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# PROJECT „surf:guide”

Project content and conditions of participation

The logo for 'surf:guide' features the word 'surf' in a lowercase, sans-serif font. Above the 'r' is a stylized wire bonding symbol consisting of a thin line that curves over the letter and ends in a small circular terminal. The word 'ace' is written vertically in red, lowercase letters between 'surf' and 'guide'. The word 'guide' is written in a lowercase, sans-serif font to the right of 'ace'.

surf:aceguide

Use the strength of a Multi-Client-Project to drive research with low investment at highest possible return on your invest.

# Introduction/Motivation

*„We have to change something. We are in a position to do so. Right now is the right time.“*

This project addresses the challenge of establishing guidelines for the specification of surfaces and bond pads suitable for wire bonding processes. These will be summarized in a guideline (factsheet, industrial recommendation) that will serve as the basis for the creation of an industrially recognized standard. Companies and users are thus enabled to:

- Specify bonding surfaces more clearly and thus more reliably
- Monitor the limits of surface properties by means of inspection, testing and measurement procedures.
- Process complaints more quickly and in a more targeted manner on the basis of a widely agreed and industry-recognized document
- Accelerate development times through short coordination paths and reduce risks for wrong decisions
- Implement even more stable wire bonding processes with fewer errors and process interruptions

The work packages of the project, which are divided into thematic areas, will be processed by expert groups (formed from the companies participating in the project). Bond-IQ GmbH will coordinate the communication, document the input from these expert groups and compile it in such a way that industrial recommendations can be derived from it. For topics where data is not sufficiently reliable, suitable experiments and analyses will be used to obtain the necessary data. Experiments and analyses are carried out by Bond-IQ GmbH and analysis service providers specifically selected to match the research question. All explanations of test methods, specifications, limits, best practice for wire bonding applications and image catalogs of defects will be summarized in a single document that can be used for communication with customers and suppliers by the project partners after completion of the project.

Large companies with multiple manufacturing sites and development teams have long used such documents for supplier parts assurance. But even these documents need updating. And this is where those responsible for the technology repeatedly come up against limits if there is insufficient validated data and industry experience available for a more secure and up-to-date specification.

Medium-sized companies use their own specifications, but often find it difficult to fully enforce them with their suppliers because there is no general industry consensus.

Small companies and startups new to wire bonding technology usually have the challenge of gathering all the important information in a short time and deciding which aspects are important.

It is necessary to create a consensus here and establish a reference that all companies and users in wire bonding technology can equally refer to in order to draw a positive common benefit from it.



**You do not have to provide any employees or resources (materials, machines)** for the surf:guide project. You finance the project and receive the results. If you do not have time to participate in the project but want to access all the results, this option is available to you. You always have access to video recordings of the project meetings and all information on the companion projects in which you participate.

## Content of this project description

|   |    |
|---|----|
| <b>Introduction/Motivation</b> .....  | 2  |
| <b>Project structure</b> .....  | 4  |
| Core project - Guide for bond surfaces.....   | 6  |
| Companion project P1 - Cleanliness.....   | 7  |
| Companion project P2 - Topography and roughness.....  | 9  |
| Companion project P3 - Layer Interfaces and Adhesion.....                                     | 11 |
| Companion project P4 – Pre-treatment and Cleaning.....  | 13 |
| Companion project P5 – Visual Failures / Failure Catalogue.....                               | 14 |
| <b>References</b> .....   | 15 |
| Project “Wire bond testing standard”.....   | 15 |
| Project “SpeedCycle”.....   | 16 |
| Project “QUALSi”.....   | 16 |
| <b>Project financing and organizational matters</b> .....                                     | 17 |
| Financial plan - investment for participation in the core project and companion projects..... | 18 |



**Link to the project participation form (Click here)**

# Project structure

*„That's how we get to the goal.“*

The project is divided into a core project and supplementary companion projects. The task of the **core project** is to bundle all available information on bonding surfaces in one document and to prepare it in such a way that companies are able to specify their bonding surfaces and bonding processes on the basis of it. The resulting document is a consensus of all companies involved in the project and reflects the experience of more than 60 years of industrial practice in wire bonding. The document is the starting point and basis for a transition into an international standardization process.

Financial participation in the core project is mandatory for all project partners. The financial contribution is the same for all project partners. This financial contribution ensures the basic financing of the project. Therefore, each partner receives access to the central project objective - a guide for surfaces used in wire bonding processes - upon completion of the project.

The **companion projects** provide missing data that has been requested for a specification of bond surfaces for decades. The following five<sup>1</sup> companion projects have already been defined and, with enough partners in each case, will start together with the core project:

- P1** Cleanliness
- P2** Topography and Roughness
- P3** Layer Interfaces and Adhesion
- P4** Pre-treatment and Cleaning
- P5** Visual Failures / Failure Catalogue

A condition for participation in a companion project is a financial contribution to this companion project. In addition, each project partner can decide how intensively it wants to participate in terms of content. In principle, it is possible to access the data and findings of a companion project without

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<sup>1</sup> It is possible that further topics will be identified that make additional companion projects necessary. In this case, these new companion projects will be defined and launched with the appropriate partners while the core project is still running.

participating in its content. In terms of content, a companion project is significantly more complex than the core project. Experiments and analyses are the central subject of the work here. These analyses are tailored to very specific issues, which are of decisive importance for complex bonding processes with high demands on process stability and product durability. Therefore, only project partners with a specific interest in carrying out the analyses and accessing all the results of these analyses will come together in a companion project. Only the most important results and key figures from a companion project will be included in the document that is produced in the core project.

All companion projects are handled individually and independently. This ensures that each companion project can be started and completed regardless of whether funding is secured for other companion projects.

The entire project is designed as a **multi-client project**. In a multi-client project, different companies (partners) enable the implementation of the project through their financial participation. Each partner decides individually on the content-related participation. The results of the core project are made available to all partners. The results of a companion project are only provided to those partners who participate from the beginning or by joining later. Each partner thus saves significant costs that would be incurred if he were to carry out the project alone and only with his own financial resources.



Exchange of experience and know-how profit through cooperation with experienced experts and the participation of numerous market players



Always up to date on all information. Efficient web meetings, recorded presentations, and team folders for smooth collaboration.



Networking and market overview. What are the market competitors doing? Where is the benchmark?



Secured findings from specifically selected experiments and analyses



Cost savings and maximum return on investment through cost sharing with like-minded partners



Access to numerous surface measurement data and parameters derived from them



**Link to the project participation form (Click here)**

## Core project - Guide for bond surfaces

The aim of the core project is to produce the guide with the working title "Requirements for cleanliness and condition of surfaces for wire bonding applications". This guide bundles all the important **information, method descriptions, characteristic values** and **limit values** that are essential in the specification of bond surfaces. It is the long-needed supplement to existing test standards for wire bonded connections. The standards available to date have focused on visual and mechanical testing of bond quality. The properties of a bond surface required for stable wire bonding processes have not been centrally summarized in any document to date. The following chapters<sup>2</sup> will be part of the guide:

1. Scope, preliminary remarks, structure
2. Definitions of terms, abbreviations, applicable standards  
(e.g. contamination, impurity, foreign layer, discoloration, scratches, scores, notches, holes, bumps, layer peeling, pad detachment, stains)
3. Description of surface properties with influence on the bonding behavior  
(e.g. filmic impurities, particles, organic impurities, oxides, impurities diffused from the metallization system, silicones, adsorbates, Ni corrosion in the ENIG system)
4. Layer systems and surfaces  
(material composition/ purity, layer thicknesses, manufacturing processes)
5. Visual inspection (manual, automatic)
6. Topography measurement
7. Bond testing with and without preconditioning
8. Specialized test/measurement methods  
(e.g. material and surface analysis, rapid tests)
9. Pre-treatment, cleaning and storage
10. Recommendations for best practice in the handling of bond surfaces

The guide serves as a basis for the specification of bond surfaces and as a reference in case of complaints and the discussion of causes and remedial actions. It is thus a document applicable to a wide audience, e.g. for:

- Inexperienced and experienced technologists and process owners
- Persons responsible in quality inspection and supplier management (SQM)
- Designers, developers, constructors, technical sales people

All partners are actively involved in the creation of the guide, defining and deciding on the content. At any time, all partners have access to all draft versions of the guide. In addition, the technical possibilities for joint editing of the document and comment functions are provided.

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<sup>2</sup> The order and naming can still change in the course of the project.

## Companion project P1 - Cleanliness

In the companion project P1, the focus is on surface cleanliness - a surface property that is very difficult to measure and specify. Cleanliness is of central importance when wire bonded connections have to be manufactured with high strength, in very stable production processes and with assured delivery capacity. Typically, this applies to manufacturers in the automotive and aerospace industries and, in particular, fabricators of sensitive active components in power electronics. However, companies from other industries with very tightly scheduled production lines must also ensure that their processes run without interruptions and that sources of error are detected early on so that corrective measures can be installed in good time.

For the validation of surface cleanliness, the following are required:

- Proven, readily available and easy-to-interpret measurement methods for the quantification of contaminants
- Rapid tests for surface contamination and surface changes for in-process release of production jobs
- Limit values for acceptable contamination on bond surfaces

The following measurement methods and rapid tests will be evaluated in this companion project:

### Chemical/physical - measurement methods

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- Material analysis / EDX
- Material analysis / Raman spectroscopy
- Surface analysis / FTIR
- Surface analysis / TOF-SIMS
- Surface analysis / ellipsometry
- Surface tension
- Color measurement / spectrophotometer

### Chemical/Physical - Rapid Tests

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- Test inks / wetting tests
- Handheld instruments for Raman spectroscopy, FTIR, surface tension, X-ray fluorescence
- Light microscopy

The bondability of the samples on which the measurements and rapid tests are performed is verified by bonding tests with gold and aluminum wires. Quality is evaluated according to industry recognized standards (MIL-883, ASTM F458/F459/F1269, JEDEC JESD22-B116B/B120, AEC-Q100/Q101 and DVS-2811). Testing is performed on various types of contaminants typical of manufacturing processes and fabrication processes of plated bond surfaces. This ensures that by correlating wire bonding results and measured values, it is possible to establish limit values and derive recommendations for practical methods.

Example of a typical analysis procedure in the companion project:

- 1.** Selection of suitable samples from partners or preparation of suitable samples
- 2.** Bond tests before further analyses, documentation of bond quality
- 3.** Analyses with 2-3 reference methods to determine the surface condition
- 4.** Evaluation and correlation of wire bonding result and surface analysis
- 5.** Comparison with other analytical methods and rapid tests
- 6.** If the combination of the data from this and other tests draws a clear picture, the definition of the methodology, derivation of characteristic values and limit values follows



## Companion project P2 - Topography and roughness

The roughness of a bond surface is required by many users as an important indication in the specification of a component. Roughness values are quantifiable parameters that are measured with specially designed measuring systems and calculated using algorithms that are individually adapted to the application. In industrial practice in wire bonding, there are currently no roughness parameters that are individually specified for the wire diameter, bonding process and surface type. Rather, it is common practice to use very old industrial experience. When they were defined, these were already not adapted to individual bonding processes and have not been replaced by modern methods and characteristic values for more than 20 years.

It is now known that critical topographies exist in bond surfaces that severely limit bond formation and degrade bond quality to such an extent that valid industrial standards cannot be met. In addition, it is known that fluctuating roughnesses on surfaces in series production affect the internal monitoring systems of wire bonders (e.g. deformation signals). This makes 100% monitoring of each individual wire bonded connection much more difficult.

For the validation of the roughness of bond surfaces are needed:

- Validated measuring systems capable of measuring bond surfaces traceable to roughness standards - small smooth bond pads (< 100  $\mu\text{m}^2$ ) as well as large, very rough bond surfaces (< 2  $\text{mm}^2$ ).
- Limits for permissible roughness parameters, tailored to bonding method and wire diameter
- Instructions for roughness measurement on bond surfaces, creation of suitable measurement value filters, selection and comparison of measurement systems

The following topography measurements will be performed in this companion project<sup>3</sup>:

- Printed circuit board metallization systems  
(e.g. ENIG, ENEPIG, DIG, electroplated Ni/Au, ASIG, EP, EPAG)
- DCB/AMB surfaces  
(e.g. Cu (unbehandelt): blank / + Ni/Au / + Ag, Cu (eingeebnet): blank / + Ni/Au / + Ag)
- AISi1 roll cladding
- Lead frame  
(e.g. electroplated Ni/Pd, electroplated Ni/Pd/Au, electroplated Ag, electroplated Ni/NiP)

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<sup>3</sup> It is likely that other, less frequently used surfaces will be added as the project progresses.

- TO-header / Pin housing  
(e.g. ENIG, electroplated Ni/Au)
- Machined metal parts  
(e.g. Busbars for battery modules, milled surfaces, ground surfaces)
- Printed pastes on ceramics  
(e.g. Au-, AgPt-, AgPd paste after the firing process and, if necessary, subsequent plating processes)
- Testing and comparison of measurement systems by means of round-robin tests  
(confocal microscopes, tactile measurement instruments, AFM on suitable samples/structures)

The bondability of the samples on which the topography measurements are made is verified by bonding tests with gold and aluminum wires (depending on which bonding method is suitable for the particular metallization). Quality is evaluated according to industry recognized standards (MIL-883, ASTM F458/F459/F1269, JEDEC JESD22-B116B/B120, AEC-Q100/Q101 and DVS-2811). Tests are performed comparatively in different roughness classes of specimens when multiple roughness classes are available. Those roughnesses that are typical for manufacturing processes and production processes of plated bond surfaces are identified. This ensures that by correlating wire bonding results and measured values, it is possible to define limit values and derive recommendations for practice-oriented methods.

Example of a typical analysis procedure in the companion project:

1. Measurement of suitable samples from series production processes of partners
2. Comparison of measurement results between different measurement systems in predefined reference regions (round-robin test)
3. Tests to compare the different measuring systems, identification of surface parameters that are sensitive and robust to different measuring systems
4. Bonding tests, documentation of bond quality
5. Correlation of wire bonding results and surface topography, derivation of limit values for surface parameters

Partners of this companion project will receive, in addition to the results of the roughness measurements and bonding tests, **instructions for the correct measurement of bond surfaces**, which can be used as an internal reference document and for coordination with service providers (e.g. laboratories).

## Companion project P3 - Layer Interfaces and Adhesion

The focus of the companion project P3 is on the structure and quality of metallization layer systems for wire bonding applications. In all plating systems, variations and defects can occur in the manufacturing process that affect the interface formation within the plating system and have an unfavorable influence on the quality of a wire bonding process. These metallization layer systems include in particular:

- ENIG (Electroless Nickel Immersion Gold)
- SAG-Varianten (Semi-Autocatalytic Gold)
- ENEPIG/ENIPIG (Electroless Nickel Electroless/Immersion Palladium Immersion Gold)

Other industrially relevant plating systems are: electroplated metallizations, DIG, ASIG, EPAG, sputtered or vapor-deposited coatings, thick layers of paste metallizations.

Currently, there is no widely available standard or data sheet that provides specific details on allowed and disallowed interfaces, such as corrosion artifacts in ENIG plating systems, pore seams, and local defects, especially for wire bond applications. Furthermore, there are no proven test procedures for the evaluation of metallization adhesion or documented test series for metallization adhesion tests and a comparison with wire bonding results for these surfaces.

The companion project P3 addresses this challenge and will provide the following data for a specification and validation of the coating quality:

- Methods for a safe (and ideally fast) identification of weak points at interfaces within layer systems
- Boundary samples and limit values for acceptable layer systems
- Documentation and categorization of the different states of layer systems (good and bad samples) using optical methods
- Testing of methods for mechanical testing and measurement of the adhesion strength of metallizations on bond pads
- Testing of rapid tests for adhesion properties of platings for the in-process release of production jobs

The following three mechanical test procedures will be tested:

- Stamp / stud pull-off test
- Tape test
- Combined tape / scratch test

Example of a typical interface quality analysis procedure in the companion project:

- 1.** Compilation of samples of specific defect patterns from manufacturers, partners and other accessible sources (e.g. networks such as the AG2.4 bonding, AEC, IMAPS)
- 2.** Documentation of the layer quality with suitable methods  
(e.g. Focused-Ion-Beam FIB, scanning electron microscopy, light microscopy, cross-sectioning, etching methods)
- 3.** Bonding tests on selected variants to document the defect patterns on the wire bond in the initial state and after appropriate aging

Example of a typical analysis procedure for layer adhesion in the companion project:

- 1.** Compilation of samples with weaknesses in the metallization layer structure, e.g. from the parallel investigation of interface quality, from partners, plating manufacturers or specifically generated by modification of plating processes
- 2.** Adhesion tests with the above-mentioned methods
- 3.** Bonding tests on the investigated variants and in particular on the variants conspicuous in the adhesion test in conjunction with a detailed visual inspection with regard to metallization peeling in the pull test
- 4.** Correlation of wire bonding results and adhesion properties, derivation of recommendations for metallization and interface conditions

## Companion project P4 – Pre-treatment and Cleaning

The focus of the companion project P4 is on pre-processes which are intended to ensure even better wire bondability of surfaces and assemblies. These are usually cleaning processes designed to remove residues and foreign layers (e.g. from component handling, from soldering and gluing processes, long and unfavorable storage).

The following cleaning process types are being investigated as part of the companion project P4:

- Wet chemical cleaning  
(e.g. solvent-based, surfactant-based, specialized cleaners)
- CO2 snow jet cleaning
- Plasma cleaning  
(e.g. atmospheric pressure plasma, vacuum plasma)
- Laser cleaning  
(e.g. focus on battery cells and busbars)

In this companion project, particularly close cooperation with (and between) the partners is sought, since not all cleaning processes are available in one competence center. Bond-IQ GmbH will be responsible for communication, coordination and evaluation of the experiments. The cleaning experiments will be performed by participating partners and/or external service providers. Bond experiments will be carried out by Bond-IQ GmbH before and after the execution of cleanings in order to evaluate the effectiveness of the measures and to be able to make final recommendations. In addition, residual contamination analyses are carried out on suitable samples on the surfaces after cleaning.

Example of a typical analysis procedure in the companion project:

- 1.** Compilation of samples with characteristic impurities
- 2.** Bond tests and selection of samples with significant influences by the impurities present
- 3.** Surface analysis to determine the composition of the impurities
- 4.** Cleaning tests with selected processes in corresponding competence centers with industrial cleaning processes
- 5.** Bond tests and surface analysis after cleaning
- 6.** Correlation of wire bonding results and impurities, derivation of limit values for cleaning results

## Companion project P5 – Visual Failures / Failure Catalogue

Many features of bond surfaces need to be inspected using a light microscope. This is one of the most effective methods of performing an initial or incoming inspection quickly and with little investment in equipment and personnel. However, to leave the decision on acceptable and unacceptable features to the respective inspecting person would be negligent. Instead, a catalog of characteristics is needed that can be used for training/education and serves as a basis for decision-making and reference during the inspection.

In the companion project P5, the focus is on creating an illustrated catalog of defects across a wide range of bond surfaces and inspection methods. The defect images will be recorded and documented on the stereomicroscope (ring illumination), metallographic microscope (in-lens illumination), and scanning electron microscope at various magnifications. The samples for the various defect types are specially prepared or provided by project partners. The defect catalog covers the defect types that are most frequently observed and all defect types that are described in the guide to the project "surf:guide" (core project).

In addition, in every production there are product-specific error patterns that cannot be represented in a general defect catalog. Such defect images can be added individually by the participating partners after completion of this companion project. To make this possible, the defect catalog will be made available in an editable format after project completion.

The error catalog will be structured as follows:

- Description of the defect pattern
- Summary of potential causes for the defect pattern
- Explanation of possible effects of the defect on quality and durability
- Recommendations for best practice in dealing with the defect
- Image documentation:
  - Stereomicroscope: overview and detail (approx. 20-40x magnified)
  - Metallographic microscope: 200x and 1000x magnification
  - SEM: overview 300x, 1000x, 5000x (excitation voltage depending on defect type)

## References

In the past, successful multi-client projects have already been carried out by Bond-IQ GmbH with numerous industry partners. In all projects Bond-IQ GmbH has coordinated the project and at the same time generated the essential technical content. A selection of these projects and their effects are briefly presented here.



### Project “Wire bond testing standard”

**Project focus:** Update of the test standard for wire bonded connections DVS-2811

**Status:** finished

**Partners:** 26



#### Short description:

The aim of the project was to revise the 20-year-old DVS bulletin 2811, which is used as a reference for numerous wire bonding processes. After only 18 months, a 20-page new draft was submitted for review in the technical literature. Only 4 months later, in February 2017, the document was officially published, is still valid today and remains a key reference for industrial wire bond testing processes. The document has also been translated into English, serving an even wider range of users as a basis for stable bonding processes. The automotive manufacturer Volkswagen has incorporated the revised bulletin DVS-2811 unchanged into the VW80818 test standard for wire bonded connections.

## Project "SpeedCycle"

**Project focus:** Evaluation of a test method for thick wire bond joints

**Status:** finished

**Partners:** 16



### Short description:

The shear test is typically used to test the joint quality of thick wire bonded connections. However, the meaningfulness of the shear test with regard to the connection quality and the durability of the wire bonded connection is limited. An innovative method (BAMFIT), in which the wire bonded connection is mechanically aged at an accelerated rate using ultrasonic coupling, opens up new possibilities for testing thick wire bonded connections. In the SpeedCycle project, the BAMFIT method was compared with the shear test and, in addition, new possible applications for this test method were evaluated. Each participating company was able to save costs of at least \$100,000 that would have been incurred if they had tested this method with their own resources.

## Project "QUALSi"

**Project focus:** Qualification and analysis of AISi1 thin wires

**Status:** running since 02/2023, participation possible (<https://bond-iq.de/qualsi-project/>)

**Partners:** 21



### Short description:

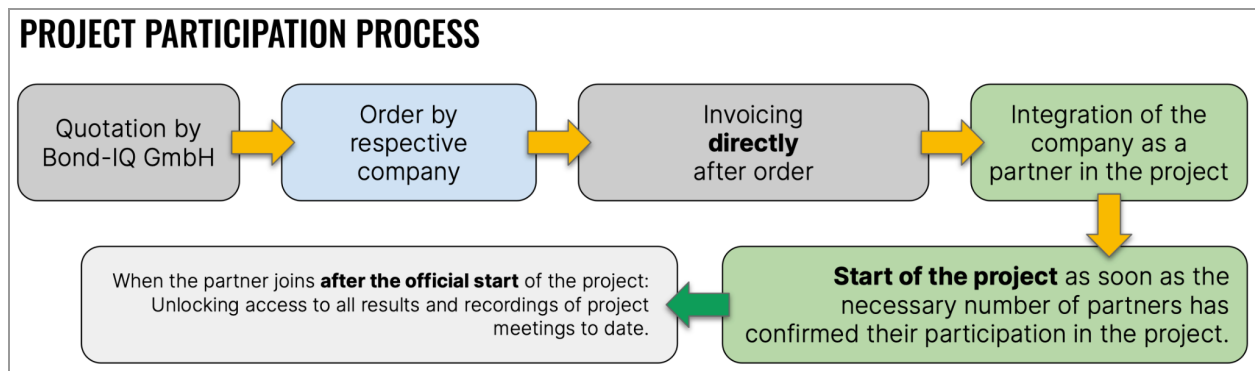
The QUALSi project is working on open questions relating to AISi1 thin wires. A lot has happened in this area in recent years - from new materials and the relocation of production sites to new suppliers. The investigations are clarifying what this means for processes already established and new product developments of the participating companies. The project will run at least until Q2/2024 and is designed in such a way that new partners can participate at any time.



## Project financing and organizational matters

The total financing of the project "surf:guide" is made possible by the sum of the financial contributions of several partners (multi-client project). Therefore, the participation of a minimum number of partners is required for the project start. The binding start date for the project can only be set once this minimum number of partners has confirmed their participation in the project. The commitment to participate in the project is made by sending an official purchase order.

The targeted start date for the project is **Q1 / 2024**.

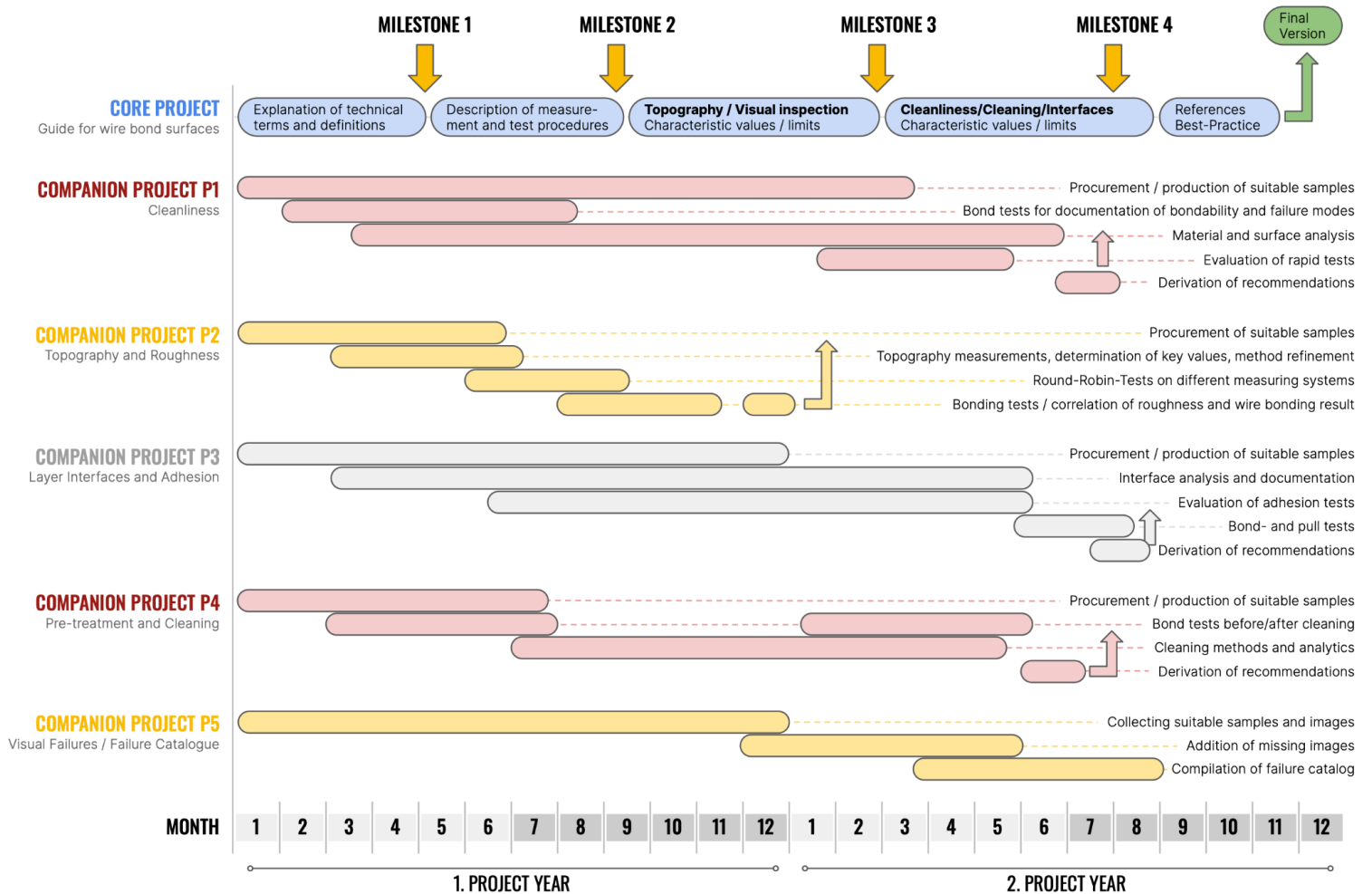


For an efficient coordination of the investigations and communication with the project partners, the project will be organized as follows:

- Access to a shared project folder with access control
- Regular project meetings per Microsoft teams (approx. every 8 weeks)
- Live meetings at intervals of approx. 6 months
- Provision of all project meetings as video recordings  
(e.g. for the follow-up of a meeting, as backup in case of non-participation due to conflicting appointments or illness, staff turnover or change of responsible persons)
- Formation of smaller expert groups for the exchange of experience and coordination on special topics

A period of **24 months** is targeted until the completion of the guide in the core project.

The most important measure of success for the "surf:guide" project is the completion of the core project by finalizing the guide "Requirements for Cleanliness and Condition of Surfaces for Wire Bond Applications". The following **milestones** are defined:



## Financial plan - investment for participation in the core project and companion projects

Core project – Guide for wire bond surfaces: **4.500 €<sup>4</sup> (min. 40 Partners)**

P1 – Cleanliness: 12.000 € (min. 20 Partners)

P2 – Topography and Roughness: 6.500 € (min. 20 Partners)

P3 – Layer Interfaces and Adhesion: 10.500 € (min. 15 Partners)

P4 – Pre-treatment and Cleaning: 9.000 € (min. 15 Partners)

P5 – Visual Failures / Failure Catalogue: 4.000 € (min. 15 Partner)



**Link to the project participation form (Click here)**

<sup>4</sup> All prices in Euro and plus valid sales tax (if applicable)