2018 Annual INCOSE
Great Lakes Regional Conference
SYSTEMS AT THE CROSSROADS
17 - 20 October 2018 | Indianapolis, Indiana

Model-based System Driven Product Development (MB-SDPD, or *SDPD*) Course for Engineers & Professionals

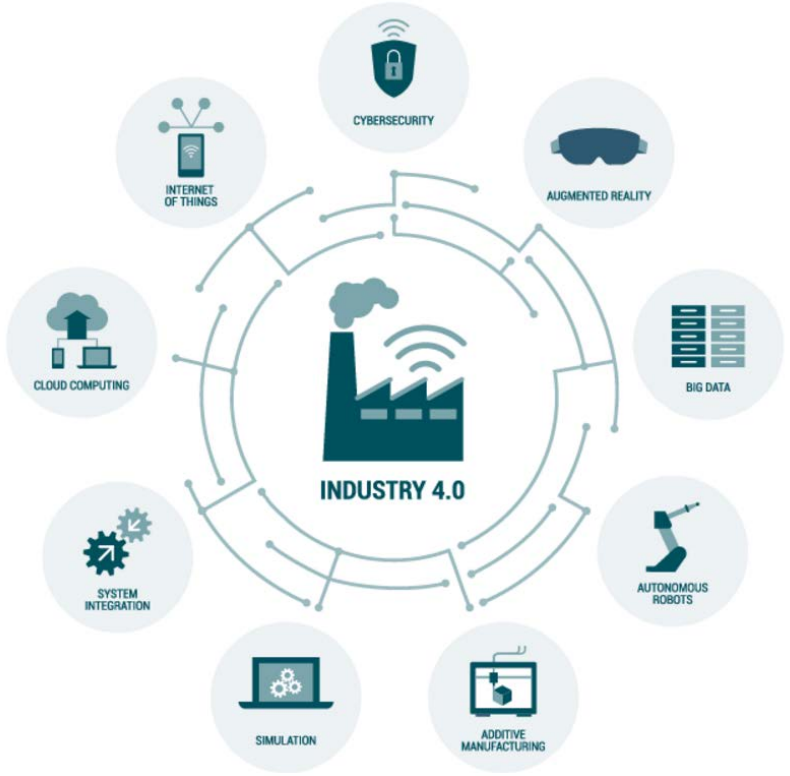
www.incose.org/glrc2018

Outline

- Background
  - Industry 4.0
  - Business challenges
  - IUPUI & IPLI
- Proposed solution
- Proposed curriculum
- Results (curriculum, assessment, case study, impact)
- Summary
- Future work

Industry 4.0

1st	2nd	3rd	4th
Mechanization, water power, steam power	Mass production, assembly line, electricity	Computer and automation	Cyber Physical Systems
Enabled by steam power	Enabled by electricity	Enabled by electronics & IT (digitalization: From analog to digital)	Enabled by further *digitalization & fusion of technologies to build cyber physical systems and the smart factory*/product. It calls for an "Enterprise digital transformation"



Industry 4.0 marries advanced manufacturing techniques with the Internet of Things to create a digital manufacturing enterprise that is not only interconnected, but communicates, analyzes, and uses information to drive further intelligent action back in the physical world

Business Challenges

To address industry 4.0 need to competitively develop modern products, which are increasingly becoming smart connected systems or “systems of systems”.

Complexity resulting from managing:	Complexity resulting from dealing with:
• Multiple sub-systems • Multiple design groups and multiple sites • Multiple engineering domains • Multiple disparate tools in each domain • Growth of software / electronic systems • Multiple variants and system architectures • Exploding requirements and test cases	• Subsystem interactions • System integration

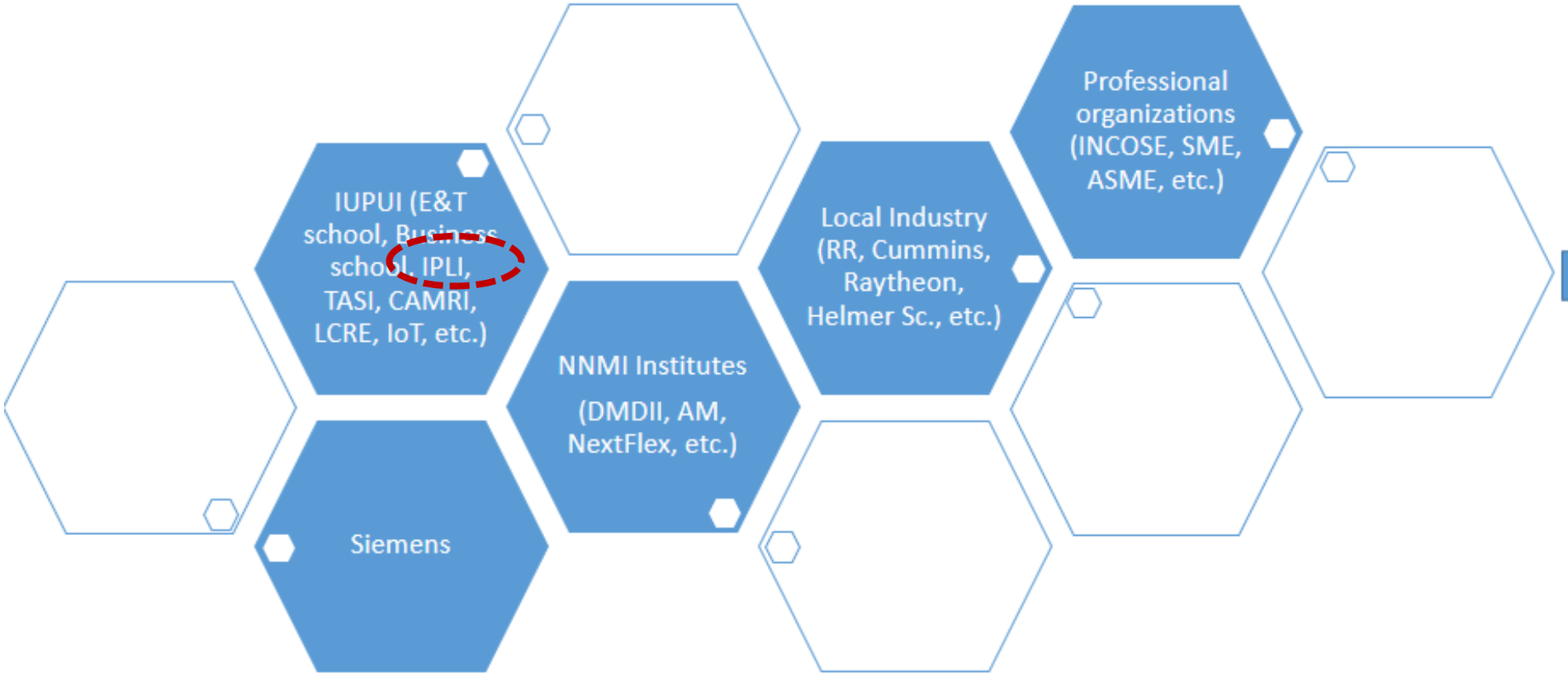
To establish a MBE (Model-based Engineering) framework & simulator for the digital enterprise that can be used to demonstrate best practice in developing modern products.

To educate the next generation of engineers for industry 4.0

IUPUI

IUPUI, a public research university with close to 30,000 students, offers both Indiana University as well as Purdue University degree programs totaling around 250. In addition to Indiana University schools such as Medicine and dentistry, IUPUI includes two Purdue University schools, namely school of Science and school of Engineering and Technology. The latter has more than 3,500 students, including 500 at the graduate level.

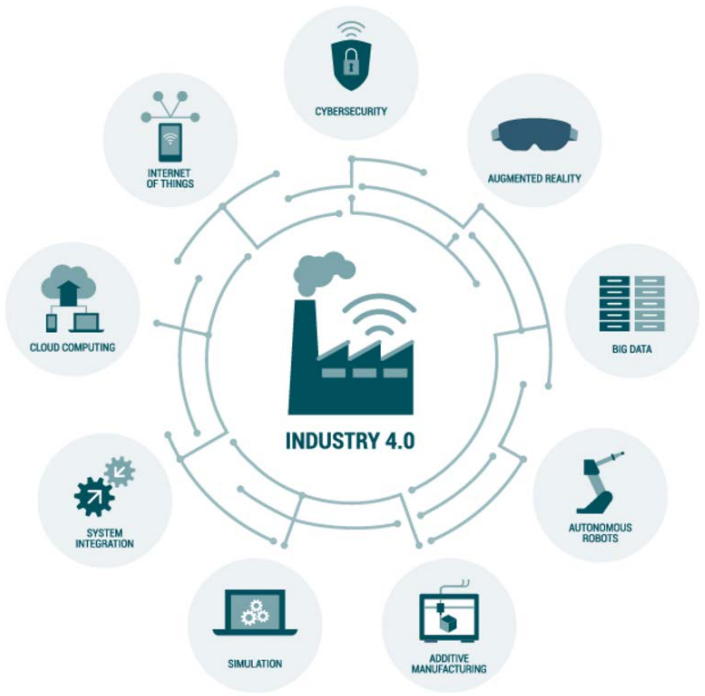
Partnership Ecosystem needed to enable/support Industry 4.0



INDUSTRY 4.0:

1. Education
2. Workforce
3. Enabling technologies
4. Best practice
5. Roadmap

IPLI



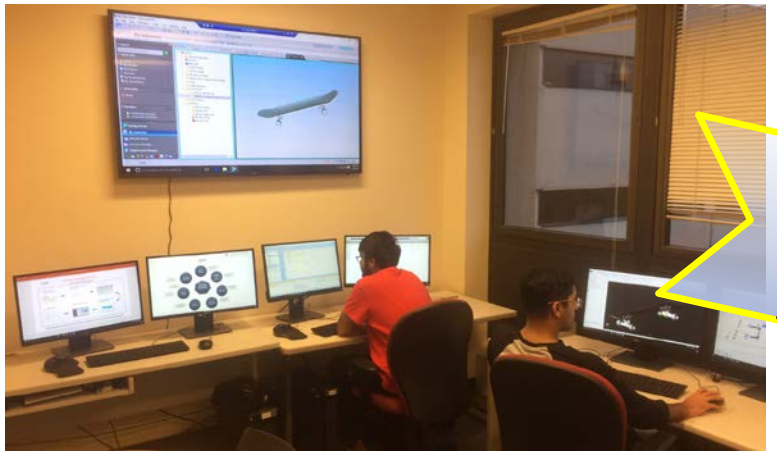
IUPUI | INITIATIVE FOR PRODUCT LIFE CYCLE INNOVATION
INDIANA UNIVERSITY-PURDUE UNIVERSITY Indianapolis

IPLI aim is to advance the field of product and process lifecycle and to drive innovation through an interdisciplinary team from IUPUI as well as consortium of industry, key stakeholders, national initiatives, and professional organizations.

IUPUI campus wide inter-disciplinary initiative that focuses on advancing the state of disruptive technologies of industry 4.0

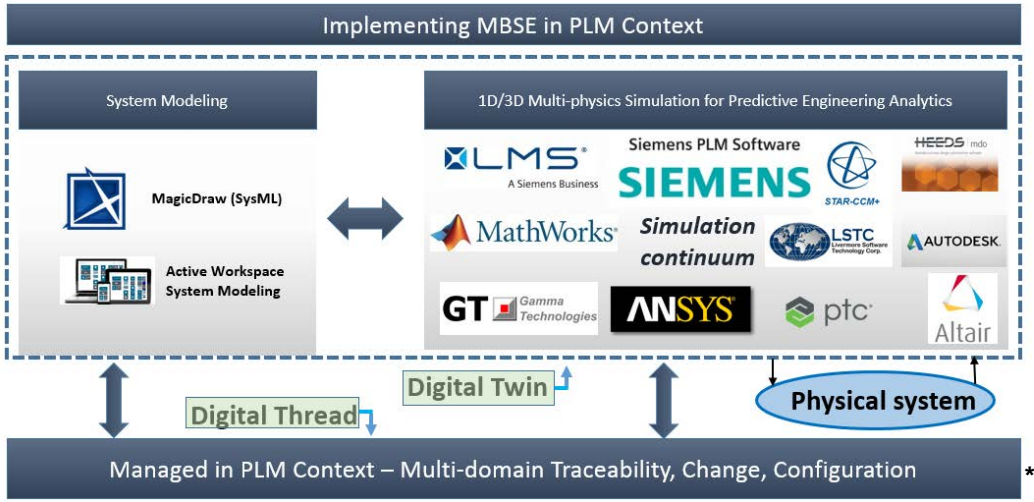
Consortium to support the digital transformation and enable/facilitate the implementation of the digital enterprise

IPLI – Simulator & Infrastructure



IPLI SDPD Simulator facility (ET 314C)

Dedicated Simulator



****NoMagic/Siemens**

SDPD ecosystem (Digital twin + Digital thread)

SDPD Educational facility (45 workstations)

More than 30 Software tools & 1,000's of license seats

- **Access to Simulator: Testbed, Digital twin, modeling & simulation continuum, Assessment platform.**
- **Access to State-of-the-art tools**
- **Training/Workforce development**
- **Certificate/Certification**
- **Consulting**
- **Implementation (Industry case studies)**
- **Special projects**

Current challenges/Limitations (faced by Academia)

Lack of education (curriculum/certification) for industry 4.0, including MBSE, MBE (SDPD), Digital twin, and digital thread.

MBE (SDPD) skills not clearly articulated/defined by industry

Cost of infrastructure (both hardware and software)

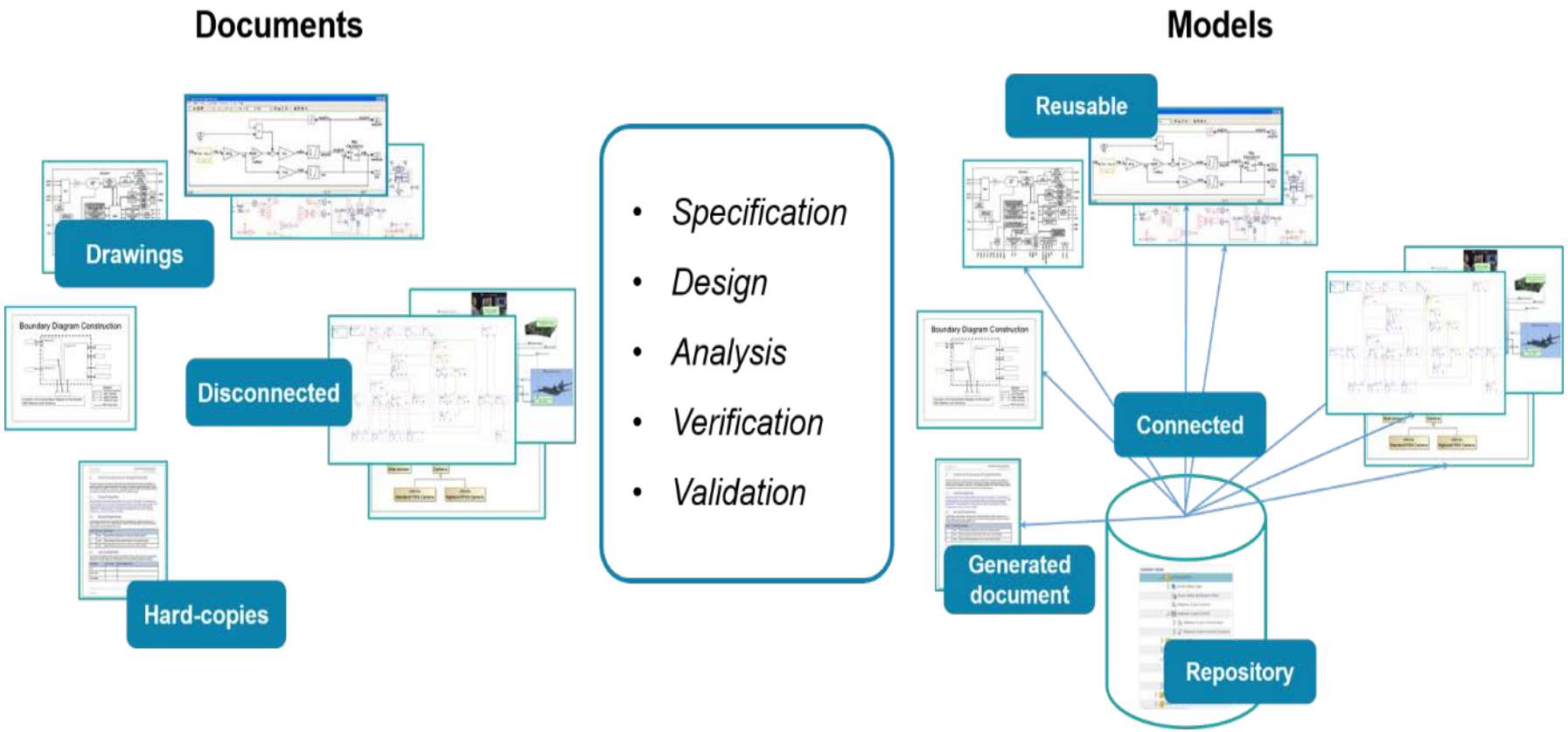
Limited ability to deliver graduates with the required skills to support/drive the digital transformation

Limited ability to support the needs of industry for the digital transformation

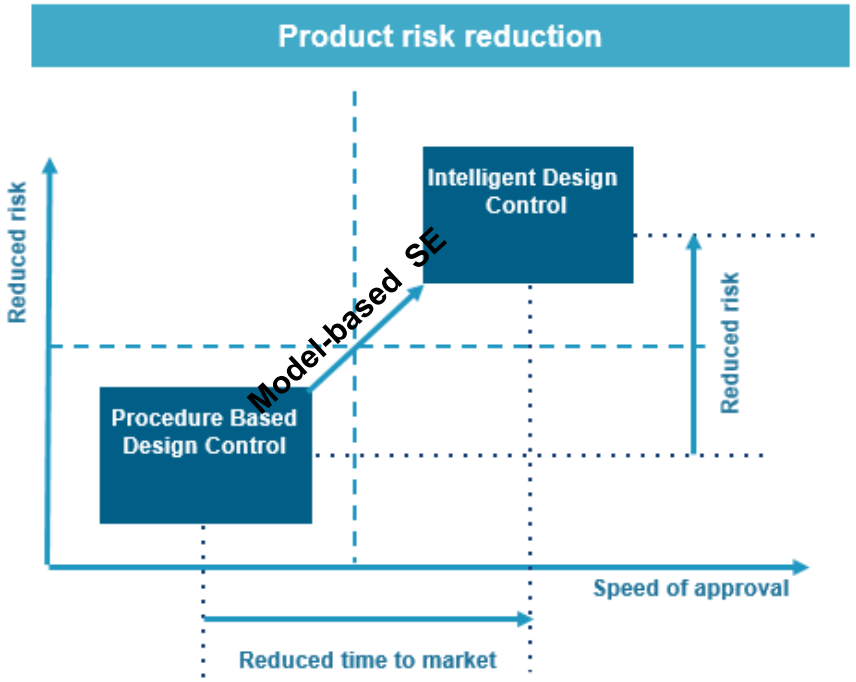
Engineering Education: Traditional vs. Industry 4.0

Current Engineering Education landscape	Engineering Education for Industry 4.0
Single domain/discipline	Multi-disciplinary
Technology/Tools taught by technology programs/community colleges	Offered by Engineering colleges (4 year)
Limited relevance to Industry practice, including Industry 4.0	Driven by Industry (consortium)
Traditional/Typical role of Engineering programs vs. Technology programs/Community colleges	Applied and closely relevant/related to Industry 4.0

Proposed solution: Digitalization of SE process or MBE



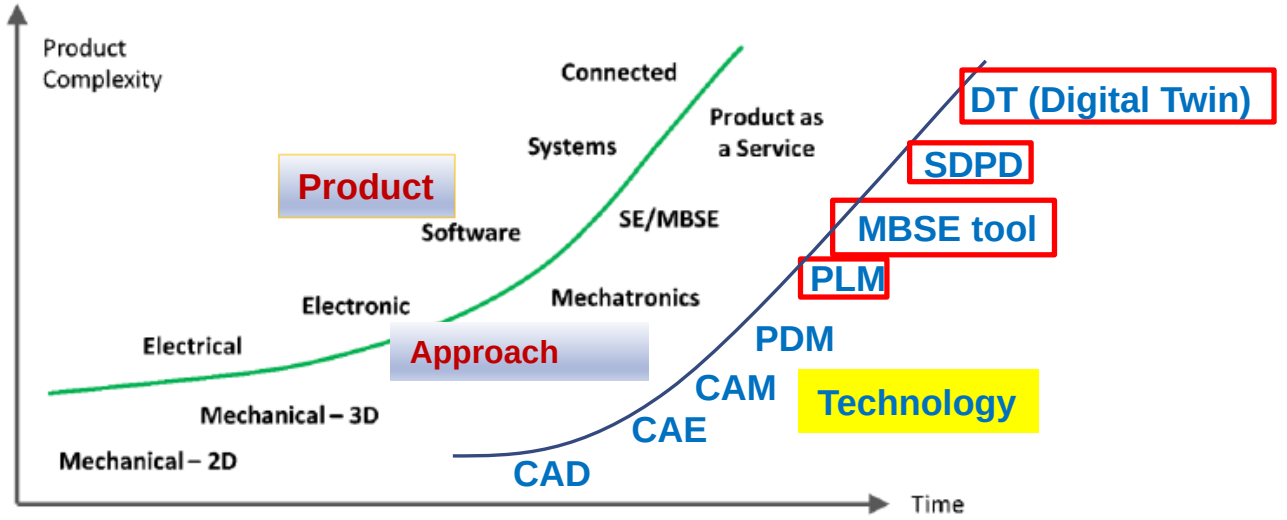
Proposed solution: Digitalization of SE process or MBE (*Example: Medical Device Industry*)



Document-based process	Model-based process
Error prone - Missing elements - Poor element traceability Vulnerable to company silos	Workflow enforced Design element based Source driven through design elements Fully integrated

Proposed solution: Digitalization of SE process or MBE

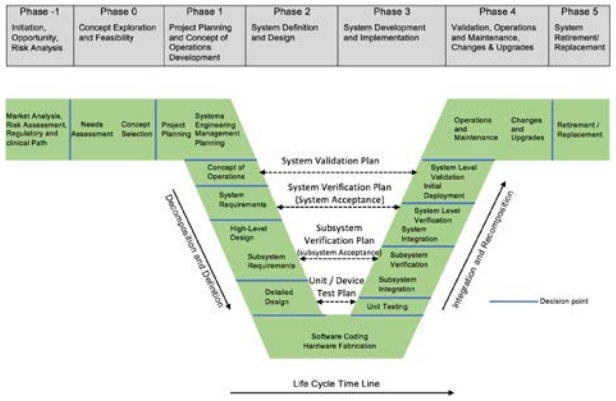
	Traditional products	Modern products
Managing the system view of the product	Using simple tools (e.g. Excel, Visio, Word, Powerpoint, etc.)	Simple tools cannot manage the behavior of Complex Systems or “Systems of systems”



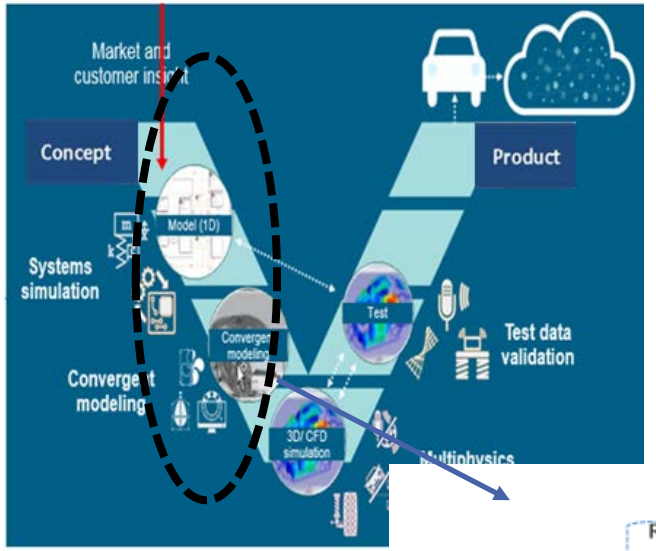
Increase product complexity with time

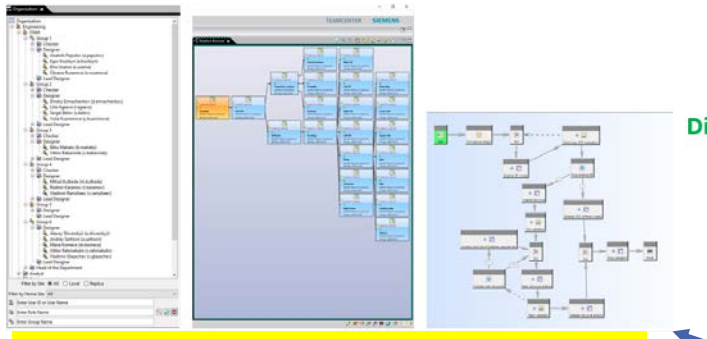
MBSE and the Business of Engineering: The case for Integrating MBSE and PLM, Aras corp.

Proposed solution: Digitalization of SE process or MBE

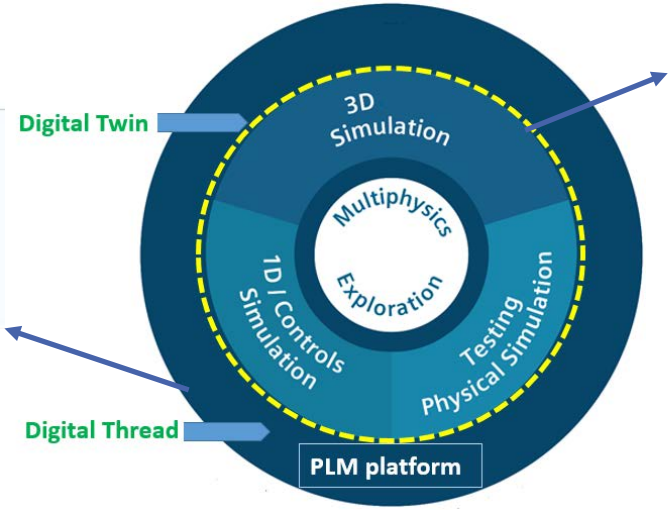


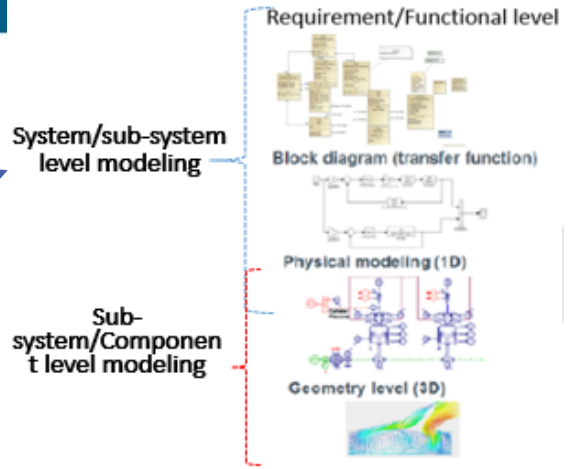
Digitalization of SE V-model





PLM platform: Management

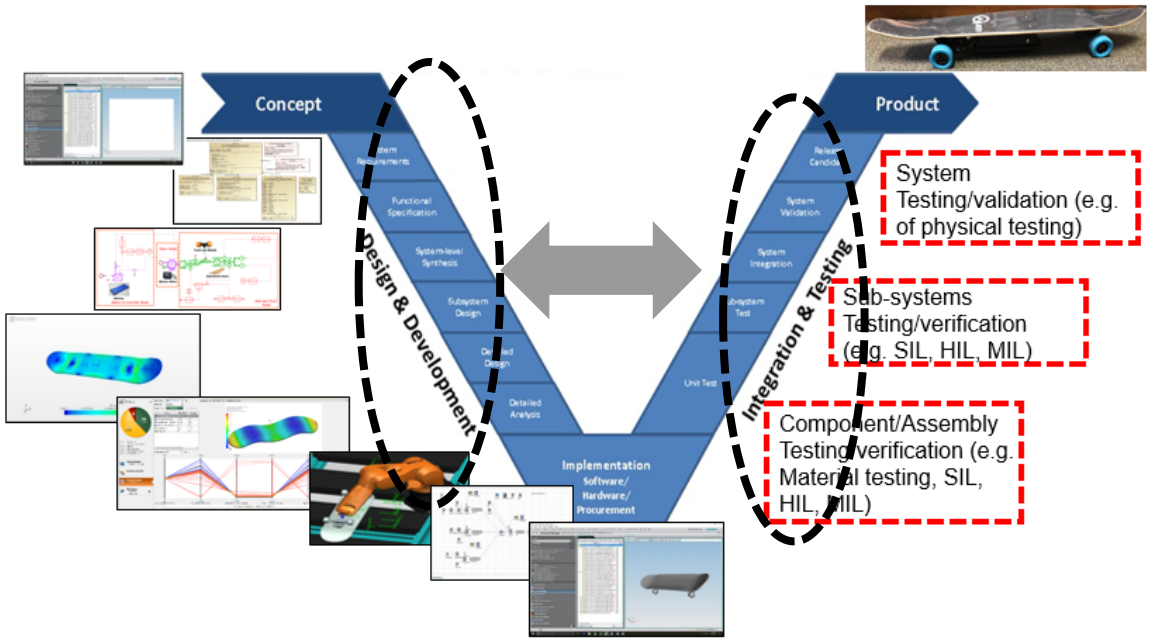




MBSE: Modeling

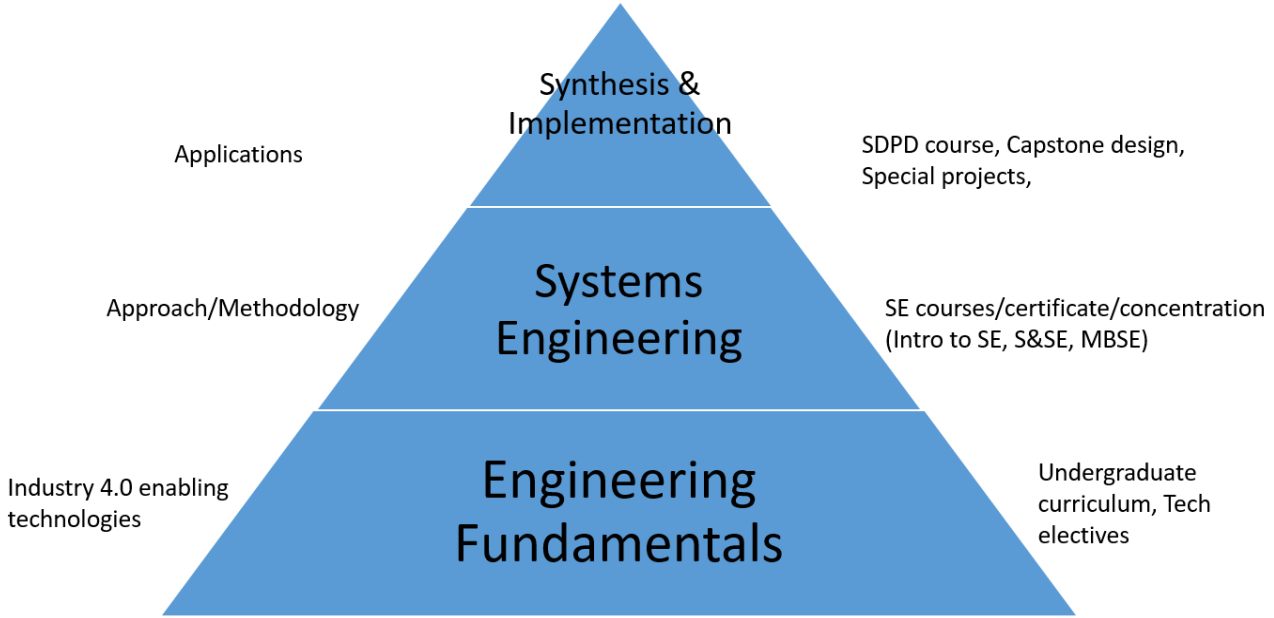
Digitalization of SE process

Proposed solution: Digitalization of SE process or MBE



Digitalization of SE process also supports verification and validation

Proposed Curriculum: *Towards an Engineering education for Industry 4.0*



			Courses
Level 2	Synthesis & Applications	Implementation	SDPD, Capstone design, Special projects, etc.
Level 1	Approach / Methodology	Systems Engineering	SE courses / certificate/concentration (Intro to SE, S&SE, MBSE)
Level 0	Industry 4.0 enabling technologies	Engineering Fundamentals	Undergraduate curriculum, Tech electives

SDPD (or MB-SDPD) course

A unique curriculum that demonstrates the **digitalization of the SE** (Systems Engineering) **process** through the integration of modelling and simulation continuum (in the form of MBSE) with Product lifecycle management (PLM), which is referred to as Model based System Driven Product Development, or SDPD (Systems Driven Product Development) for short.

SDPD (or MB-SDPD): is a form of MBE (Model-based Engineering) that drives the product lifecycle from the systems requirements and traces back performance to stakeholders' needs through a RFLP traceability process. At the core of this coursework is a shift of focus from theory to implementation and practice, through an *applied synthesis of engineering fundamentals and systems engineering, that is driven by a state-of-the-art digital innovation platform for product (or system) development*. The curriculum provides training to the next generation of engineers for Industry 4.0.

SDPD course – Key aspects/Elements

1. **Implements the digitalization of the SE V-model**
2. **Consists of three key components**
    a. *Modeling & simulation continuum*
        i. To use different models of different fidelity level at different point in the system development process because each serves a different/specific/specialized role/purpose, in order to make the development process more efficient and practical
        ii. To interface/integrate the different models
            1. Full integration (e.g. through model transformation)
            2. Co-simulation
    b. *Traceability*
        i. RFLP (Requirements, Functional, Logical, and Physical)
    c. *Digital thread*
        i. Using a central model (e.g. MBD)
        ii. Supported by PLM as backbone
3. **Forms the basis for developing/implementing the (holistic) digital twin**

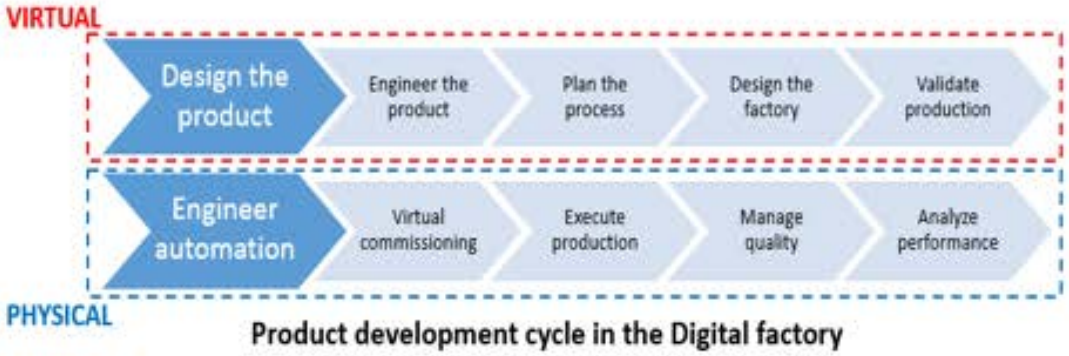
SDPD course – As part of SE certificate/education at IUPUI

SE curriculum/certificate at IUPUI: Integrates SE theory and principles with a framework of tools, methods, and applications to increase effectiveness and improve the alignment with the vision and need of Industry 4.0.

Course	Subject/content	SDPD tools
Introduction to Systems Engineering	SE theory and implementation	PLM (e.g. Teamcenter & Teamcenter Systems Engineering)
Systems and Specialty Engineering	SE theory and implementation	PLM (e.g. TC AW and TC AW systems modeling)
Model-Based Systems Engineering (MBSE) using SysML	MBSE theory and implementation using SysML	MBSE (e.g. Cameo/MagicDraw)
Model-Based Systems Driven Product Development: SDPD	SDPD theory and implementation	Ecosystem of software tools

Developed in partnership with *Industry*

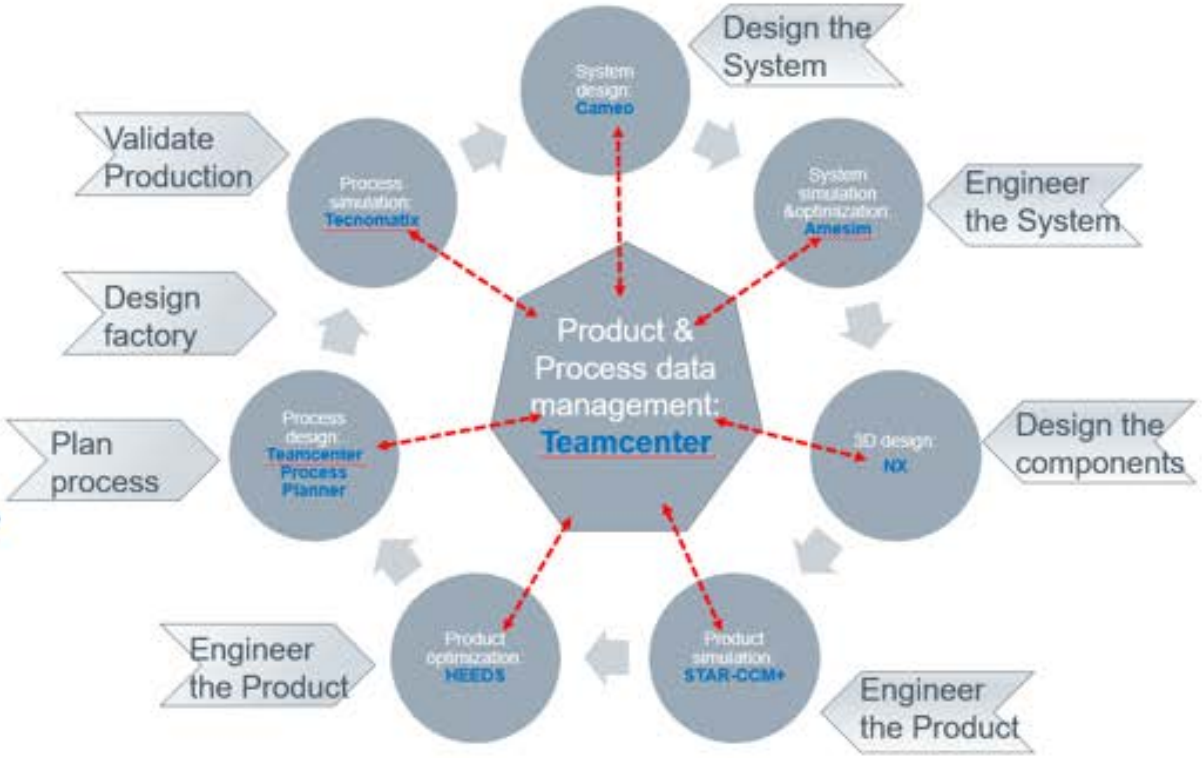
SDPD course - Workflow



Product development cycle in the Digital factory

Virtual cycle

Design the product	Engineer the product	Plan the process	Design the factory	Validate production
NX for Design Cameo Amesim Teamcenter (TC) Engineering	NX for Design Cameo Amesim Simcenter (STAR-CCM+, HEEDS) TC Requirements TC CAE Manager	TC Manufacturing TC EWI	TC Manufacturing Tecnomatix Process simulate Tecnomatix Plant Simulation	TC Manufacturing Tecnomatix Process Simulate Tecnomatix Plant Simulation



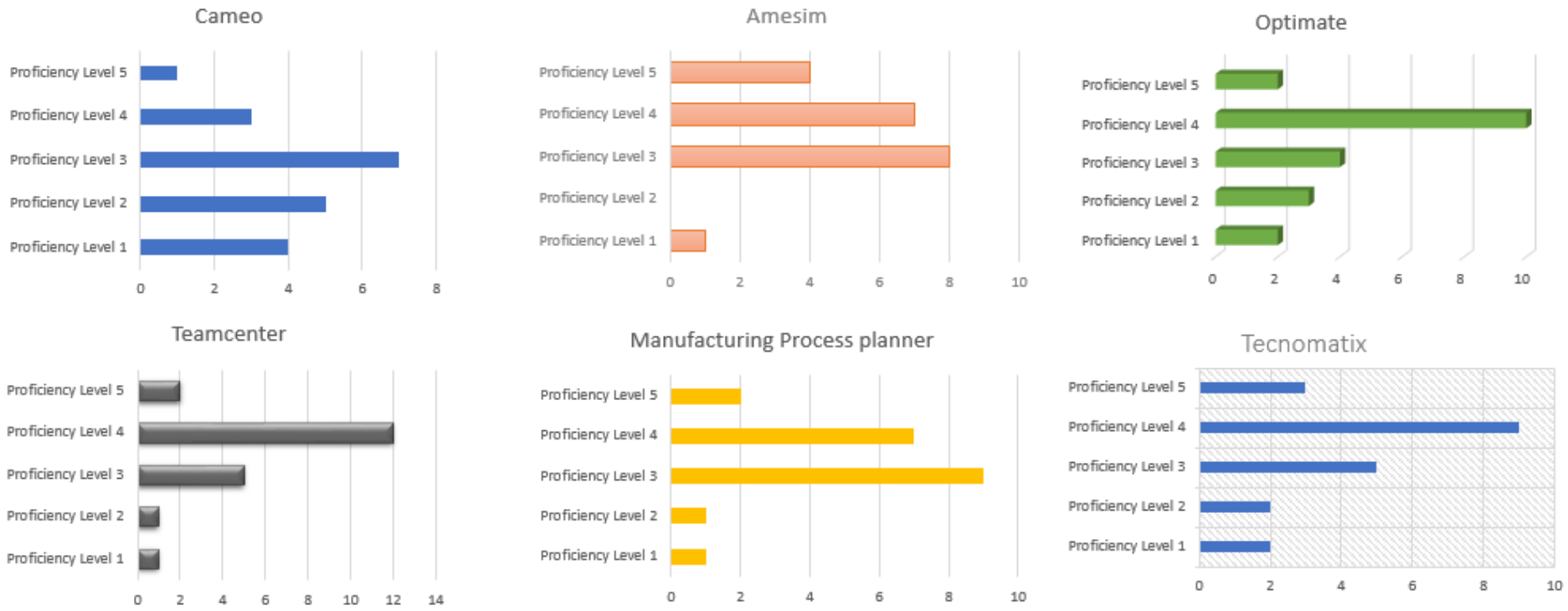
Results - Curriculum

Ability to synthesis knowledge and skills acquired over the course of college engineering education and apply it effectively to complete a real life modern product development within the time line of one semester

1. Demonstrates the digitalization of the SE V-model
2. Implements three key elements of digitalization (1. Modeling & simulation continuum; 2. Traceability; 3. Digital Thread)
3. Forms the basis for implementing the digital twin and curriculum for industry 4.0

Results – (Student) Assessment

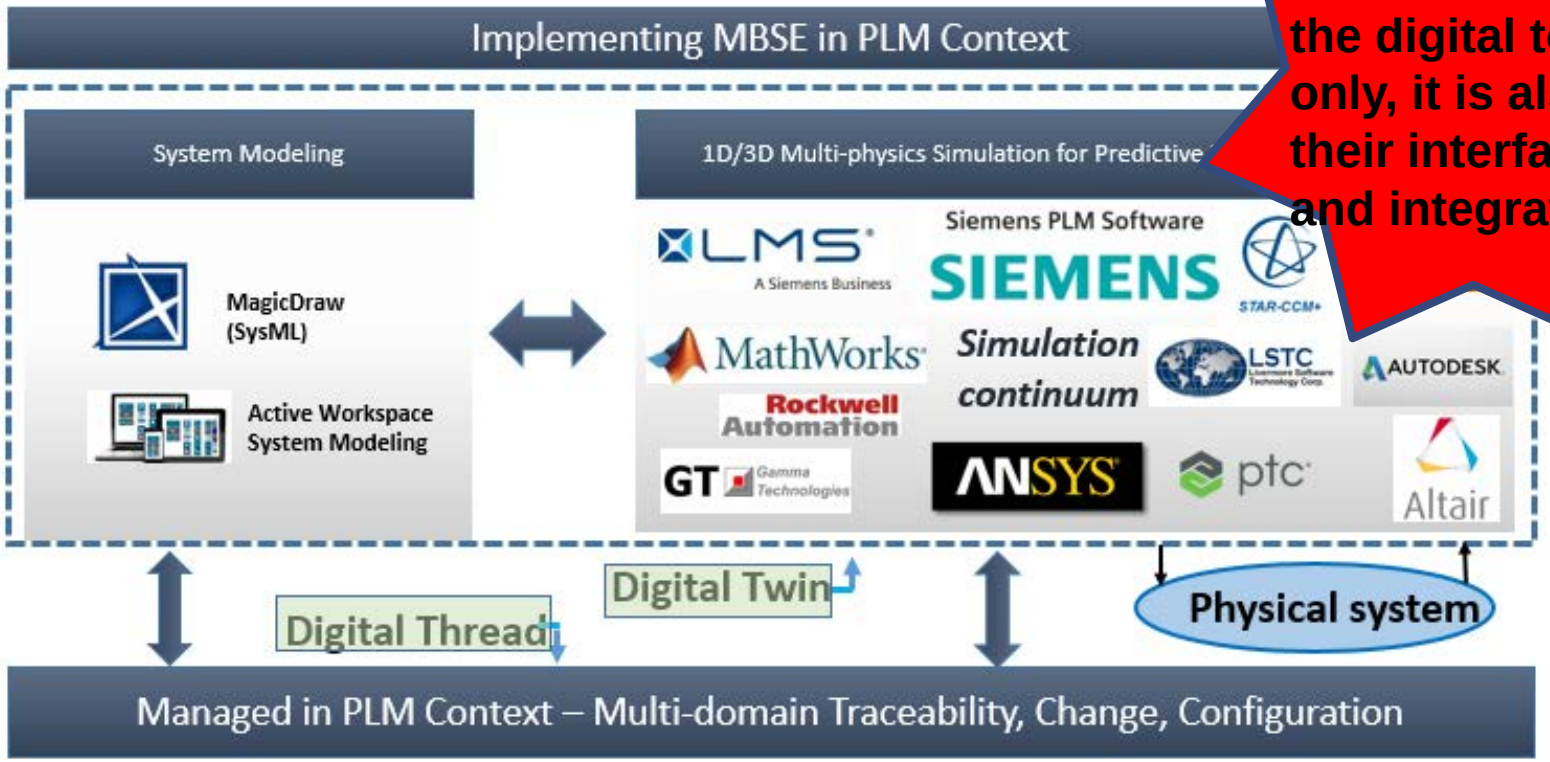
Assessing the ability to develop integrated and comprehensive skills for industry 4.0



Skill competency self-assessment (partial) – Average score higher than 3 out of 5

Results – SDPD Simulation

Ability to demonstrate the digitalization/model-based engineering to industry



It is not about the digital tools only, it is also their interfacing and integration

SDPD simulator

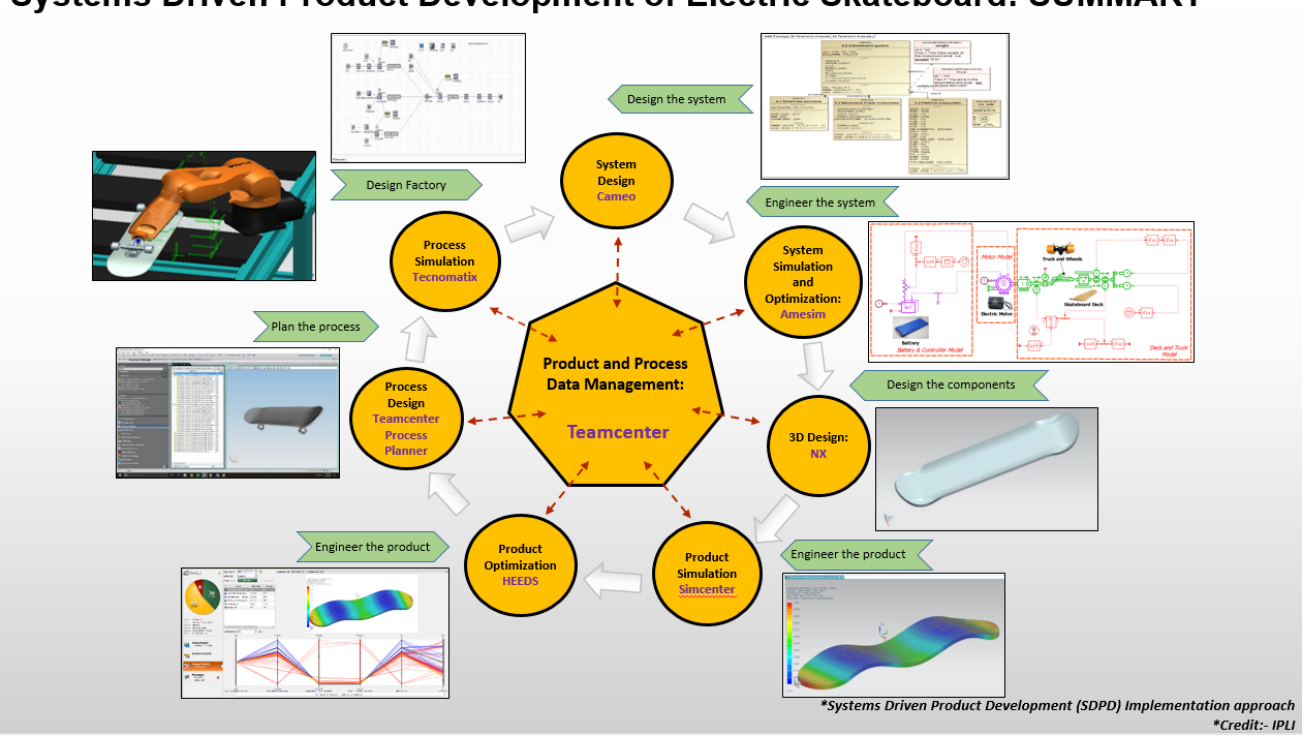
- Modeling & simulation continuum: Ecosystem
- State-of-the-art tools
- Software agnostics
- Expandable
- Digital Twin & Digital Thread
- Testbed
- Simulator
- Assessment platform
- Training/Workforce development
- Certification
- Consulting
- Implementation (Industry case studies)
- Special projects

The SDPD platform at IPLI is built on a modeling continuum using state-of-the-art suites of software tools and is meant to provide a testbed for industry/developers

Results – Case study

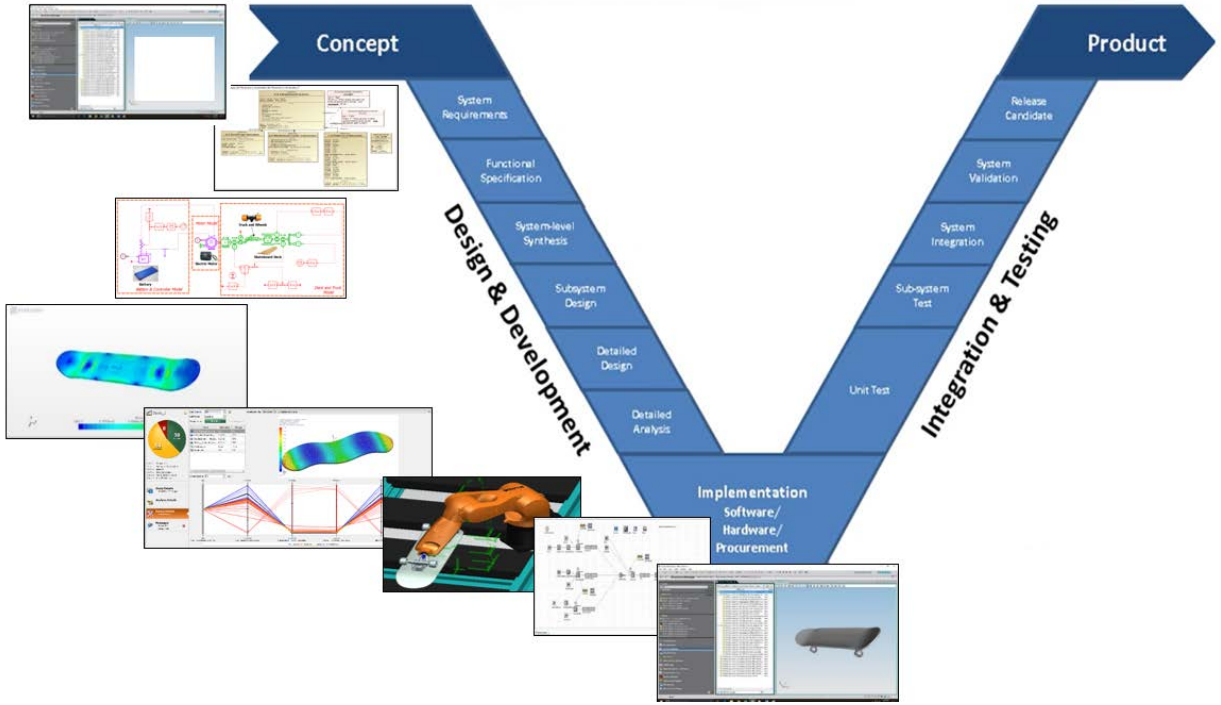
Ability to demonstrate the digitalization/model-based engineering to industry

Systems Driven Product Development of Electric Skateboard: SUMMARY

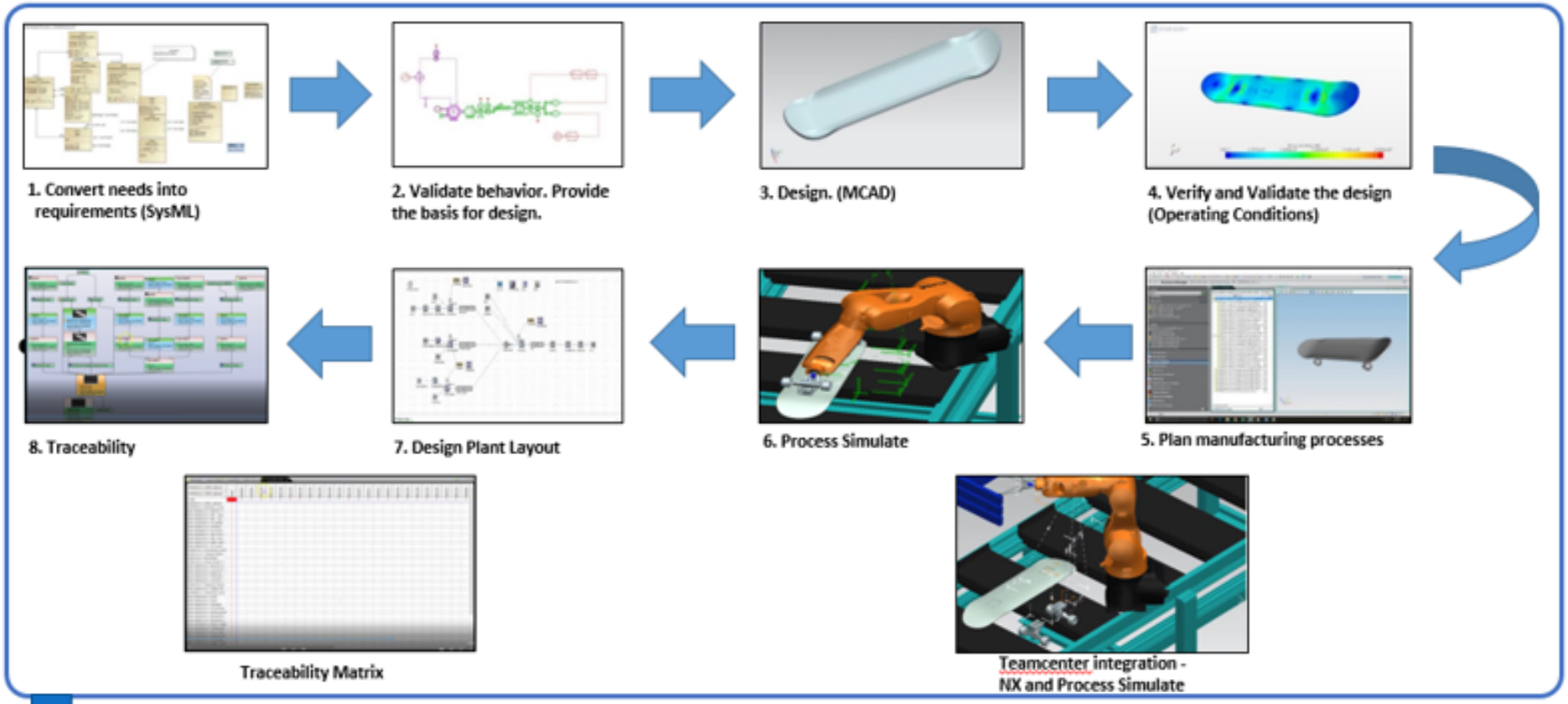


*Systems Driven Product Development (SDPD) Implementation approach

*Credit:- IPLI



Results – Case study (cont')



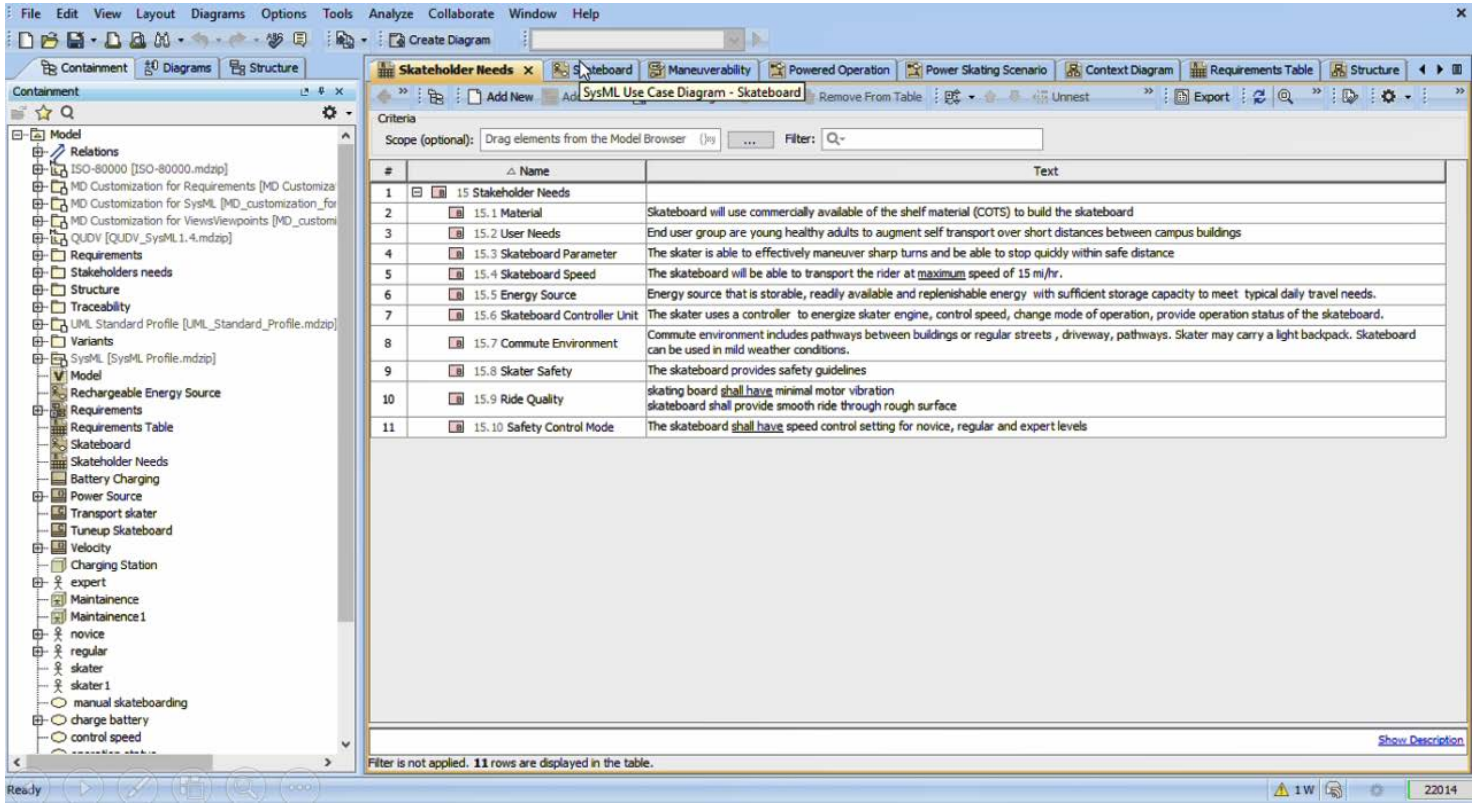
SDPD Workflow implementation for Electric Skateboard case study

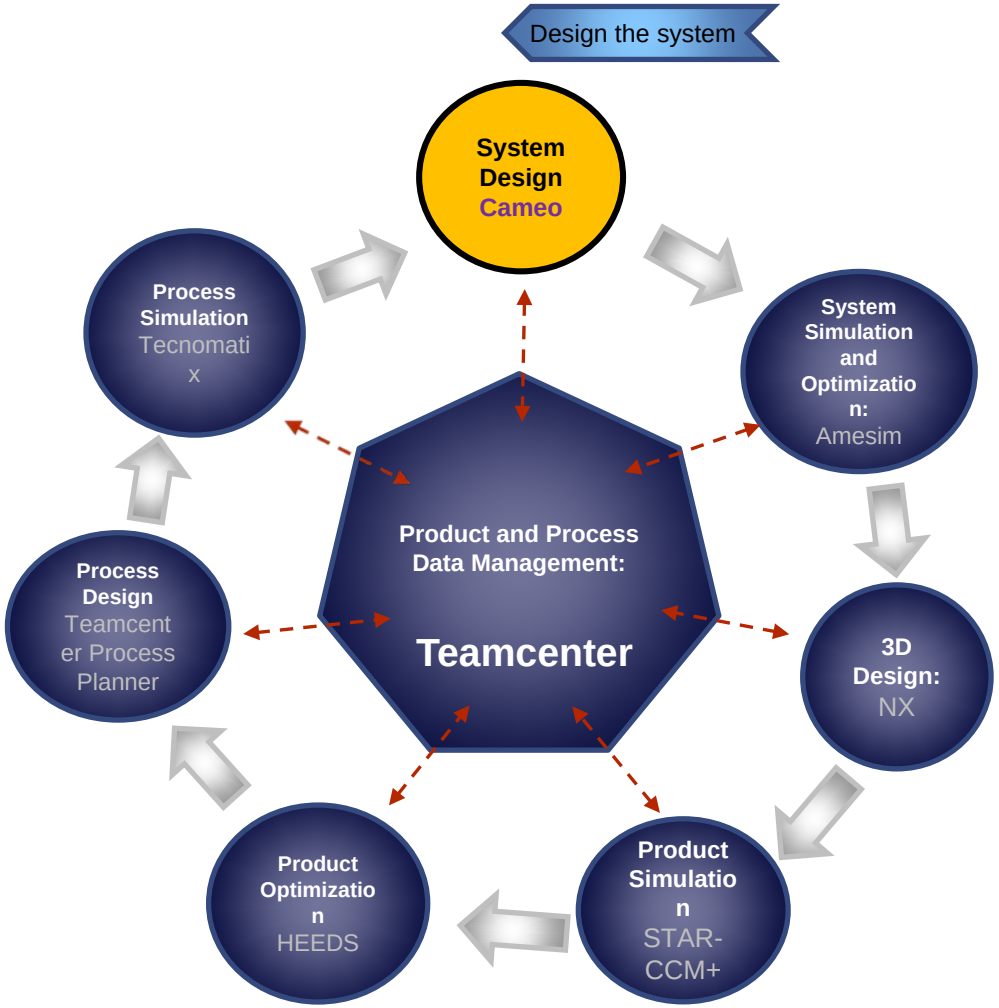
Final system

Systems Driven Product Development – Skateboard

System Design Requirements

Cameo Systems Modeler:
- Model Based Systems Engineering (MBSE) software
- Create a systems model and a single source of information
- Requirements, behaviors, parametric and activities General insight of purpose of creating the Skateboard





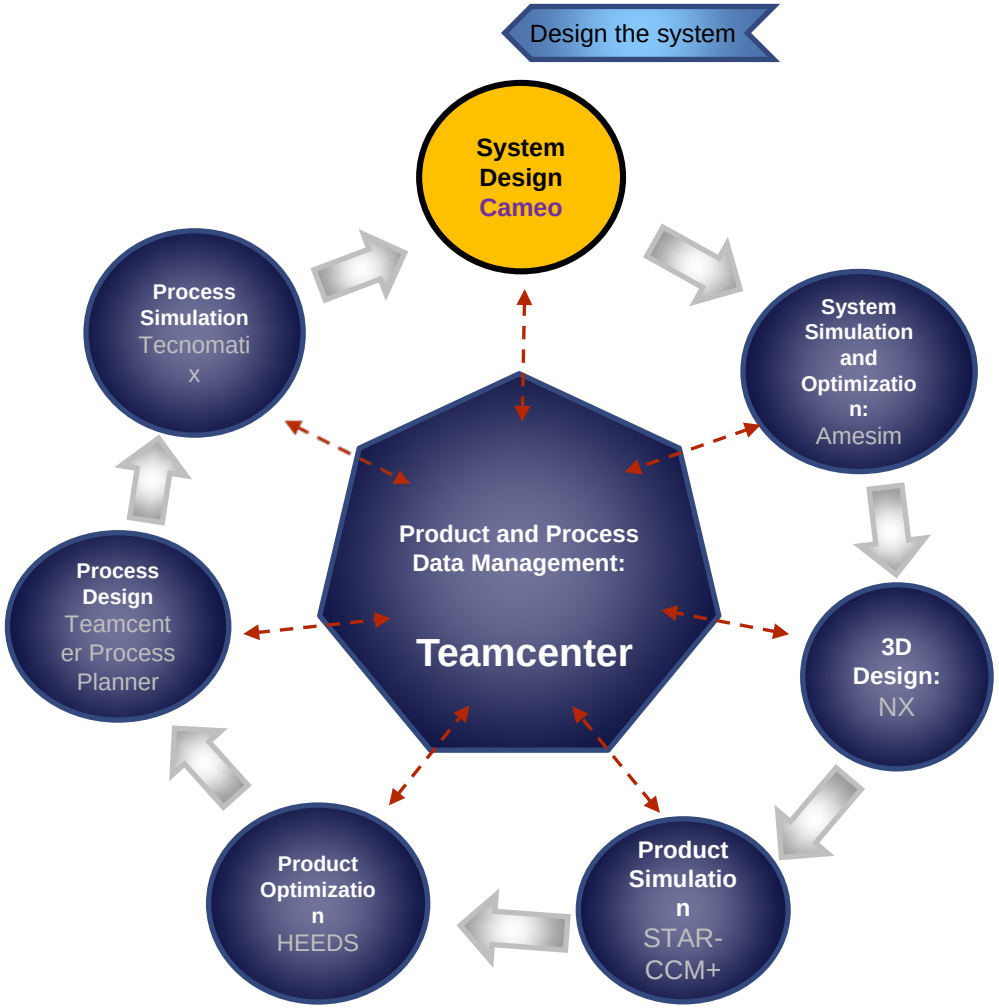
Stakeholders needs for Electric skateboard in Cameo

Systems Driven Product Development – Skateboard

System Design Requirements

Cameo Systems Modeler:
- Model Based Systems Engineering (MBSE) software
- Create a systems model and a single source of information
- Requirements, behaviors, parametric and activities General insight of purpose of creating the Skateboard

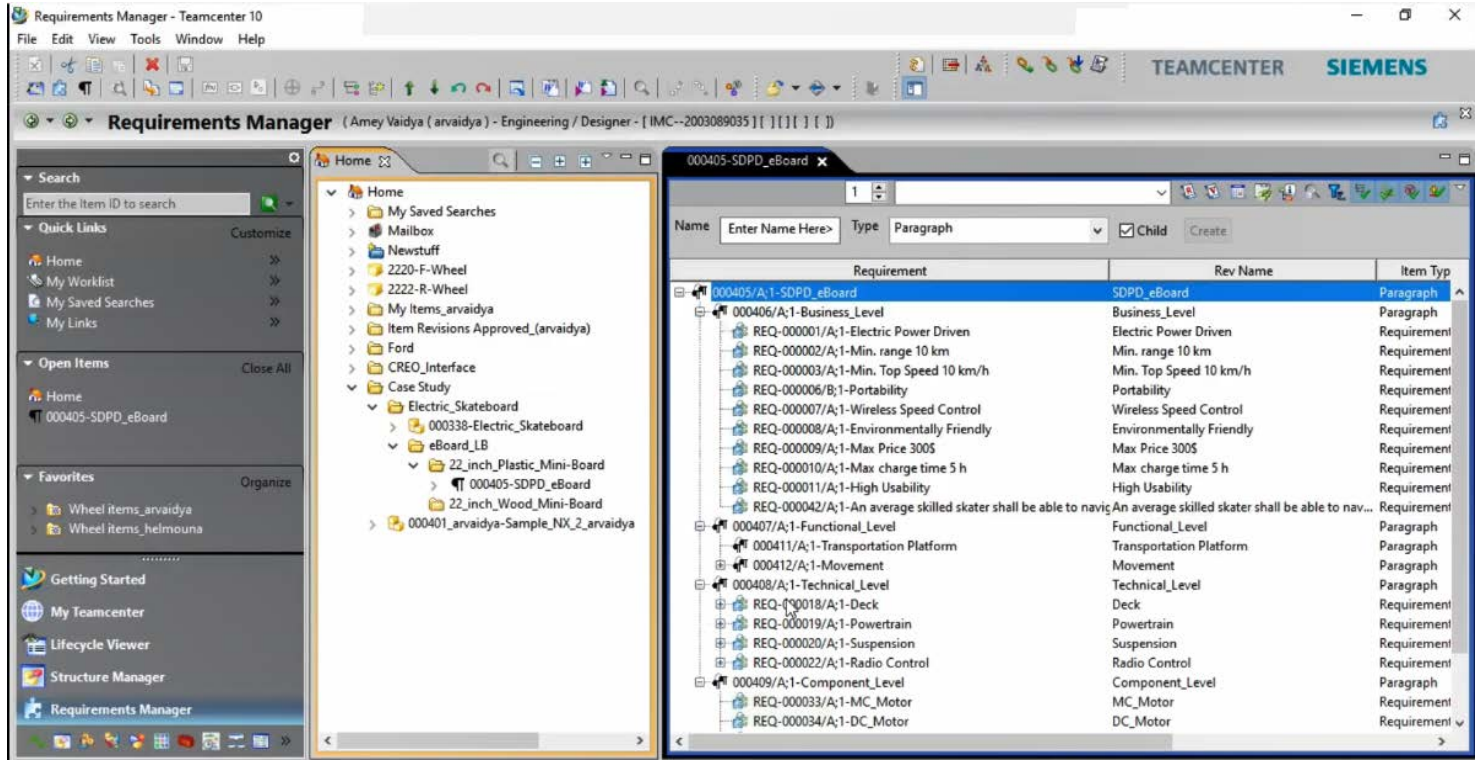
VIDEO – To be added

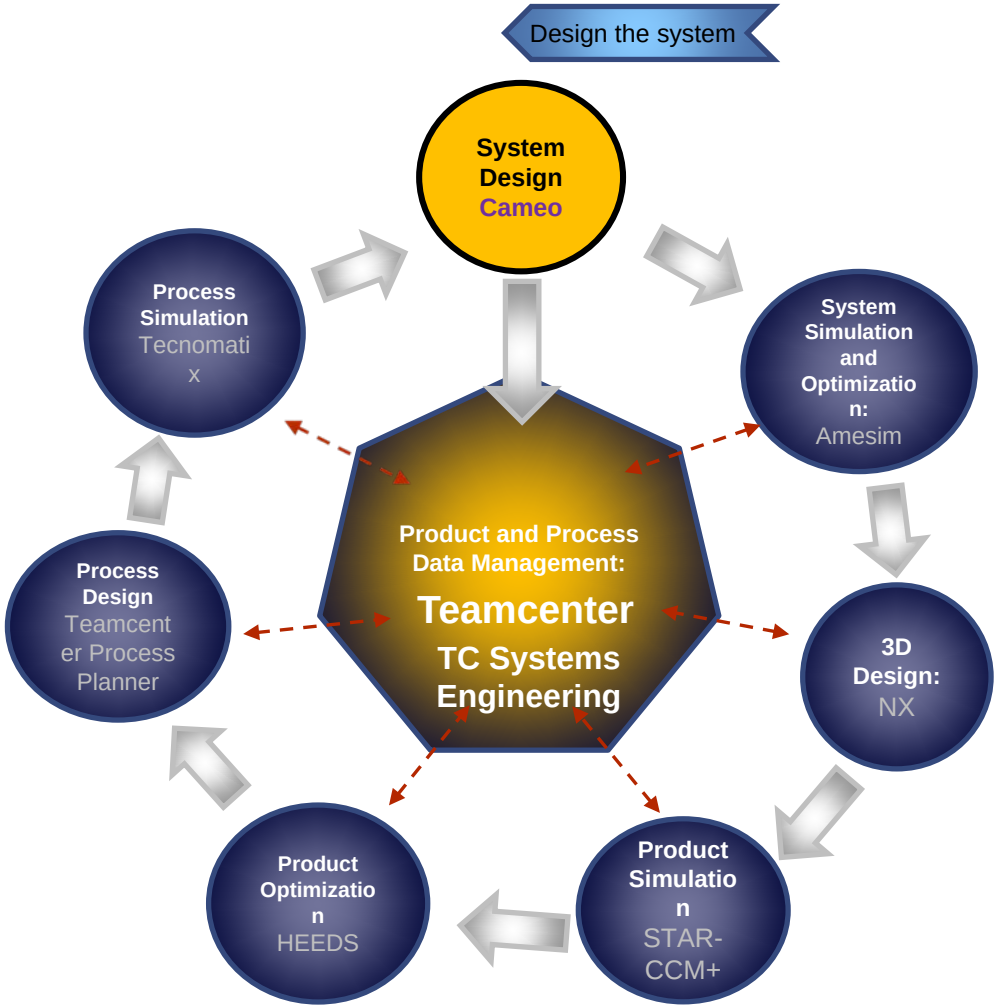


Systems Driven Product Development – Skateboard

System Design Requirements (Management/Traceability)

Teamcenter (TC) Systems Engineering:
- Requirements, behaviors, parametric and activities General insight of purpose of creating the Skateboard

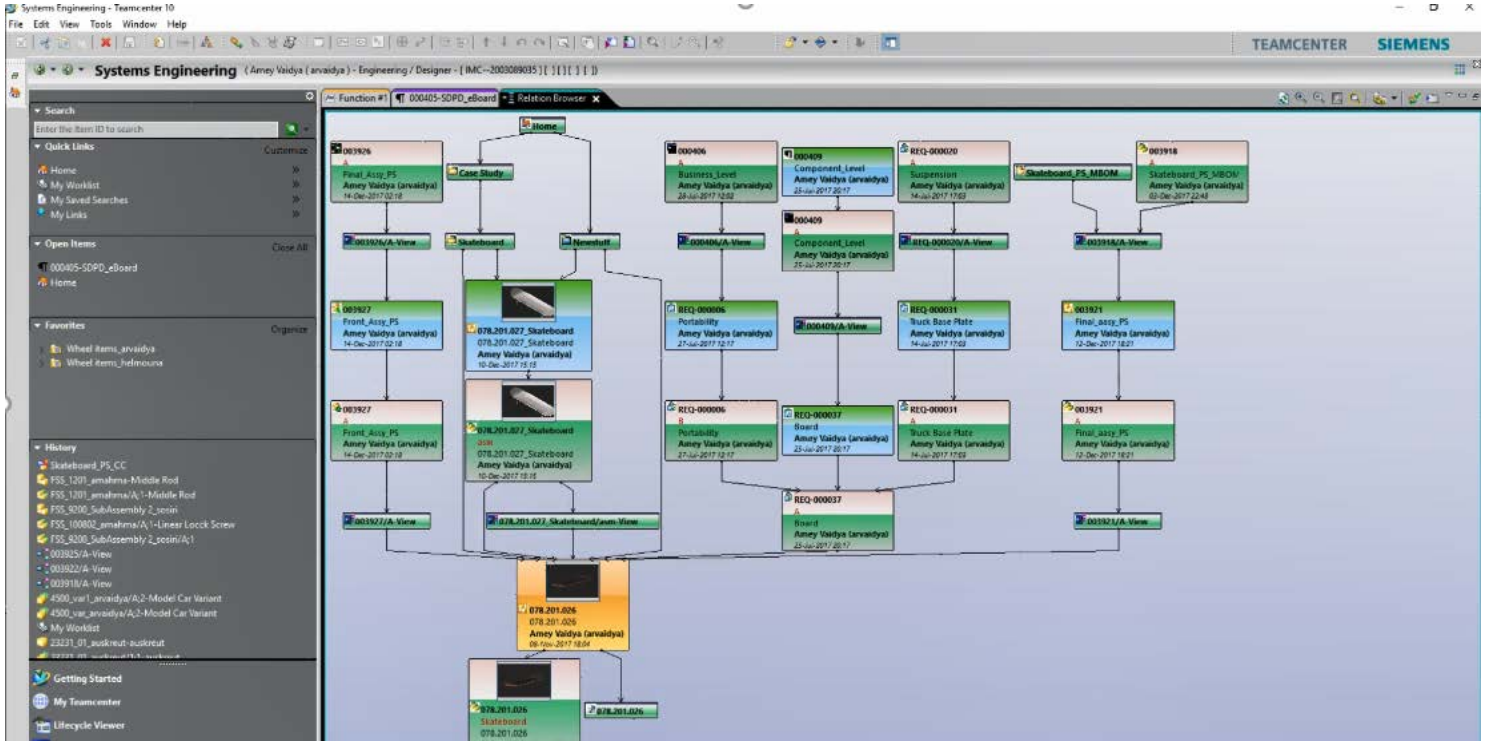


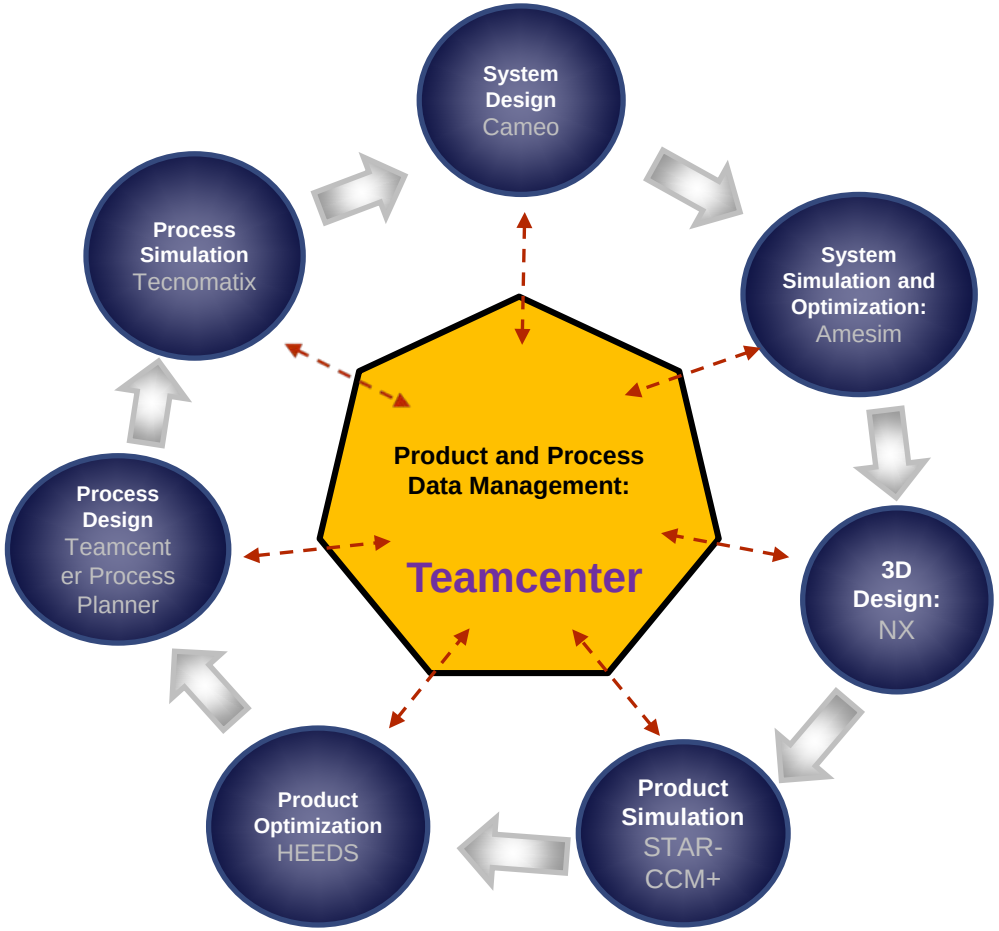


Systems requirements in Teamcenter (TC) Systems Engineering

Systems Driven Product Development – Skateboard

Requirements Traceability



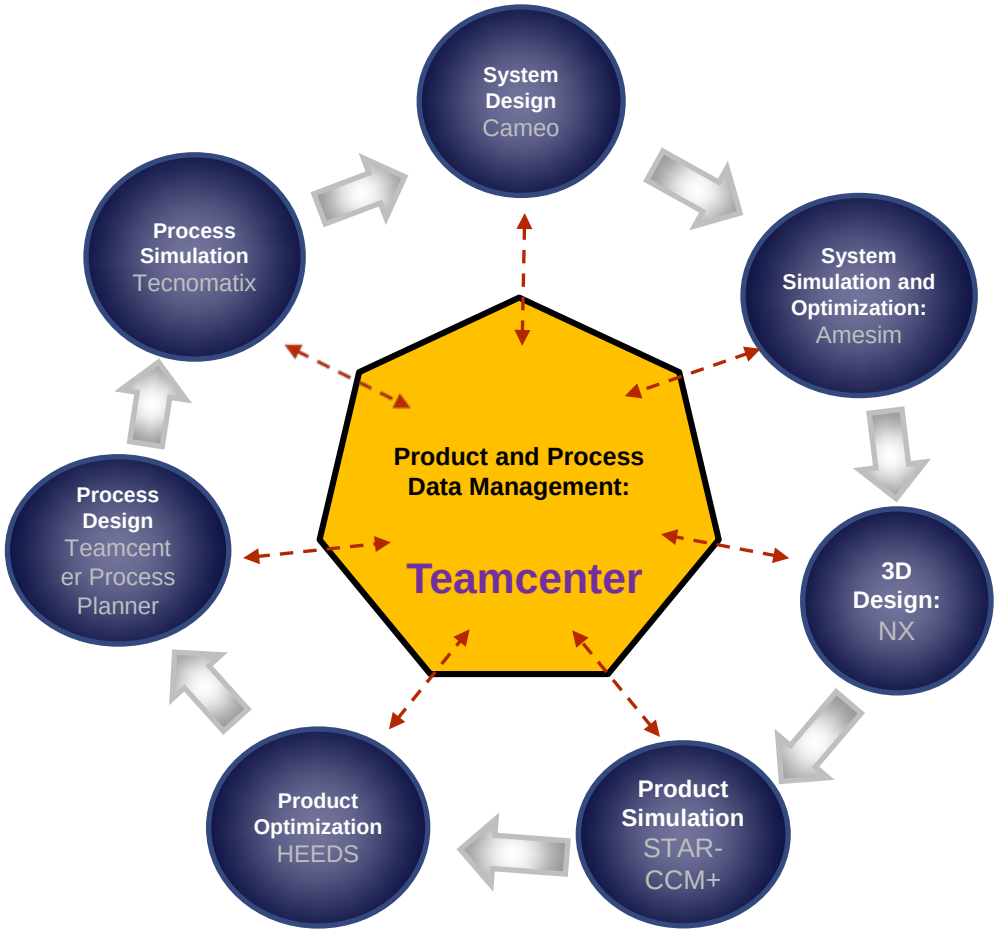


Requirements Traceability in TC Systems Engineering

Systems Driven Product Development – Skateboard

Requirements Traceability

VIDEO – To be added

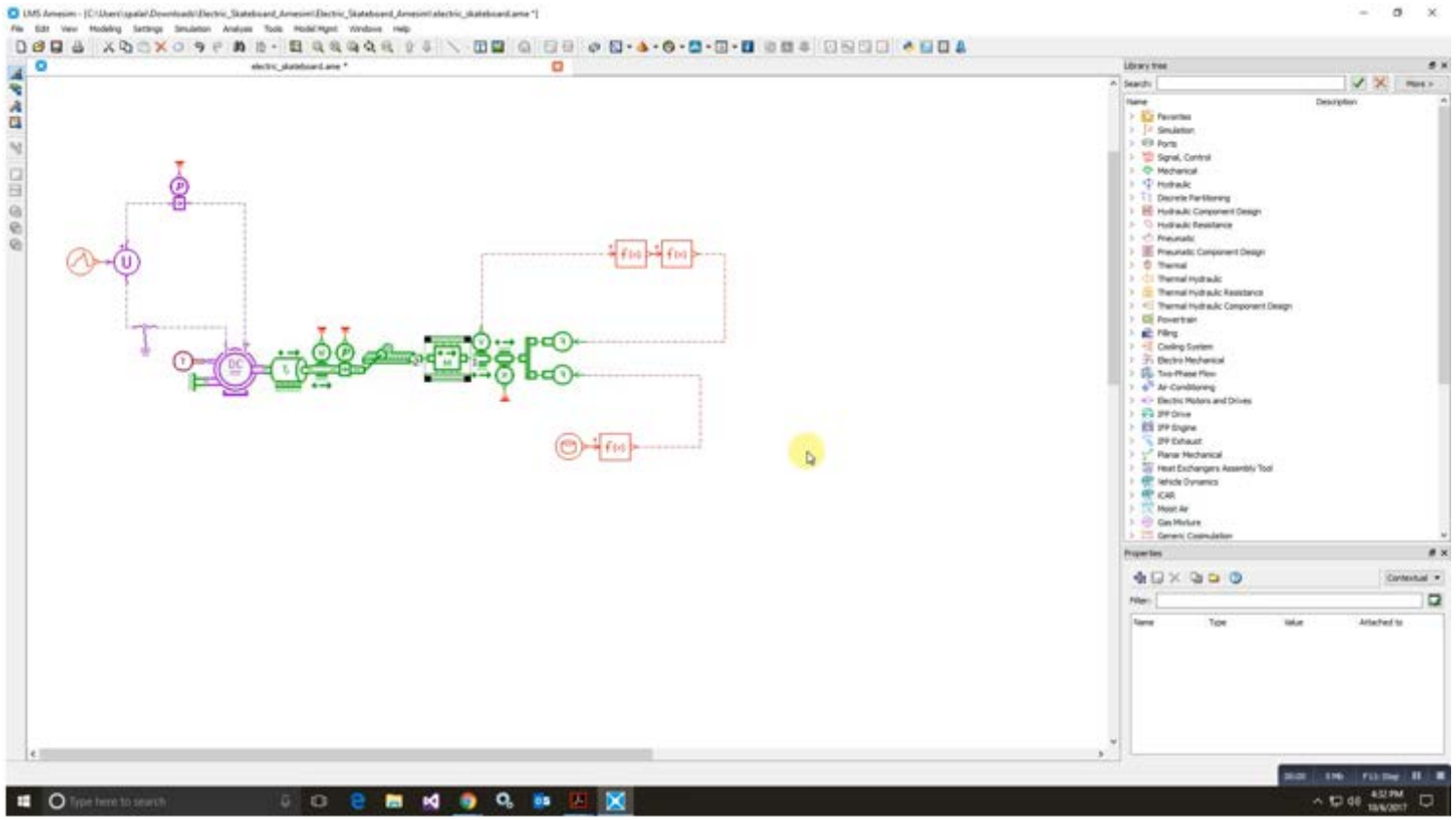


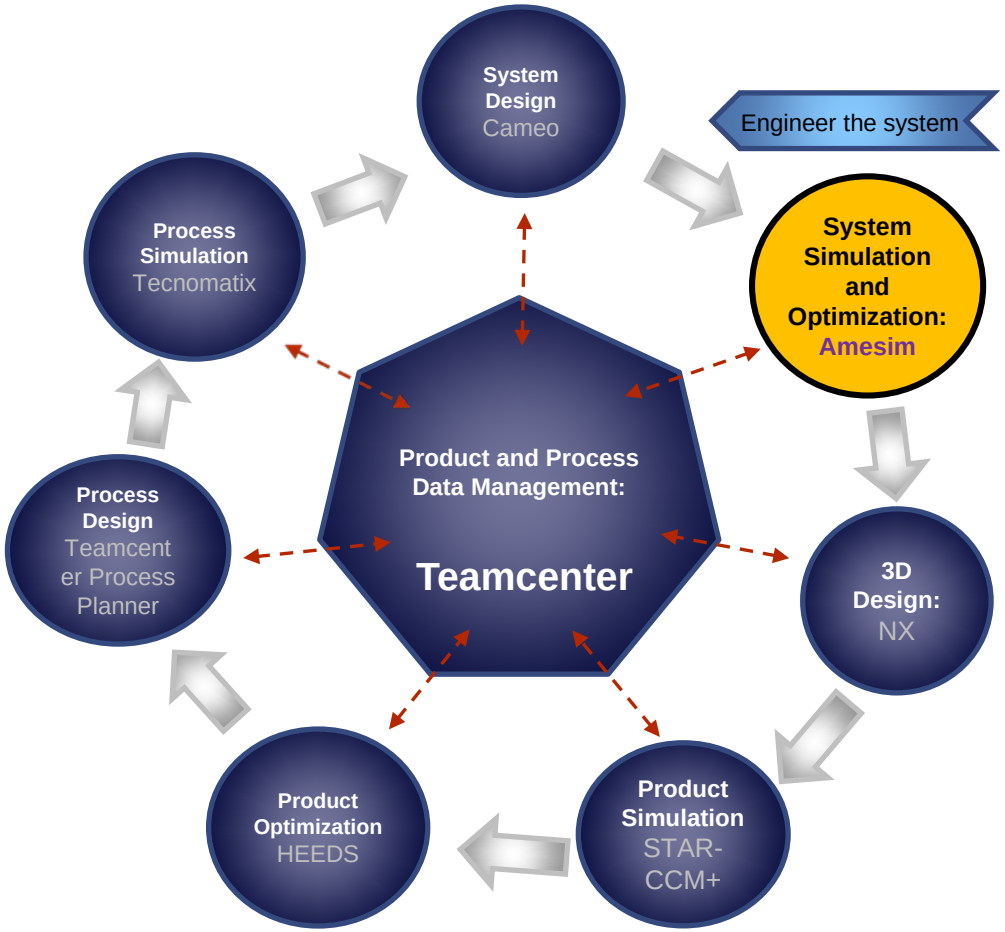
Requirements Traceability in TC Systems Engineering

Systems Driven Product Development – Skateboard

System Simulation and Optimization

LMS Imagine. Lab Amesim:
- Modeling and analysis of multi-domain systems
- Create 1D system simulation
- Graphical representation of the whole system
- Performance plots of the skateboard as the output
- Outputs caused by different user's weight





1D simulation model using Amesim

Systems Driven Product Development – Skateboard

System Simulation and Optimization

LMS Imagine. Lab Amesim:
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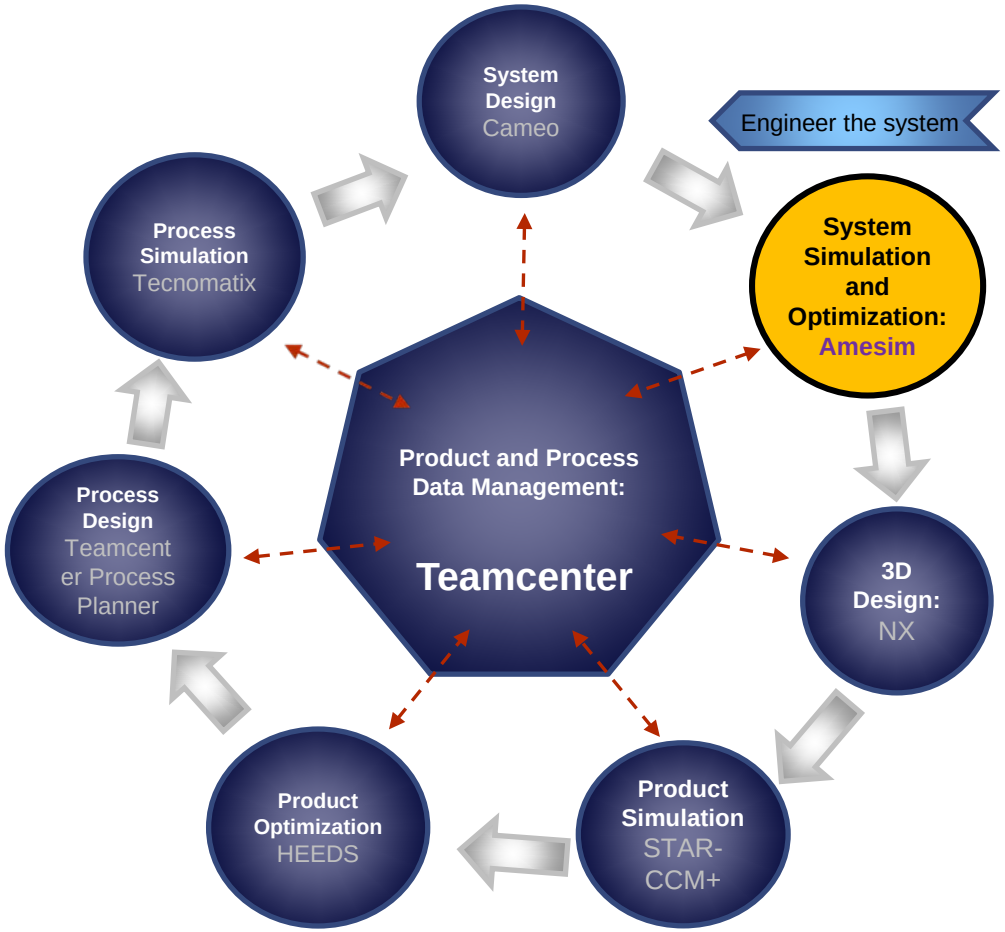


Systems Driven Product Development – Skateboard

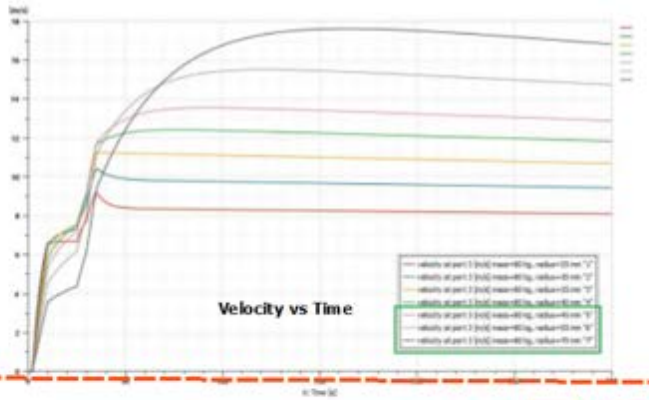
Traceability (cont')

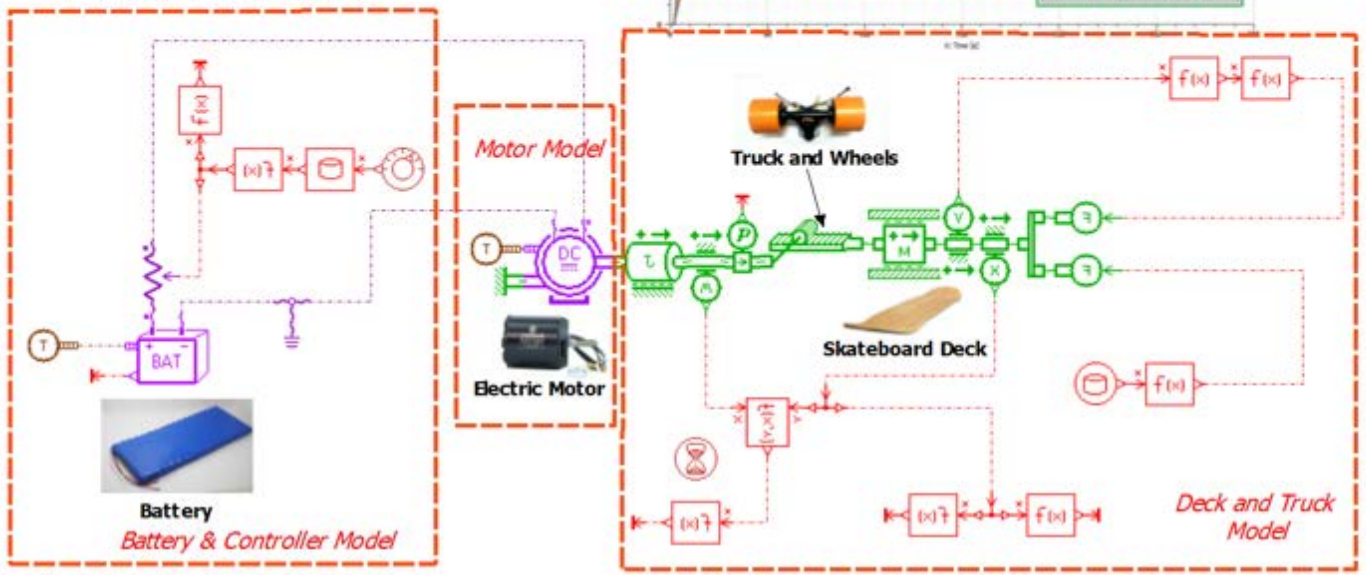
Requirements to be verified:

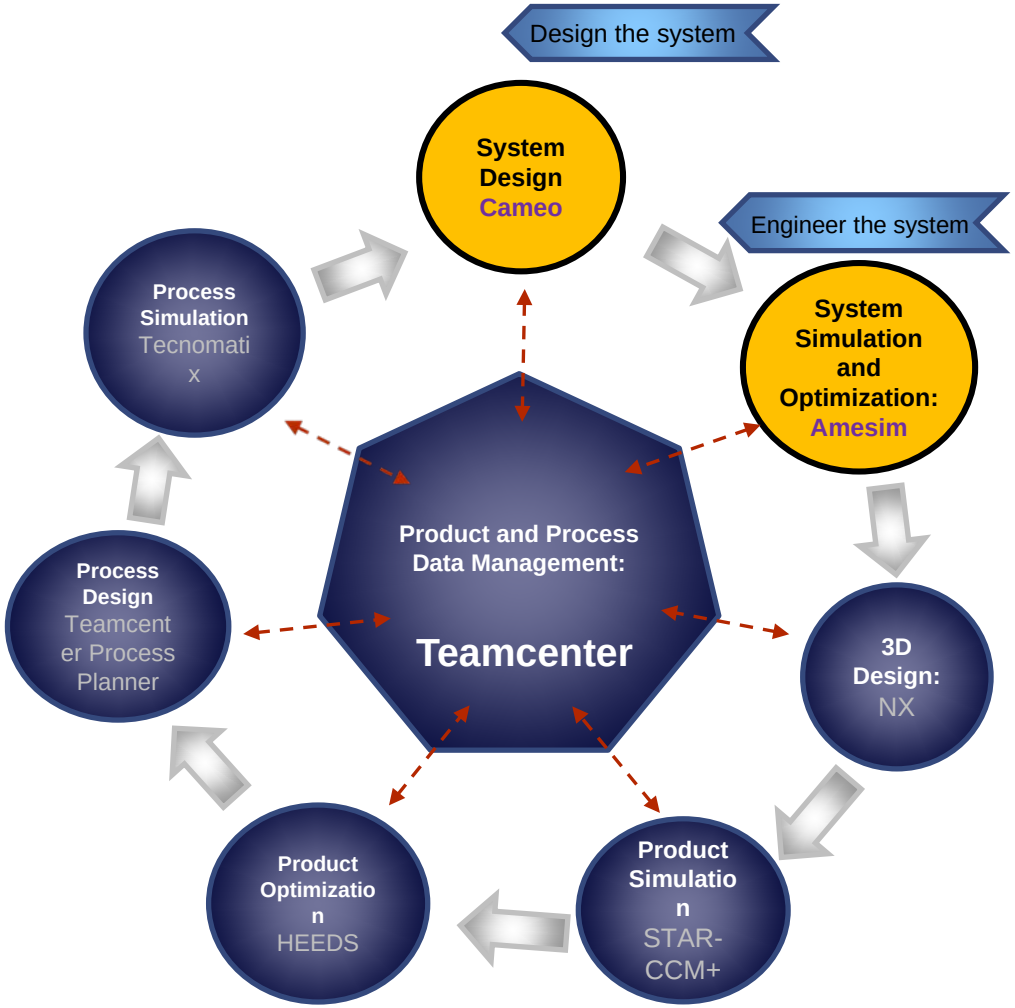
1. The velocity shall be greater than 12 m/s
2. The cost shall be less than $200

Parameters to be varied:

1. Wheel radius
2. Battery size (# of cells)



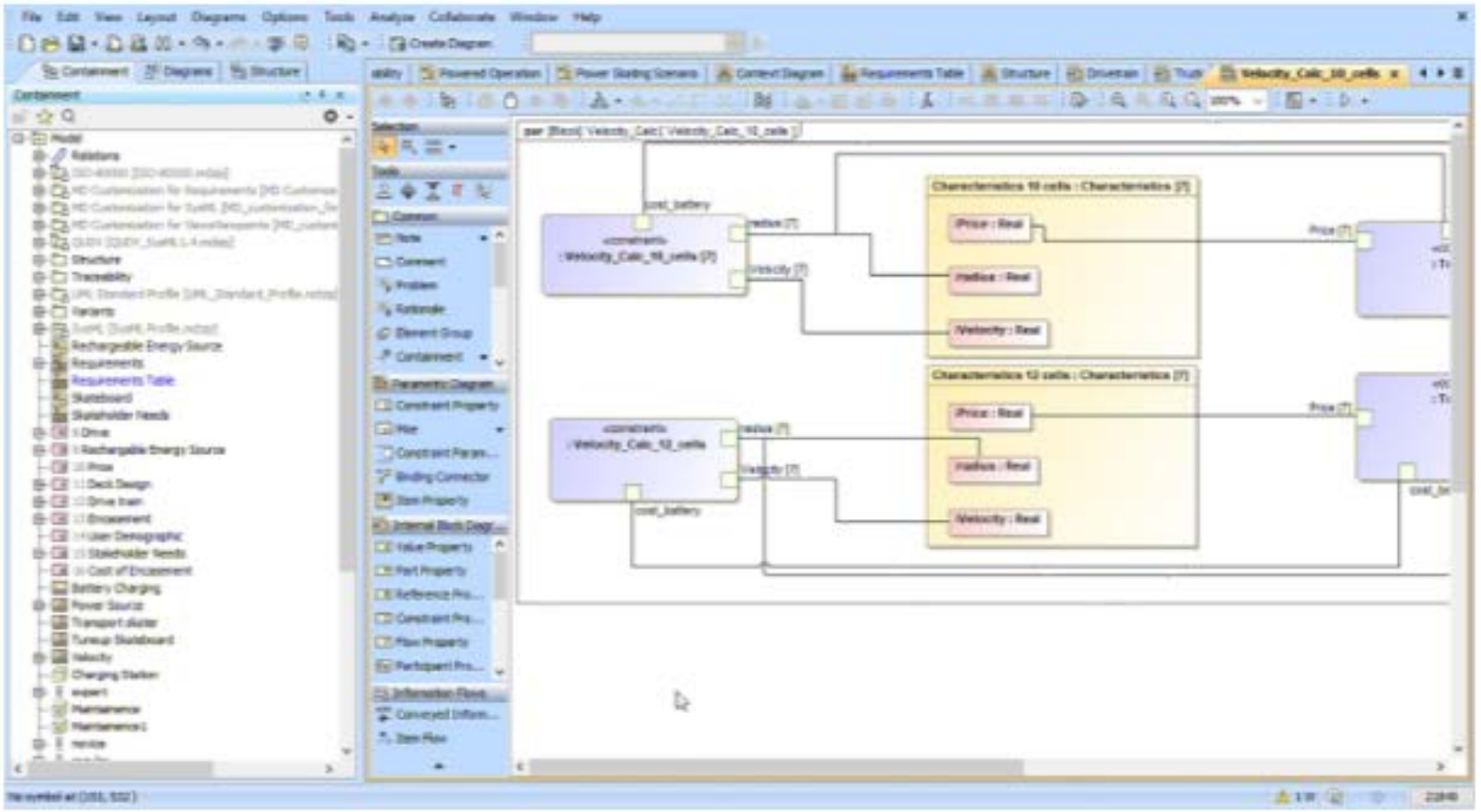


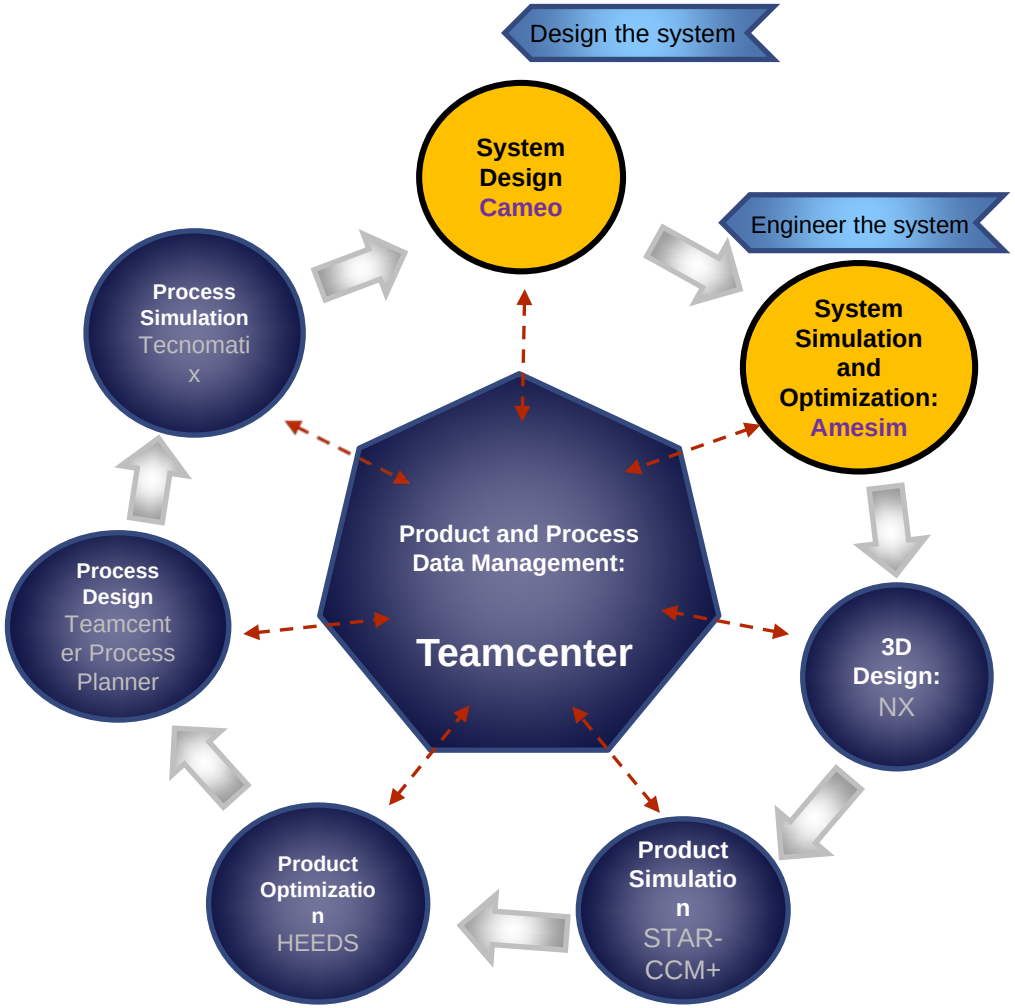


Requirement verification: 1) Maximum velocity; 2) Cost (Prediction using Amesim)

Systems Driven Product Development – Skateboard

Traceability (cont’)



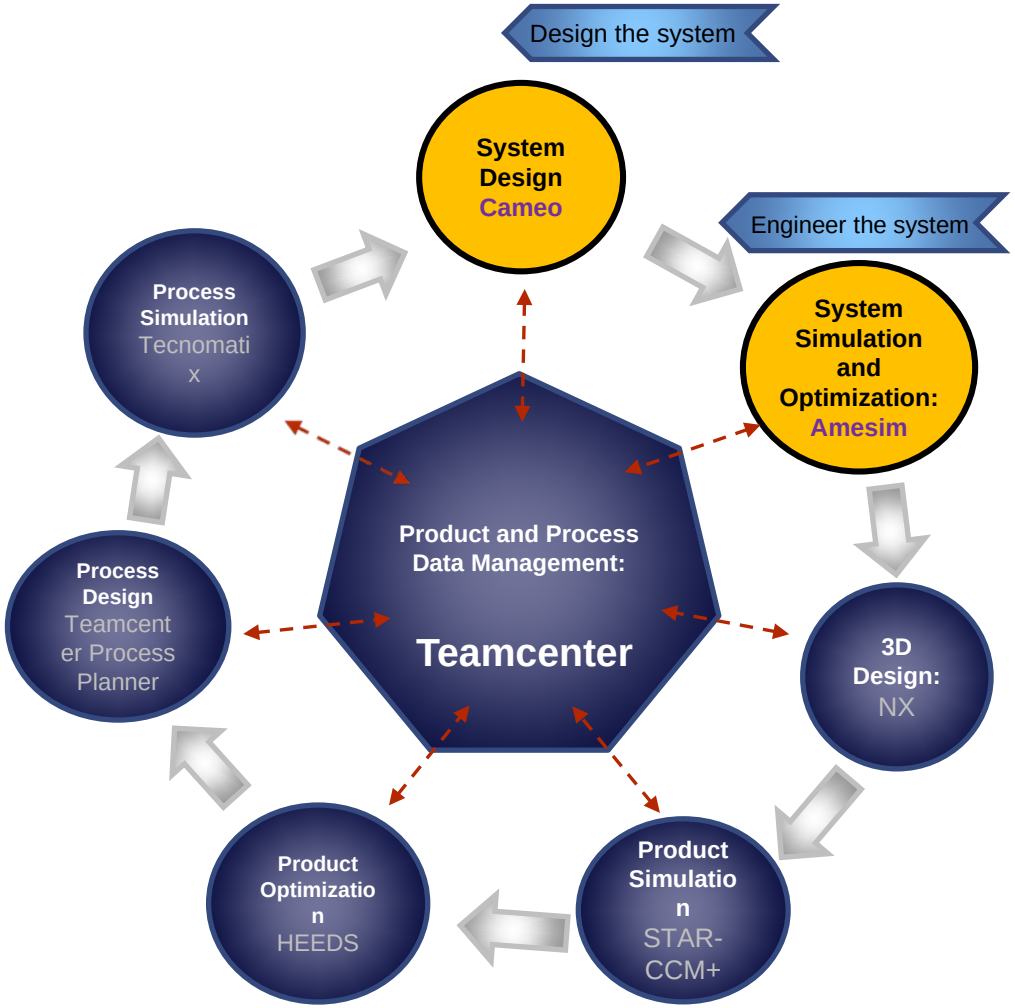


Requirement verification (Amesim – Cameo)

Systems Driven Product Development – Skateboard

Traceability

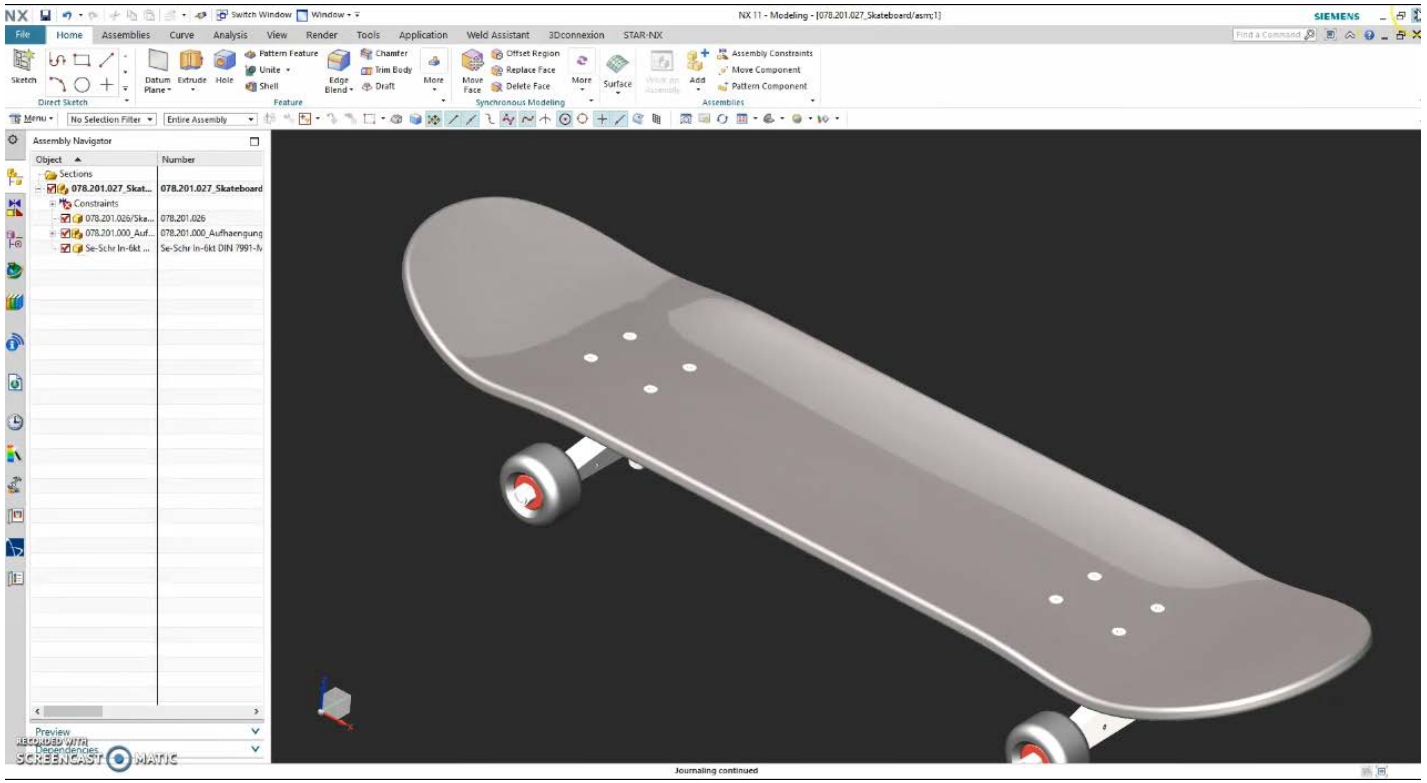
VIDEO – To be added

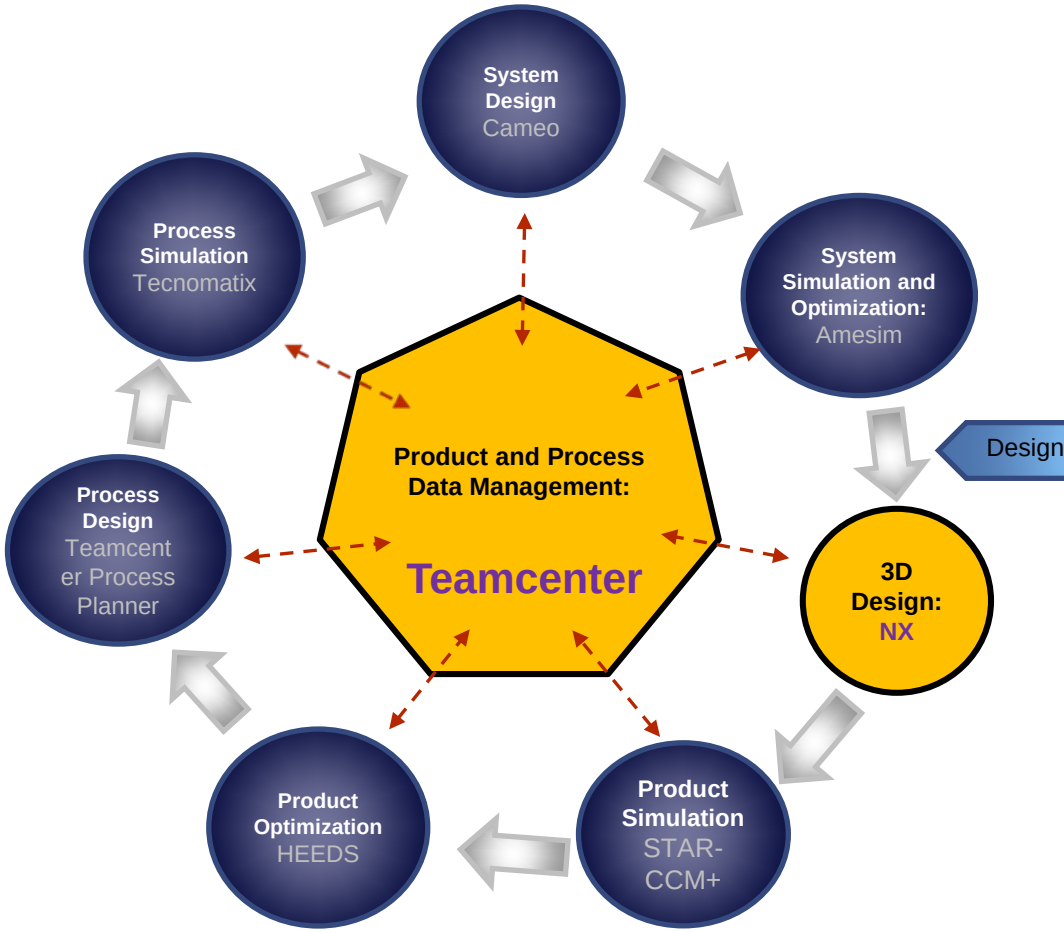


Systems Driven Product Development – Skateboard

3D Design

NX:
- Design and Modelling
- Board is to be modeled





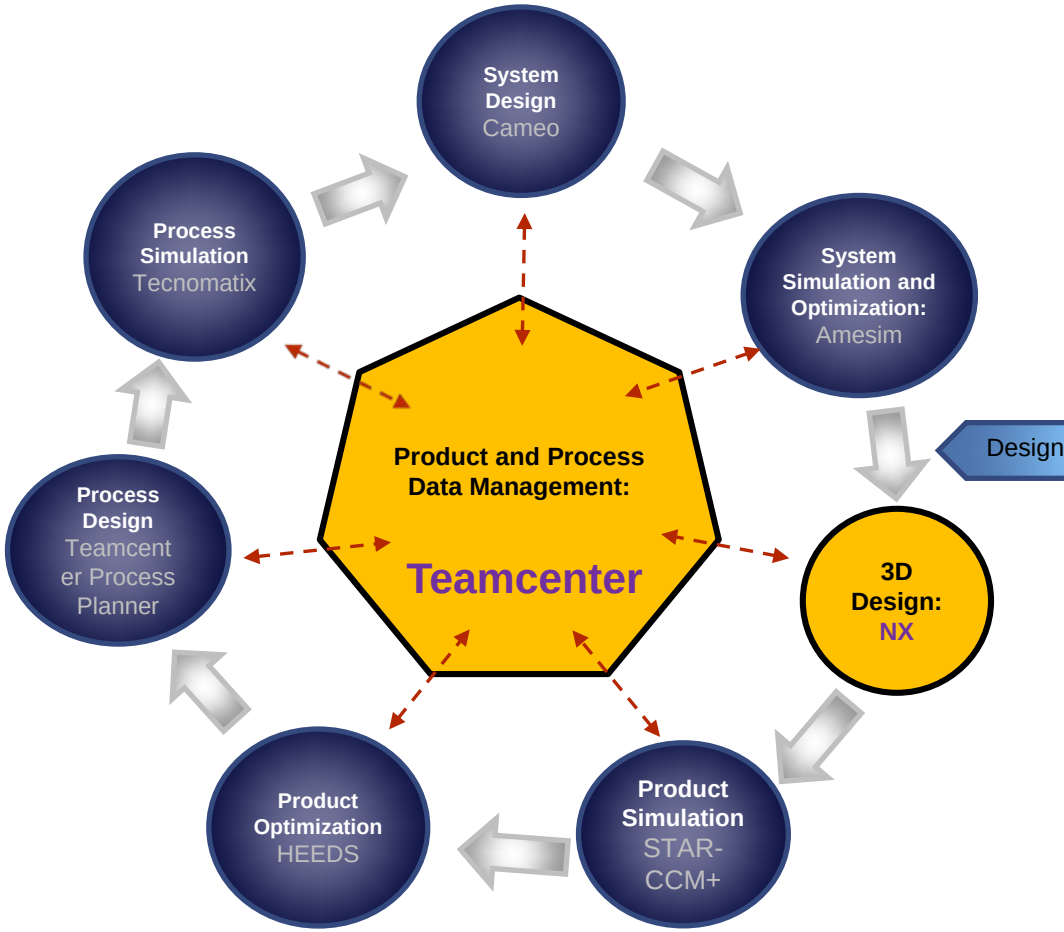
3D modeling of skateboard using NX

Systems Driven Product Development – Skateboard

3D Design

NX:
- Design and Modelling
- Board is to be modeled

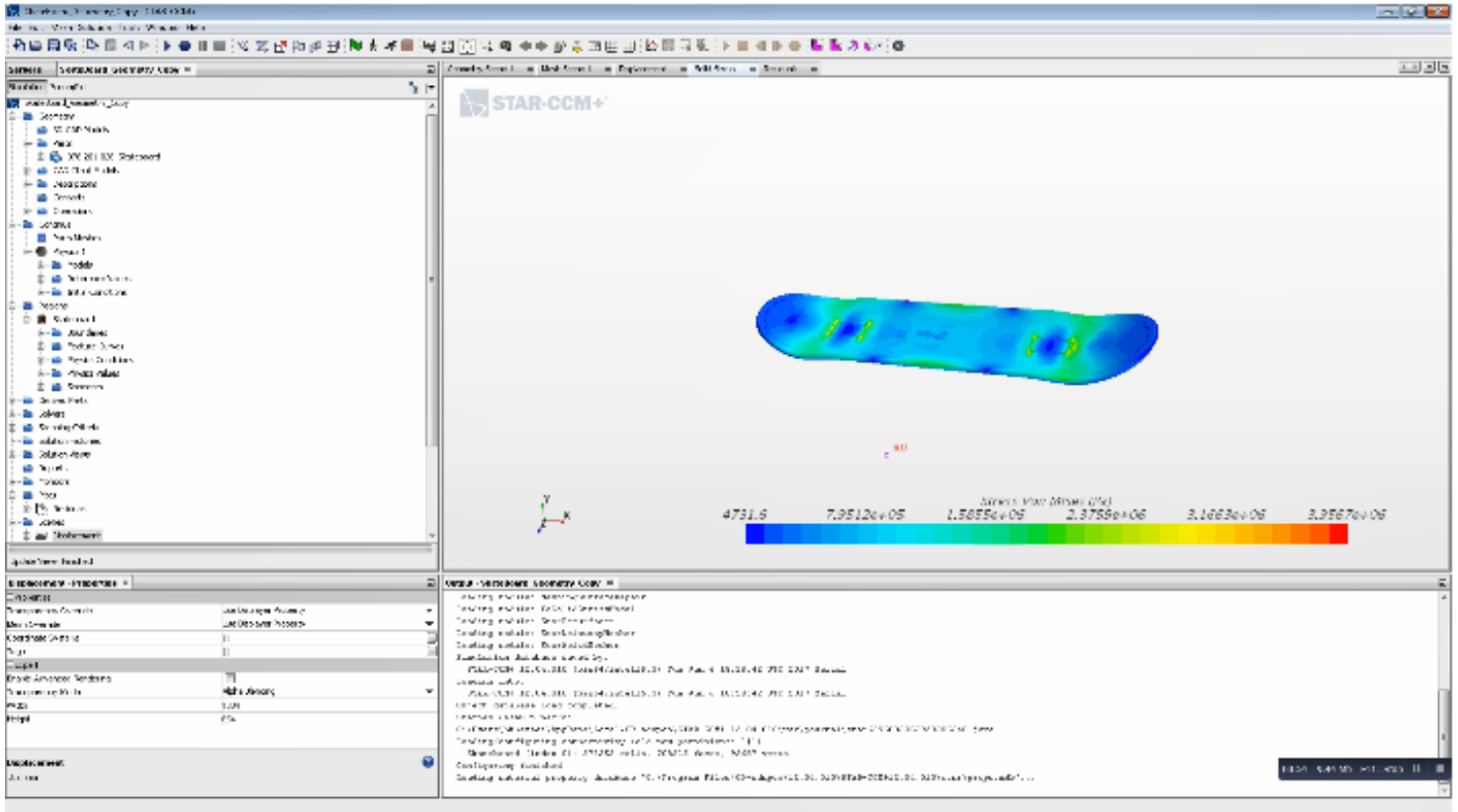
VIDEO – To be added

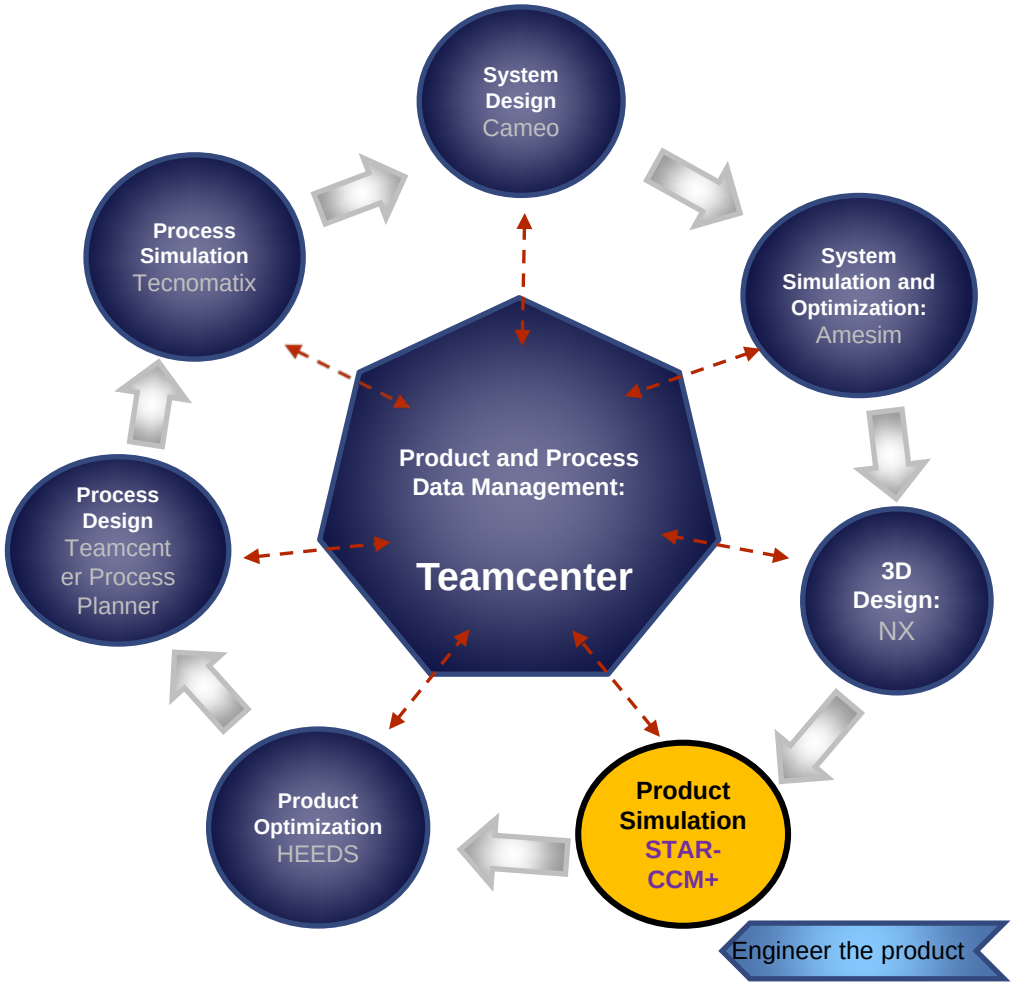


Systems Driven Product Development – Skateboard

Product Simulation

Star-CCM+:
- CFD and Structural analysis
- The structural analysis of the board with static loads 200 lb.
- Von-Mises stress and displacement of the board





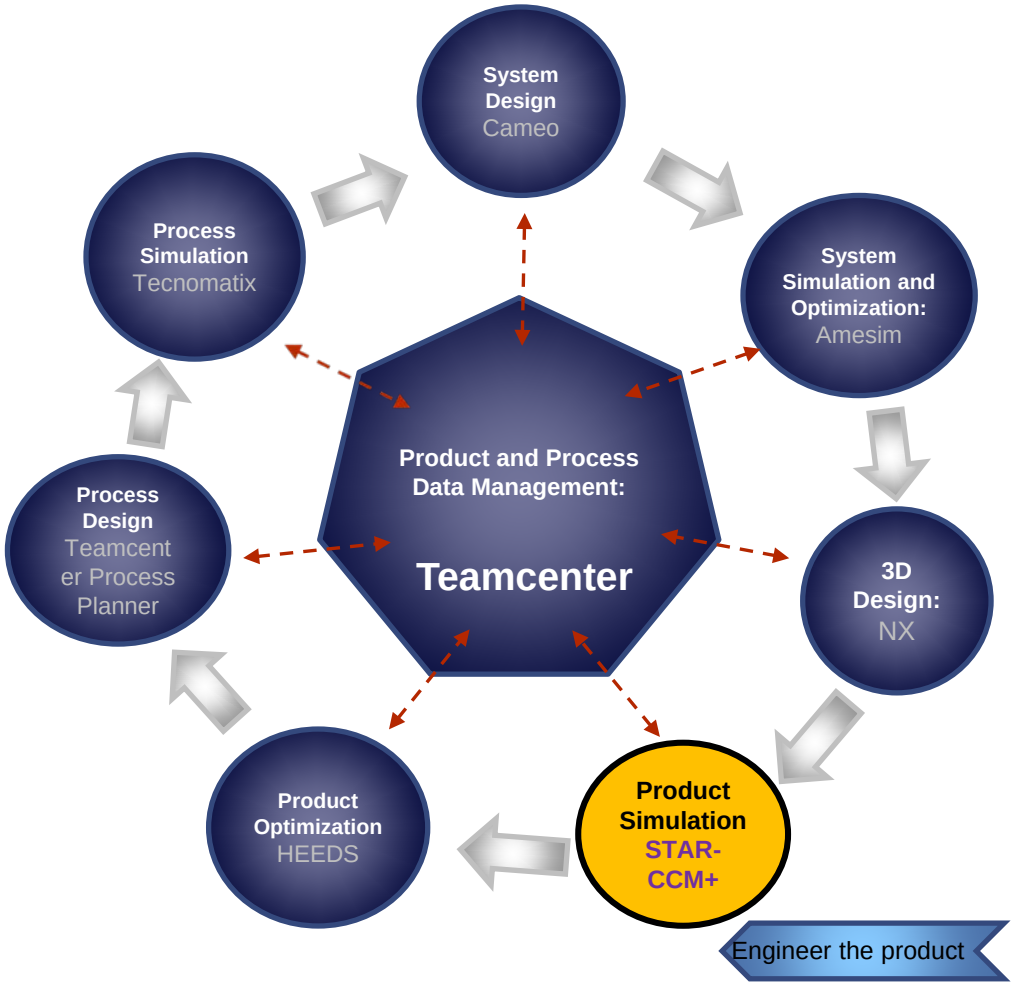
FE structural analysis of skateboard deack using Simcenter Nastran

Systems Driven Product Development – Skateboard

Product Simulation

Star-CCM+:
- CFD and Structural analysis
- The structural analysis of the board with static loads 200 lb.
- Von-Mises stress and displacement of the board

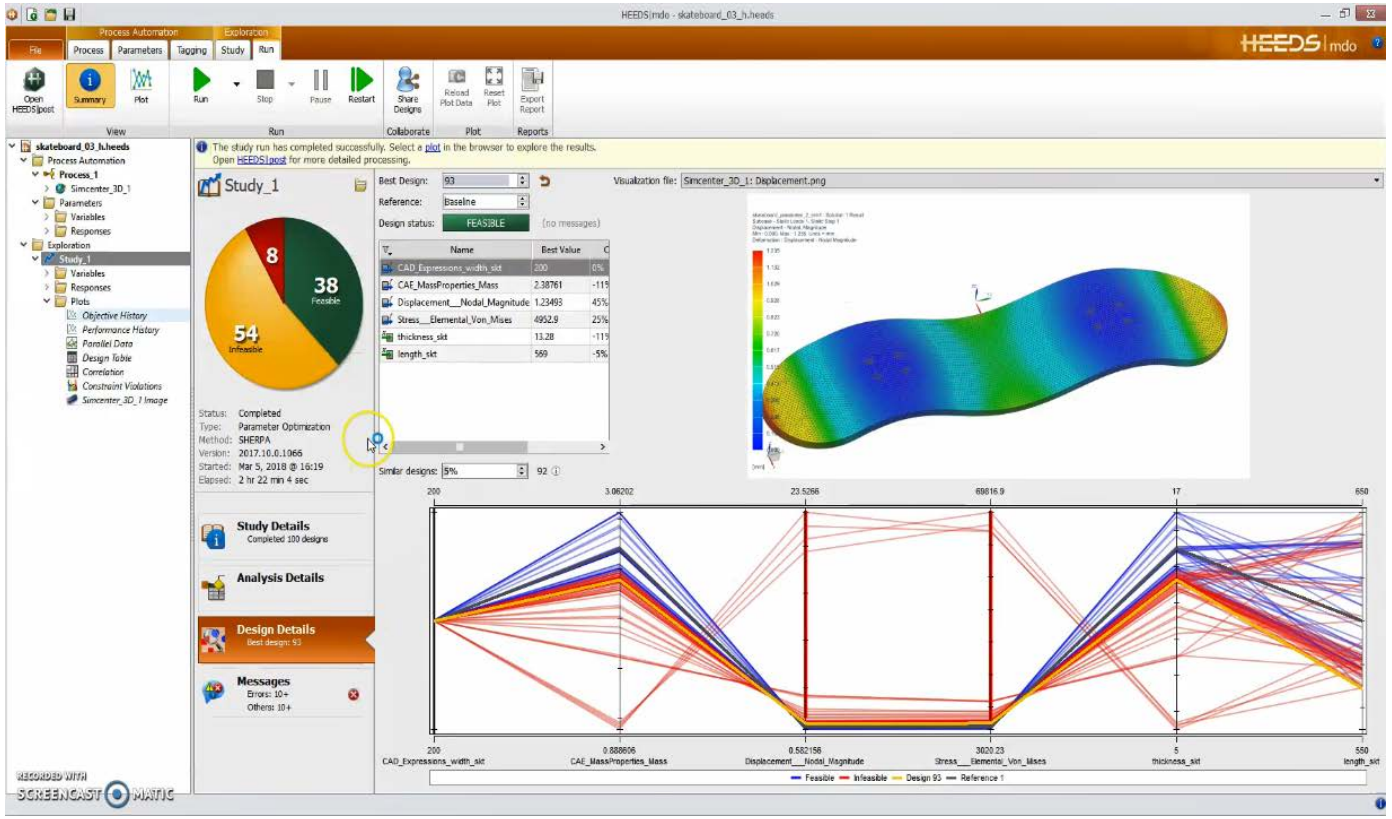
VIDEO – To be added

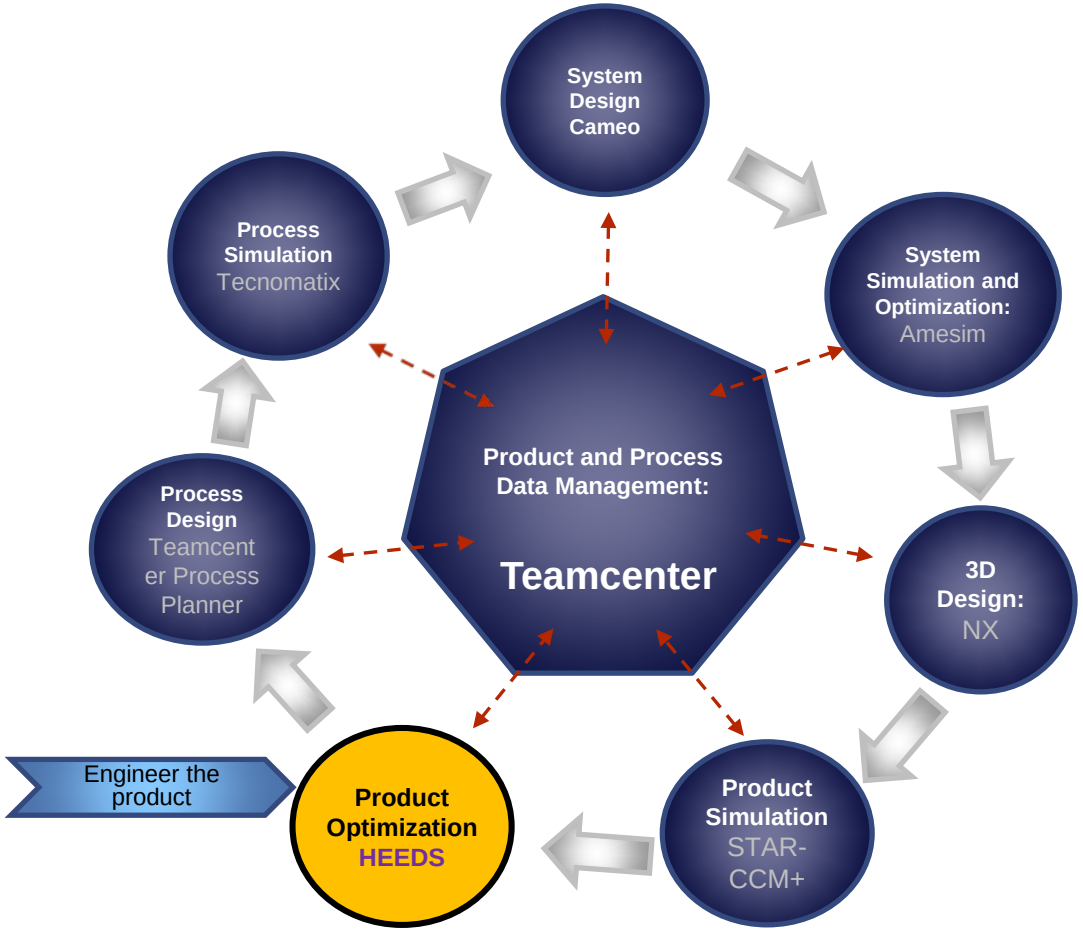


Systems Driven Product Development – Skateboard

Product Optimization

HEEDS (Hierarchical Evolutionary Engineering Design System):
- Optimization for better and more robust solutions within a given design space and reduce design time





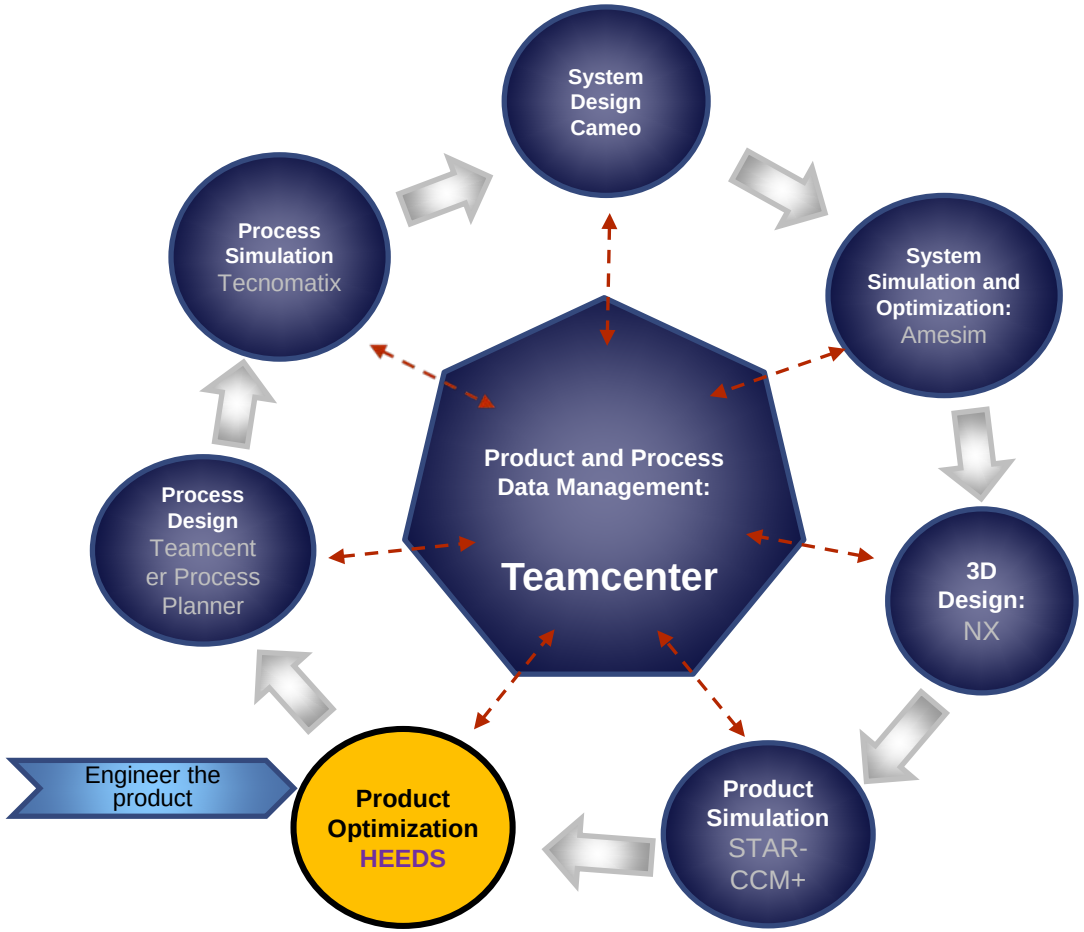
Optimization of skateboard deck using HEEDS

Systems Driven Product Development – Skateboard

Product Optimization

HEEDS (Hierarchical Evolutionary Engineering Design System):
- Optimization for better and more robust solutions within a given design space and reduce design time

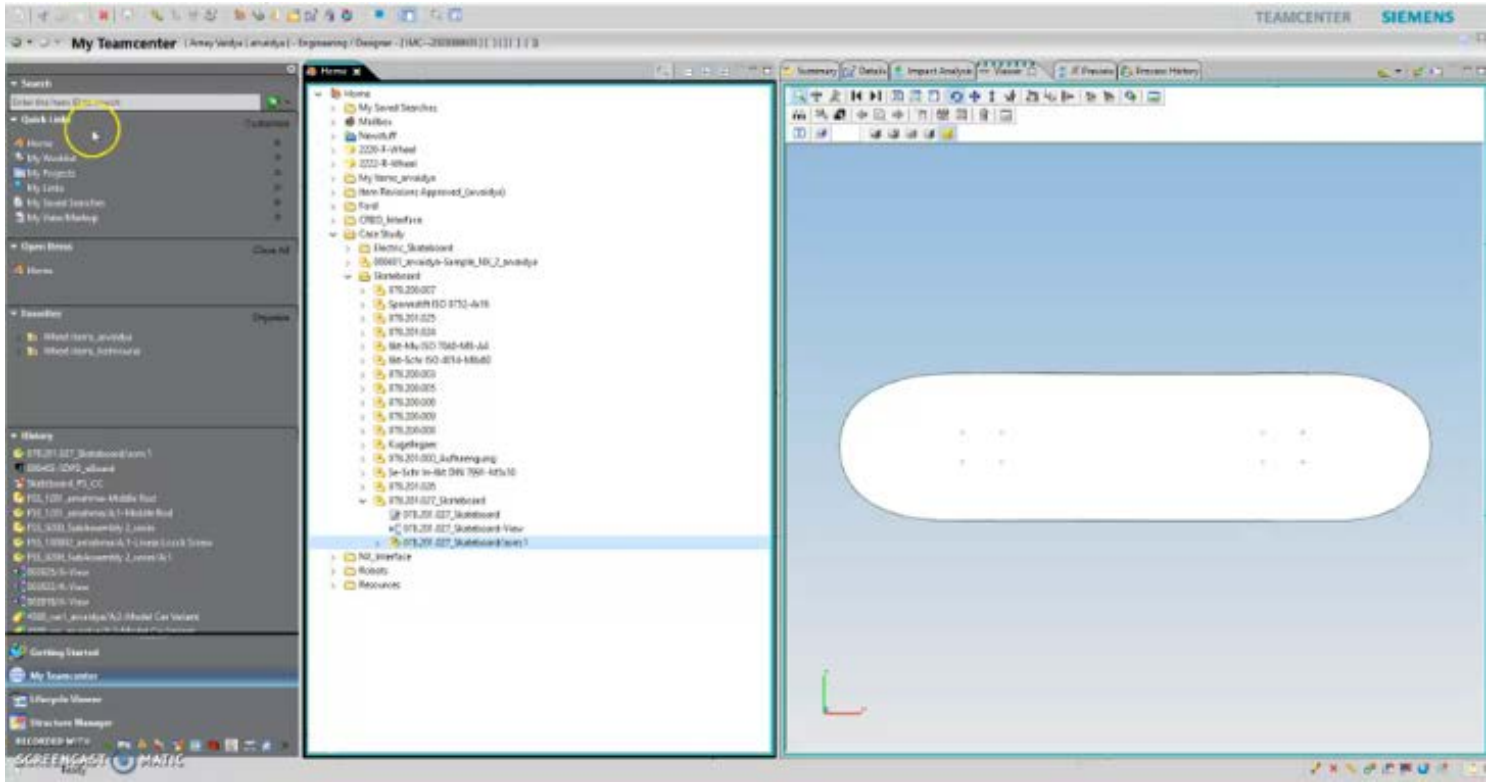
VIDEO – To be added

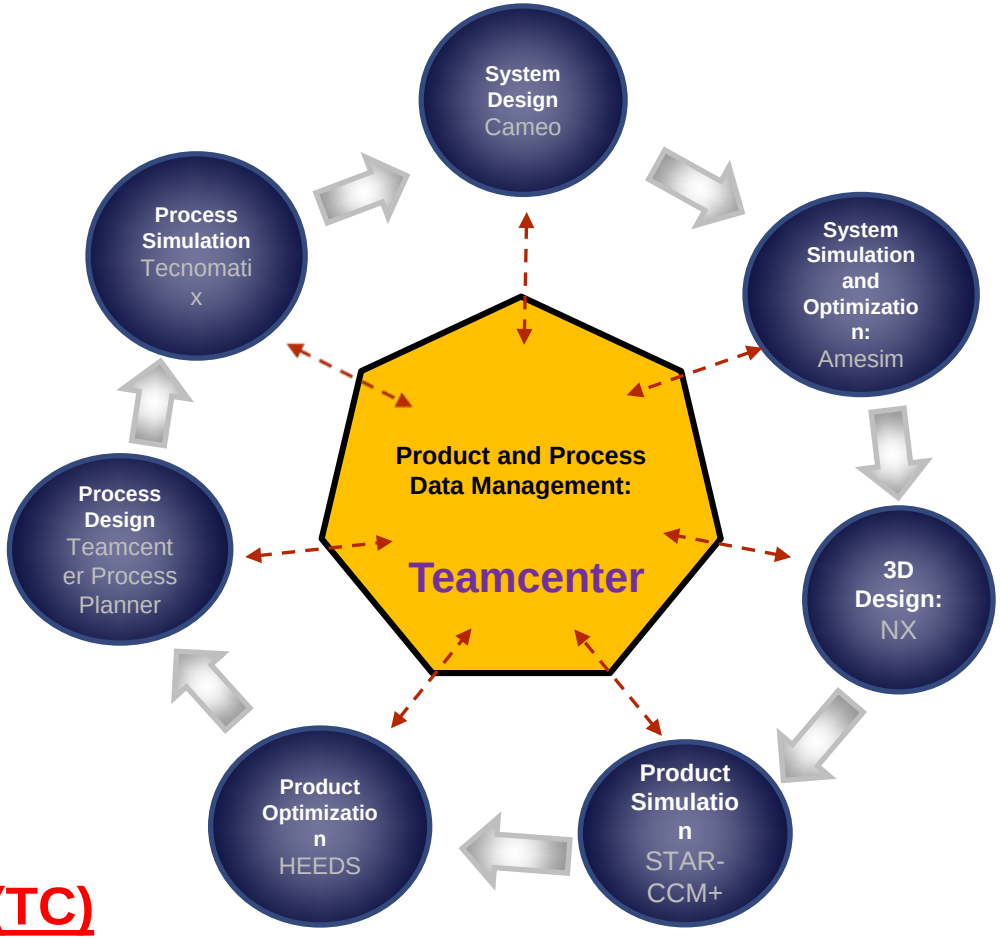


Systems Driven Product Development – Skateboard

Product and Process Data Management

Centralized storage and overall product flow management in Teamcenter





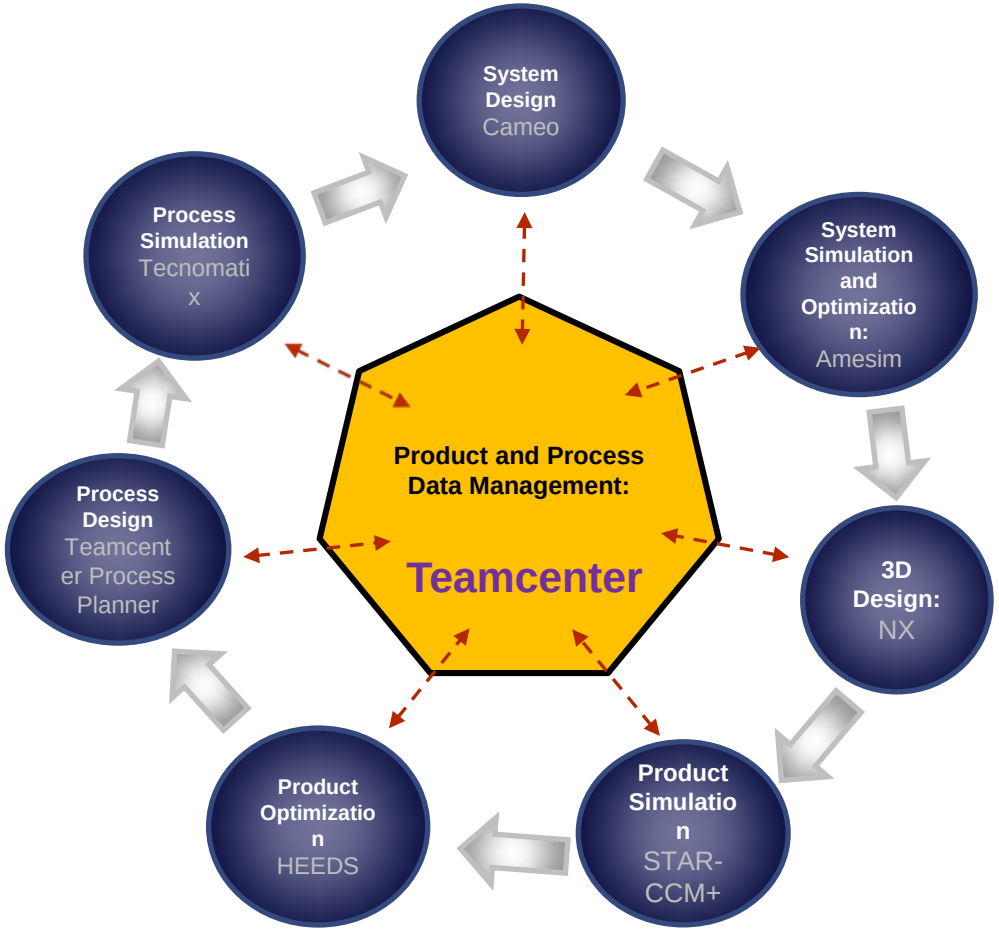
Product and Process Data Management using Teamcenter (TC)

Systems Driven Product Development – Skateboard

Product and Process Data Management

Centralized storage and overall product flow management in Teamcenter

VIDEO – To be added

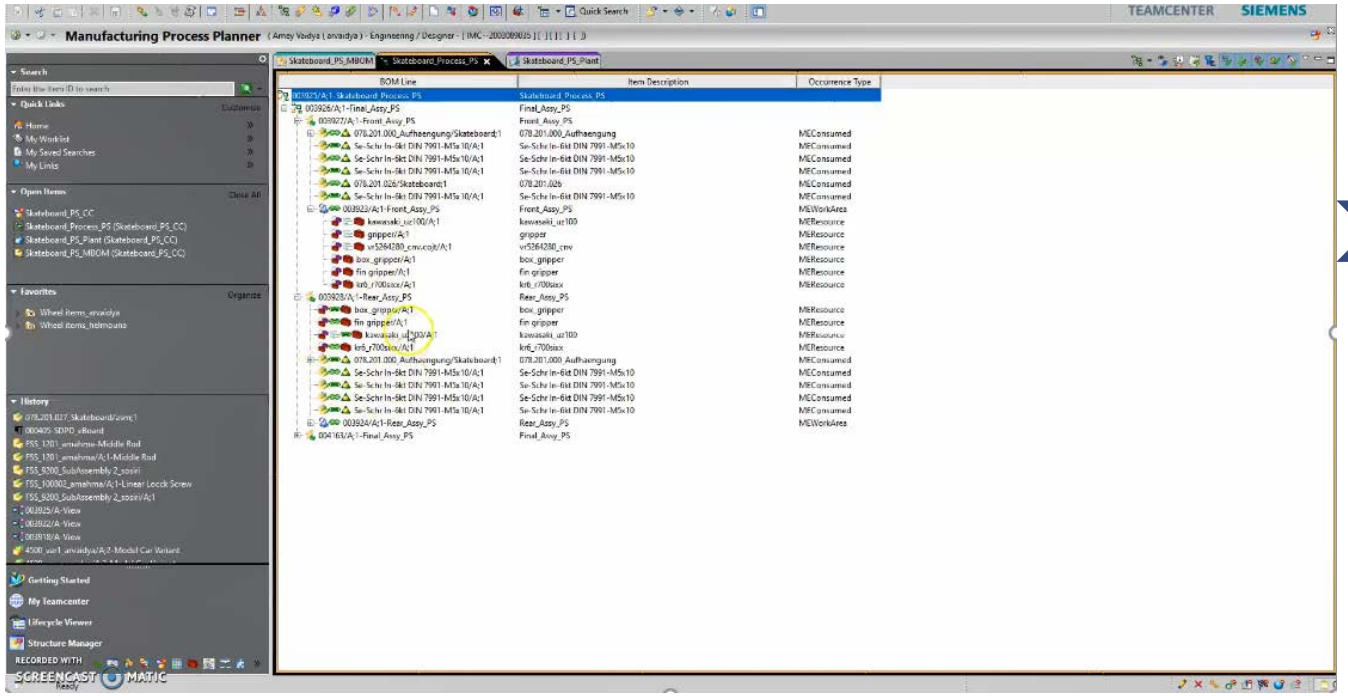


Product and Process Data Management using Teamcenter (TC)

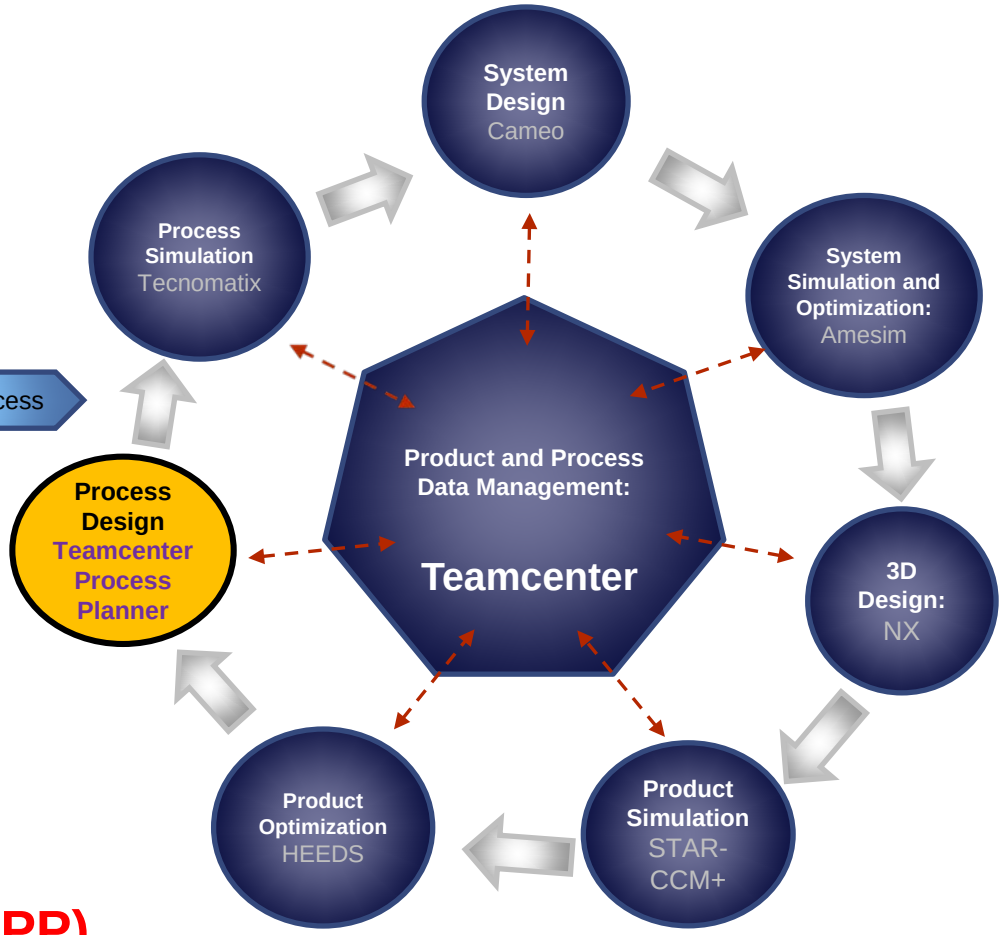
Systems Driven Product Development – Skateboard

Manufacturing Process Design

Teamcenter Manufacturing Process Planner (MPP):
- Product Lifecycle Management (PLM)
- Develop product and manufacturing process
- Manage manufacturing data, process, resource and plant information
- Seamless alignment between engineering bill of materials (BOM), manufacturing BOM and the manufacturing bill of process (BOP)



Plan the process



Process design using TC Manufacturing process planner (MPP)

Systems Driven Product Development – Skateboard

Manufacturing Process Design

Teamcenter Manufacturing Process Planner (MPP):
- Product Lifecycle Management (PLM)
- Develop product and manufacturing process
- Manage manufacturing data, process, resource and plant information
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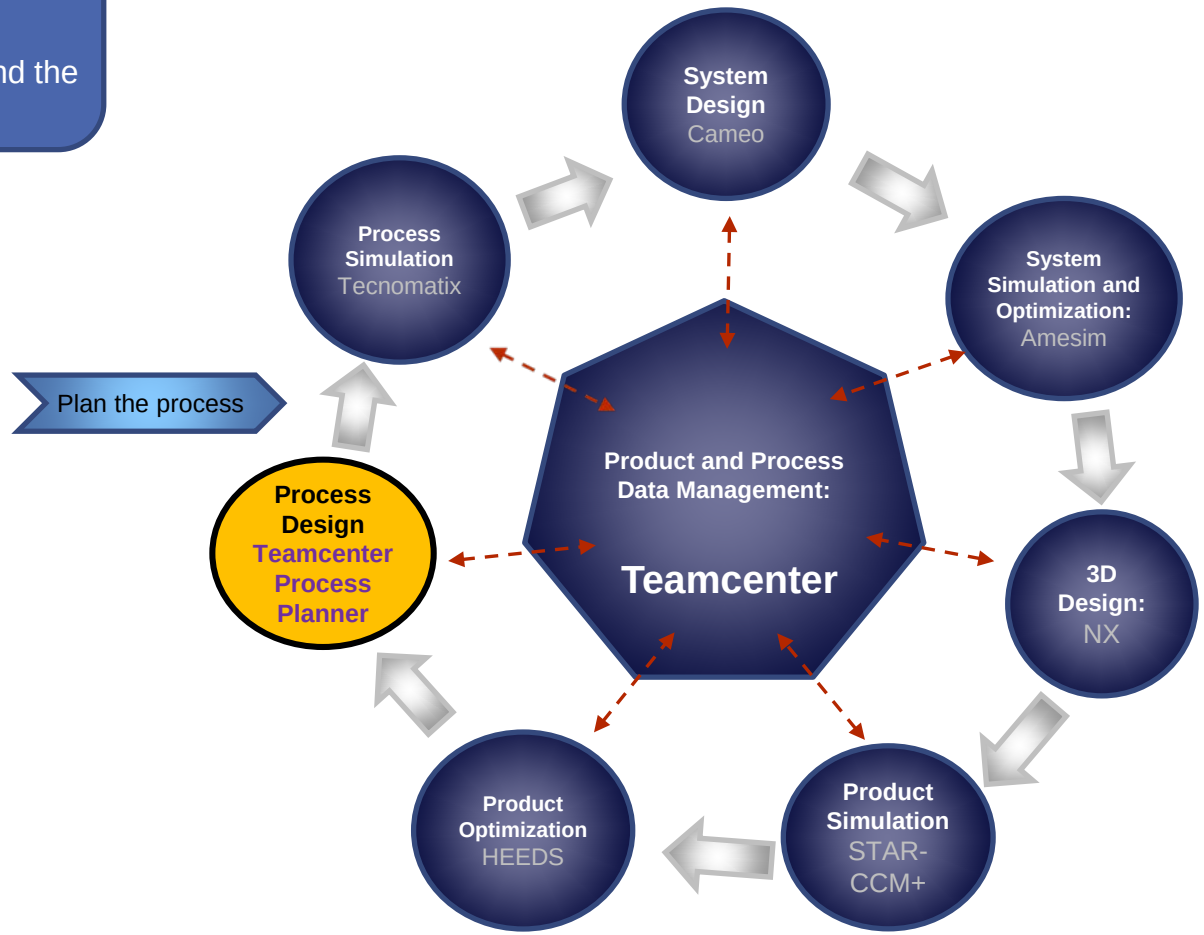
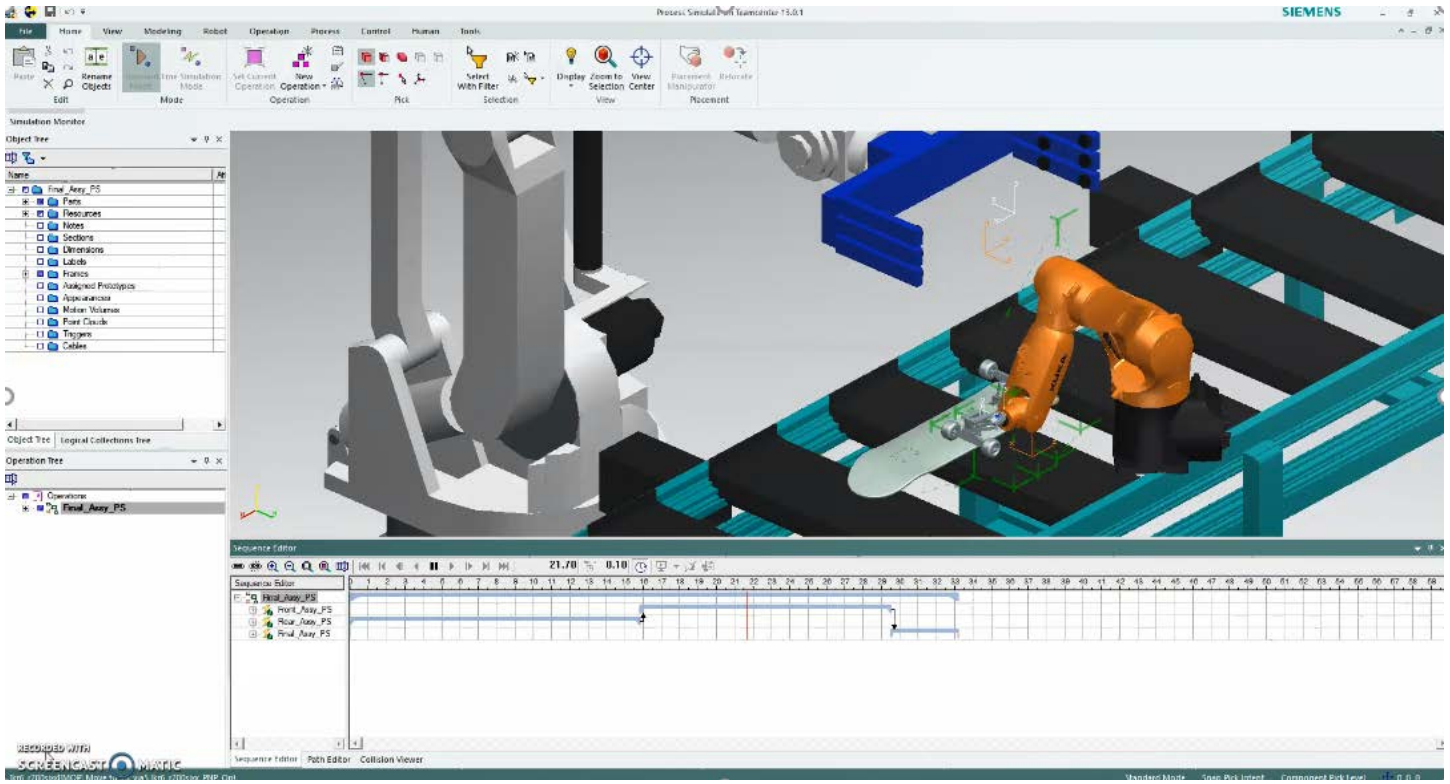
VIDEO – To be added

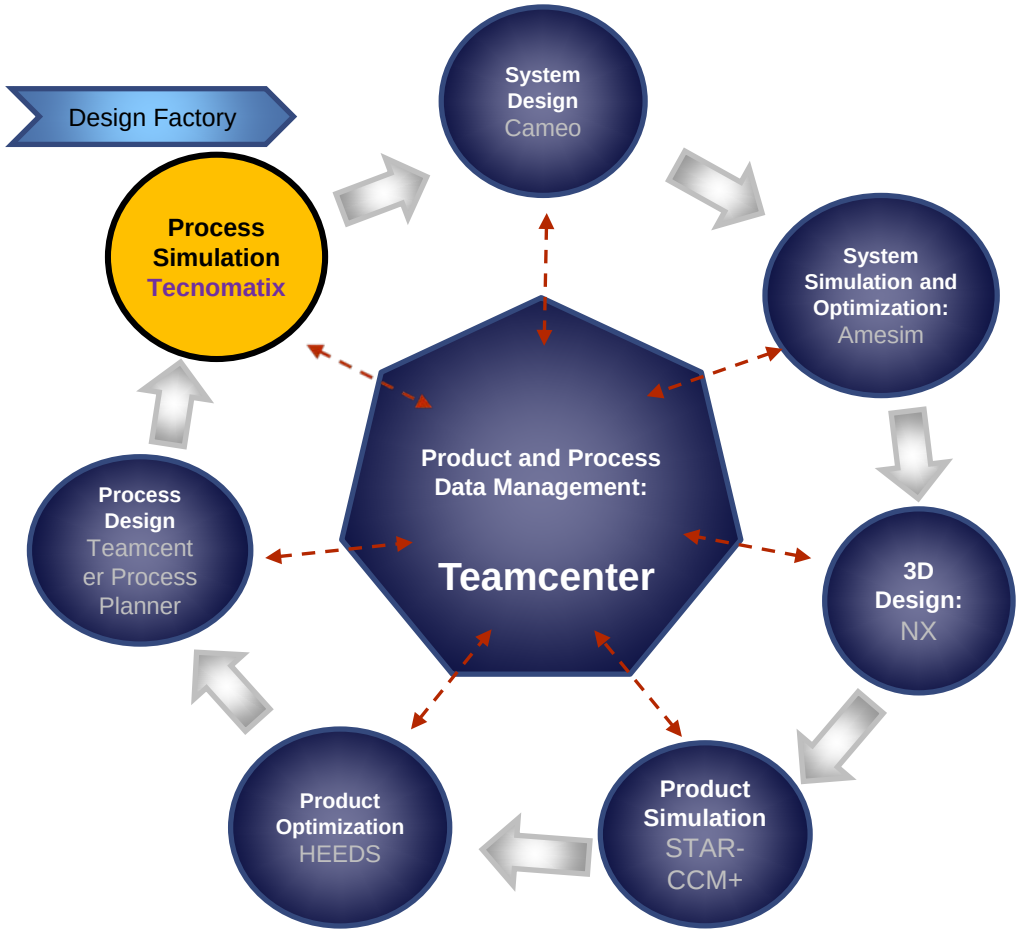


Systems Driven Product Development – Skateboard

Manufacturing Process Simulation

Tecnomatix Plant Simulation:
- Simulation and optimization of production systems and processes
- Taking skateboard through production
- Virtual validation, optimization and commissioning of complex manufacturing processes
- Verify reachability and collision clearance
- Simulating the full assembly sequence of the product and the required tools





Process Simulation using Tecnomatix

Systems Driven Product Development – Skateboard

Manufacturing Process Simulation

Tecnomatix Plant Simulation:
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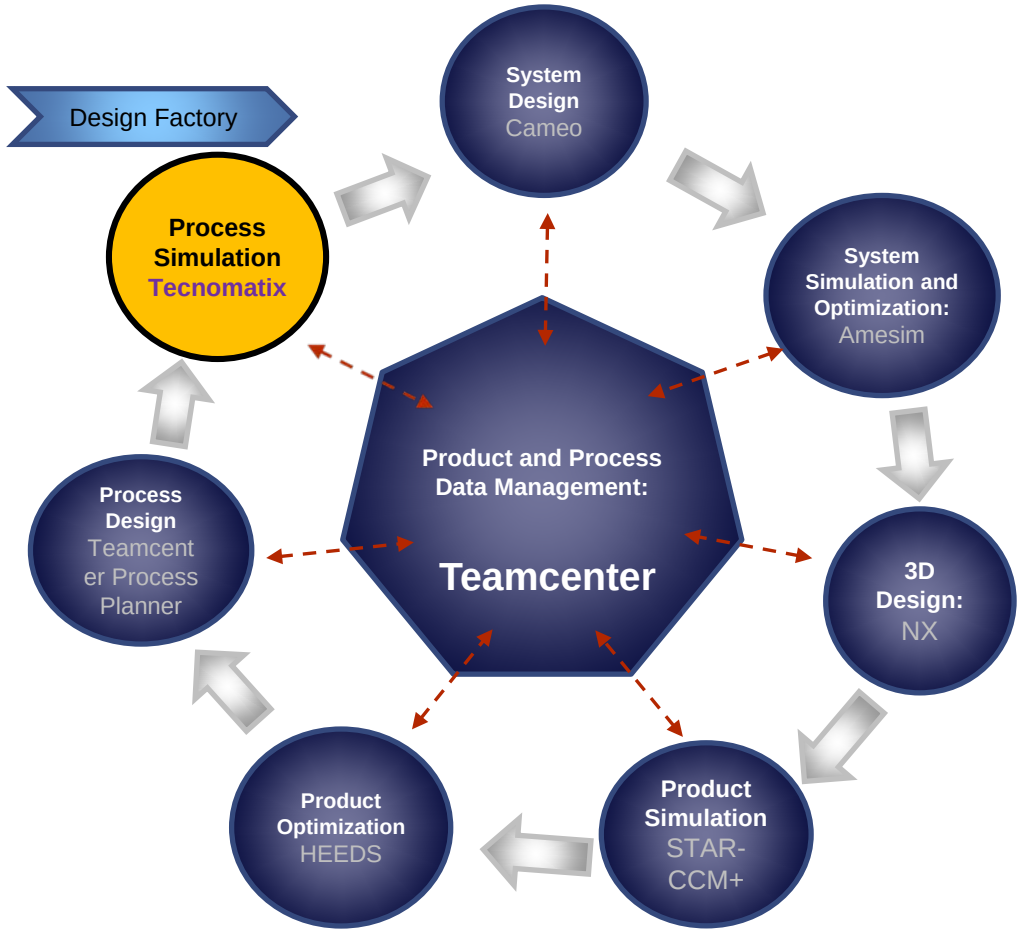
VIDEO – To be added



Process Simulation using Tecnomatix

Systems Driven Product Development – Skateboard

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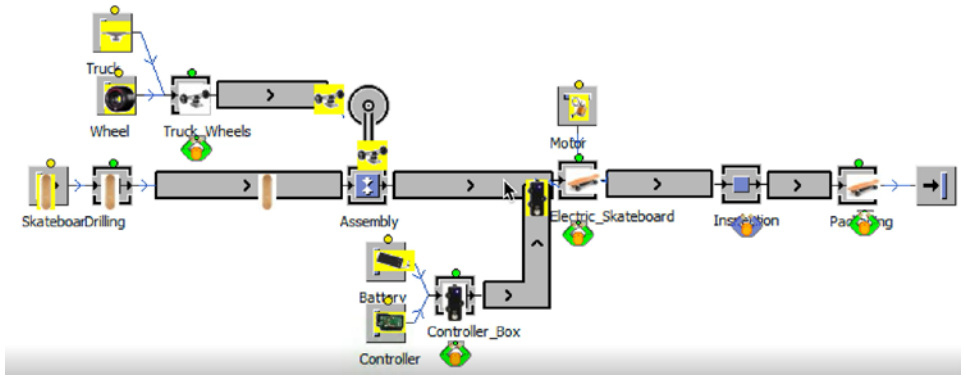
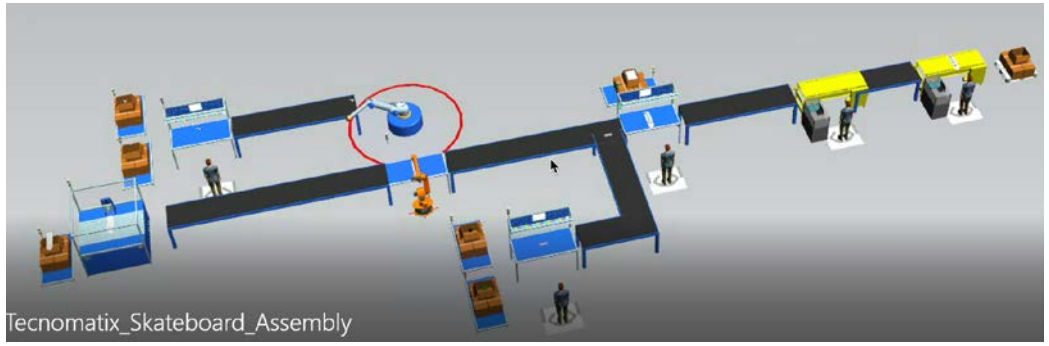
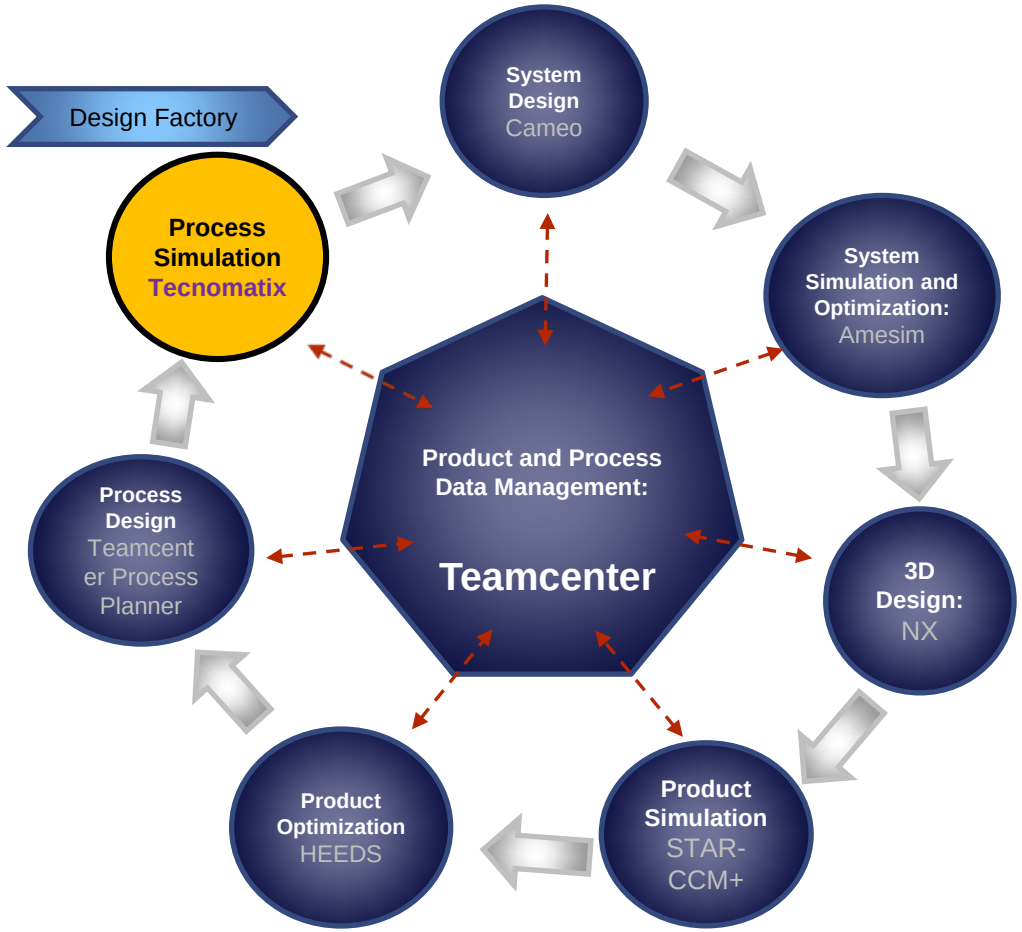


2D



3D



Plant Simulation using Tecnomatix

Systems Driven Product Development – Skateboard

Manufacturing Process Simulation

Tecnomatix Plant Simulation:
- Simulation and optimization of production systems and processes
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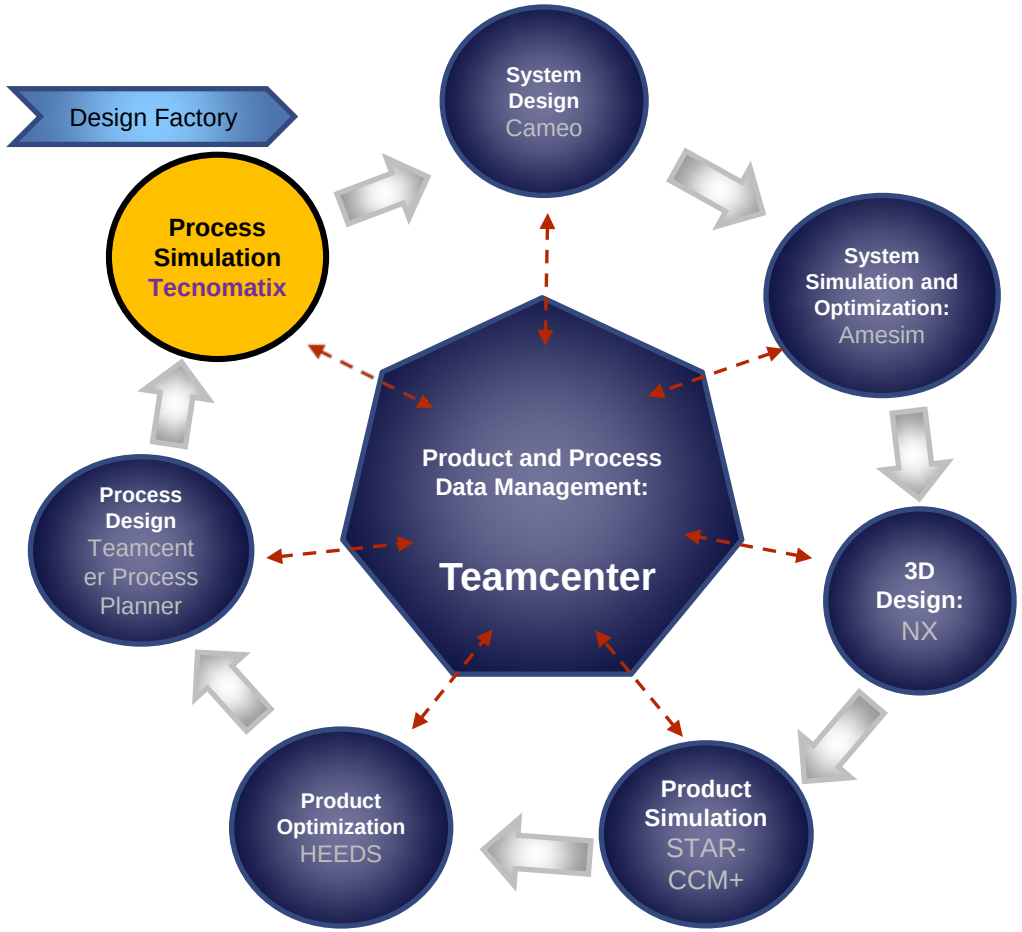
VIDEO – To be added



Plant Simulation using Tecnomatix (2D)

Systems Driven Product Development – Skateboard

Manufacturing Process Simulation

Tecnomatix Plant Simulation:
- Simulation and optimization of production systems and processes
- Taking skateboard through production
- Virtual validation, optimization and commissioning of complex manufacturing processes
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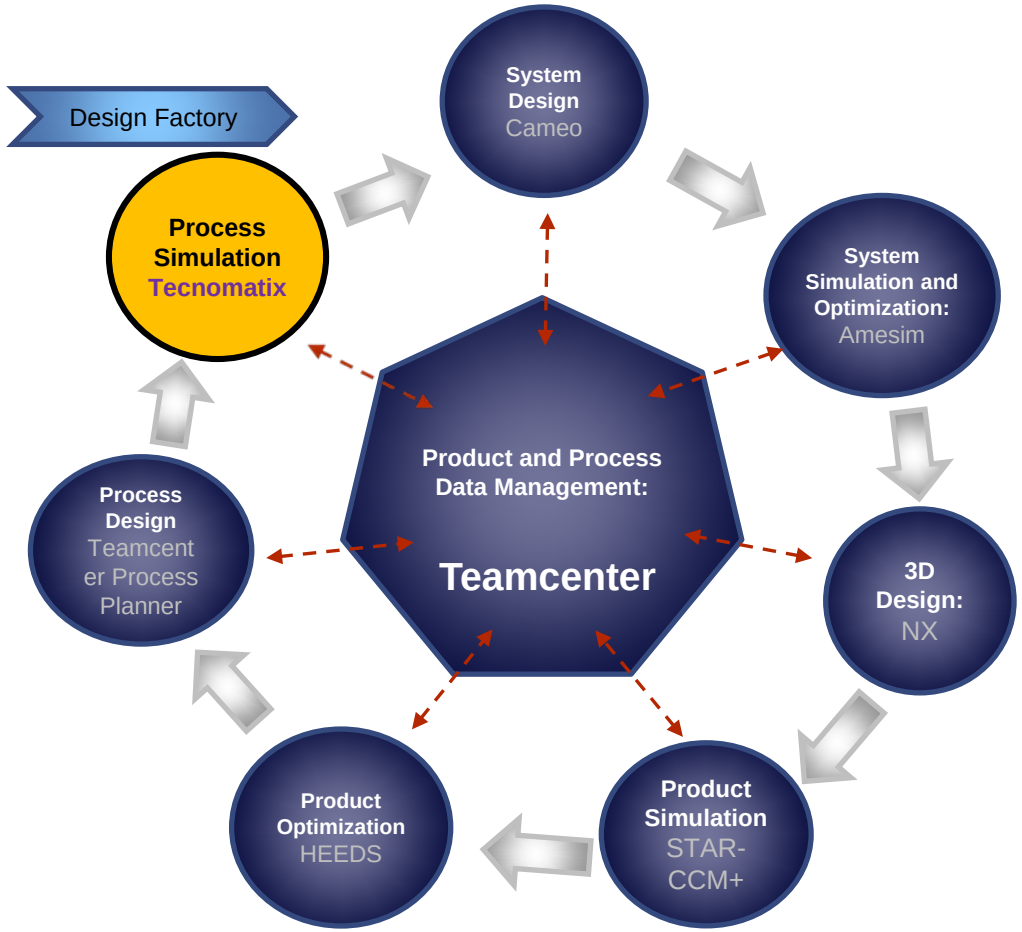
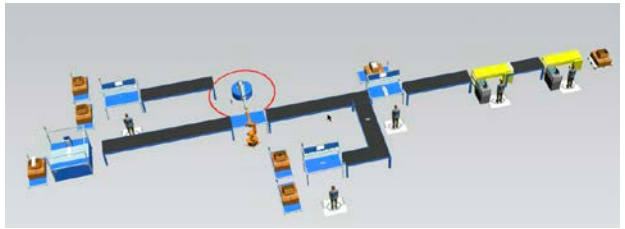
VIDEO – To be added

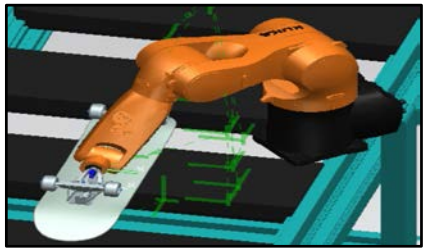


Plant Simulation using Tecnomatix (3D)

VIDEO

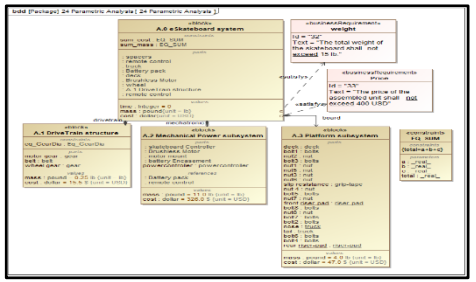
Systems Driven Product Development of Electric Skateboard: SUMMARY





Design Factory

Design the system

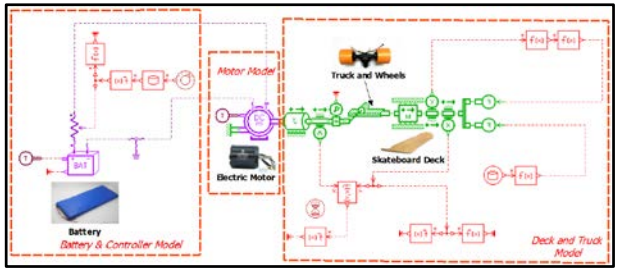


System Design Cameo

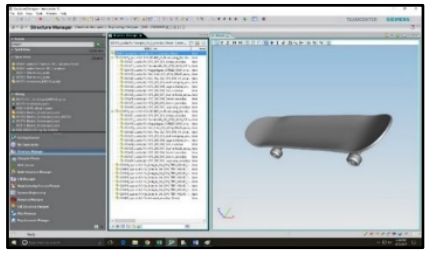
Engineer the system

Process Simulation Tecnomatix

System Simulation and Optimization : Amesim



Plan the process

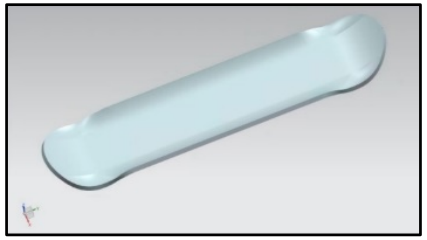


Product and Process Data Management: Teamcenter

Design the components

Process Design Teamcenter Process Planner

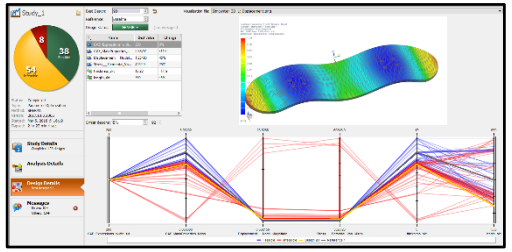
3D Design: NX

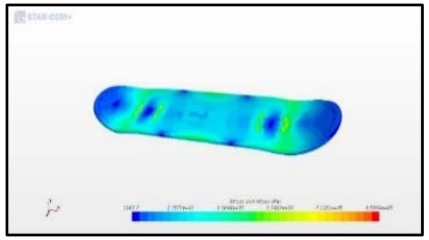


Engineer the product

Product Optimization HEEDS

Product Simulation STAR-CCM+





Results – Impact (Engineering careers)

Name	Position	Company & location	Job title & role	Relevant education/experience[1]
Shashank Ali (spalai@iupui.edu)	Intern (Summer 18)	Siemens PLM software Michigan	SDPD (Systems Driven Product Development) Intern	SDPD course, framework, and tools. Also, SDPD research
Arnold Morales (arjmoral@iupui.edu)	Full time job (Summer 18)	Boeing Seattle, WA	Systems Engineer II	Courses and credentials which contributed/helped you get the job: Systems engineering graduate certificate
Rajat Gupta (rg6@iupui.edu)	Full time engineer (Summer 18)	Cummins Columbus	Systems Lifecycle Analyst *Implementing MBSE and training employees in MBSE*	SE courses, including SDPD and MBSE courses, and Research thesis on integrating MBSE with PLM.
Kalpak Kalvit (kkalvit@iupui.edu)	Full time engineer (Summer 18)	John Deer Waterloo, Iowa	Project coordinator *Implementing MBSE and training employees in MBSE*	SDPD and MBSE courses, and Research thesis on developing a MBSE-Matlab co-simulation for health casre application.
Kalpak Kalvit (kkalvit@iupui.edu)	Full time engineer (Summer 18)	Ford Talent center Dearborn, MI	Autonomous Vehicles Functional Safety Engineer. *Use MBSE concepts and tools to build models for autonomous vehicles*	Systems Engineering 1 Systems Engineering 2 MBSE using SysML Skateboard project for SDPD Course. Eli Lilly project MS thesis in MBSE
Amey Vaidya (arvaidya@iupui.edu)	Full time engineer (Summer 2018)	Whirlpool Benton Harbor, MI	Systems Engineer Analyst *Systems Engineering and Analysis*	1. Introduction to Systems Engineering. 2. Systems and Specialty. 3. Systems Driven Product Development. 4. Knowledge & Training of Sysml. Working on case and delivering Demo to industry (emphasis on systems engineering part)
Nikhil Raosaheb Chougule (nchougul@iupui.edu)	Intern (Summer 2018)	Hyperfine Research Inc. Guilford, Connecticut	Intern *Systems design: Device for health care applications*	SDPD, Systems Engineering, Robotics, Automotive controls
Mayur Khirid (mskhirid@iupui.edu)	Full time engineer (Fall 2018)	Dassault Systemes Americas Corp Seattle, WA	Application consultant Support customers in the areas of PLM, MBSE, and IoT in terms of training, implementation, and process improvement	SDPD course, MBSE with SysML course, IoT & digital twin project (IPLI), CAD/CAM course, Experience with Dassault back in India
Mohamed Elshal (melshal@iupui.edu)	Full time engineer (Fall 2018)	Lumentum Milpitas, CA	Sr. Systems Engineer	Research thesis, SE courses including Intro to SE, SDPD, and MBSE with SysML

Sample of students hired in Summer 2018 based on SE education (including MB-SPDP)

Results – Impact (Engineering careers, cont')

Name	Position	Company & location	Job title & role
Shashank Ali (spalai@iupui.edu)	Intern (Summer 18)	Siemens PLM software Michigan	SDPD (Systems Driven Product Development) Intern
Arnold Morales (arjmoral@iupui.edu)	Full time job (Summer 18)	Boeing Seattle, WA	Systems Engineer II
Rajat Gupta (rg6@iupui.edu)	Full time engineer (Summer 18)	Cummins Columbus	Systems Lifecycle Analyst *Implementing MBSE and training employees in MBSE*
Kalpak Kalvit (kkalvit@iupui.edu)	Full time engineer (Summer 18)	John Deer Waterloo, Iowa	Project coordinator *Implementing MBSE and training employees in MBSE*
Kalpak Kalvit (kkalvit@iupui.edu)	Full time engineer (Summer 18)	Ford Talent center Dearborn, MI	Autonomous Vehicles Functional Safety Engineer. *Use MBSE concepts and tools to build models for autonomous vehicles*
Amey Vaidya (arvaidya@iupui.edu)	Full time engineer (Summer 2018)	Whirlpool Benton Harbor, MI	Systems Engineer Analyst *Systems Engineering and Analysis*
Nikhil Raosaheb Chougule (nchougul@iupui.edu)	Intern (Summer 2018)	Hyperfine Research Inc. Guilford, Connecticut	Intern *Systems design: Device for health care applications*
Mayur Khirid (mskhirid@iupui.edu)	Full time engineer (Fall 2018)	Dassault Systemes Americas Corp Seattle, WA	Application consultant Support customers in the areas of PLM, MBSE, and IoT in terms of training, implementation, and process improvement
Mohamed Elshal (melshal@iupui.edu)	Full time engineer (Fall 2018)	Lumentum Milpitas, CA	Sr. Systems Engineer

Sample of students hired in Summer 2018 based on SE education (including MB-SPDP)

Results – Impact (Engineering careers, cont')

Systems Lifecycle Analyst at Cummins

- Rajat Gupta graduated in Dec 2017 with Masters Degree in Mechanical Engineering at the MEE department. He worked extensively in the area of System Engineering (SE), Model-based Systems Engineering (MBSE), and Product Lifecycle Management (PLM).
- His Masters Thesis was based on implementing Model Based System Engineering on a PLM platform. His thesis was highly appreciated and supported at major conferences organized by INCOSE (International Council on Systems Engineering) such as GLRC 10 and GLRC 11. Soon after his graduation, he worked with IPLI (Initiative of Product Lifecycle Innovation) team on various MBSE projects to demonstrate the capabilities of SDPD (Systems Driven Product Development) platform. He also participated in the development of Systems Engineering Training to local Industry.
- In his role as Systems Lifecycle Analyst at Cummins, he will be working on projects which aim at providing Model Based Systems Engineering solutions to various parts of the company.

"It was in my 1st semester (Fall 2015) I was introduced to the Systems Engineering community at IUPUI as part of my graduate course work. I was always encouraged to attend various Systems Engineering conferences held across the states. Since then this field has provided me immense exposure and helped me build a strong career path with promising opportunities in future. I am very fortunate to have worked under the guidance of Dr. Hazim El-Mounayri who always motivated me to explore this area" – Rajat Gupta

SDPD Summer Internship at Siemens PLM Software!

- Shashank Alai is one of our graduate research assistants pursuing his MS in Mechanical Engineering degree at the MEE department. He is working on his Master's thesis in Model-Based Engineering (MBE). Shashank will be working as a student intern this summer at Siemens PLM Software in the area of Systems Driven Product Development (SDPD), which is the application of MBE in Product Development. SDPD can be simply defined as Product Design and Development using Systems Engineering principles.
- During his internship, he will be working on product development case studies to push the limits of new technology through projects in design, configuration, physical behaviors, electronics, controls & SW. He will be working on topics such as:
  - Systems Engineering,
  - Model-Based Design,
  - Additive Manufacturing,
  - Smart Products/Smart Manufacturing,
  - Industry 4.0.

During Fall 2017, he worked as an R&D Intern at XPLM, Germany in a similar area.

"I am very thankful to my advisor (Dr. El-Mounayri) and mentors for their guidance and sharing their expertise which allowed me to explore and securing such an opportunity. I believe that the graduate courses like 'Systems Driven Product Development', 'MBSE Using SysML' and 'Introduction to Systems Engineering' were instrumental in gaining a solid understanding of MBE and Systems Engineering. I am looking forward to a promising career in this field." – Shashank Alai

SIEMENS

Project Coordinator at John Deere!

Kalpak Kalvit is one of our graduate research assistants who graduated with MS in Mechanical Engineering degree at the MEE department. He was working on his Master's thesis in Model-Based Systems Engineering (MBSE). Kalpak will be working as a project coordinator at John Deere in the area of Model Based Systems Engineering using SysML.

During his employment, he will be training employees at John Deere in MBSE using SysML. He will be responsible to teach the relevant software to the employees and will be involved in MBSE implementation at John Deere. He will be working on topics such as:

- Systems Engineering,
- Model-Based Systems Engineering
- SysML
- Requirements Management
- Engine Design and Control

After completing his thesis Kalpak worked as a Research Associate and was responsible to develop case studies for companies like Siemens, Eli Lilly etc. He has also successfully trained students in using the SysML tool for applying MBSE.

JOHN DEERE

"I am very thankful to my mentor Dr. Hazim El-Mounayri who has always encouraged me and provided me with ample exposure. I believe that the graduate courses like 'Systems Driven Product Development', 'MBSE Using SysML', 'Introduction to Systems Engineering', 'Systems and Specialty Engineering' were instrumental in gaining a solid understanding of MBE and Systems Engineering. I am looking forward to a promising career in this field." – Kalpak Kalvit

Autonomous Vehicles Controls & Functional Safety Engineer at FORD Motor Company!

Ford Go Further

Kalpak Kalvit is one of our graduate research assistants who graduated with MS in Mechanical Engineering degree at the MEE department. He was working on his Master's thesis in Model-Based Systems Engineering (MBSE). Kalpak will be working as a Autonomous Vehicles Controls & Functional Safety Engineer at FORD Motor Company in the area of Model Based Systems Engineering using SysML.

His Job responsibilities will be :

- Leverage a model-based approach (e.g. descriptive/architectural SysML models in combination with executable/analysis models in Simulink/etc) to architecting, defining, and analyzing complex systems involving a mix of hardware and controls
- Develop and manage a set of core systems engineering work products including use cases, strategy concepts, requirements, robustness artifacts, and verification methods/plans/results
- Develop physically and empirically based models & simulations and use them to conduct design option and trade-off studies

After completing his thesis Kalpak worked as a Research Associate and was responsible to develop case studies for companies like Siemens, Eli Lilly etc. He has also successfully trained graduate students and faculty in using the SysML tool for applying MBSE

"I am very thankful to my mentor Dr. Hazim El-Mounayri who has always encouraged me and provided me with ample exposure. I believe that the graduate courses like 'Systems Driven Product Development', 'MBSE Using SysML', 'Introduction to Systems Engineering', 'Systems and Specialty Engineering' were instrumental in gaining a solid understanding of MBE and Systems Engineering. I am looking forward to a promising career in this field." – Kalpak Kalvit

Results – Potential Benefits

FOR STUDENTS:

SDPD (or MB-SDPD) curriculum allows a paradigm shift in engineering education, for improved synthesis of engineering knowledge and its implementation in different modern product lifecycle applications

SDPD approach and framework allows student (teams) to successfully complete modern product development within the timeline of one semester, which is a paradigm shift in engineering education.

FOR INDUSTRY:

Greater innovation in product development
Increased efficiency
Faster time-to-market
Increased adaptability/agility/customization
Knowledge re-use
Better ability to comply with standards

overall, ***MBE (SDPD) can lead to significant competitive advantage***.

Summary – Technical challenges

Broad spectrum of SDPD in terms of the underlying theory (e.g. disruptive technologies of Industry 4.0) as well as the enabling digital tools.	Preparedness of students to take such course work	Traditional/current college engineering education as well as the focus of educators are not supportive/embracing such a broad implementation of digital technology (tools) in one course/application/project
Teamcenter installation and deployment	Software integration	Modeling and simulation continuum not streamlined
Traceability process not fully established	Infrastructure readiness	Availability of SDPD case studies for training or as a reference
Compatibility between different software modules.	SDPD digital tools continuously being updated/upgraded/revised	Overhead for implementing SDPD framework and training students on its digital tools (e.g. license cost).

Summary - Keys to success in our case

SDPD framework, supporting PLM software tools, technical support, and (Siemens) PLM publications.

Comprehensive suite of digital tools that enables the implementation of Model-based engineering

(Teamcenter) PLM as the platform for integration and collaboration, realizing the digital thread

Modeling and simulation continuum for Model-based implementation of SE process through Siemens as well as third digital party tools, enabling the digital twin

Open architecture to support third-party tools integration

Software capabilities that enables the implementation of SDPD

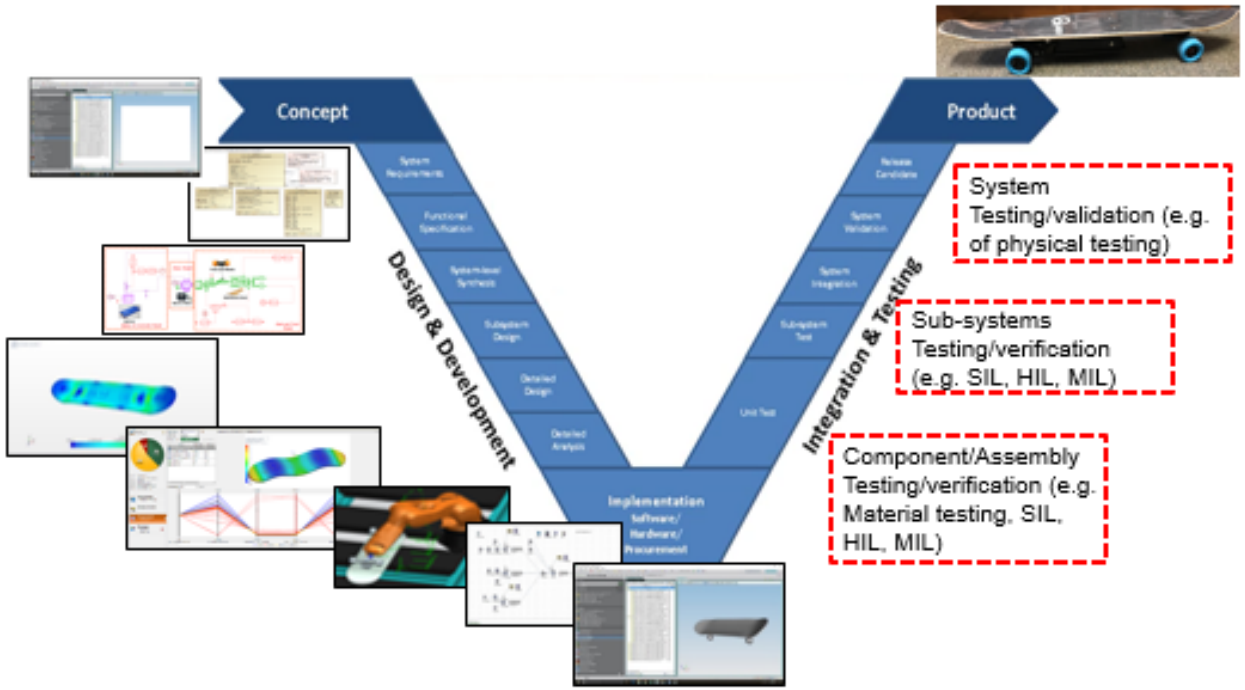
Software-hardware platform that supports MIL, HIL, and SIL

Continuous growth and expansion of SDPD software suite aimed at enabling the digital enterprise and realizing the holistic digital twin (i.e. digital twins of product, production, and performance)

Future work

Case study:
- Building the digital twins (Product, production, and performance)

Curriculum:
- Industry 4.0 (e.g. Enabling technologies of Industry 4.0: Theories & Implementations)
- Extending the digital SE framework (MBE) to other courses, including Capstone design
- Testing, verification, and validation (MIL, HIL, and SIL)



More complete Digitalized SE process