Research Prototypes versus Products: Lessons Learned from an Interdisciplinary Research Project

Dietmar Winkler

Vienna University of Technology

Christian Doppler Laboratory “Software Engineering Integration for Flexible Automation Systems (CDL-Flex)”

http://cdl.ifs.tuwien.ac.at
http://qse.ifs.tuwien.ac.at/~winkler

Motivation & Goals

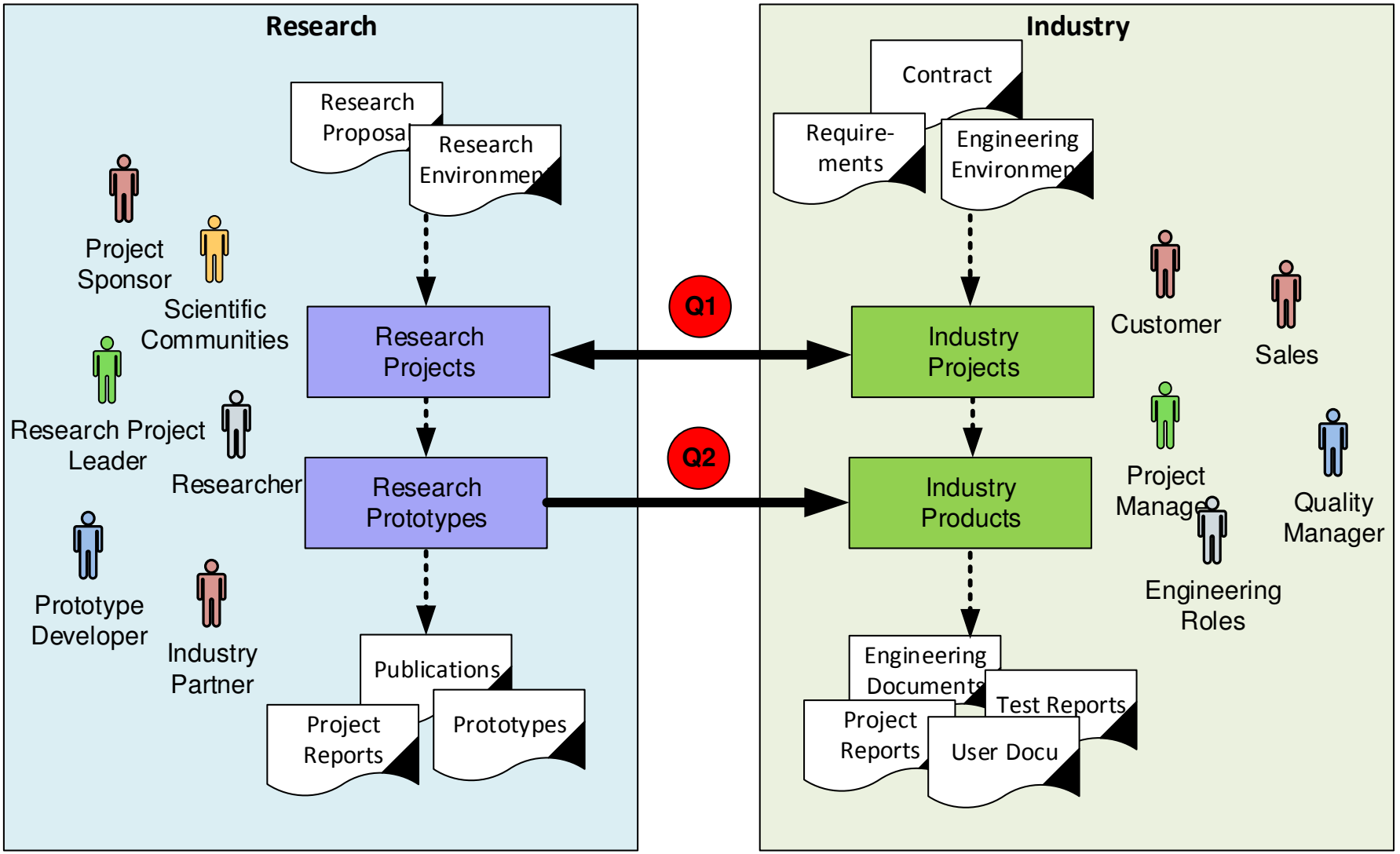
Motivation:

- Research Projects typically focus on prototype development investigating novel concepts.
  - Highly flexible processes, e.g., new ideas, concepts, and evaluations.
- Industry projects focus on the development of robust and high-quality products.
  - Typically more stable environment and processes.
  - Additional effort for quality assurance, documentation and usability.
- Different strategies and goals of researchers and industry.

Goals of the presentation:

- Introduction to the CDL-Flex Research Project
- Comprehensive approach to support
  (a) research prototype handling,
  (b) industry product development, and
  (c) transition from prototypes to products.
- A (hybrid) project management approach that supports traditional and agile development practices.

Key Questions

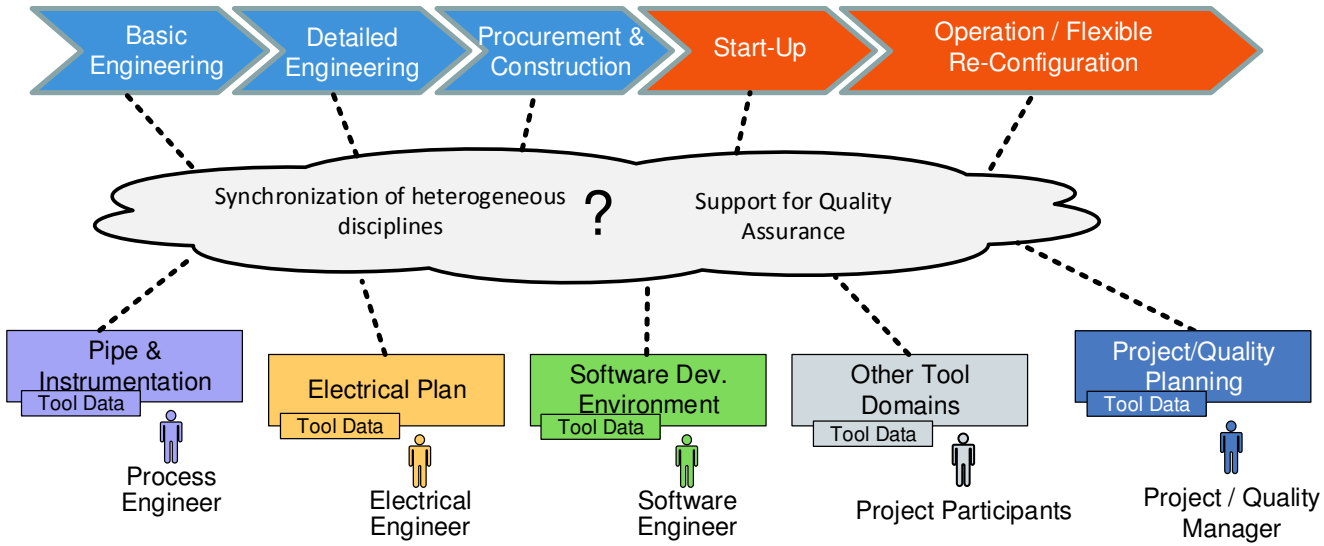


- Q1. How can we bridge the gap between research projects and industry projects?
- Q2. How can we transfer research prototypes to industry products?

CDL-Flex Research Project*

Context

- Automation Systems Development Projects, e.g., Hydro Power Plants.
- Large-Scale Industry Projects.
- Involvement of various disciplines, e.g., mechanical, electrical, and software engineers.

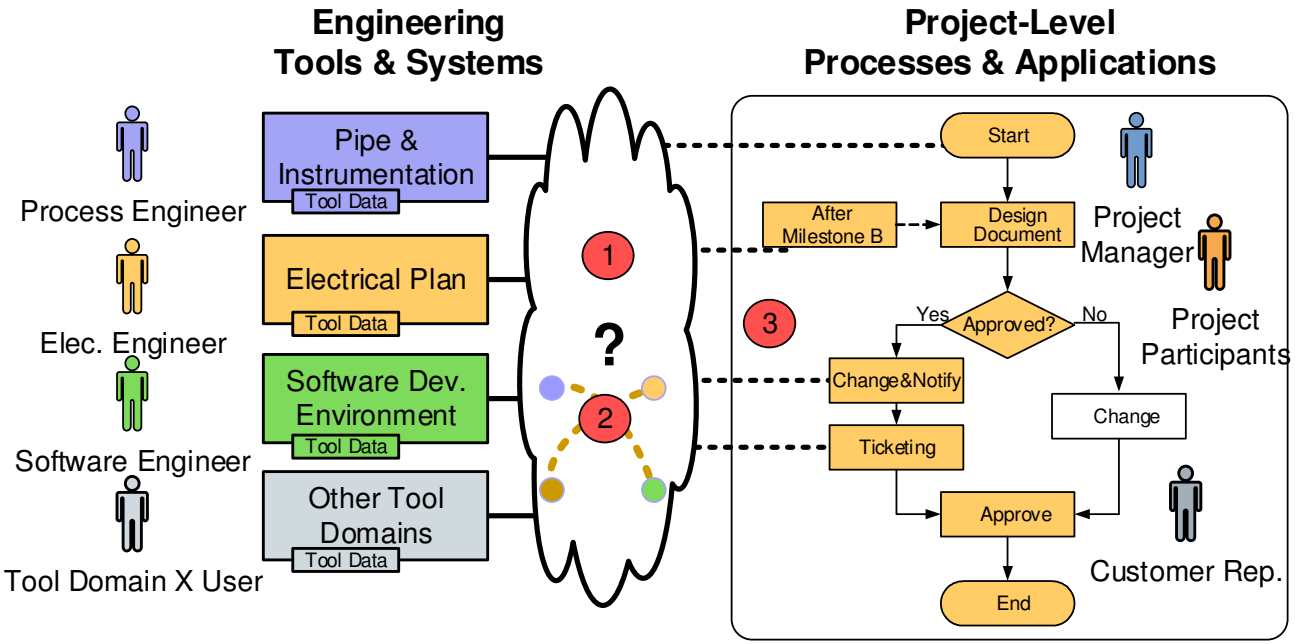


Overall Project Goal:

- Engineering process support in heterogeneous engineering environments.

Challenges from Heterogeneity in the Engineering Process of Automation Systems

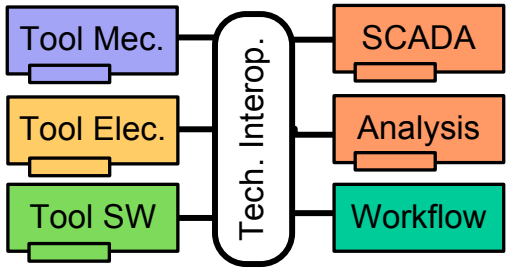
1. **"Engineering Polynesia"**: tool islands with interfaces that do not fit seamlessly.
2. **"Engineering Babylon"**: engineers use project-level concepts, tools do not.
3. **"Engineering Culture Diversity"**: business processes are lived in many ways.



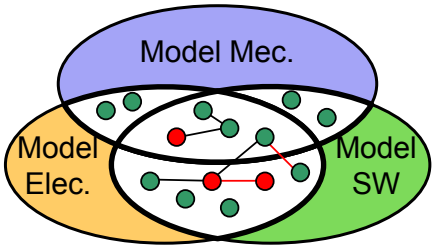
Biffl St., Mordinyi R., Moser T., „Anforderungsanalyse für das integrierte Engineering – Mechanismen und Bedarfe aus der Praxis", atp edition 5/2012.

Automation Industry Needs

- **Efficient data exchange** between
  - heterogeneous (loosely coupled) tools.
  - and incompatible data models.
- **Process support**: e.g., efficient change management process.
- **Project support**: project monitoring and control.
- **Added value components**, e.g.,
  - Versioning of models and data,
  - Navigation between engineering plans,
  - Observation of critical project parameters,
  - Offline compatibility,
  - Spreadsheet support,
  - Support of run-time data,
  - Querying, Simulation, …



Technical Integration



Semantic Integration

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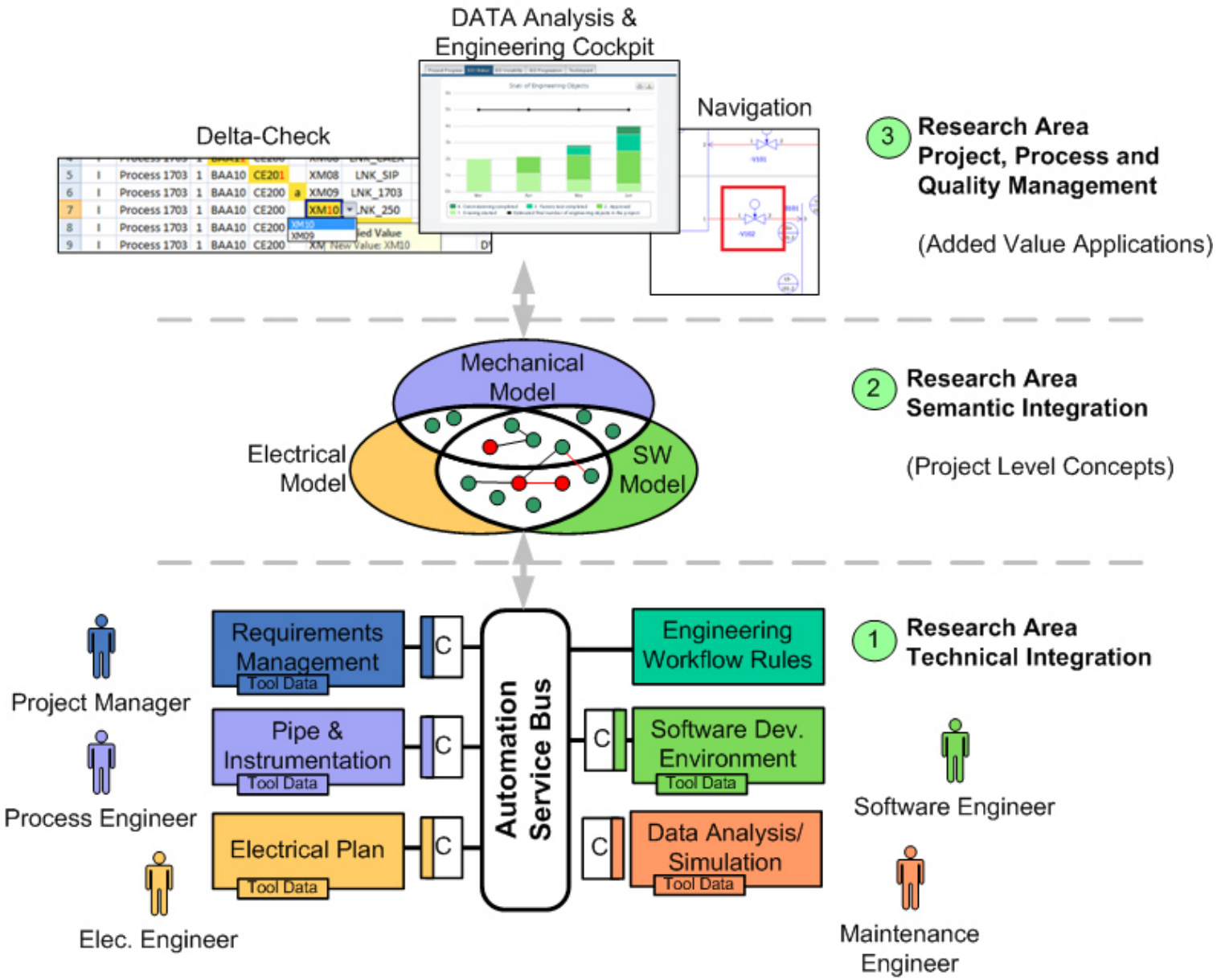
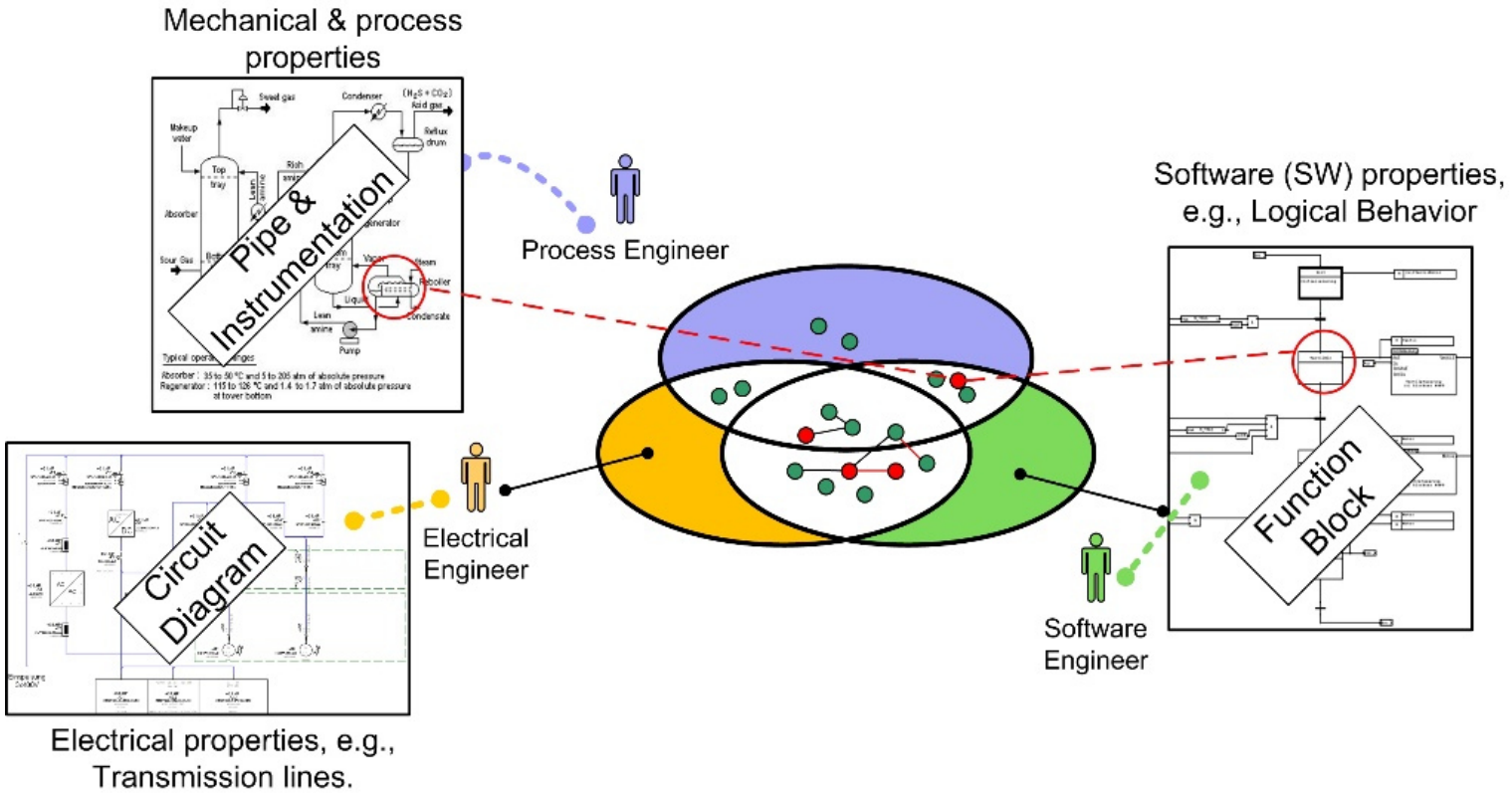
Research Area Overview (Module 1)



Semantic Integration – Integrated Data

- Individual local tools and data models.
- Overlapping (data) areas to enable synchronization between engineering plans coming from different disciplines.
- Mapping of local representations to the common data model (contribution of a knowledge engineer).



- Foundation for engineering process support and added value applications.

Selected Use Cases from the CDL-Flex

- **Engineering change management** across disciplines and domain boarders
  - Engineers: Build on agreed and versioned engineering data.
  - Engineers: Notifications on changes that affect their work.
  - Project / Quality Managers: Awareness regarding critical changes.

- **Engineering Cockpit**
  - Project / Quality Managers: Project Observation and Monitoring.

- **Multi-Model Dashboard**
  - Engineers / Project / Quality Managers: Definition and observations of critical project, process, and product parameters and constraints.

- **Efficient Navigation** between engineering plans
  - Engineers: Navigation between heterogeneous engineering plans.
  - Commissioning Engineer / Tester: Defect detection during commissioning phase.

- Find more use cases at: http://cdl.ifs.tuwien.ac.at/download

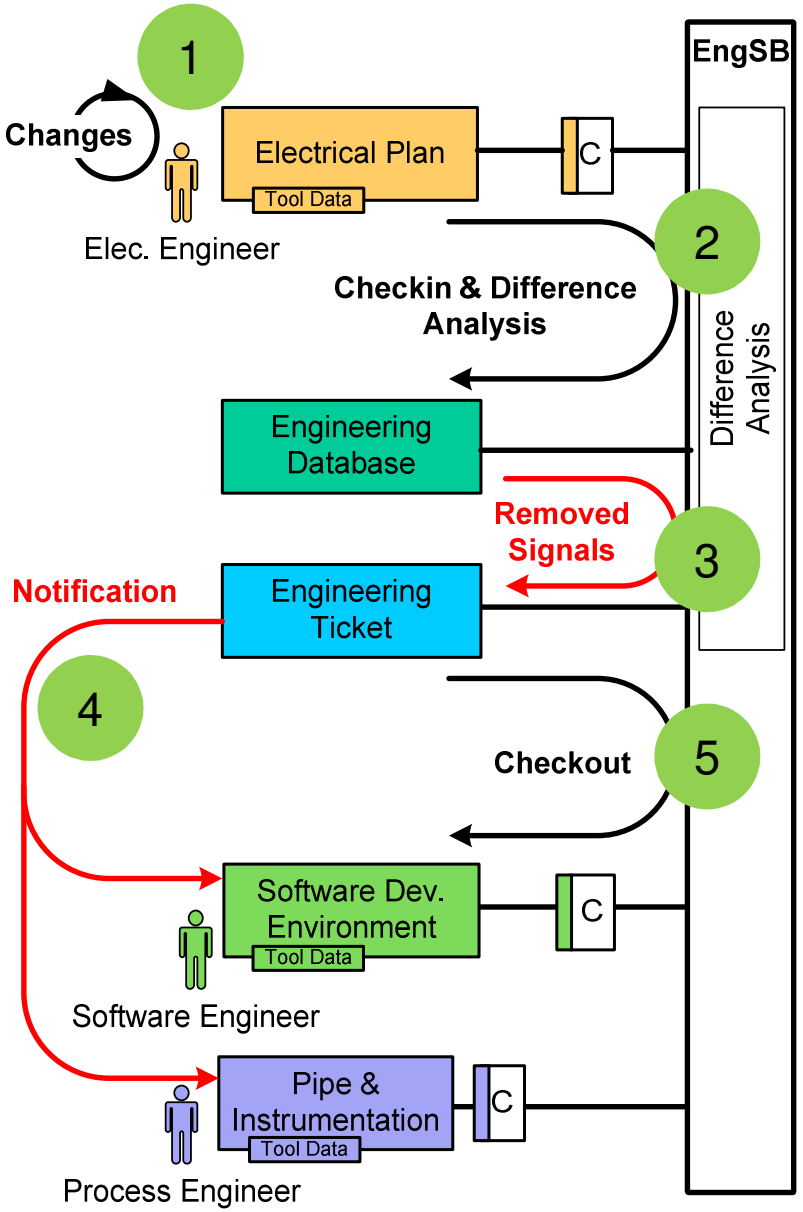
Use Case: Signal Change Management

Goals

- Efficient data exchange.
- Automation-supported change and conflict detection.
- Notification of related engineers to minimize surprises in the engineering team.

Conceptual Process Approach

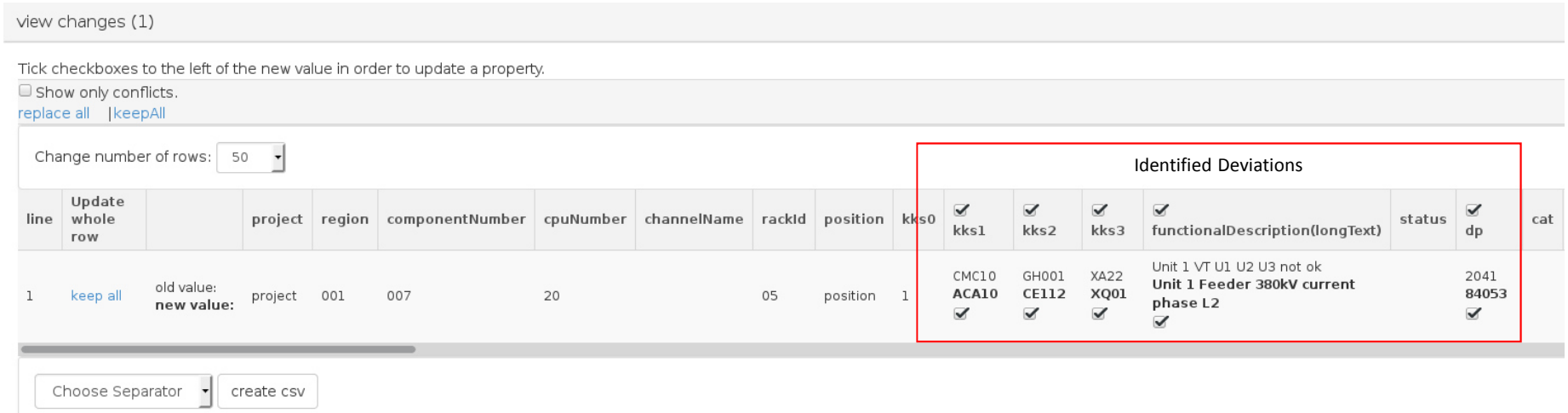
1. Execute Changes (electrical engineer)
2. Conduct Difference Analysis.
3. Identify “Removed Signals”
   → generate Engineering Ticket.
4. Notify (multiple) related stakeholders (software and process engineer).
5. Checkout (software engineer)



Use Case: Signal Change Management
Feasibility Study & Prototype

Feasibility Study of the Prototype

- Initial Data: 152 signals.
- New Testing Data Set (150 signals):
  - 3 new signals has been introduced, 1 signal updated, 5 signals removed, 147 unchanged signals.
- Merge-View: A set of changes can be accepted or rejected.



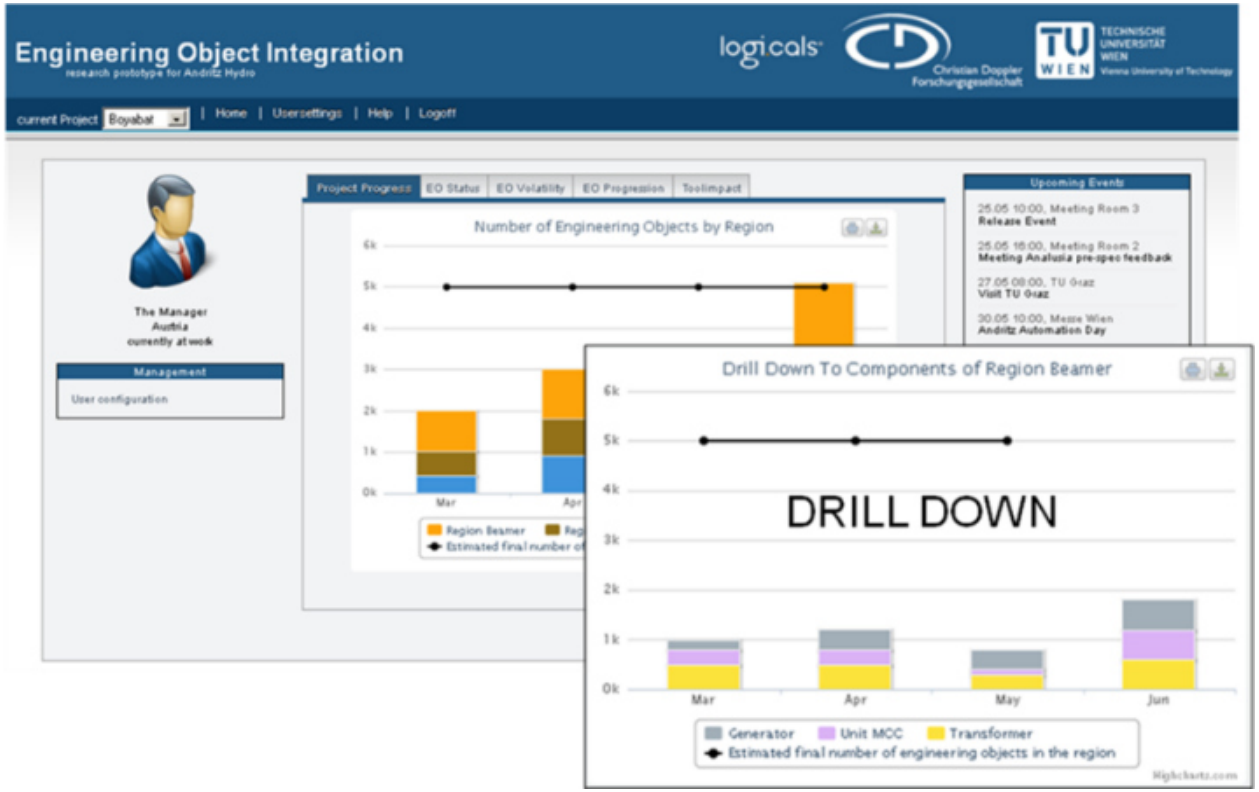
Research Prototype:

- Research prototype has been evaluated by industry partners and customers.
- Now, they want robust and stable product for a world-wide roll-out.

Use Case: Engineering Cockpit

Goals:

- Efficient project monitoring on team level.
- Avoid high effort to collect, analyze, and aggregate data from different disciplines.



Conceptual Prototype

- GUI Prototype with mocked test data have been presented to the industry partner.
- Engineering Cockpit needs to be implemented.

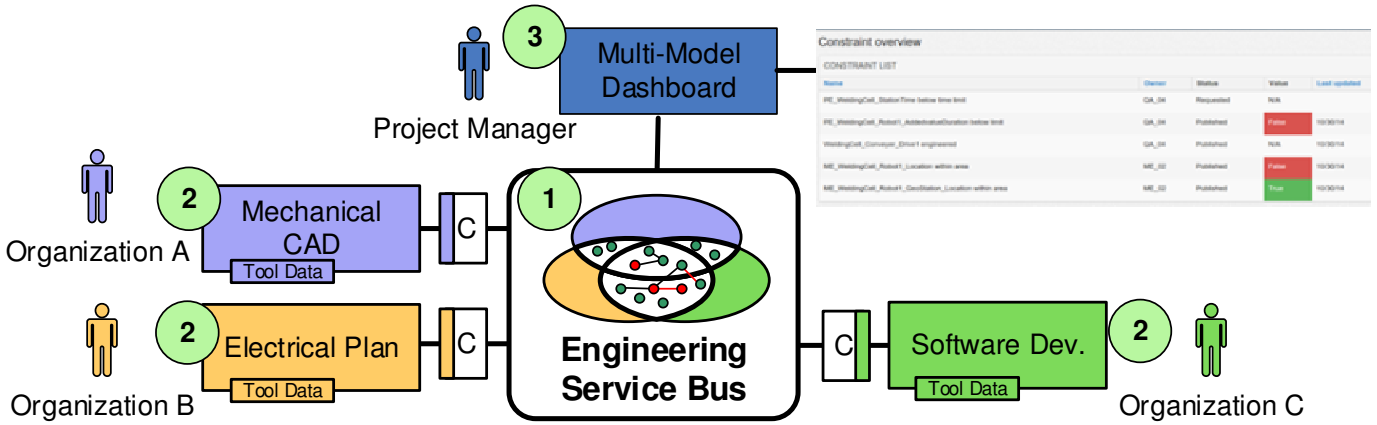
Use Case: Multi-Model-Dashboard

Goal:

- Observation of critical project and process parameters.

Multi-Model Dashboard process can support

1. Early identification of risks.
2. Observation of project-critical parameters and constraints.
3. Identification and notification of/on changes and constraint violations.



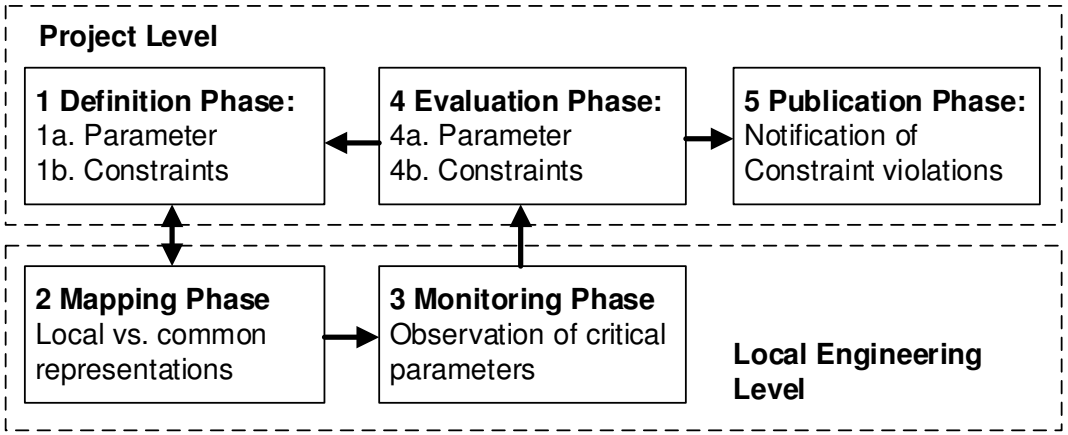
Applicable to **different domains**, e.g.,

- Building automation: loading capacity.
- Factory Automation. Power consumption monitoring of turbines.
- Project Management in project consortia: planned effort vs. aggregated distributed time sheets.

Use Case: Multi-Model-Dashboard

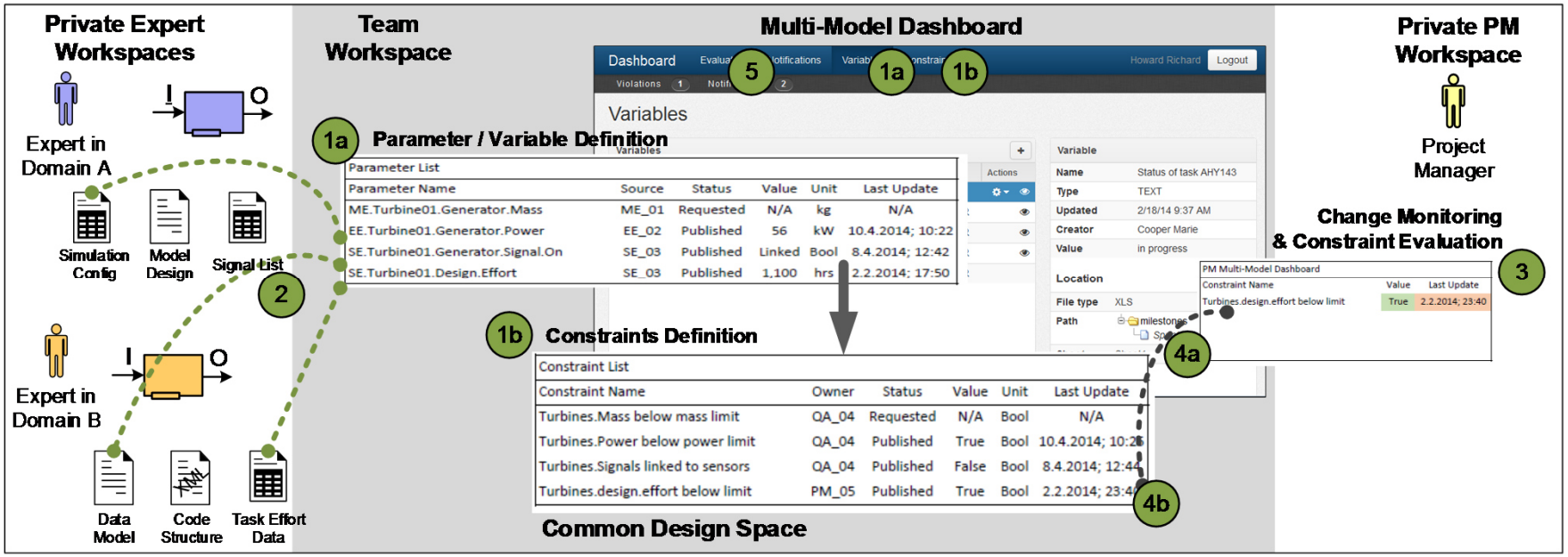
Feasibility Study & Prototype

Process support:



Conceptual Prototype:

- Feasibility study successful.
- Based on industry partner feedback, additional features needs to be considered.
- Product version requested from industry partners.



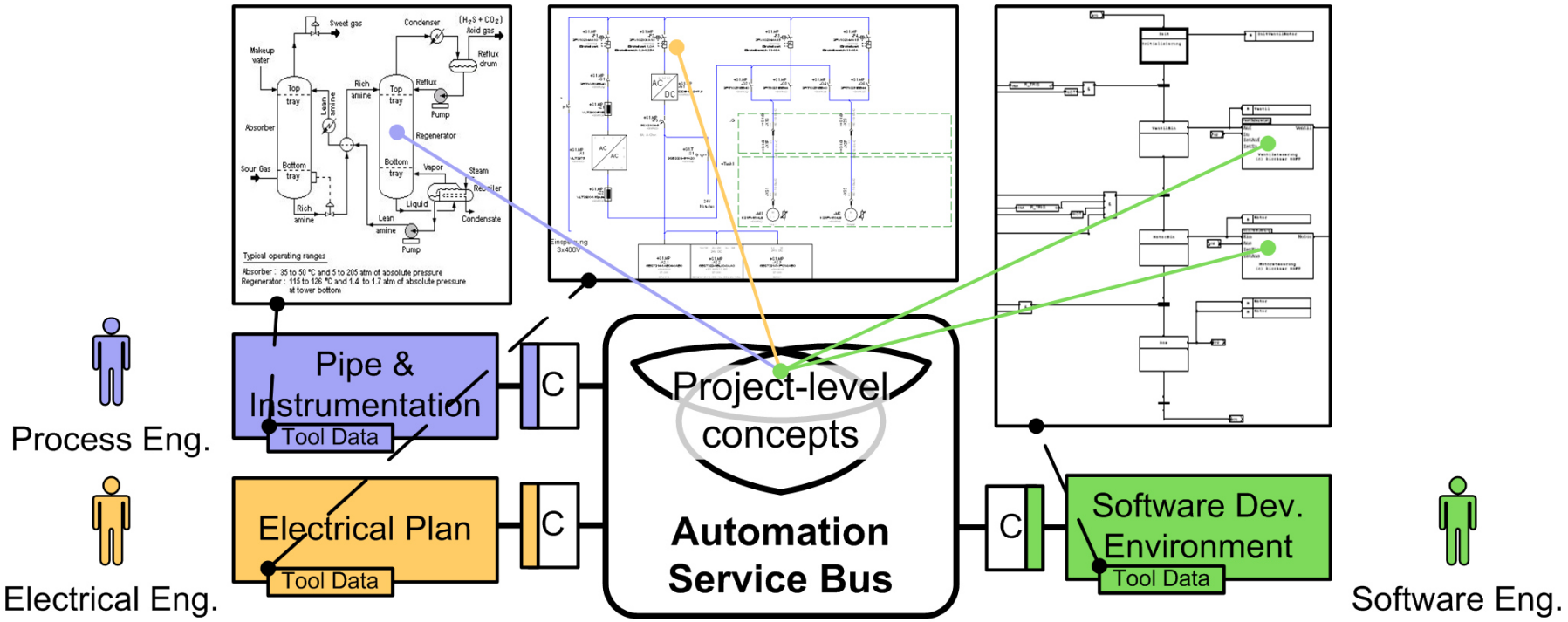
Use Case: Navigation

Goal

- Fast navigation between engineering plans of different disciplines, e.g., from PLC program code (function block diagram) to electrical plans.

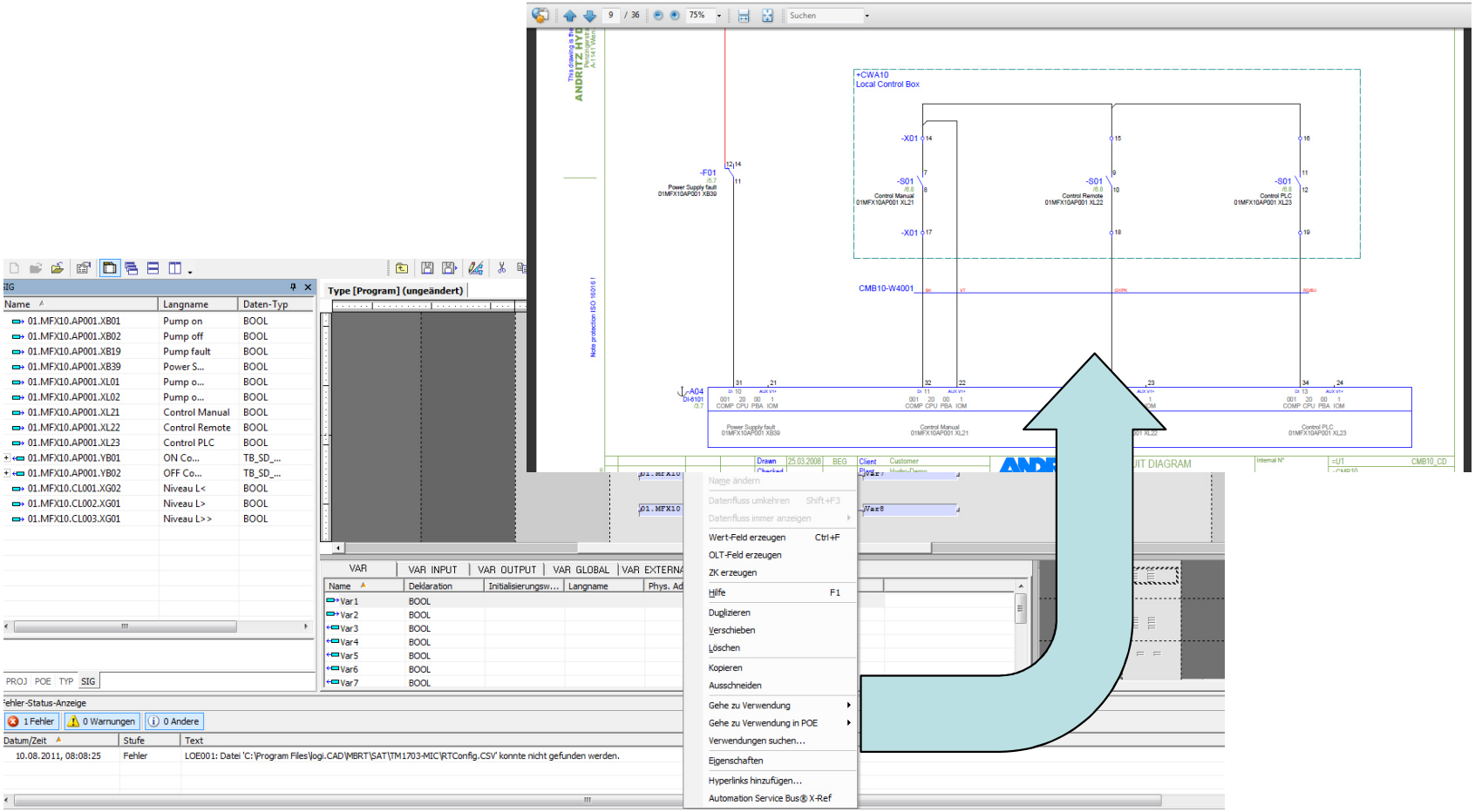
Benefits

- Engineers: Navigation between different planning data (during engineering).
- Commissioning: Defect detection and avoidance during commissioning (onsite).



Use Case: Navigation
Feasibility Study & Prototype

- Navigation from logi.CAD to EPLAN PDF via context menu



From Prototype to Product:

- Concept and feasibility study successfully completed.
- Industry partner included the navigation use case in his tool suite.

Summary of Use Case Status

Use Case	Prototype	Product
Change Management Process & Notification	Functional research prototype	Product version requested
Engineering Cockpit	GUI Prototype available	Product version requested
Multi-Model Dashboard	Research prototype with limited functionality	New feature requests
Navigation	Functional research prototype	Product version available

- **Limitations of Research Prototypes (Selection)**
  - Performance: small test data sets vs. real-world test data.
  - Robustness & stability: error and exception handling.
  - Limited documentation, basic testing on unit and system level.

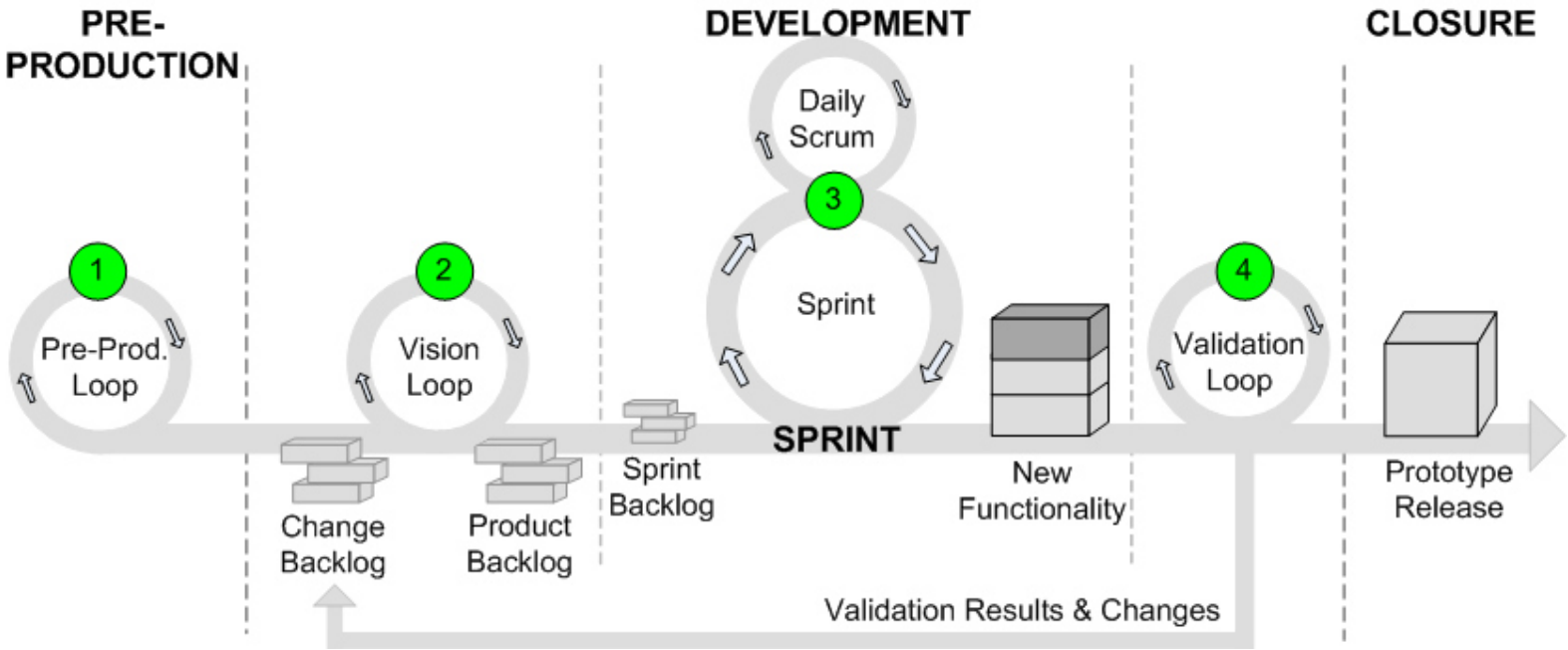
→ Need for a strategy to transfer research prototypes to products ..

How to develop such a platform?
Software Engineering Processes

- Traditional approaches, e.g., V-Model
  → hardly applicable in a research project with highly flexible and unclear requirements.

- Agile approaches, e.g., Scrum
  → Basically applicable for prototype and product development within a stable environment.
  → In research prototypes tools, methods, and development environment may change.

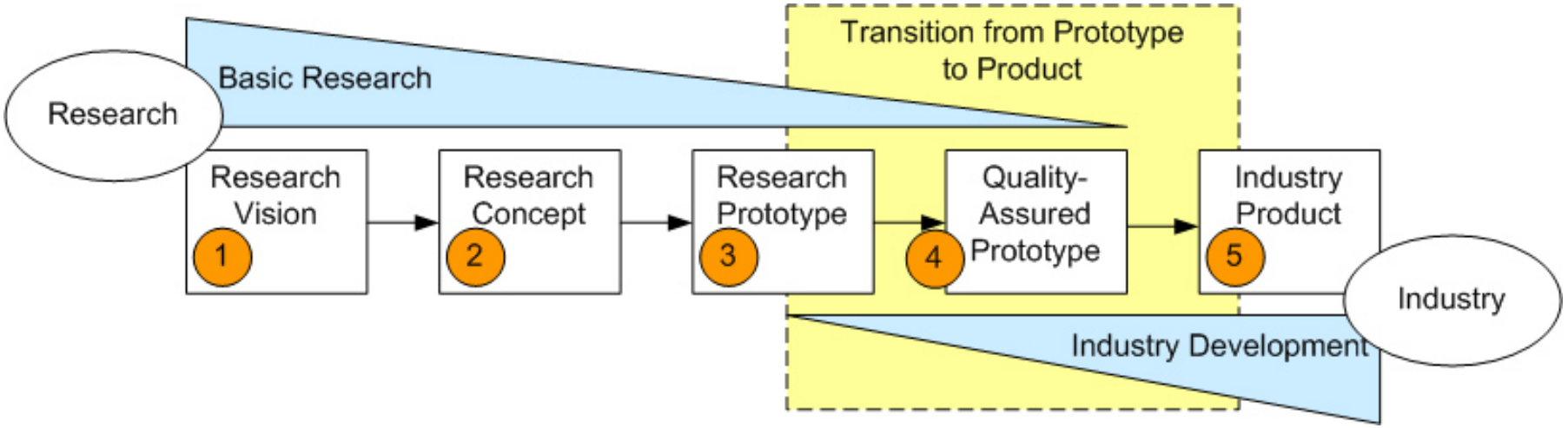
- Extended Scrum model based on a gaming development process approach*.



*Musil J., Schweda A., Winkler D., Biffl S.: Improving Video Game Development: Facilitating Heterogeneous Team Collaboration Through Flexible Software Processes", EuroSPI 2010.

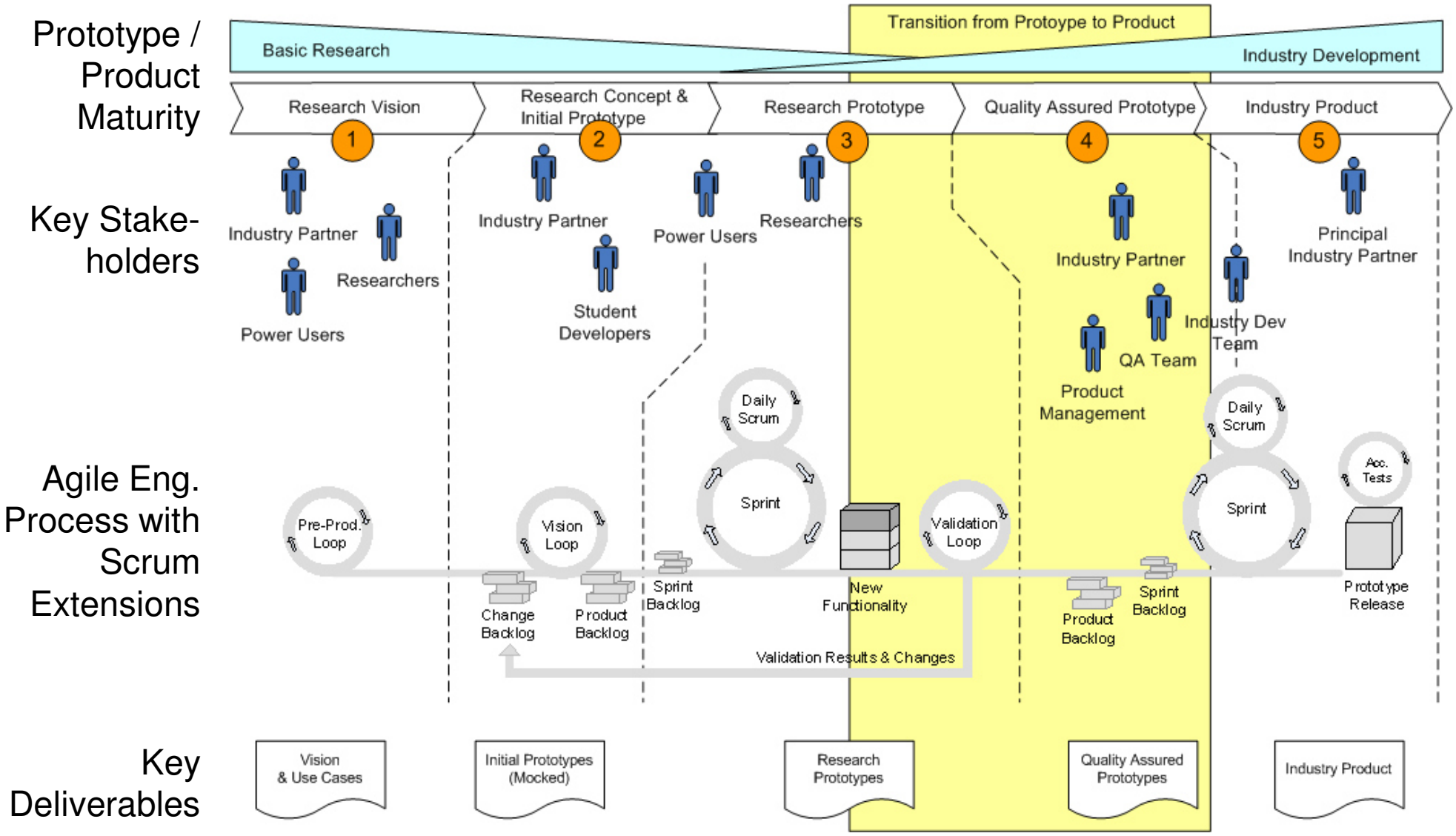
Prototype / Product Maturity Levels
Solution Approach

- Level 1: Creative Processes, Concept finding
- Level 2: Proof-of-Concept prototypes, Mockup prototypes
- Level 3: Functional prototype to show concept feasibility
- Level 4: Quality Assured Prototype including quality assurance activities
- Level 5: Application of industry-related environments.



- How to link maturity levels to software engineering processes to support (a) prototype, (b) product and (c) transition phases?

Comprehensive Engineering Process
Solution Approach



Lessons Learned and Key Findings

- Application of tools and methods for prototype and product development according to defined maturity levels.

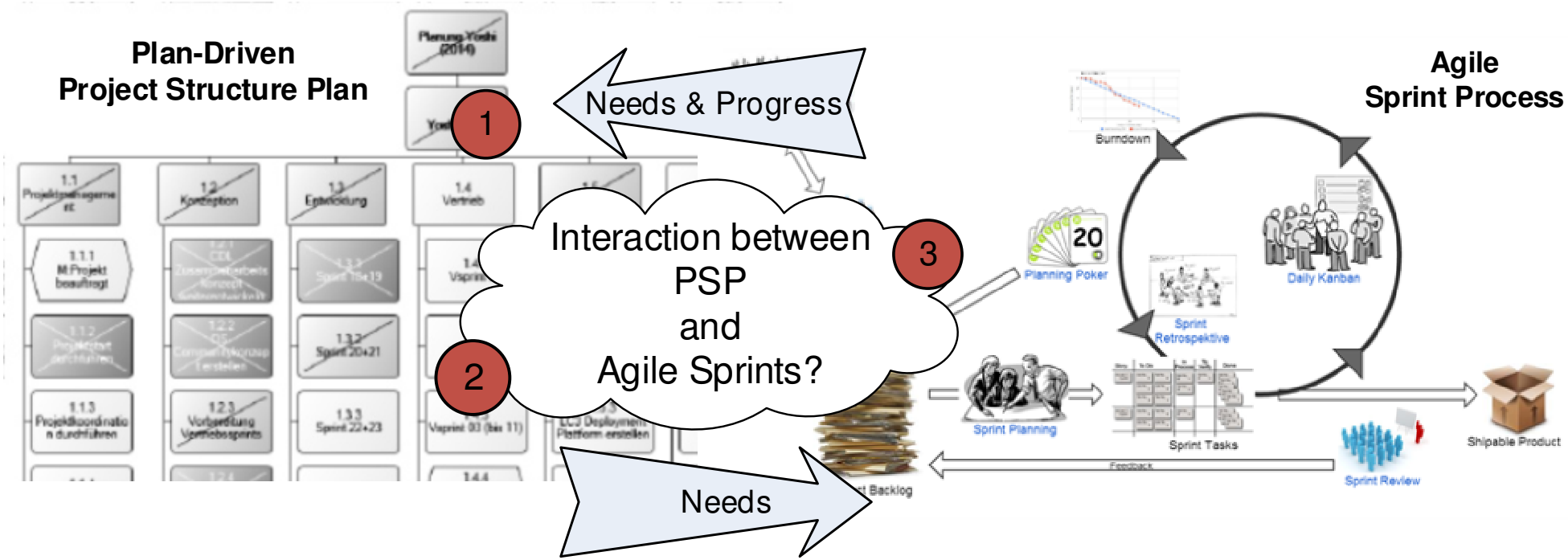
	Vision	Concept	Research Prototype	Quality Assured Prototype	Industry Product
Outcome	Research Vision	Reserach Concept	Use Case / Features	Use Case / Features	Use Case / Features
		Mock-Up Prototype Proof of Concept Feasibility Study	Functional Prototype	Prototype: robust, stable, and fault tolerant	Industry product
Maturity Level	n/a	low	low	medium	high
QA approaches applied	informal feedback	systematic feedback test case definition	test case definition manual tests	automated tests QA metrics	According to engineering process definition
Users	Researcher	Researcher Developers	Researcher Developers Power Users	Industry Partners Power Users End Users	Industry Partners Power Users End Users
Evaluation	informal discussion	interviews and feedback	basic tests	Automated tests QA metrics Acceptance Tests	Automated tests QA metrics Acceptance Tests
Cost/Value evaluation	Estimation of experts and researchers.	Expected benefits based on state of the practice (Experts)	Basic measurement results from pilot applications,	Comparative evaluations in real world settings (pilot application)	Comparative evaluations in real world settings (pilot application)

A Hybrid Project Management Approach
Motivation & Goals

Key Question: How to manage such a project?

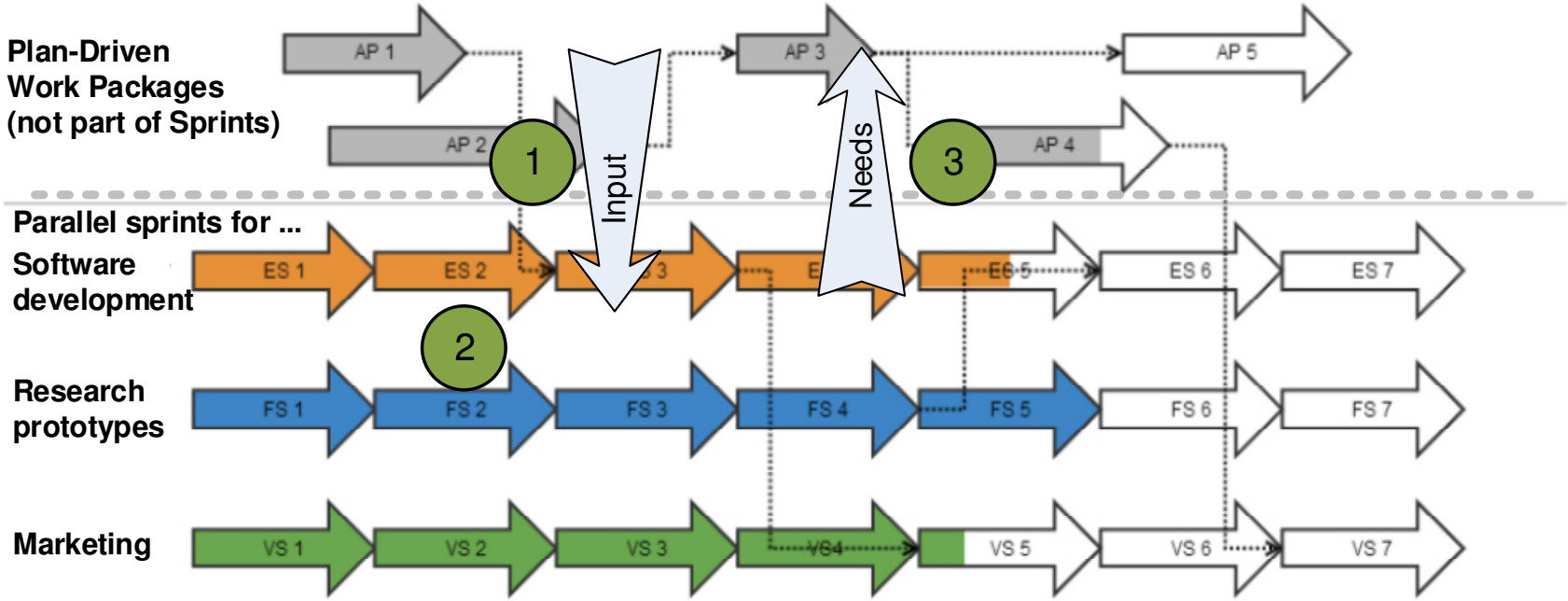
- Plan Driven Project Management?
  - Widely spread in industry because of defined plans.
  - Separation of individual phases (including quality assurance steps).
  - Require stable requirements with limited capability of changes.
- Agile Project Management?
  - Growing importance in the last decade of software development.
  - High level of customer interaction and collaboration.
  - Flexibility regarding requirements changes.
- **Small and medium enterprises typically need to align plan-driven (heavy-weight) and agile (light-weight) software development processes.**
- Main goal is to enable
  - high flexibility (e.g., considering frequent changing customer requirements, new research findings) aligned with a
  - plan-driven approach (e.g., defined by contracts),
  - i.e., some hybrid approach to benefit from both engineering processes.

A Hybrid Project Management Approach
Conceptual Approach



1. In the plan-driven project structure plan (PSP) the agile sprints have to be represented for planning, coordination, controlling, and measurement of progress;
2. The process interface between PSP and sprints has to be defined; and
3. In the sprint backlog the needs coming from other work packages in the PSP have to be represented for effective coordination.

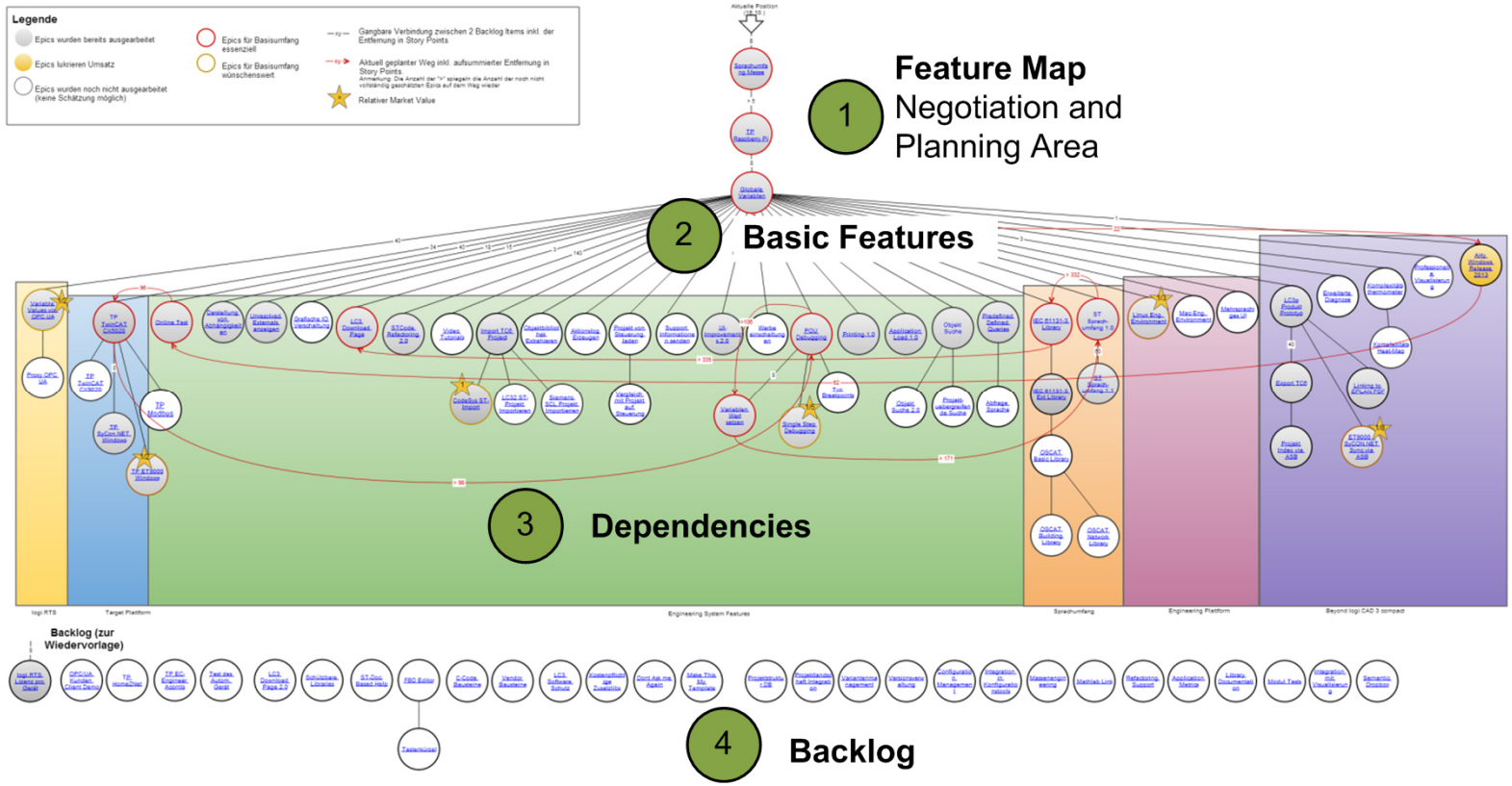
Interaction of Agile / Non-Agile Work Packages



1. Plan-Driven PM. Basic project management framework, e.g., technology exploration, training, concept development → stories/sprints.
2. Parallel Sprints. Individual sprints aligned with plan-driven work packages. Parallel sprints for software development, research prototypes, marketing → simplification of communication.
3. Synchronization. Needs coming up from sprint tasks get communicated to the PM and get planned in plan-driven WPs.

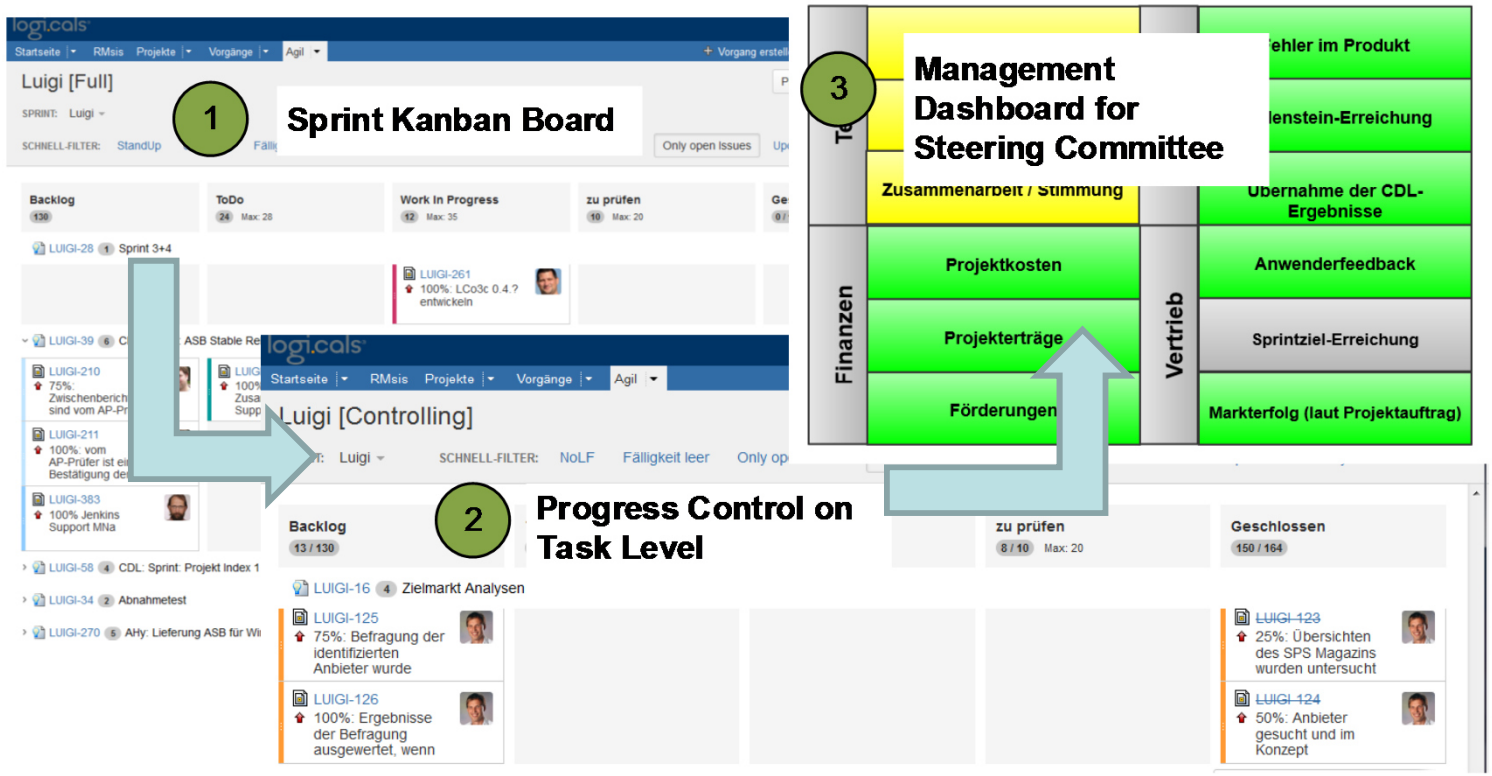
Legend: AP .. Work Packages; ES: Engineering / Development Sprints;
FS: Research Sprints; VS: Marketing sprints

Balancing the Software Development Process



1. Feature Map. Epics and stories driven by marketing and research; concrete requirements or innovative ideas → dependencies become visible.
2. Basic Features are planned for shipment to the key customers → (Research) Prototypes.
3. Dependencies. Selected features sets for different versions of the product (different colors)
4. Backlog holding ideas as candidate for future development (not planned yet)
   → Foundation for Sprint planning.

Tool Support



1. Sprint Planning. Kanban boards, used by the development team, to organize the work tasks in sprints, showing the work load of resources and progress control.
2. Plan-Driven progress control. Kanban boards also provide for the project management progress control on task level from sprints.
3. Management dashboard. The data from the Kanban boards is aggregated in the bi-weekly project team meetings for controlling to allow the effective and efficient update of the management dash-board for reporting.

Lessons Learned & Benefits

Lessons Learned of Applying the Hybrid Approach

- Software delivery was effective to fulfill contracts with customers and provide competitive products to the market within the planned effort and time plan.
- A systematic, goal-oriented approach for priority setting mitigates the risk of jumping between ideas and not achieving overall goals.
- Agile approaches need a strong framework for success in practice.
- Well-defined milestones can avoid losing the overall perspective on progress goals; the progress of sprint WPs has to be translated to the progress of plan-driven WPs.
- PM planning and control was effective and considerably more efficient than planned.

Benefits from Integrating Agile Sprints in plan-driven PM:

- Improvement of cost, effort, and progress controlling in all parts of the project.
- Transparent overview on needs and status of work for all project participants enabled a very effective and flexible work culture.
- An efficient and tool-supported continuous integration and test process provides visibility of progress and ensures the required software product quality
- A feature network that provides planning data enables goal-oriented negotiation of the development strategy.

Summary & Future Work

Summary

- Bridging the gap between research prototypes and industry products require process and tool support.
- Five steps from research prototype to industry products can help in structuring the project.
- Enhanced quality assurance activities are required on higher levels of “product” maturity.
- From project management perspective
  - A hybrid project management approach bridges the gap between traditional and agile approaches to address research/industry projects.
  - Parallel coordinated sprints of software development, research, and marketing.

Future Work

- Further development of the platform, e.g., towards AutomationML support
- Empirical evaluation of the
  - transition process and maturity level model.
  - hybrid PM approach in research and development groups at a variety of research organizations and SMEs.
- Support of continuous integration and test in engineering environments across organization boarders.

Thank you ...

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Vienna University of Technology, Institute of Software Technology,
Christian Doppler Laboratory “Software Engineering Integration for Flexible Automation Systems” (CDL-Flex)

http://cdl.ifs.tuwien.ac.at
http://qse.ifs.tuwien.ac.at/~winkler

dietmar.winkler@tuwien.ac.at

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