotive Electronics Council (AEC), originally established by Chrysler, Ford, and GM, is the standardization body for establishing standards for reliable, high quality electronic components suitable for use in the harsh automotive environment without additional component-level qualification testing. AEC web site makes available the technical documents developed by the AEC Component Technical Committee. These documents can be downloaded directly.

7.2.1 AEC-Q100

Failure Mechanism Based Stress Test Qualification for Integrated Circuits

7.2.2 AEC-Q101

Failure Mechanism Based Stress Test Qualification for Discrete Semiconductors

7.2.3 AEC-Q100/Q101 Appendix 7.3 'Method to assess a mission profile'

This appendix demonstrates how to perform a more detailed reliability capability assessment in cases where the application differs significantly from existing and proven situations:

- Application has a demanding loading profile
- **Application has an extended service lifetime requirement**
    - AEC-Q100 test conditions do apply
    - Mission Profile specific test conditions may apply
    - Robustness Validation may be applied with detailed alignment between user and supplier.
        - For details on how to apply this method, it is recommended to refer to SAE J1879 / SAE J1211, and/or ZVEI RV (Robustness Validation).
- Application has a more stringent failure rate target over lifetime

7.2.4 AEC WBG TG (Wide Band Gap Task Group)

This TG intends to create a document that defines minimum stress test driven qualification requirements and references test conditions for qualification of discrete and bare die semiconductors in Wide Band Gap technologies (SiC and GaN), when used in an Automotive application. It is a top-down approach from car makers to semiconductor providers.

7.3 JEDEC (Joint Electron Device Engineering Council)

For over 50 years, JEDEC has been the global leader in developing open standards and publications for the microelectronics industry. JEDEC committees (JC-XX) provide industry leadership in developing standards for a broad range of technologies, including Quality and Reliability for silicon products (JC-14) and GaN, SiC Wide Bandgap Power Electronic Conv. Semiconductors (JC-70). In opposite to 7.2.4 AEC WBG TG (Wide Band Gap Task Group), it is a bottom-up approach from semiconductor providers to final users (consumer, industrial and automotive).

7.3.1 JC-14

JC-14 is responsible for standardizing quality and reliability methodologies for solid state products used in commercial applications such as computers, automobiles, telecommunications equipment, etc.

7.3.1.1 JESD22 - Reliability of packaged solid state devices

JESD-22 (A1xx – B1xx) is a series of uniform methods and procedures for evaluating the reliability of packaged solid-state devices. JESD-22 establishes the physical, electrical, mechanical, and environmental conditions under which these packaged devices are to be tested.

7.3.1.2 JESD47 - Stress-Test-Driven Qualification of Integrated Circuits

The standard describes a baseline set of acceptance tests for use in qualifying electronic components as new products, a product family, or as products in a process which is being changed.

This qualification standard is not aimed at extreme use conditions such as military applications, automotive under-the-hood applications, or uncontrolled avionics environments, nor does it address 2nd level reliability considerations, which are addressed in JEP150.

7.3.1.3 JEP122 - Failure Mechanisms and Models for Semiconductor Devices

This publication provides a list of failure mechanisms and their associated activation energies or acceleration factors that may be used in making system failure rate estimations when the only available data is based on tests performed at accelerated stress test conditions. The method to be used is the Sum-of-the-Failure-Rates method.

7.3.1.4 JEP148B - Reliability Qualification of Semiconductor Devices Based on Physics of Failure Risk and Opportunity Assessment

This procedure provides a consistent framework for reliability qualification using the Physics-of-Failure (PoF) Risk and Opportunity Assessment concept, which:

- is flexible with respect to the requirements of the intended application and market,
- makes optimum use of the supplier's advance quality planning and demonstration results gained during design and development and applicable knowledge based on design and technology similarities.

7.3.1.5 JESD91 - Method for Developing Acceleration Models for Electronic Component Failure Mechanisms

The purpose of this standard is to provide a reference for developing acceleration models for defect-related and wear-out mechanisms in electronic components.

7.3.1.6 JESD94 - Application Specific Qualification using Knowledge Based Test Methodology

JESD94 provides a method for developing an application specific reliability evaluation methodology based on the use conditions the solid-state device is expected to experience in the field. It assumes that the failure mechanisms and models, relevant to the product being tested, are a known entity.

JESD94 Annex A gives application specific qualification methodology examples to access mission profile.

From 2022, a task force is working on updating JESD94 to include more mission profiles and use case used by multiple electronics end sub-industries: Consumer, industrial and Transportation. Extensive mission profiles of automotive will be documented under Transportation that will include combustion and electric profiles. A corresponding white paper exposes a case of standardized Mission Profiles classification (Nominal, Enhanced, Cabin).

7.3.1.7 IPC/JEDEC-9702

This publication specifies a common method of establishing the fracture resistance of board-level device interconnects to flexural loading during non-cyclic board assembly and test operations.

7.3.2 JC-70

JC-70 is responsible for standardizing quality and reliability methodologies for Wide Bandgap Power Electronic Conversion Semiconductors, more precisely Silicon Carbide (SiC) and Gallium nitride (GaN), based on the unique behaviours of this semiconductor material compared to well-known silicon material. The objectives of the committee are:

- Develop guidelines and standards for wide bandgap (WBG) components, covering unique behaviours of Silicon Carbide (SiC) and Gallium Nitride (GaN)
- Facilitate the widespread adoption and integration of WBG components in various applications like power electronics, automotive systems, and renewable energy'

The JC-70 committee is divided in two subcommittees, one for SiC and one for GaN technologies:

– JC-70.1 Subcommittee GaN Power Electronic Conversion Semiconductor Standards
– JC-70.2 Subcommittee SiC Power Electronic Conversion Semiconductor Standards

The main focus areas are: (i) Reliability and Qualification Procedures; (ii) Datasheet Elements and Parameters; (iii) Test and Characterization Methods.

The documents already published, are listed in Table 5: List of Published Documents for and Table 6: List of Published Documents for SiC.

Total 13 documents issued since 2019: 5 for GaN and 8 for SiC.

TABLE 5: LIST OF PUBLISHED DOCUMENTS FOR GAN

Publications of JC-70.1 Subcommittee (GaN)		
Year	**Reference**	**Title**
Nov. 2023	JEP198	Guideline for Reverse Bias Reliability Evaluation Procedures for GaN approved and released
Jan 2021	JEP180.01	Guideline for Switching Reliability Evaluation Procedures for GaN

Dec 2021	JEP186	Guideline to Specify a Transient Off-State Withstand Voltage Robustness Indicator in Datasheets for Lateral GaN Power Conversion Devices
Jan 2021	JEP182	Test Method for Continuous-Switching Evaluation for GaN
Jan 2019	JEP173	Dynamic ON-Resistance Test Method Guidelines for GaN

TABLE 6: LIST OF PUBLISHED DOCUMENTS FOR SIC

Publications of JC-70.2 Subcommittee (SiC)		
Year	**Reference**	**Title**
Nov 2023	JEP197	Guideline for Evaluating Bipolar Degradation of SiC approved and released
Fev 2023	JEP195	Guideline for Evaluating Gate Switching Instability of SiC
Fev 2023	JEP194	Guideline for Gate Oxide Reliability and Robustness Evaluation Procedures for SiC
Jan 2023	JEP192	Guidelines for Gate Charge (QG) Test Method for SiC
Jan 2023	JEP183A	Guidelines for measuring the threshold voltage (VT) of SiC MOSFETs
Aug 2022	JEP190	Guideline for Evaluating dv/dt Robustness of SiC
Mar 2021	JEP184	Guideline for evaluating Bias Temperature Instability of SiC MOSFETs
Dec 2021	JEP187	Guidelines for Representing Switching Losses of SiC Mosfets in Datasheets

7.4 ECPE (European Center for Power Electronics e.V.)

ECPE promotes education, innovation, science, research and technology transfer in the area of Power Electronics in Europe.

7.4.1 ECPE-AQG324

AQG324: Automotive Power Module Qualification. It defines a common procedure for characterizing module testing as well as for environmental and lifetime testing of power electronic modules for automotive application. The grade of automotive maturity of the power semiconductor in use within the power module has to be shown by a chip technology qualification conducted in advance. Future releases of AQG 324 addresses newer semiconductor and assembly technologies with other failure mechanisms.

7.5 IEC (International Electrotechnical Commission)

The International Electrotechnical Commission is an international standards organization that prepares and publishes international standards for all electrical, electronic and related technologies – collectively known as "electrotechnology".

7.5.1 IEC TC 47 - Semiconductor devices

7.5.1.1 IEC TC47 WG 8 - Wide Bandgap Semiconductor Quality and Reliability

- TC 47/WG 8 covers Wide Bandgap Electronic Technologies and is responsible for the development and establishment of industry standards concerned with test and characterization methods; data sheet elements and device specification; and Qualification procedures and reliability verification, unique packaging considerations, and other related engineering issues. Activities also include cataloguing and consideration of mission profiles,

and formulation of terms, definitions, and symbols for Wide Bandgap electronic products initially aimed at Power Conversion applications.

7.5.1.2 IEC TC47 WG 2 - Semiconductor Quality and Reliability

Activity within TC 47 / WG 2 includes the generation, coordination, and review of testing methods to assess and quantify the quality and reliability of semiconductor products including the design, manufacturing processes as well as component integration into systems.

7.5.1.3 IEC TC47 WG 5 - Wafer Level Reliability

Generates terms, definitions and reviews or establishes general specifications and standards relating to wafer-level reliability assessment of semiconductor devices in the points of failure mechanism for wafer process and test methods. Excluding specialty devices and/or applications. To accomplish these functions, the working group maintains liaison with and utilizes information and help from other groups and technical experts.

7.5.1.4 IEC 60749 - IEC/EN60068

IEC 60749 has taken into account, wherever possible, IEC 60068. The object of this standard is to establish uniform preferred test methods with preferred values for stress levels for judging the environmental properties of semiconductor devices.

7.5.1.5 IEC 63287-2:2023

Semiconductor devices - Guidelines for reliability qualification plans - Part 2: Concept of mission profile

IEC 63287-2:2023 gives guidelines for the development of reliability qualification plans using the concept of mission profile, based on the environmental conditioning and proposed usage of the product.

Temperature-Time distributions for 3 different automotive applications are used to illustrate how to calculate the equivalent time for an operating life test (HTOL) assuming TDDB as dominant failure mode.

7.5.2 IEC TC 56 - Dependability

7.5.2.1 IEC TC56 WG1-2-3-4

Working Group Activities - IEC TC 56

7.5.2.1 IEC TC56 WG4

IEC TC56 WP4 aims to develop a standardized Mission Profile and Capability Data Exchange Format (MPFo) that should be independent from the automotive domain. This will allow to translate overall mission profile requirements down to component levels and match this with the components and systems capabilities. In particular, it will allow to match extended lifetime requirements with component capabilities which fully enters in the scope of ARCHIMEDES.

7.5.2.2 IEC 61709 - Semiconductor failure rates

It gives guidance on the use of failure rate data for reliability prediction of electric components used in equipment. It uses the concept of reference conditions which are the typical values of stresses that are observed by components in the majority of applications.

7.5.2.3 IEC 62380 - reliability prediction methods

The IEC 62380 module supports reliability prediction methods based on the latest European Reliability Prediction Standard.

7.5.3 IEC TC 28 - Insulation coordination

7.5.3.1 IEC 60664/IEC 60747-17 Galvanic Insulation Test for Power Modules

IEC 60664-1:2020 deals with insulation coordination for equipment having a rated voltage up to AC 1 000 V or DC 1 500 V connected to low-voltage supply systems. This document applies to frequencies up to 30 kHz. It applies to equipment for use up to 2 000 m above sea level and provides guidance for use at higher altitudes. It provides requirements for technical committees to determine clearances, creepage distances and criteria for solid insulation. It includes methods of electrical testing with respect to insulation coordination.

The internation standard IEC 60747-17 covers the qualification of galvanic isolation products based on SiO2 or polymer as isolation stack, typically featured as MOSFET or IGBT gate drivers. Conversely from other standards related to the qualification of similar devices (IEC 60747-5-5 or UL1577 for optocouplers), IEC 60747-17 prescribes requires the collection of insulation lifetime data using the time-dependent dielectric breakdown (TDDB) test method, with stringent requirements in terms of cumulated failure and robust safety margins.

7.5.4 IEC TC 42 – High- voltage test techniques

7.5.4.1 IEC 60270

IEC 60270 is applicable to the measurement of partial discharges which occur in electrical apparatus, components or systems when tested with alternating voltages up to 400 Hz or with direct voltage.

7.5.5 IEC TC 65 - Industrial-process measurement, control and automation

7.5.5.1 IEC 61508 - Functional safety of electrical/electronic/programmable electronic safety-related systems

IEC 61508 covers aspects to be considered when electrical/electronic/programmable electronic (E/E/PE) systems are used to carry out safety functions.

7.5.6 IEC TC 69 - Electrical power/energy transfer systems for electrically propelled road vehicles and industrial trucks

7.5.6.1 IEC 61851-1:2017 for EVSE charging safety requirements

This part of IEC 61851 applies to EV supply equipment for charging electric road vehicles, with a rated supply voltage up to 1 000 V AC or up to 1 500 V DC. and a rated output voltage up to 1 000 V AC. or up to 1 500 V DC. The aspects covered in this standard include:

- the characteristics and operating conditions of the EV supply equipment
- the specification of the connection between the EV supply equipment and the EV
- the requirements for electrical safety for the EV supply equipment

7.5.6.2 IEC 61851-23:2018 - DC electric vehicle supply equipment

This part of IEC 61851 applies to the EV supply equipment to provide energy transfer between the supply network and electric vehicles (EVs), with a rated maximum voltage at side A of up to 1 000 V AC or up to 1 500 V DC and a rated maximum voltage at side B up to 1 500 V DC.

7.5.6.3 IEC 61851-21-2 - – EMC requirements for off-board electric vehicle charging systems

This part of IEC 61851 defines the EMC requirements for any off-board components or equipment of such systems used to supply or charge electric vehicles with electric power by conductive power transfer (CPT), with a rated input voltage, according to IEC 60038:2009, up to 1 000 V AC or 1 500 V DC and an output voltage up to 1 000 V AC or 1 500 V DC. This document covers off-board charging equipment for mode 1, mode 2, mode 3 and mode 4 charging as defined in IEC 61851-1:2017.

7.5.7 IEC TC 77 - Electromagnetic compatibility

7.5.7.1 IEC 61000-6-2 - Immunity standard for industrial environments

This part of IEC 61000 for EMC immunity requirements applies to electrical and electronic equipment intended for use in industrial locations, as described below. Immunity requirements in the frequency range 0 Hz to 400 GHz are covered. No tests need to be performed at frequencies where no requirements are specified.

7.5.7.2 IEC 61000-6-3 - Emission standard for equipment in residential environments

This part of IEC 61000 for emission requirements applies to electrical and electronic equipment intended for use at residential (see 3.1.14) locations. This part of IEC 61000 also applies to electrical and electronic equipment intended for use at other locations that do not fall within the scope of IEC 61000-6-8 or IEC 61000-6-4.

7.5.8 IEC TC 107 - Process management for avionics

7.5.8.1 IEC TS 62686-1 - Electronic components for aerospace, defence and high performance (ADHP) applications

IEC TS 62686-1:2020 defines the minimum requirements for general purpose "off the shelf" COTS (commercial off-the-shelf) integrated circuits and discrete semiconductors for ADHP (Aerospace Defence and High Performance) applications.

7.5.8.2 IEC TR 62240-2 - Electronic components capability in operation

IEC TR 62240-2:2018(E) describes a process and a method for selecting digital semiconductor microcircuits by ensuring that their lifetime is compatible with the requirements of Aerospace Defence and High Performance (ADHP) applications (generally in connection with functional environments).

This method was developed and submitted to IEC for standardisation by the French cluster of aeronautic industry (GIFAS). Starting from 2017 it has been further developed by IRT Saint Exupery under AIRBUS patronage, and called FRAME (Failure Risk Assessment Methodology).

7.5.8.3 IEC TS 62564-1 (AQEC)

IEC TS 62564-1 defines the minimum requirements for integrated circuits and semiconductors which are designated as an "Aerospace Qualified Electronic Component (AQEC)". A next revision of IEC

62564-1 is being created to add additional sets of data to assist with EASA AMC20-152A certification of complex electrical components and system safety analyses.

7.6 CENELEC / CEN / ETSI

CENELEC (French: Comité Européen de Normalisation Électrotechnique; English: European Committee for Electrotechnical Standardization) is responsible for European standardization in the area of electrical engineering. Together with ETSI (telecommunications) and CEN (other technical areas), it forms the European system for technical standardization. CEN/CENELEC/ETSI are the only 3 authorities allowed to release harmonized standards which can be adopted in countries outside Europe which follow European technical standards.

7.6.1 CENELEC TC47X

CENELEC TC47X is the continuation to the European regulation 2023/1781 known as 'European Chips Act' published in September 2023.

CENELEC TC47X is a new European Technical Committee that will mirror the activities of IEC TC47 "Semiconductors devices" and extend its scope to include the European "Trusted Chips" initiative, in response to the European semiconductor legislative work, to provide standards and certification for safe, secure, authentic chips and traceability throughout the supply chain.

7.6.2 CEN-CLC/JTC 24 'Digital Product Passport'

CEN-CLC/JTC 24 will elaborate deliverables for the deployment of the Digital Product Passport (DPP) and the data delivering ecosystem while ensuring cross sectoral and cross system interoperability.

The DPP is intended to support three major policy objectives of the European Commission:

- increase environmental sustainability
- promote circularity
- support legal compliance.

Consequently, the implementation of interoperable DPP systems and an associated data structure will ensure transparency and quality throughout the value chains, particularly with a view to strengthening the resilience of the European market.

7.7 ISO (International Standardization Organization)

ISO brings together experts to share knowledge and develop voluntary, consensus-based, market relevant International Standards that support innovation and provide solutions to global challenges in all the domains.

7.7.1 ISO TC 22 – Road Vehicles

7.7.1.1 ISO 16750-4 - Environmental conditions and testing for electrical and electronic equipment

7.7.1.1.1 ISO 16750-1,2,3 General, Electrical, Mechanical Loads

These documents apply to electric and electronic systems and components for vehicles including electric propulsion systems and components with maximum working voltages according to voltage

class B ([60V-1500V] DC). It describes the potential environmental stresses and specifies tests and requirements for the specific mounting location on/in the vehicle.

7.7.1.1.2 ISO 16750-4 - Environmental conditions and testing for electrical and electronic equipment

AEC-Qx does not provide recommendation of temperature grade versus mounting location of the component in the car. However, such recommendations are given by the annex A of ISO 16750-4 (Road vehicles — Environmental conditions and testing for electrical and electronic equipment — climatic loads).

7.7.1.2 ISO 26262 - Functional Safety for EE systems

ISO 26262 mandates a functional safety development process (from specification all the way through production release) that automotive OEMs and suppliers must follow (liability is therefore transferred down the chain), and document (for compliance) to have their devices qualified to run inside commercial and passenger vehicles. It outlines a risk classification system (Automotive Safety Integrity Levels, or ASILs) and aims to reduce possible hazards caused by the malfunctioning behaviour of electrical and electronic (E/E) systems, through procedures against systematic faults and detection or avoidance counter measures for random failures.
In aeronautic the DAL (Design Assessment Level) is used instead. As specified by the RTCA-DO-x.

7.7.1.3 ISO/SAE 21434:2021 - Cybersecurity engineering

This document specifies engineering requirements for cybersecurity risk management regarding concept, product development, production, operation, maintenance and decommissioning of electrical and electronic (E/E) systems in road vehicles, including their components and interfaces.

7.7.1.4 ISO 24089 - Road vehicles - Software update engineering

This document specifies requirements and recommendations for software update engineering for road vehicles on both the organizational and the project level. This document is applicable to road vehicles whose software can be updated.

7.7.1.5 ISO/AWI TS 5083 - Safety for automated driving systems — Design, verification and validation

This document provides an overview and guidance of the steps for developing and validating an automated vehicle equipped with a safe automated driving system. The approach is based on top level safety goals and basic principles derived from worldwide applicable publications. It considers safety by design, verification and validation methods for automated driving focused on SAE level 3 and level 4 vehicles according to ISO/SAE PAS 22736. In addition, it outlines cybersecurity considerations throughout all described steps.

7.7.1.6 ISO 15118 - Road vehicles - Vehicle to grid communication interface

This document specifies the secure communication between the Electric Vehicle (EV), including Battery Electric Vehicle (BEV) and Plug-in Hybrid Electric Vehicle (PHEV), and the Electric Vehicle Supply Equipment (EVSE). The application layer messages defined in this document are designed to support the electricity power transfer between an EV and an EVSE. This document defines the communication messages, sequence and security requirements for bidirectional power transfer.

7.7.2 ISO TC 108 – Mechanical vibration, shock and condition monitoring

7.7.2.1 ISO 13373-9, ISO 13374, ISO 17359, ISO 13379-2 and ISO 13381-1

These documents provide general guidelines for the measurement and data collection functions of machinery vibration and shock for condition monitoring.

7.7.3 ISO TC 176 - Quality management and quality assurance

7.7.3.1 ISO 9001:2015

ISO 9001 is a globally recognized standard for quality management. It helps organizations of all sizes and sectors to improve their performance, meet customer expectations and demonstrate their commitment to quality. Its requirements define how to establish, implement, maintain, and continually improve a quality management system (QMS).

7.7.3.2 ISO/TS 16949

ISO/TS 16949, in conjunction with ISO 9001, defines the quality management system requirements for the design and development, production and, when relevant, installation and service of automotive-related products.

7.8 VDE VDE

The VDE e. V. (German: Verband der Elektrotechnik, Elektronik und Informationstechnik) is a German technical-scientific association. VDE is known for creating and maintaining standards in the field of electric safety.

7.8.1 VDE ITG MN5.7 WG

Scope and objectives:

- Establish a platform for automotive semiconductor requirements discussion and exchange along the value chain.
- Deliver a white Paper on Extended Mission Profiles

7.8.2 VDE DKE/K 132

The DKE/K 132 works as a mirror committee of IEC/TC 56 in the field of reliability, which is understood to mean the ability of a product or technical system to function as and when required. In that context, activities about development of a standard for an electronic data format to describe mission profiles is ongoing.

7.9 IEEE (Institute of Electrical and Electronics Engineers) IEEE

The Institute of Electrical and Electronics Engineers is the world's largest technical professional organization dedicated to advanced technology. IEEE Standards Association (IEEE SA) aims to develop appropriate standards.

7.9.1 IEEE P2851- Semiconductor dependability

This standard defines a dependability lifecycle of products with focus on interoperable activities related to functional safety and its interactions with reliability, security, operational safety and time-

determinism. The standard defines methods, description languages, data models, and databases that have been identified as necessary or critical, to enable the exchange/interoperability of data across all steps of the lifecycle encompassing activities executed at IP, SoC, system and item levels, in a technology independent way across application domains such as automotive, industrial, medical and avionics safety critical systems, and to support developing methodologies such as Artificial Intelligence.

7.9.2 IEEE 1856-2017 - Framework for Prognostics and Health Management of Electronic System

This standard covers all aspects of PHM of electronic systems, including definitions, approaches, algorithms, sensors and sensor selection, data collection, storage and analysis, anomaly detection, diagnosis, decision and response effectiveness, metrics, life cycle cost of implementation, return on investment, and documentation. This standard describes a normative framework for classifying PHM capability and for planning the development of PHM for an electronic system or product. The use of this standard is not required throughout the industry. This standard provides information to aid practitioners in the selection of PHM strategies and approaches to meet their needs.

7.10 USDOD (United States Department of Defense)

7.10.1 MIL-STD-883

The MIL-STD-883 standard establishes uniform methods, controls, and procedures for testing microelectronic devices suitable for use within military and aerospace electronic systems including basic environmental tests to determine resistance to deleterious effects of natural elements and conditions surrounding military and space operations; mechanical and electrical tests; workmanship and training procedures; and such other controls and constraints as have been deemed necessary to ensure a uniform level of quality and reliability suitable to the intended applications of those devices.

7.10.2 MIL-HDBK-217F (Plus) Handbook

Handbooks of failure rate data for various components are available from government and commercial sources. MIL-HDBK-217F, Reliability Prediction of Electronic Equipment, is a military standard that provides failure rate data for many military electronic components. Several failure rate data sources are available commercially that focus on commercial components, including some non-electronic components.

7.10.3 MIL-PRF-38535

MIL-PRF-38535 establishes the general performance and verification requirements of single die integrated circuit device type electronics. It is a performance-based specification document defining the general requirements, as well as the quality assurance and reliability requirements, for the manufacture of microelectronic or integrated circuits used in military applications and high-reliability microcircuit application programs.

This standard is no longer supported and is not including model for WBG.

7.11 ZVEI

ZVEI stands for Zentralverband Elektrotechnik- und Elektronikindustrie eV (translation from german: electrical and electronic manufacturers' association).

7.11.1 ZVEI Automotive Mission Profile Application Questionnaire for Electronic Control Units and Sensors

This Automotive Application Questionnaire (downloadable from here) helps the parties involved (OEM, Tier1, Tier2...) to select critical application parameters (= environmental loads) in a simplified and standardized way.

7.11.2 ZVEI RV (Robustness Validation)

This handbook (downloadable from here) deals with Robustness Validation process for stand-alone Electronic Control Units. In that approach, knowledge of the basic failure mechanisms of the electrical/electronic module is required.

7.11.3 ZVEI Knowledge Matrix Device level

The Knowledge Matrix Device level (Excel) contents a table of different failure mechanisms in respect to the stage where they occur and the related stress method, acceleration model and references to existing test methods / standards.

7.12 FIDES

No acronym, latin word meaning 'trust'.

7.12.1 FIDES Guide (UTE C80-811)

UTE : 'Union Technique de l'Electricite', former french national body AFNOR.

The FIDES Guide 2022 Edition A (July 2023) (free registration) is a reliability prediction handbook published by a group of European defense and aerospace manufacturers under the supervision of the French Ministry of Defense.
The FIDES methodology models cover failures due to intrinsic causes (the technology or quality of manufacturing and distribution of the items studied) as well as extrinsic causes (the specification, design, sourcing, production, or integration of the equipment). The methodology covers the following:

- Failures resulting from errors in development or manufacturing
- Overstresses (electrical, mechanical, and thermal) linked to the use of the items and not listed as such by the user (i.e. where the overstress remains undetected).

The methodology does not cover:

- Failures caused by software
- Unconfirmed failures
- Failures linked to the non-performance of preventive maintenance
- Failures linked to accidental exposure when identified or established (propagation of failures, use outside the specifications, improper handling: i.e. where overstress is known to have occurred).

The FIDES methodology can be employed to study non-operating phases, whether dormancy periods between uses or actual storage.
The reliability prediction is expressed in FITs. American companies like Boeing, Japanese organisations like JAXA (Japan Aerospace Exploration Agency) as well as French companies or organisations like EDF (Electricité de France, French electricity provider) or CNES (Centre National d'Etudes Spatiales, the

French space agency) showed an interest in FIDES methodology, but none of them are using FIDES at this time.
As for the MIL-HDBK-217F (Plus) Handbook, FIDES does not cover WBG components. Some activities are being studies to provide Constant failure rate model (CFR) for SiC and GaN components.

7.13 Siemens AG

7.13.1 SN 29500 Handbook

SN 29500 is a Siemens AG standard for the reliability prediction of electronic and electromechanical components. It provides component failure rates for a list of categories. It also contains the underlying conditions for which the component failure rates apply (reference condition).

7.14 ANADEF (Default Analysis) AnaDef

ANADEF is a french industrialists and scientists assocaition concerned with the failure mechanisms of electronic components and assemblies, with a view to PREVENTION, DETECTION and ANALYSIS.

7.15 JEITA (Japan Electronics and Information Technology Industries Association) JEITA

7.15.1 EIAJ ED-4704

Failure mechanism driven reliability test methods for LSIs.

7.15.2 EDR-4708C

Guideline for IC reliability qualification plan.

7.16 SAE International (Society of Automotive Engineers) SAE

SAE International is a global standards organization for automotive, aerospace and other transport industries as self-driving cars, trucks, surface vessels, drones, and related technologies.

Key published documents:

7.16.1 SAE-J3101

This document is a common set of requirements, defined through fundamental use cases, to be implemented in hardware-assisted functions to facilitate security-enhanced ground vehicle applications over their lifecycle.

7.16.2 SAE J1879 / SAE J1211

The first version of these standards is equivalent to ZVEI RV (Robustness Validation).

The New J1879 Robustness Validation Standard as a new approach for optimum performance levels is currently under development by the SAE/ZVEI Joint Task Force.

7.16.3 SAE J3168

SAE J3168 standard is a Reliability Physics Analysis (RPA) standard developed specifically for use in the aerospace, automotive, defense and other high-performance (AADHP) industries.

RPA is the process of using scientifically derived algorithms and robust simulation techniques to predict how the evolution of physical, chemical, mechanical, thermal or electrical mechanisms can cause degradation and induce failures.

SAE J3168 provide a methodology of assessing durability, it does not document a library of mission profiles.

7.16.4 AS9100/EN9100

AS9100/EN9100 is a widely adopted and standardized quality management system for the aerospace industry, released by the Society of Automotive Engineers and the European Association of Aerospace Industries. AS9100 replaces the earlier AS9000 and fully incorporates the entirety of the current version of ISO 9001, while adding requirements relating to quality and safety. Major aerospace manufacturers and suppliers worldwide require compliance and/or registration to AS9100 as a condition of doing business with them.

7.17 ESCC (European Space Components Coordination) ESCC

The ESCC is established with the objective of harmonising the efforts concerning the various aspects of EEE (Electrical, Electronic and Electro-mechanical) space components by ESA (the European Space Agency), European national and international public space organisations, the component manufacturers, and the user industries. The goal of the ESCC is to improve the availability of strategic EEE space components with the required performance and at affordable costs for institutional and commercial space programmes.

7.17.1 ESCC9000

This specification defines the general requirements for the qualification, qualification maintenance, procurement, and delivery of Integrated Circuits for space applications as follows:

- Monolithic and Multichip Microcircuits, wire-bonded, hermetically sealed packaged components
- Flip-chip Monolithic Microcircuits, solder ball bonded, hermetically and non-hermetically sealed packaged components with and without passive (i.e. capacitors and resistors) Add-on Components
- Monolithic Microcircuit die components.

This specification contains the appropriate inspection and test schedules and also specifies the data documentation requirements.

7.18 ASAM (Association for Standardisation of Automation and Measuring Systems) ASAM

7.18.1 ASAM OpenX

ASAM OpenX is a shorthand notation for the ASAM Standards for testing and validation of highly automated resp. autonomous cars by simulation. Originally, these standards comprised:

- ASAM OpenCRG: for describing road conditions
- ASAM OpenDRIVE: for describing the static aspects (i.e., road networks including number of lanes, crossings, etc.), street signs, buildings, trees, etc. of traffic situations (ie., ‘scenarios’).

- ASAM OpenScenario: for describing the dynamic aspects of traffic situations ('scenarios'), like vehicles and their movements, other road users and their movements, etc.
- ASAM OSI (Open Simulation Interface): defining a common interface between different simulation tools.

Meanwhile, the family of standards has been extended by

- OpenXontology: Common definitions, properties, and relations for central concepts of the ASAM OpenX standards (still in concept phase)
- ASAM OpenLabel for labelling ground truth in scenario desriptions and collected data.
- ASAM OpenScenario DSL (Domain Specific Language) and OpenScenario XML, which both represent follow ups of the OpenScenario standard, defining a DSL as well as an XML scheme for describing the dynamic aspects in traffic situations (scnearios).
- OpenODD: For describing Operational Design Domains (also in concept phase, publication of standard envisoned this year).

7.19 ASTM International

ASTM (American Society for Testing and Materials) International is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services.

7.19.1 ASTM D1868-20

This test method covers the detection and measurement of partial discharge (corona) pulses at the terminals of an insulation system under an applied test voltage, including the determination of partial discharge (corona) inception and extinction voltages as the test voltage is raised and lowered. This test method is also useful in determining quantities such as apparent charge and pulse repetition rate together with such integrated quantities as average current, quadratic rate, and power. This test method is useful for test voltages ranging in frequency from zero (direct voltage) to approximately 2000 Hz.

7.19.2 ASTM B809-95

Standard Test Method for Porosity in Metallic Coatings by Humid Sulfur Vapor ("Flowers-of-Sulfur").

7.20 GB/T from Standardization Administration of China (SAC)

Issued by the Standardization Administration of China (SAC), recommended national standards are prefixed "GB/T" and are addressing all domains.

TABLE 7: CHINESE GB/T STANDARDS RELATIVE TO EVS

Reference	Name	Scope
GB/T 24347-2021	The DC/DC converter for electric vehicles	Electric vehicle DC/DC converter requirements and test methods for low power supply system class A (≤ 60 V DC).
GB/T 18384.Parts 1/2/3-2015	Electric Vehicles - Safety Specifications	Safety of On-board rechargeable energy storage system (REESE) of electrically propelled road vehicle's voltage class B ([60V-1500V] DC).

GB/T 18487.1-2015 GB/T 18487.2-2001 GB/T 18487.3-2001	Electric vehicle conductive charging system--Electric vehicles requirements for conductive connection to an A.C./D.C. supply.	Electromagnetic compatibility (EMC) requirements of the electric vehicle power supply charging equipment (Electric Vehicle Supply Equipment - EVSE).
GB/T 20234.Parts 1/2/3-2015	Connection set of conductive charging for electric vehicles	Voltage and current ratings, appearance, structure, environmental adaptability, electrical performance, and mechanical performance of connection set for conductive charging of electric vehicles.
GB/T 31498-2015	Safety requirements for electrical vehicle post crash	Safety requirements and test methods for pure electric vehicles and hybrid electric vehicles with level-B voltage circuits after frontal, side, and rear crashes with level-B voltage circuits in M1 and N1 vehicles.
GB/T 18387-2017	Performance Levels and Methods of Measurement of Magnetic and electric field strength from electric vehicles, Broadband, 9kHz to 30MHz.	Electric field and magnetic field emission intensity and the test methods for all types of EVs.
GB/T 18388-2005	Electric vehicles – Engineering approval evaluation program	Implementing conditions, test items, test methods, basis of evaluation, and test reports of new product design and approval evaluation test of pure electric vehicles (BEV).
GB/T 31466-2015	Voltage Ratings of Electric Vehicles High Voltage Electricity System	DC voltage rating requirements for high voltage HEV and for BEVs.
GB/T 29307-2022	Reliability Test Methods of Drive Motor System for Electric Vehicles	Test conditions, test procedures, test methods, inspection and maintenance, arrangement of test results, reliability evaluation and test report for bench reliability tests of drive motor systems for EVs.
GB/T 28046.2-2019	Road vehicles - Environmental conditions and testing for electrical and electronic equipment - Part 2: Electrical loads	Electrical environmental loads of electrical and electronic equipment on the vehicles and specifies the tests and requirements.
GB/T 28045-2011	Road vehicles – Electrical and electronic equipment for supply of voltage of 42V – Electrical loads	Single or multiple voltage systems tests and requirements for 42V electrical load.
GB/T 31484-2015	Cycle life requirements and test methods for traction battery of electric vehicle	Requirements, test methods, inspection rules of standard cycle life and the test methods and inspection rules of operating-condition cycle life of traction battery of electric vehicle.

8 Certifications/homologations in link with ARCHIMEDES activities

8.1 Certifications/homologations overview

TABLE 8: CERTIFICATION & HOMOLOGATION OVERVIEW

	All SCs	SC1 – SC2 – SC3	SC4	SC5
Qualification methods		ASAM OpenX ISO 34500 series	DO-160G	
Safety		ISO 26262 (Functional Safety, FuSa) ISO 21448 (SOTIF, Safety of the intended functionality ISO 24089 (OTA updates)	DO-178C (SW) DO-254 (HW)	

Colour code: Under definition – Defined, not yet in effect or partly in effect – In effect

8.2 ASAM OpenX

For the ASAM OpenX standards, see section ASAM OpenX.

8.3 ISO (International Standardization Organization)

8.3.1 ISO 34500 series

Regarding a scenario-based testing approach, the ISO 34500 series of standards has recently been published resp. is currently under development. This series comprises:

- ISO 34501:2022: Road vehicles -- Test scenarios for automated driving systems – Vocabulary (definition of the used vocabulary and terms)
- ISO 34502:2022: Road vehicles -- Test scenarios for automated driving systems – Scenario based evaluation framework (definition of a scenario based test and evaluation framework, conformant with and extending ISO 2148 SOTIF)
- ISO 34503:2023: Road vehicles -- Test scenarios for automated driving systems -- Specification for operational design domain. (defines a taxonomy for ODD attributes (like scenery, environmental/whether conditions, dynamic elements, etc.) and requirements for the definition format)
- ISO 34504: Road vehicles -- Test scenarios for automated driving systems – Scenario categorization (under publication; will define a uniform way to categorize scenarios

Whereas the ASAM standards define interchange and description formats, these standards give the 'higher level view' of describing ontologies, frameworks, ODDs, etc.

8.3.2 ISO 26262 Functional Safety

See also section ISO 26262 - Functional Safety for EE systems.

ISO 26262 is mostly concerned with ensuring that the residual risk of a malfunction of a system functionality having not acceptable impact on its operators, other humans or the environment is sufficiently low. Thus, it comprises methods to show that (a) the chances of a system malfunction because of wrong implementation or because of a (hardware) failure is sufficiently low and (b) that in

case of such malfunctions occurring there are sufficient measures in effect that mitigate the effects of such errors.

8.3.3 ISO 21448 SOTIF

The SOTIF (Safety of the intended functionality) standard leverages ISO 26262 to the next higher level. It contains measures to ensure that – given a fully functioning system according to ISO26262 – the intended functionality of that system is sufficient to cope with any situation (scenario) that the system might encounter in its Operational Design Domain, i.e. in that environment, for which it is intended to work. As a simple example, consider an autonomous car that detects objects in its pathway by radar sensors and that is intended to drive fully autonomously on 2 lane motorways. Validation according to ISO21448 would then comprise tests to show that any possible obstacle in front of the car is detected (even during lane change, in all whether conditions, with all road conditions, any type of object, etc.) resp. that the residual risk of this detection failing is sufficiently low.

8.3.4 ISO 24089 OTA updates

OTA (over-the-air) updates are increasingly needed for highly automated vehicles in order to (a) correct errors detected only during runtime, (b) increase performance, and (c) even add additional functionalities to systems already in the field. Especially for systems containing AI-based components, those updates will be essential. ISO 24089 covers methods and processes to implement, test, and deploy such updates safe and securely.

8.4 RTCA (Radio Technical Commission for Aeronautics) RTCA

Standards RTCA-DOx are key in aeronautic.

8.4.1 DO-160G

This document outlines a set of standard environmental test conditions and corresponding test procedures for airborne equipment for the entire spectrum of aircraft.

For Electromagnetic Compatibility (EMC), section 19 covers immunity and section 21 covers emission.

8.4.2 DO-178C

DO-178C, Software Considerations in Airborne Systems and Equipment Certification is a guideline dealing with the safety of safety-critical software used in certain airborne systems.

8.4.3 DO-254

RTCA DO-254 / EUROCAE ED-80, Design Assurance Guidance for Airborne Electronic Hardware is a document providing guidance for the development of airborne electronic hardware, published by RTCA, Incorporated and EUROCAE. The DO-254/ED-80 standard was formally recognized by the FAA in 2005 via AC 20-152 as a means of compliance for the design assurance (Verification Flow) of electronic hardware in airborne systems.

9 Gap Analysis

9.1 Introduction

Analysis of gaps, that determines which technologies or innovations requirements enabled by the project are not yet covered or not fully covered by State-of-the-Art existing or evolving standards, is a key target of Task 7.4. This section of the document (delivery D7.8) reports a first analysis observable at that step of the project, based on the key standards to be focused on classified in three sections:

- Gap analysis versus Wide Bandgap standardization activities
- Gap analysis versus Extended Lifetime standardization activities
- Gap analysis to aeronautic requirements

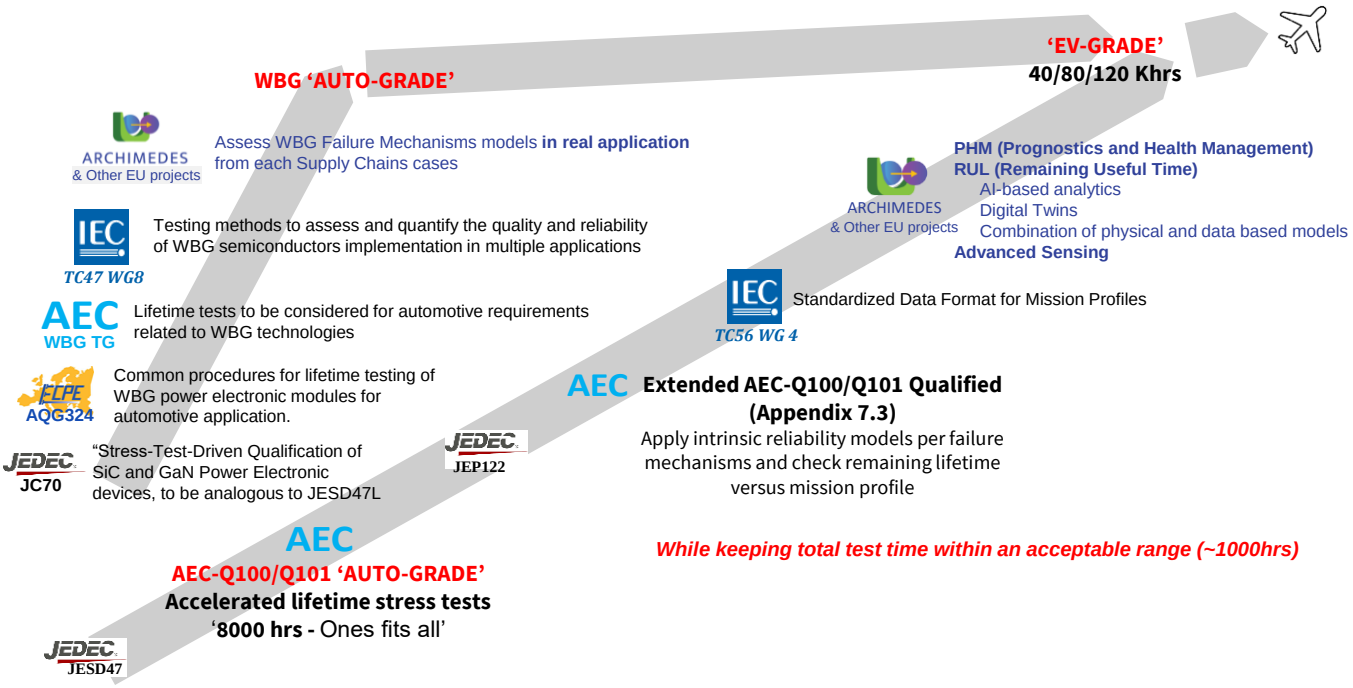


FIGURE 5: ARCHIMEDES IN THE STANDARDIZATION ECOSYSTEM

9.2 Gap analysis related to Wide Bandgap

9.2.1 JEDEC

9.2.1.1 JC70 gap analysis

Although the JC-70 committee has made significant strides in standardizing GaN and SiC power transistors, certain areas still require development, and current documents may benefit from further investigation and a deeper comprehension of failure physics.

To bridge the gap between existing qualification protocols and the specific physics of failure of WBG technology (that differs from Silicon), it is essential to conduct test-to-fail experiments. These tests involve subjecting components to high stress levels, potentially exceeding datasheet limits, with the aim of inducing failure mechanisms to estimate acceleration factors and enhance understanding of failure physics. The objective is to pinpoint new potential stress areas that need consideration in the qualification protocol (test-to-pass).

JC-70.1 Gap Analysis (GaN)

The following topics will be addressed in the project:

- **Gate Lifetime**: Several articles have demonstrated that in GaN power transistors, the gate lifetime decreases with decreasing temperature [1], [2]. However, the qualification protocol used to evaluate gate reliability is conducted at high temperature, and this might be not representative of the worst-case. Indeed, the qualification protocol is the so-called "High Temperature Gate Bias" (HTGB), where a constant electrical stress is applied to the gate (80% of the maximum rating) while keeping the device at the maximum temperature allowed by the datasheet. Currently, there are no qualification standards for low temperatures. In this project, test-to-fail experiments will be conducted to understand the failure mechanisms occurring at low temperatures, with the objective of determining if it is necessary to include gate qualification at colder temperatures or not.
- **Gate Switching Stress***:* the gate switching stress is a test-to-fail that consists in applying a switching electrical stress on the gate, while keeping the drain and the source shorted. Given the presence of traps in the semiconductor, results might differ with respect to the more classical test where the stress on the gate is constant. Within the project, dynamic test-to-fail will be conducted with the objective to understand if the worst case is at constant stress or not. Depending on the outcome, a qualification protocol (test-to-pass) that includes a dynamic stress applied on the gate will be then suggested to the JEDEC committee, as an important test to include. The test to-fail will permit to understand what the most important stressors are (Vg+, Vg-, temperature, frequency, tec) that need to be considered in the qualification protocol.
- **Dynamic Reverse Bias**: As for above, dynamic test will be conducted to evaluate the effect on a dynamic stress between drain and source.
- **Preconditioning**: Regarding GaN, additional effort is required for the characterization of this technology. Indeed, like for SiC devices, the threshold voltage of GaN HEMT is subject to fluctuations that are due do traps; these traps are present in the semiconductor (and not int he oxide layer as for SiC); several studies have demonstrated that the biases applied to the gate and drain contribute to the observed variations of the threshold voltage (V_{th}) [3]. However, to properly characterize a component and to correctly investigate its reliability is fundamental to have a robust and repeatable way to measure the Vth (called preconditioning protocol). For this reason, the establishment of a preconditioning protocol is fundamental to address the reliability of GaN technology. This subject will be investigated within the project Archimedes (Task 2.1)

JC-70.2 Gap Analysis (SiC)

In comparison to GaN, the SiC technology is more mature. The community can leverage on multiple automotive field experiences.

The following topic will be addressed in the project:

- Creation and the validation of digital models for respectively the PHM (Prognostics and Health Management) and the RUL (Remaining Useful Time) using the mission profiles issued by the SC1 and SC5.
- **Gate Switching Instability:** The high bandgap overlaps at the SiC/SiO2-interface leads together with a more complex fabrication process of the gate oxide to specific peculiarities of SiC MOSFETs

[4]. During switching transition, the released energy due to the de-trapping/recombination process of charge carriers leads to further degradation resulting in a further positive shift of the threshold voltage. Within the project, the GSS (Gate Switching Stress, JEP195) should be undertaken. This test is driven by some parameters, such as the maximum allowed gate-switching frequency for acceleration, dV_{GS}/dt, V_{GS} ON and OFF levels plus over/undershoots and the duty cycle during the stress period. $V_{GS(Th)}$ and $R_{DS,ON}$ drifts are to be monitored.

- **Switching Behavior:** For evaluating power device performance submitted to a certain stress, it is important to monitor parameters as drain-source voltage/current peaks, and total switching energy (JEP187). This characterization is strongly depending on the test setup, therefore same measurement conditions should be ensured [5].
- **Application Stress Test:** In order to obtain a more realistic stress, it should be considered to monitor parameters evolution under a real operation, i.e. by considering conduction and switching losses. In this case, SiC MOSFETs would be stressed by strong electric field (during switching transient), and high temperature (conduction phase). In recent studies, an Inverter-like Topology has been considered, and it is a good candidate to lead a real switching stress [6]. This test is essential to better estimate the lifetime of the device.
- **Short-circuit Behavior:** Accelerated tests and a lot of work have been already done on this topic. Thus, it is well-known that degradation mechanisms occur on SiC MOSFETs caused by short -circuit events [7]. A wide investigation is needed to understand the impact of short-circuit events on device lifetime based on parameters drifts. The failure criterion is related to the end-user application.

9.3 Gap analysis related to Mission profile and Extended Lifetime

9.3.1 AEC

9.3.1.1 AECQ100 versus AECQ101 about GROUP D – DIE FABRICATION RELIABILITY TESTS

One of the main gap noticed between AEC Q100 and AEC Q101 is for the group D 'Die fabrication reliability tests' : stress tests to be performed at WLR/TQ[8] (Electromigration EM, Time Dependent Dielectric Breakdown TDDB, Hot Carrier Injection HCI, Bias Temperature Instability BTI, Stress Migration SM) are mandatory for ICs and not listed for Discrete devices (only Dielectric Integrity DI is listed into group D in AECQ101).

Solving this equivalence is fundamental, because part of the mitigation in lifetime End-Of-Life must be carried out in WLR (Design Rules or key parameters for intrinsic reliability). WLR assessment is the triggering point to determine the failure mechanisms and associated parameters driving the aging acceleration and the limitation. JEP001 qualifications guidelines at front-end transistor level is a reference document to drive this assessment. Extended operating lifetime can be assessed at the

[4] Aichinger, T., Rescher, G., & Pobegen, G. (2018). Threshold voltage peculiarities and bias temperature instabilities of SiC MOSFETs. Microelectronics Reliability, 80, 68-78.

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[6] Sievers, M., Findenig, B., Glavanovics, M., Aichinger, T., & Deutschmann, B. (2020). Monitoring of parameter stability of SiC MOSFETs in real application tests. Microelectronics Reliability, 114, 113731.

[7] Reigosa, P. D., Iannuzzo, F., Luo, H., & Blaabjerg, F. (2016). A short-circuit safe operation area identification criterion for SiC MOSFET power modules. IEEE Transactions on Industry Applications, 53(3), 2880-2887.

[8] TDDB, EM, HCI may be also performed at package level, to increase parallelism or perform long-term trials.

targeted temperature grade by listing the key parameters driving the lifetime and the wort case design rules. A deep understanding of this critical parameters for reliability at transistor level is required to address long lifetime mission profile.

As reference, looking at Aerospace flight model qualification requirements, a goal of 18 years at Tj ≤ 110°C is required by AeroSpace European standards [ESCC9000 'Wafer Level Reliability Assessment' section] and 15 years by +65°C ≤ Tj ≤ +95°C by Aerospace US MIL standards [MIL-PRF-38535 'Appendix B ' Manufacturing verification].

9.3.1.2 AEC-Q100/Q101 Appendix 7.3 gap analysis

Qualification stress test strategy of AEC-Q10x relies on accelerated tests like HTOL (High Temperature Operating Life) that intends to satisfy a typical 8000 hours power-on time mission profile.
WP1 comes with mission profiles inputs as summarized in Figure 6: Power-on Hours from Supply Chains Mission profiles.

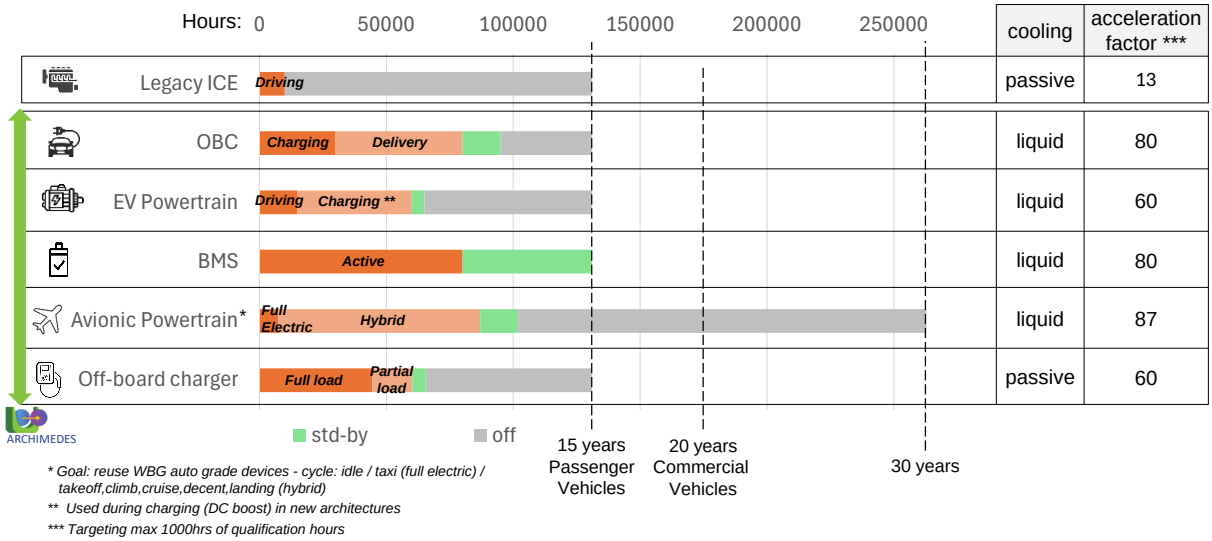

FIGURE 6: POWER-ON HOURS FROM SUPPLY CHAINS MISSION PROFILES

AEC-Q100/Q101 Appendix 7.3 'Method to assess a mission profile' gives methods to deal with EMP.

ARCHIMEDES is developing new concepts like PHM, CBM, RUL (AI-based analytics, Digital Twins, Combination of physical and data-based models) than can come in complement to these methods, as shown in Figure 7: ARCHIMEDES new concepts to deal with EMP.

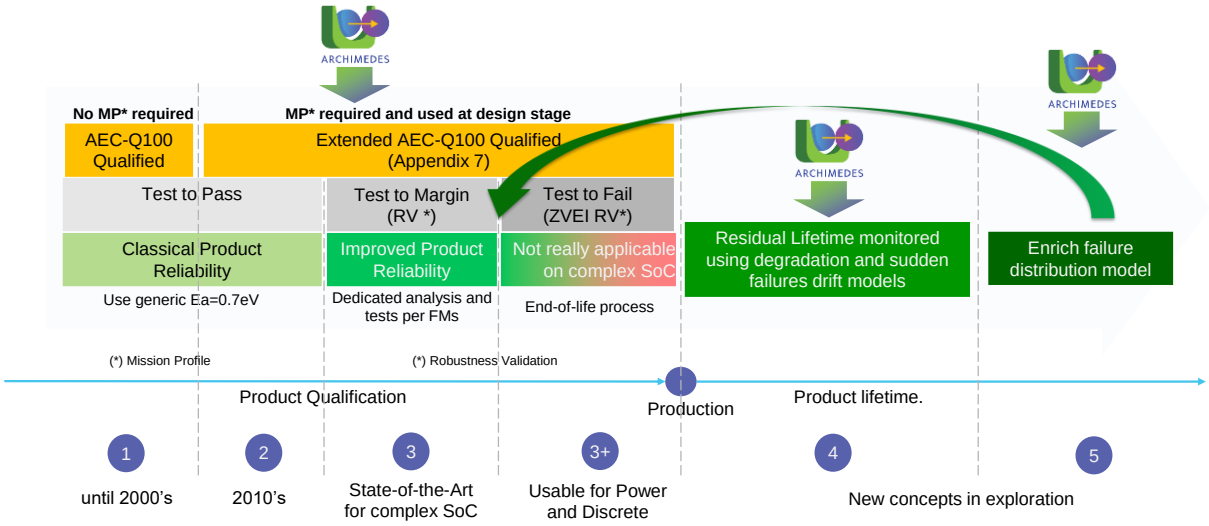

FIGURE 7: ARCHIMEDES NEW CONCEPTS TO DEAL WITH EMP

9.3.1 ECPE

9.3.1.1 ECPE AQG324 gap analysis

Gap analysis from activities in ECPE ZVEI working group regarding access of longer operation times will be addressed in the second period of this task T7.4 (D7.9).

In other hand, ECPE AQG324 gap analysis between Aeronautic (SC4) and Automotive (SC2) is addressed in section 9.4.

9.4 Gap analysis versus Aeronautic (SC4) and Automotive (SC2) qualification procedures

Supply Chain 4 of ARCHIMEDES project is dedicated to the gap analysis of specification and requirements between the aeronautic and automotive sectors, as the objective for avionic applications is to benefit from already qualified automotive technology and add some extra qualification tests if needed. The use case selected for the project is the hybridization of propulsion function for avionic application, considering an inverter up to 500 kW. Therefore, the demonstrator will be a SiC based automotive qualified power module for 800 V inverter. The proposed methodology is the following:

1. The avionic partner (SAFRAN) proposes several validation means in order to respect avionic specifications
2. Those avionic validation means are compared to the qualification sequence done for the automotive grade power module as per the overview matrix in Table 9: Aeronautic versus Automotive stress tests gap analysis plan below.
3. The gap which is existing between avionic requirements and ECPE-AQG 324 test sequence is established; as example, radiation immunity tests are not included in the ECPE-AQG 324.
4. A test plan is established to test automotive power module, in order to validate it for avionic requirements.

TABLE 9: AERONAUTIC VERSUS AUTOMOTIVE STRESS TESTS GAP ANALYSIS PLAN

Stress test	Reference for gap analysis
Thermal shock	ECPE-AQG324
Pressure Cooker Test	ECPE-AQG324
Temperature Cycling Test	JESD22 or IEC60068
Partial discharge	IEC 60270 & ASTM D1868
Single Event Burnout (SEB) resistance to altitude	*to be defined*
Sulfur resistance	ASTM B809 or equivalent
Vibration	ECPE-AQG324
Shock	ECPE-AQG324
Temperature	IEC60749-6:2002
Humidity	IEC 60747/ ECPE-AQG324
High Temperature Reverse Bias (HTRB)	ECPE-AQG324
High Temperature Gate Bias (HTGB)	ECPE-AQG324

10 Other industry initiatives in link with ARCHIMEDES activities

10.1 Overview of other industry initiatives in link with ARCHIMEDES activities

TABLE 10: OTHER INDUSTRY INITIATIVES OVERVIEW

	All SCs	SC1 – SC2 – SC3	SC4	SC5
Mission profile definition	MPFo	SEMI GAAC		
WBG Failure Mechanisms	SiCRET GaNRET			
Safety	Architect ECA 2030			
Circular Economy		SIA –lifetime & circular economy WG		

Colour code: Starting, no deliverable yet – Active, some deliverables are available – Close

10.2 SEMI GAAC (Global Automotive Advisory Council)

SEMI is the leading microelectronics industry association with programs that help members grow their business and address top challenges worldwide. The Global Automotive Advisory Council (GAAC) of SEMI initiated a WG in 2024 to work on aligning standardization of requirements for power electrification in vehicles, with a focus area for on board chargers.

10.3 Architect ECA 2030

Scope: Within the complex chain of sensing-processing-controlling-actuating, many types of ECS (Electronic Components and Systems) failures might occur and must be avoided by design or at least predicted in time during vehicle operation. These failures which occur with certain probabilities, reasons, and external influences include:

- Failure of systems-on-chip, electronic components and hardware deficiencies,
- Deficiencies in sensing road, traffic, and environmental conditions, e.g. sensors detect and respond to a non-existent event (false positive), or sensors do not detect and respond in the presence of obstacles (false negative),
- Software failures such as deficiencies in control algorithms (complex and difficult situations),
- Degraded system performance due to inoperable sensors/actuators or the vehicle is completely inoperable,
- Faulty driver and vehicle interaction (mode confusion and false commanding).

ArchitectECA2030 envisions to cover both safety assurance by design and safety assurance in-operation.

10.4 SiCRET - SiC (MOSFET) Reliability Evaluation for Transport

SiCRET project studied the reliability of Silicon Carbide power electronic devices. At the heart of the transition to electric mobility, this project aimed to enable the deployment of 'reliable' SiC MOSFET technology in the transport sector. The project brought together the main players in the high electrical energy transformation chain in various fields: stationary, aerospace, rail, automotive, heavy machinery.

The project also aimed to establish a solid knowledge base in order to achieve consensus within the consortium and subsequently leverage this to achieve greater public acceptance of the qualification procedures and design rules generated by SiCRET, through interaction with institutional standardisation bodies.

SICRET target was the SiC die technology reliability while in a follow up project presently running the target are SiC modules where the issue of die parallelisation and thermal management are at stake.

10.5 GaNRET - GaN Reliability Evaluation for Transport

Scope: Evaluation of the reliability of gallium nitride (GaN) power semiconductor technology. The main objective is to enable the insertion of GaN-based power electronics into several sectors of the electric mobility supply chain with high reliability constraints.

Similarly to SICRET, this project is a multisector driven initiative targeting the understanding of GaN power transistors physics of failure in order to pave reliable testing protocols and design guidelines.

10.6 MPFo (Mission Profile and Component Capabilities Data Exchange Format)

MPFo represents an XML based formal description of mission profiles and component capabilities. Project website: https://www.mpfo.org

See also IEC TC56 WG4 and VDE DKE/K 132.

10.7 SIA – Automotive components lifetime and circular economy WG

French association SIA (French: 'Société des Ingénieurs de l'Automobile'), that brings together manufacturers, equipment suppliers, engineering companies, start-ups, SMEs, competitiveness clusters, universities, research centres of the automotive industry to promote the development and sharing of knowledge, opened in 2024 a working group around automotive components lifetime and circular economy.

11 Conclusions and lessons learned

This exercise of referencing existing and evolving standards related to the different ARCHIMEDES activities contributed to pave the ground of the project, to clarify project objectives, to facilitate interactions between WPs and SCs, to give first visibilities on where the project outcomes can be from a standardization perspective point of view. Gap analysis section determines direction and focus of the second phase of T7.4 (D7.9).

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All other references are given in the core of the document.

13 List of tables

14 List of figures

15 Internal review

Reviewer: Fabio COCCETTI – Manager of High-Density and High-Reliability Competence at IRT Saint Exupéry

1. Is the deliverable in accordance with:

		Answer	*Comments*	*Type**
(i)	the description of work?	yes	Impressive overview of standards and guidelines with a very broad view coming from different application sector and standardization bodies. Covering such large spectrum of safety and interoperability issues is a big challenge.	M
(ii)	the international state of the Art?	yes		M

2. Is the quality of the deliverable in a status that:

		Answer	*Comments*	*Type**
	allows to send it to ECSEL JU?	yes		M
(ii)	needs improvement of the writing by the originator of the deliverable?	yes	Comments incorporated.	m
(iii)	needs further work by the partners responsible for the deliverable?	yes	What is missing or less evident is the notion of supply chain, (material-device-module-equipment-systems-function or whatever it is the definition). For instance, nowadays there are already a number of challenges in going from SiC/GaN dies to SiC /GaN modules due to the parallelization and very few standardization bodies or specialized organizations are dealing with that. This enters in the gap analysis follow-up studies that will be addressed during next phase of ARCHIMEDES and reported in D7.9 (M24).	a

* Type of comments: M = major comment; m = minor comment; a = advise

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