

# SYSTEMS ENGINEERING

## INTERDISCIPLINARY COORDINATED SYSTEMS ENGINEERING



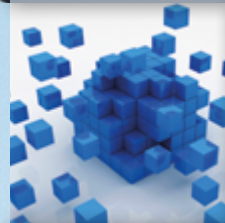
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# AGILE SOFTWARE DEVELOPMENT

## SPRINT BY SPRINT TO SUCCESS

### “AGILE” IS NOT A BUZZWORD FOR US, BUT AN ESTABLISHED MINDSET

By now, agile development methods have been established as a new mindset in many companies. Coming originally from software development, agile methods have fought their way into mechatronic development. Where processes used to be based on rigid project plans and strict, but often only theoretical, plan fulfillment, today they aim for short development cycles and regular learning experiences.

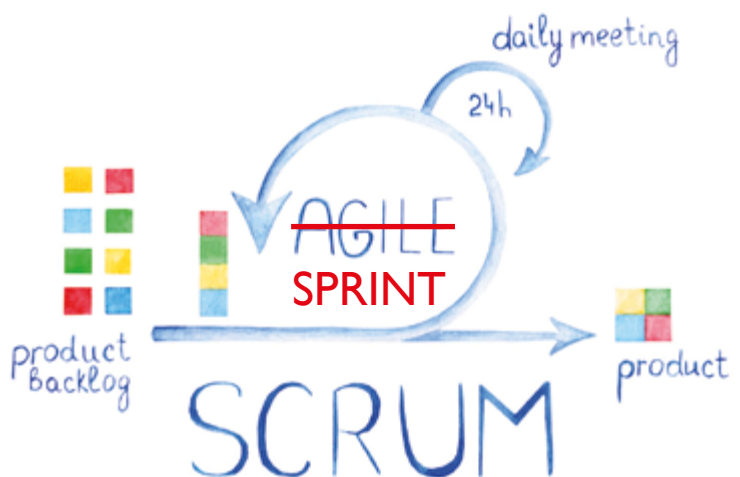
#### Agile methods hold a lot of potential – Do you use them?

Today's machines have numerous functionalities that can only be realized by software. The software development process is therefore crucial for the overall success of a product or project.

Our consultants usually find long-standing process landscapes with rigid schedules in the companies.

In order to efficiently introduce agile methods, we rely on established development frameworks such as Scrum, Lean Startup or Software Kanban.

In the course of the project, we gradually adapt them to the specifics of your company.



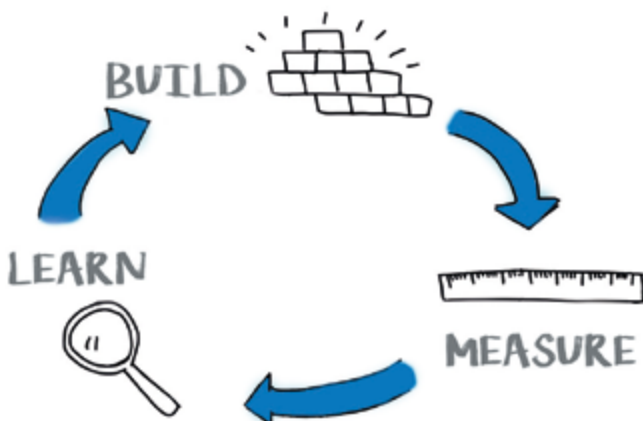
### Together we achieve the best possible result!

The **Build-Measure-Learn** approach is the foundation of almost all agile methods. We take the following steps with you in each sprint:

**Build:** At the beginning of each iteration, the most minimal working product is defined and developed.

**Measure:** This minimum viable product (MVP) is specifically tested by users for the implemented function. The development team checks whether the selected approaches are suitable and the solution is viable.

**Learn:** Conclusions about the concept and the product can be drawn and further developed based on practical experience. The final decision is which MVP will bring the greatest business advantage in the next iteration.



## THIS IS IMPORTANT FOR US

With agile methods, intermediate steps are validated ad-hoc and subsequent processes optionally changed in order to come to the perfect solution. The iterative work facilitates the adaptation to changing boundary conditions. Both are made possible by three priorities:

- Transparency in project progress and communication
- Quality review through continuous reviews
- Adjustment in short cycles (2-4 weeks)

The required functions of a product are mastered through a structured reduction in complexity. The typical non-functional requirements such as safety, security and compliance can be perfectly mapped.

The customers we support develop their software projects in a goal-oriented manner and with continuous optimization of process and product quality.



*"By using agile methods, the actual progress in the project becomes transparent very quickly."*

**Karl-Heinz Wind**  
Senior Consultant

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## BENEFITS

### How to profit from our cooperation

- Transparency of the development progress after each sprint
- Requirements-centered development
- Goal-oriented development with clearly defined function packages
- Feature-driven, efficient synchronization of large development teams
- Focus on customers and users through early and regular practice tests
- Integration of test and quality assurance
- Documentation, safety and security as integral part of development
- Planning and buy-in of stakeholders and development teams

## SERVICES

### How to sprint to success with us

- In-house training on agile methods and selected models
- Introduction of agile methods adapted to your individual needs
- Communication as a central tool for successful process implementation
- Agile requirements engineering
- Consulting and implementation of infrastructure (continuous integration, test and quality assurance)
- Support as a product owner with in-depth industry knowledge and experience
- Support as a Scrum Master for guiding the team and communication to stakeholders
- Support from software developers using modern technologies



## REQUIREMENTS MANAGEMENT

### THE CORNERSTONE OF SUCCESSFUL ENGINEERING

#### WHAT IS NEEDED FOR SUCCESS?

Regardless of whether it is a web application, a process engineering system or a software for an embedded system – the requirement analysis is one of the basic stages of a project, in which the essential course is set for the later progress of the project.

#### Set the right course from the start

Complex software systems, IoT connection and a multitude of interfaces as well as ever shorter product life cycles demand a fast response to changed requirements necessary.

In order to counter the dynamics in the development project and contract business, professional requirements management must exist, which guarantees a uniform and interdisciplinary definition as well as comprehensible documentation of the project goals. At the same time, changes in requirements must be documented and tracked in order to be able to react to these adjustments in an agile manner during development.

Without a structured, holistic approach to requirements management, there is a risk that important project parameters such as quality, budget and deadlines cannot be met.



#### Let's face the challenge!

We help you develop and implement professional requirements management. This always happens on the basis of specific developments or orders. Consideration of your development process and the subsequent anchoring of optimizations in the existing process are part of our services.

For tracking the requirements across the entire development process and adapting them flexibly, a higher-level tool is necessary, which monitors the requirements and transparently tracks changes.

Of course, we also support you in the selection and implementation of suitable tools and interfaces and adapt new or existing solutions to your specific application.



### APPROACH

#### It starts with a meaningful structure

Requirements management starts as early as possible in the course of the project by collecting information from all the disciplines involved. In a first step, it makes sense to develop a basic structure for the system under consideration.

A functional structuring makes it possible to grasp the requirements of all disciplines right from the start. Modern requirements management is – regardless of the procedural model you use in development –

of crucial importance. Regardless of whether you are working on a software solution in an agile development approach in sprints or in cross-disciplinary teams, due to special regulations, based on the V-model.

It is imperative that you know what the challenge is and what needs to be done at all times. Otherwise you run the risk that the solution does not match the task.



*“An early and well-founded clarification of requirements is a prerequisite for successful product development.”*

Jörn Linke  
ITQ Branch Manager NRW  
✉ linke@itq.de

### BENEFITS

#### What does a well-founded clarification of requirements offer you?

- Function-oriented structuring of your systems
- Early clarification of requirements
- Definition of acceptance criteria
- Focus on testability of the requirements
- Central management of all requirements
- Higher quality of your specifications
- Saving time in development through early clarification of the requirements
- Project complexity becomes more manageable
- Possibility to react to changes in an agile way
- Risk minimization in development/order processing through shorter iterations

### SERVICES

#### Our contribution to your successful engineering

- Assessment
  - Recording existing requirements management
  - Analysis of existing processes
  - Deriving recommendations for action
- Quality management
  - Definition of acceptance criteria for tests
  - Definition of key figures
- Interfaces
  - Connection of requirements management to ERP
  - Connection to the test management system
- Interdisciplinary workshops
- Clarification of requirements
- Tool benchmark for requirements management
- Holistic process support when setting up systematic requirements management

## FUNCTIONAL DESCRIPTION

### INCREASING ENGINEERING EFFICIENCY

#### MAKE ESSENTIAL DECISIONS FOR YOUR SYSTEM

In addition to the classic disciplines such as mechanics, electrics and machine control, digital networking, IoT and work across distributed locations play an increasingly important role in today's product development. In order to be able to achieve high quality at low costs and under tight schedules, a structured functional description of the system is of crucial importance.

#### Functional description for complex structures

The specification of a system – a component or a whole plant – is one of the most important stages in the development. The essential decisions for the design of the system are made here.

In order to keep time and costs low and to ensure quality when requirements increase, a detailed and hierarchically structured functional description is of crucial importance.

A description as detailed as possible for new functions is the first central step in the specification of mechatronic systems.

For projects with a high level of innovation, a function description is essential.



#### How do you bring all disciplines together?

The mechatronic description of functions for existing or planned developments is created in close cooperation of all disciplines in workshops.

At the same time, a common terminology is created that ensures the uniform description and the same understanding of the system functions for all involved.

In addition, the mechatronic function structuring enables the recognition and utilization of reusable functions.

With the help of detailed functional descriptions, it is even possible for you to reduce development times, since parallel processing is possible in different departments.



## APPROACH

### Break down complex functions

In the functional description, the overall function is divided in a tree-like structure into less complex, hierarchically structured sub-functions.

Depending on the project complexity, separate documents are created for all or only for the most important sub-functions. These documents each contain an

overview of the mechatronic structure and a description of the interfaces to other (sub) systems.

A detailed process description as well as details for example on operating modes, setting parameters and faults give the development teams a comprehensive picture of the system and its functions.



*"Our customers' machines are very complex, mechatronic systems. Functional descriptions make this complexity manageable and enable one parallel, cross-disciplinary development."*

**Simon Lehmann**  
Senior Consultant  
✉ [lehmann@itq.de](mailto:lehmann@itq.de)

## BENEFITS

### Functional descriptions enable you to

- Master complex systems
- Structure systems functionally
- Create a central documentation for everyone
- Uniform terminology
- Develop mechanics, electrics and software in parallel
- Lower response times
- Time savings through reduced development time
- Compare functions continuously
- Achieve sustainability

## SERVICES

### We accompany you on your way

- Conducting interactive workshops to develop the content and procedure using concrete examples
- Mechatronic structuring of your plants, machines and components
- Support in defining a uniform terminology
- Support in the creation of functional description
- Analysis of the development process and integration of the functional description
- Accompanying the application of the functional description in all departments



## MECHATRONIC MODULARIZATION

MAKING COMPLEX SYSTEMS CONTROLLABLE

### STANDARDS THAT ARE NOT USUAL

In the field of mechanics, the use of constructing kits has become state-of-the-art in mechanical and plant engineering. With the help of a mechanical modular construction kit, manufacturing and assembly costs can be reduced efficiently. However, if you also want to reduce engineering costs in the area of software and control, as well as commissioning costs, in the long term you need a mechatronically coordinated modular system.

### We help you customize concepts

Mechanical and plant engineering is faced with increasing market requirements regarding individual machine configuration, tailor-made concepts and the integration of subsystems.

Because of increasingly intelligent components, this challenge can no longer be met by a purely mechanical modular system.

In view of the growing proportion of electronics and above all because of the increasing portion of software, mechanical engineering needs concepts that counteract the rise in engineering costs and still allow fast response times to customer needs.



### Fast and flexible order-specific solutions

A complete mechatronic structuring of the product portfolio can be successively developed on the basis of existing or newly defined individual construction kits.

Consistent reuse of modules not only saves you engineering and material costs. It also significantly simplifies commissioning and service. This helps reduce your expenses even with increasing complexity of the overall system.

Our specialists support you in building a mechatronic library, which enables you to develop order-specific solutions very quickly and flexibly.





## APPROACH

### Sustainable and flexible structure

The first step in the modularization of a system is the analysis of the existing systems, the functions implemented by them and the operating equipment (actuators/sensors) built into them. The functional units and the corresponding interfaces and possible combinations can then be defined on this basis. This has to be done in an interdisciplinary way in order to be able to correctly weight the various pros and cons of the possible solutions.

Ideally, a set of rules is developed on the basis of which decisions can be made. Therefore, the previous work in each department must be analyzed for similarities/differences in order to define and structure modules in interdisciplinary collaboration, or to develop new variants/options. On this basis, the engineering documents in the individual disciplines have to be partially restructured or newly developed.



*"Developing a really functional, mechatronic kit is a real challenge – both technically and socially. But it's worth it in every way!"*

**Anton Fritsch**  
Senior Consultant  
✉ [fritsch@itq.de](mailto:fritsch@itq.de)

## BENEFITS

### This is how you benefit from our approach

- Reuse of modules
- Independent development of modules
- Development & production at distributed locations
- Shorter order processing times
- Less engineering effort
- All systems are based on the same standards
- Creation of a detailed product catalog
- Saving time in development through parallel work
- The complexity of the systems is kept manageable
- Modules can be tested separately
- Significant cost savings e.g. through reuse, prefabrication options and higher quality

## SERVICES

### We offer you

- Analysis of previous standards and implemented concepts
- Structuring with regard to discipline-specific and mechatronic aspects
- Development of a variant and option concept for the design of a type code
- Tool selection to support engineering
- Optimization and modularization of engineering documents
- Restructuring of software modules
- Revision of the electrical hardware documents
- Analysis of mechanical assemblies
- Support in creating mechatronic function descriptions
- Data preparation/migration of existing data
- Introduction and application support
- Moderation of the interdisciplinary design process for the modular system

## SOFTWARE ARCHITECTURE

### BASIS FOR DURABLE AND HIGH QUALITY SYSTEMS

#### CONTINUOUS DEVELOPMENT AND ADAPTATION

Software architecture is fundamental for long-lasting, high-quality systems. It must cope with current problems, offer evolution potential and avoid "over-engineering". Agile development is therefore of essential importance in the early phases of software development, but must also be continuously developed and adapted. In addition, software architecture is essential for the testability and thus the robustness of a system.

#### A cornerstone of the testability and robustness of the overall systems

Ever faster changing requirements demand continuous adaptation and further development of products and systems. Even in hardware-related industries such as mechanical engineering, the software components are meanwhile decisive for competition.

Modern software systems are increasingly complex. Medium-sized and larger projects consume many employee-years. These systems must be able to be operated, modernized and expanded for many years (investment protection).

The software architecture is a central, quality-determining artifact that essentially determines the longevity of a system. The software architecture is therefore important in the agile development process. The work on the architecture is only completely finished when the system is no longer developing.



#### We will create a prototype as soon as possible!

**Workshop:** Our consultants work with your employees in a workshop to develop storyboards, requirements and an architecture concept. We analyze existing systems and jointly decide whether to integrate new software components into the existing structures (brownfield development) or reuse parts. The further development of the architecture then takes place in the ongoing project.

**Prototype:** On this basis, we develop a prototype at an early stage. This serves as proof of feasibility and enables quick feedback.

**Agile and iterativ:** This rough concept will be further developed. If necessary, an adaptation is possible after each sprint.



## APPROACH

### Development is a team task

Every software architecture is decisively determined by the non-functional properties of the system to be developed. This includes properties such as maintainability, performance, security, and, in the modern cloud environment, operating costs and national and international regulations.

The development of these criteria is a team task. Scoping and use case workshops form the basis for developing the architecture. In these workshops, we develop

the initial rough architecture together with your experts. At the same time, we carry out a reusability analysis of the existing systems. Together with your experts, we evaluate different solutions by taking into account the team structures and the existing technological expertise.

In the next step, we evaluate and demonstrate the feasibility of the chosen approach by using a technical breakthrough. The further development of the architecture then takes place in the ongoing project.



*"The software architecture determines the functionality and longevity of a system."*

**Harald Weigold**  
Member of Management  
✉ [weigold@itq.de](mailto:weigold@itq.de)

## BENEFITS

### What does a software architecture offer you?

- Development of the system properties in the team in order to create a holistic, cross-team understanding
- Differentiation from „neighboring“ systems for a clear project focus
- Transparent development of the central system components with the involvement of team members and stakeholders
- Definition of the properties/tasks of the system components in order to be able to develop them in an agile and parallel manner
- Continuous, interactive further development of the architecture in order to incorporate new requirements
- Definition of relationships between the system components

## SERVICES

### We offer you experience in the fields

- Individually tailored holistic architectures
  - From the sensor to the cloud
  - Control systems and regulation technology
  - Machine operation/HMI
  - IoT solutions
  - Micro service architectures
  - Data acquisition and processing
- Machine learning in an industrial environment
- Teamwork with coaching
- Strong experience in operating systems and platforms
- Modular HMIs and modular distributed systems
- Documentation accompanying the project/visualization of the architecture
- DevOps



## DIGITAL TWIN

### REQUIREMENTS FOR VIRTUAL ENGINEERING

#### EFFICIENT PROJECT MANAGEMENT THROUGH DIGITAL TWIN

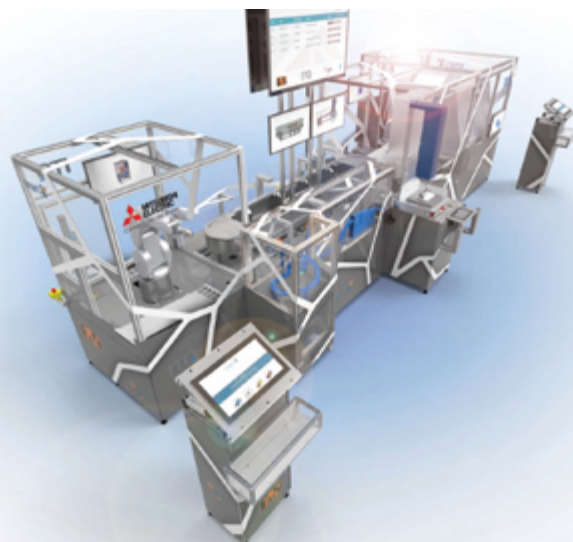
Modern simulation systems have become an important part of virtual commissioning. In other stages of the development process, simulation is still in its infancy. But the early project phases are the time when the tracks are laid for successful and costeffective project implementation.

##### Simulate right from the start

Now in the age of digitalization, it is generally recognized that the use of a digital twin can dramatically reduce commissioning times for machines and systems.

If you implement the concept of full digitalization in the development process of a machine right from the start, completely new engineering opportunities will appear. Through the use of virtual engineering, development can be carried out at different locations at the same time, different variants of machines can be compared inexpensively and development times and costs can be reduced.

Therefore, simulation tools should be used in early project phases to ensure the quality of the created solution. Today's simulation kits and a good process integration contribute significantly to this.



#### Designing processes more efficiently together!

**Selection:** We support you in selecting the best simulation tool that suits your requirements. Our broad experience from a large number of projects implemented on different platforms as well as a good market overview ensure a well-founded decision.

**Model construction:** We are also happy to work on the construction of the corresponding models or library modules and at the same time train your employees on within projects.

**Introduction:** One of the key is the introduction and fixation in all engineering disciplines and in the development process. For that, a far-sighted process concept and sensitivity in dealing with people are required.



### APPROACH

#### Simulate innovations in a tangible way

In the simulation tool, we reproduce the individual components of your machine exactly as a mechatronic module concept. This means that customer-specific machine and system concepts can be created with little effort during project planning. By using a functional demonstrator,

- new operating principles are created and tested quickly and prototypically

- different concepts are easily compared and optimizations carried out
- disciplines can be coordinated in early phases, also directly with the end customer

Then, the model serves as an interdisciplinary coordination tool in development and as the core element for the digital twin of the real machine throughout the entire life cycle.



*"Digital twins accompany the entire development cycle and enable concept, function and quality to be assessed at an early stage."*

**Jonas Fischer**  
Simulation Specialist

✉ [fischer@itq.de](mailto:fischer@itq.de)

### BENEFITS

#### What are the advantages of a simulation for you?

- Simulation enables interactive development in mechatronic teams
- Shorter order processing times
- Higher quality of your engineering documents
- The complexity of the systems can be displayed and controlled
- Early verification of the sustainability of new concepts
- Lower risk of expensive undesirable developments
- Faster and cheaper test execution
- Independence from the availability of real machines and systems
- Basis for the introduction of new technologies such as augmented reality

### SERVICES

#### Virtual Engineering throughout the entire life cycle

- Analysis of your requirements for the functionality of a simulation system
- Support in the selection of a simulation system
- Introduction and fixation of the simulation method in the development process
- Construction of simulation models and a component library
- Integration into your development process
- Training and attending your employees
- Conceptual design and construction of HiL laboratory environments

## SYSTEM SPECIFICATION

### CENTRAL WORKING BASIS FOR ALL DISCIPLINES

#### STRUCTURED DESCRIPTION OF SYSTEM AND FUNCTIONS

The system specification summarizes the requirements for a mechatronic system in a central document. It creates the basis for a uniform understanding of the system and the goal for all project participants. The clarification and documentation of functions and requirements in the specification reveal ambiguities at an early stage and help to minimize project risks from the start. It provides the basis for reliable time and cost planning needed for a successful project.

#### Minimize errors and delays

The large amount of software and the high demands on a mechatronic system require individual departments to be "structured interdisciplinarity" in order to determine the interfaces to each other and the requirements for the system at an early stage.

Classic, sequential development approaches often do not do justice to this interdisciplinary approach, as each discipline has its own requirements, processes and therefore its own schedule.

Sequential development approaches mean that risks, errors and inadequate requirements are often only recognized at an advanced stage of the project, resulting in high costs and delays in resolving these errors.



#### System specification creates acceptance!

The system specification is an important tool for creating this uniform system understanding. It is a structured description of the system and its functions.

The aim is to define, quantify and describe features and characteristics. These features serve as the basis for development work and can be used as criteria for acceptance or handover.

We help you to introduce the system specification in your company and to establish it as a central working basis for developments and order processing. In joint workshops, your template for the specification is worked out in interdisciplinary teams.





## APPROACH

### We proceed in a structured manner

The system specification describes the most important aspects of a mechatronic system in a structured document: An introduction gives a brief overview and describes the reason for the development, the rough structure and where the system is to be used. The subsequent specification contains a complete description of the system. In addition to the environment, configurations and operating

rating modes, the functions and properties of the system are also described. Test scenarios can later be derived from applications and processes. The framework conditions describe all requirements such as mechanical, electrical as well as environmental and operating conditions. Requirements for standards, guidelines, delivery, support, project management and documentation are also included in the specification of the system.



*"A good system specification at the beginning of a project is an important basis for its success."*

Jörn Linke  
ITQ Branch Manager NRW  
✉ [linke@itq.de](mailto:linke@itq.de)

## BENEFITS

### What's the offer?

- Early recording/identification of all requirements and risks in the project
- Central working document for all disciplines
- Creation of a basis for modularization
- Improvement of project management in the company
- Specification of the technical solution
- Creation of a modular system with a repeated procedure
- Possibility of systematic testing and improvement of quality assurance
- Lower project costs through shorter commissioning and lead times
- Improved development process

## SERVICES

### Our contribution to your successful engineering

- Definition and analysis of requirements for your system
- Implementation of risk assessments and containment
- Support in developing a generic system specification template
- Implementation of workshops on working with the system specification
- Support with the introduction of the system specification in your company
- Analysis and optimization of your development process