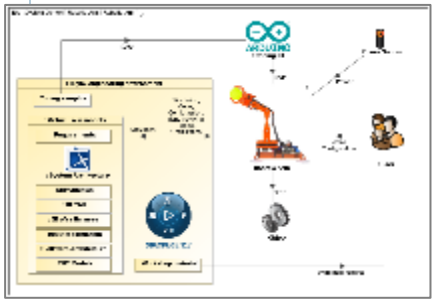
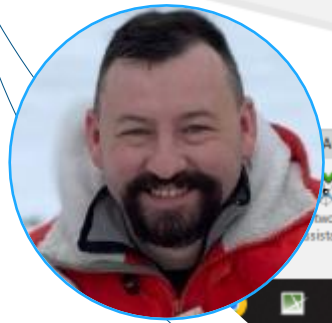
ACCELERATING DIGITAL ENGINEERING ADOPTION: A FULL ENGINEERING LIFECYCLE EXAMPLE USING MBSE AND VIRTUAL TWIN OF PORTABLE ROBOTIC ARM

From Requirements, System Engineering to Design, Analysis, Manufacturing, Implementation, V&V, and Operational Feedback using Digital Tread and Co-Simulation.

SCAN ME





Saulius PAVALKIS
MBSE EcoSystem Director | Global
MBSE R&D Cyber Portfolio Manager | NAM

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MOTIVATION (1)

INCOSE Vision 2035

KEY QUOTES:

- THE FUTURE OF SYSTEMS ENGINEERING IS MODEL-BASED, ENABLED BY ENTERPRISE DIGITAL TRANSFORMATION
- SYSTEMS ENGINEERING IS NOT JUST FOR SYSTEMS ENGINEERS – ALL ENGINEERS NEED TO PRACTICE SYSTEMS ENGINEERING

CHRIS SCHREIBER, LMCO SE MODERNIZATION SR. MGR. 2019

. . . BEYOND SIMPLY CAPTURING SYSTEMS ENGINEERING DESIGN, TO ENABLING A BETTER WAY OF ENGINEERING SYSTEMS. “

BRANDI GERSTNER, DELOITTE DIGITAL ENGINEERING -PD MANAGER 2024.

“..EVERY QUANTUM OF ENERGY EXPENDED ON ENGINEERING SHOULD MOVE YOUR TEAM CLOSER TO THE NEXT DECISION. EVERY REGRESSION, EVERY MBSE DIAGRAM, EVERY ANALYSIS OF ALTERNATIVES SHOULD EMPOWER YOUR PROJECT TO MAKE INFORMED, TECHNICALLY GROUNDED CHOICES. THAT IS HOW WE WIN..”

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ROBOTIC ARM VIRTUAL TWIN CAPABILITIES

- Requirements Management
- System Architecture
- Electrical Schematics
- Mechanical Design / 3DCAD
- 3D Wire Harness
- SysML to C code Generation

- System Traceability
- Co-Simulation
- Hardware in the Loop Sim
- Multiphysics Simulation
- Robotic Simulation
- Manufacturing and Assembly

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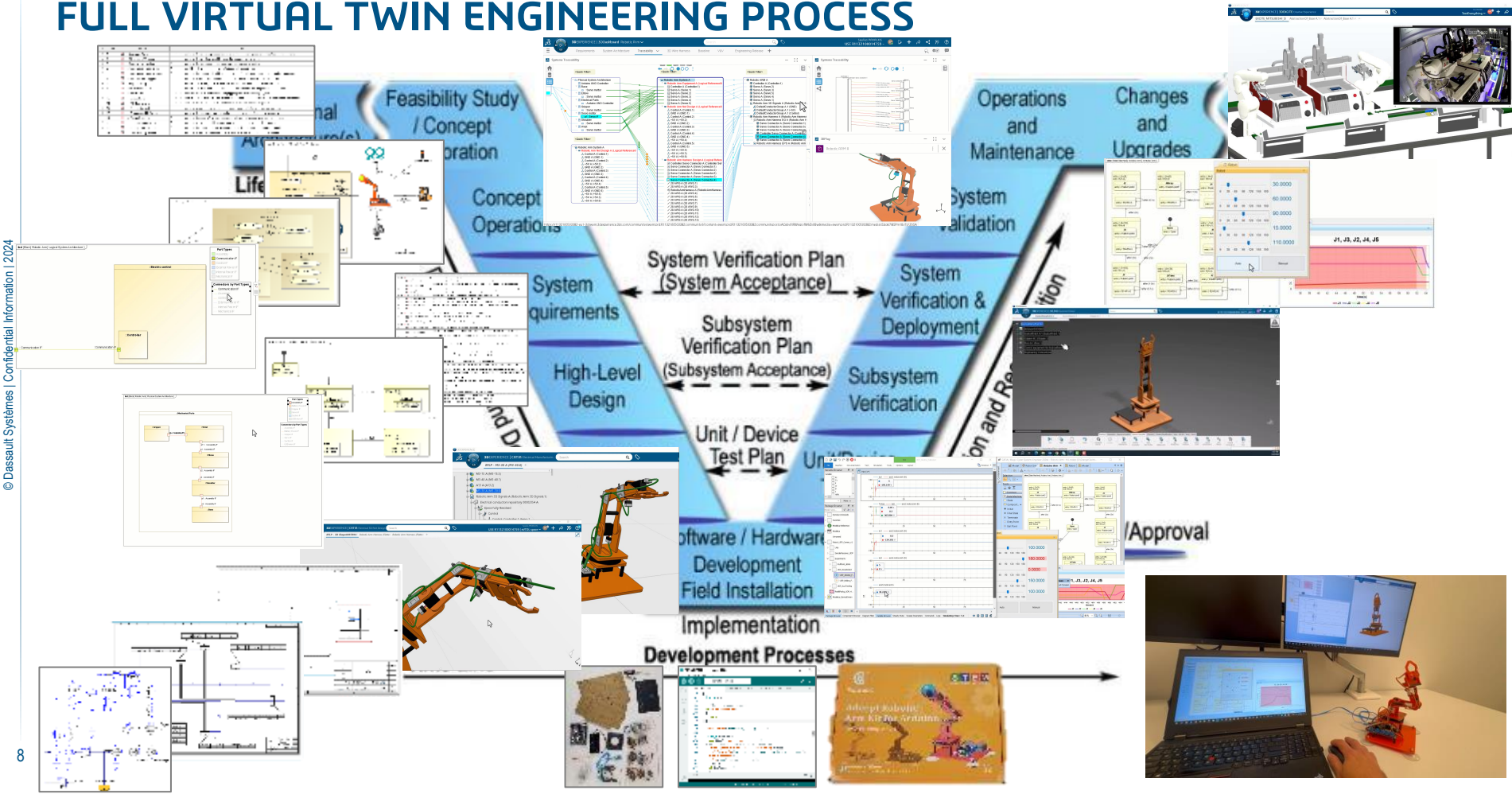
FULL VIRTUAL TWIN ENGINEERING PROCESS



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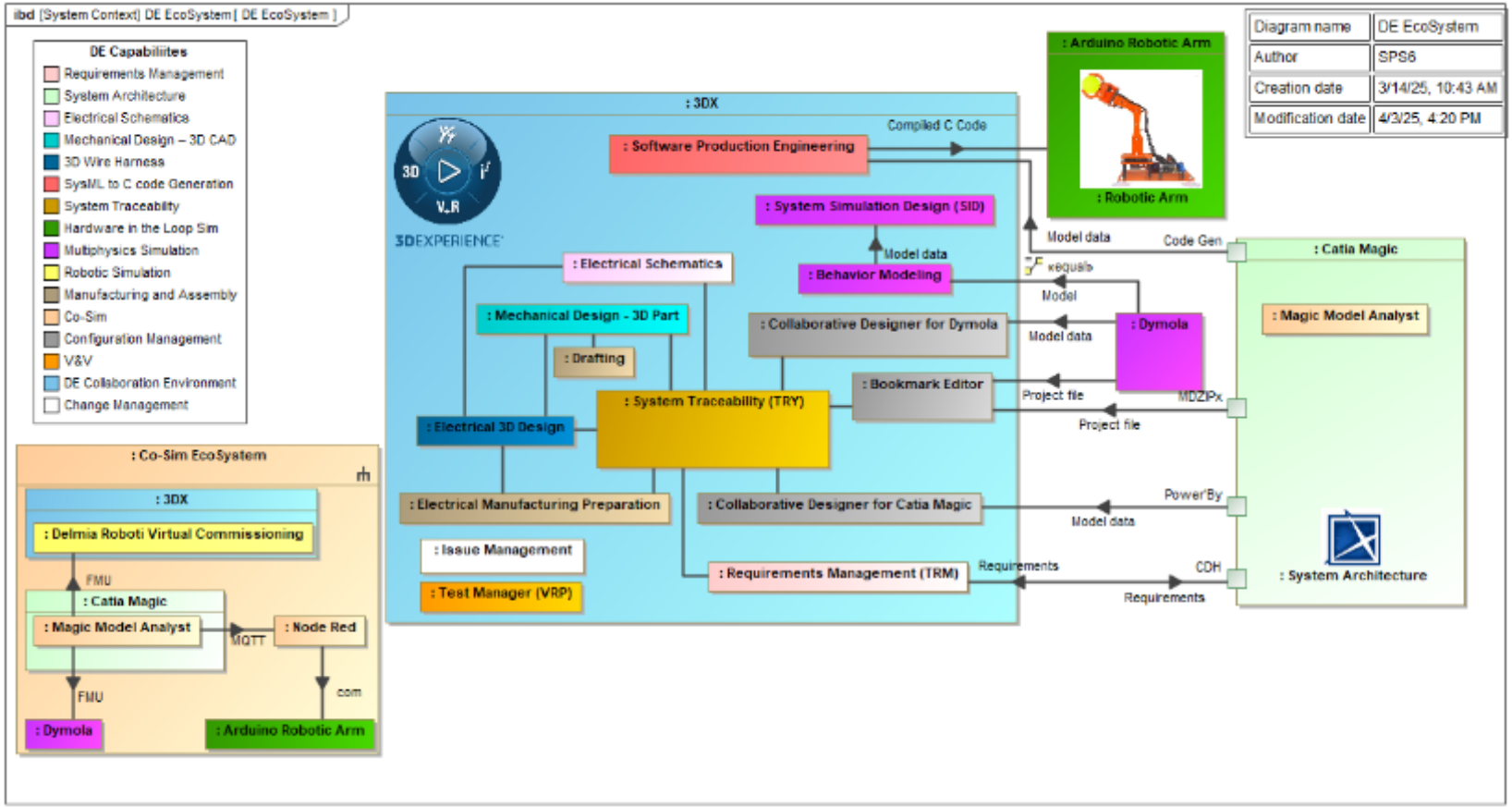
SOLUTION ECOSYSTEM ENABLING DE CAPABILITIES

- 3DEXPERIENCE, CATIA Magic, Dymola

Software_Tools_Information



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MBSE FROM STAKEHOLDER NEEDS TO SOLUTION ARCHITECTURE

Magic Cyber-Systems Engineer (MAH)

- Following MBSE method – MagicGrid
- Predictable innovation driven transition from stakeholder needs to optimal solution architecture to physical requirements for design
- Tight integration with engineering environment (3DExperience platform) through models and requirements synchronization
- SE impact:
  - Straight forward repeatable systems engineering process based on innovation and ISO 15288 standard.

Robotic Arm full digital engineering twin from requirements to implementation

	PILLAR			
DOMAIN	REQUIREMENTS	STRUCTURE	BEHAVIOR	PARAMETERS
PROBLEM (BLACK BOX)				
PROBLEM (WHITE BOX)				
SOLUTION				
IMPLEMENTATION				

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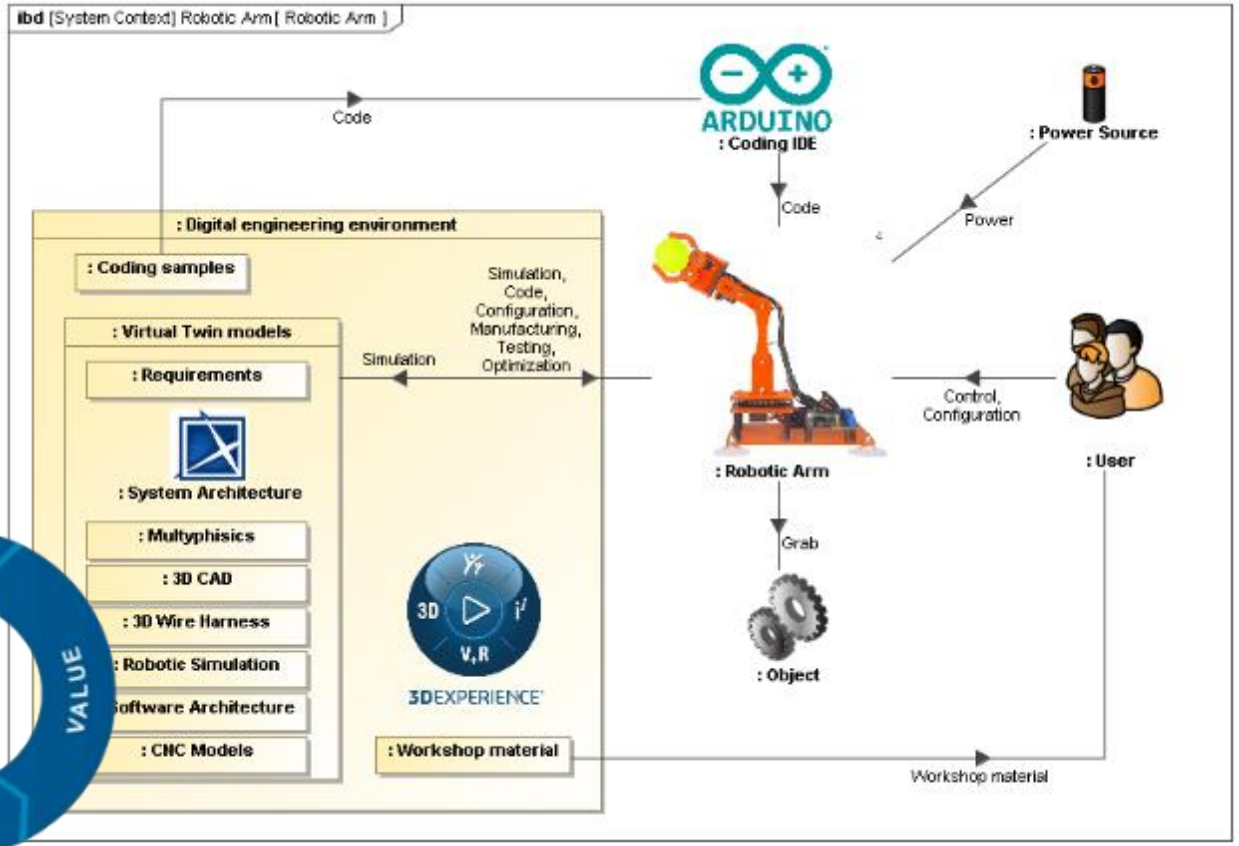
SYSTEM CONTEXT – DIGITAL ENGINEERING ENVIRONMENT

- Define system boundaries,
- Identify external interfaces
- Identify system contexts e.g.
  - Operation
  - Modification
  - Configuration

- SE impact:
  - Understood system boundaries, environments – context, high level interfaces



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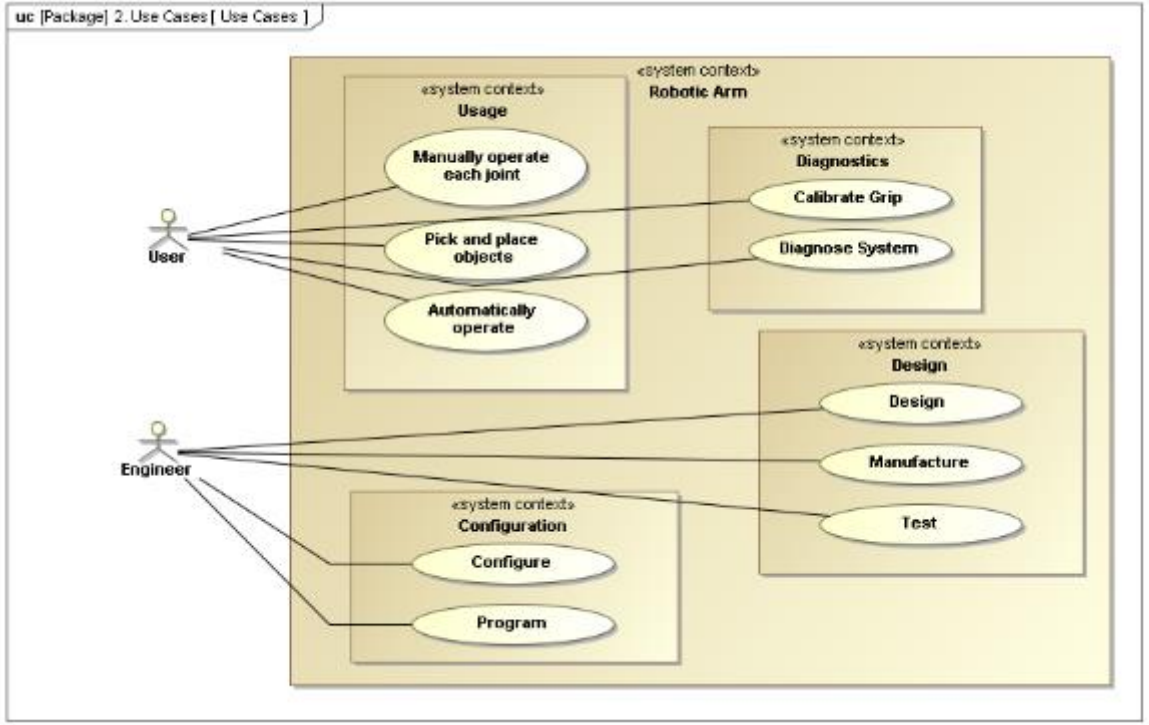
SYSTEM USE CASES AND FUNCTIONAL ANALYSIS

- System functional analysis starting from use case:
  - User perspective driven system architecture
  - Key context, use cases, and scenarios

- SE impact:
  - Stakeholder needs analysis based on system behavior from user perspective, clear understood stakeholder needs, beginning of functional analysis.



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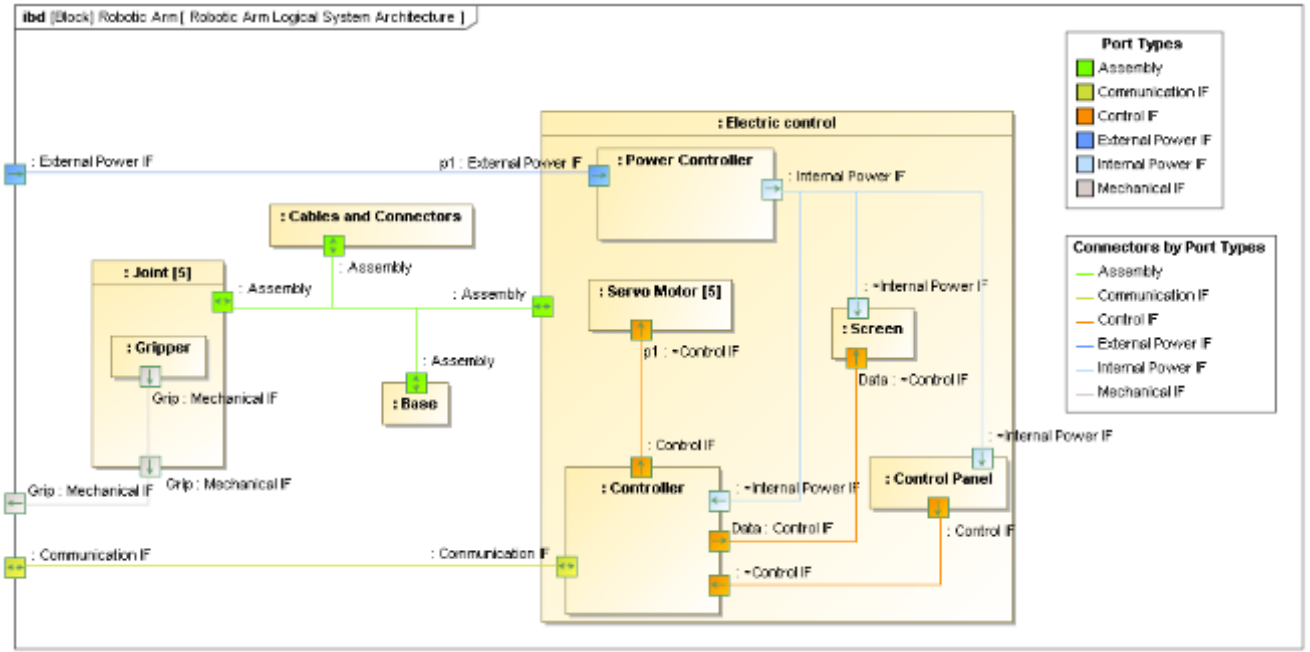
LOGICAL SYSTEM ARCHITECTURE

- Logical architecture grouping system functions
- Oriented what is flowing and what system is doing - not how
- Smallest single architecture or the system

- SE impact:
  - Aggregated solution architecture based on stakeholder needs, precondition for clear optimal system requirements



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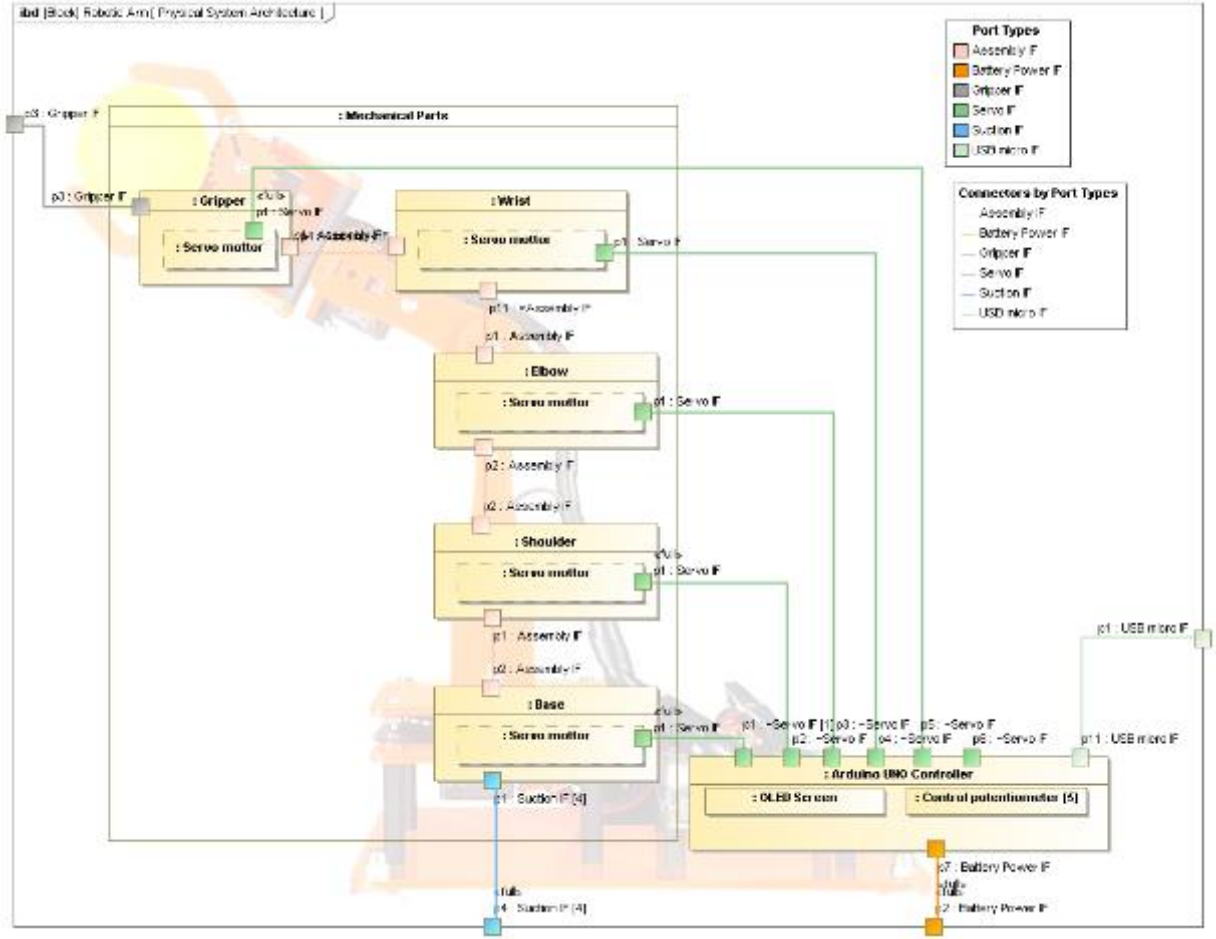
SOLUTION SYSTEM ARCHITECTURE

- Optimal solution architecture - how system will work
- Oriented into physical interfaces and components
- Primary models to communicate with design

- SE impact:
  - Optimal solution architecture based on functions, interfaces and optimized on Measure of Effectiveness (MoE)



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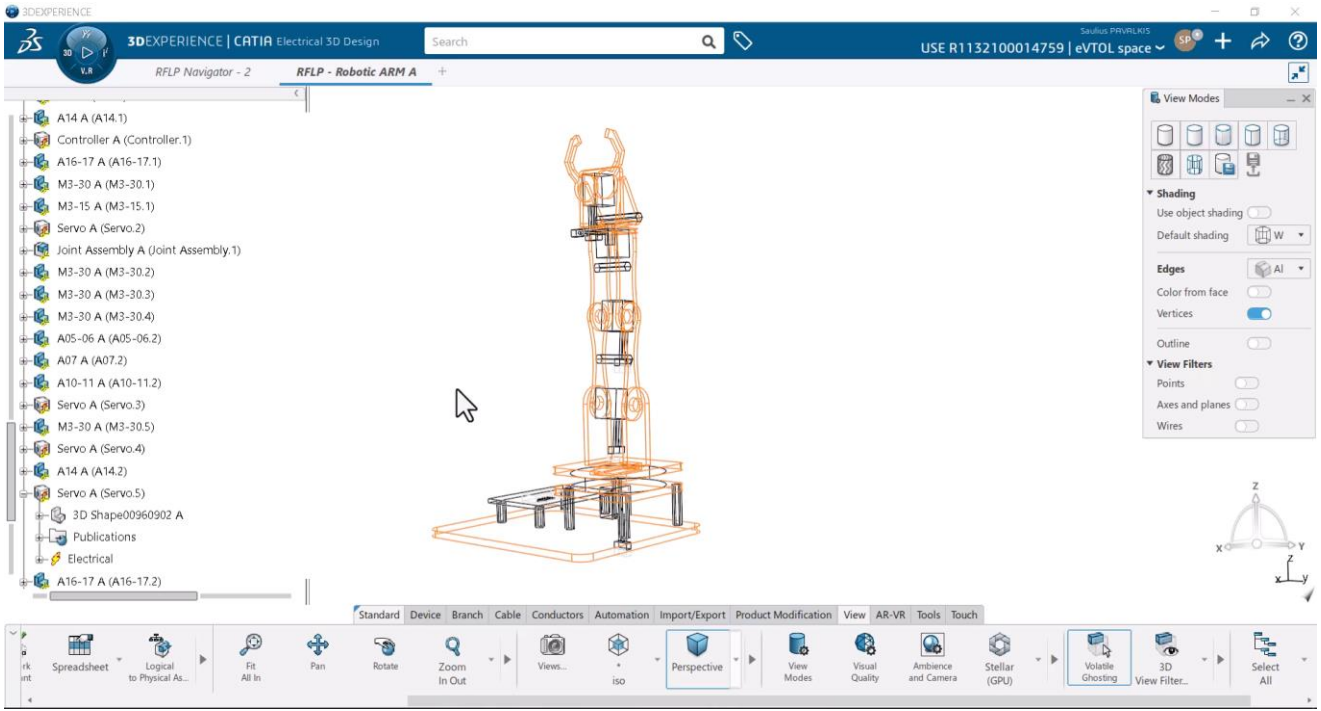
MECHANICAL DESIGN – 3D CAD

- Mechanical design with Catia
- Precondition to:
  - Structural analysis
  - 3D Wire harness
  - Manufacturing
  - Styling
- SE impact:
  - System structural, behavioral, and parametric requirement compliance



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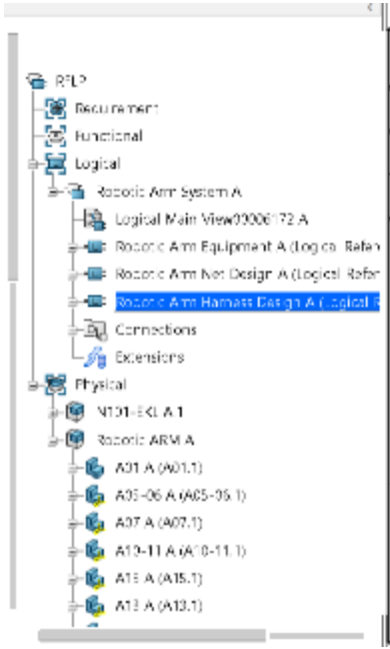
ELECTRICAL SCHEMATICS

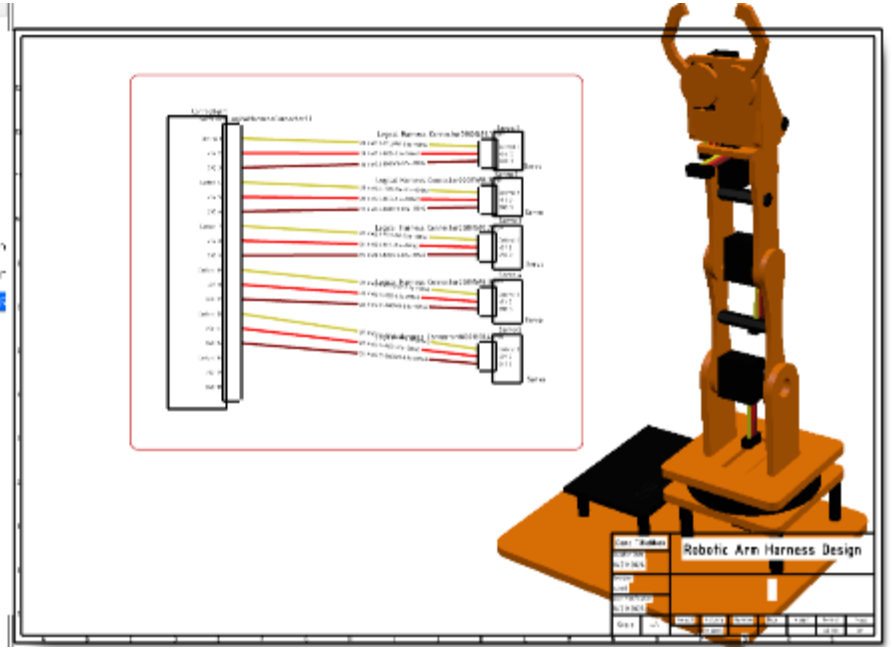
Electrical Systems Design

- Role: System Schematic Designer

- To design network schematics
- Connecting equipment's at pin level and defining signals flowing from one pin to another
- Wearing definition
- Specifying conductors (hardware): connectors, wires, cables.

- SE impact:
  - System power and precision requirements compliance





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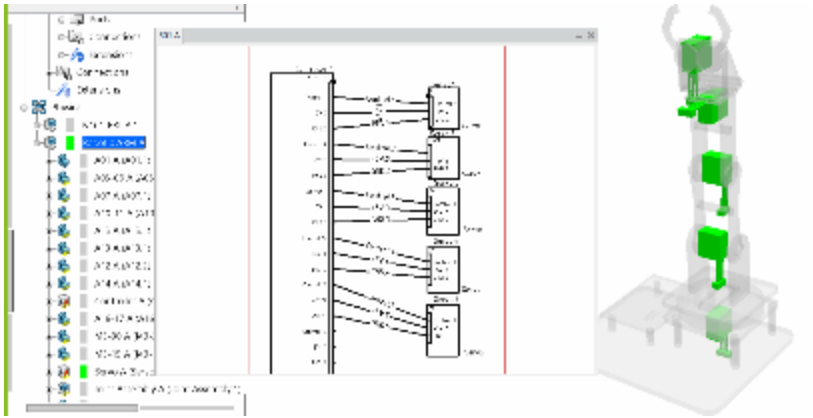
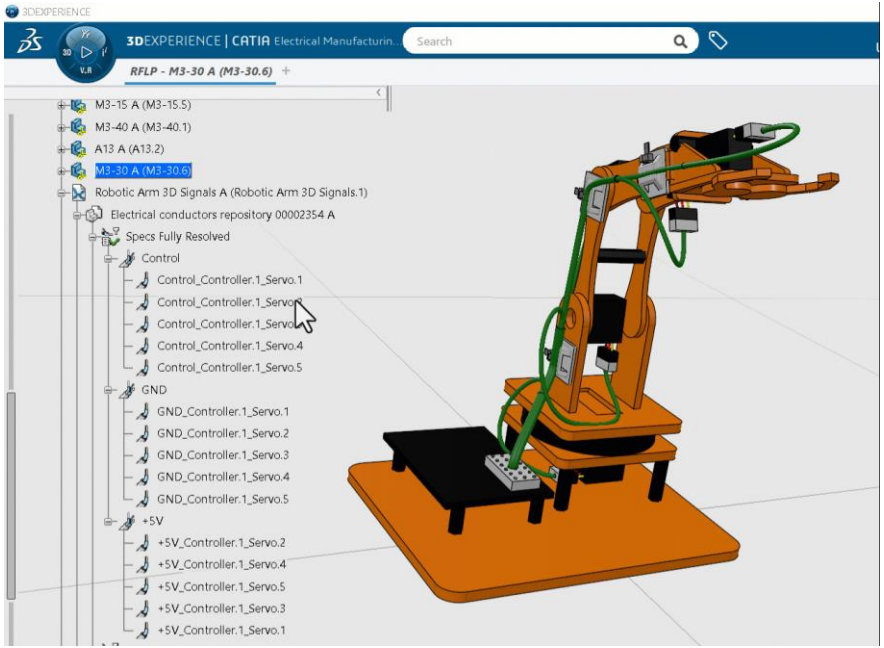
LOGICAL TO PHYSICAL ALLOCATION

Electrical 3D Design

- Role: Electrical 3D and Manufacturing Engineer
  - We use logical to physical assistant to
    - Place equipment in system 3D zones
    - Create unrouted 3D network schematics
  - Place harness connectors in 3D and connect them to corresponding equipment ports
  - Preview 3D schematics

- SE impact:
  - System power and precision requirements compliance





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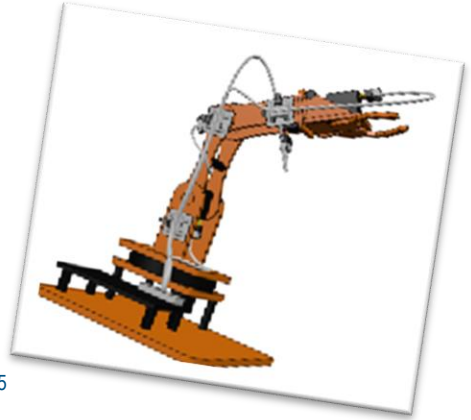
3D WIRE HARNESS

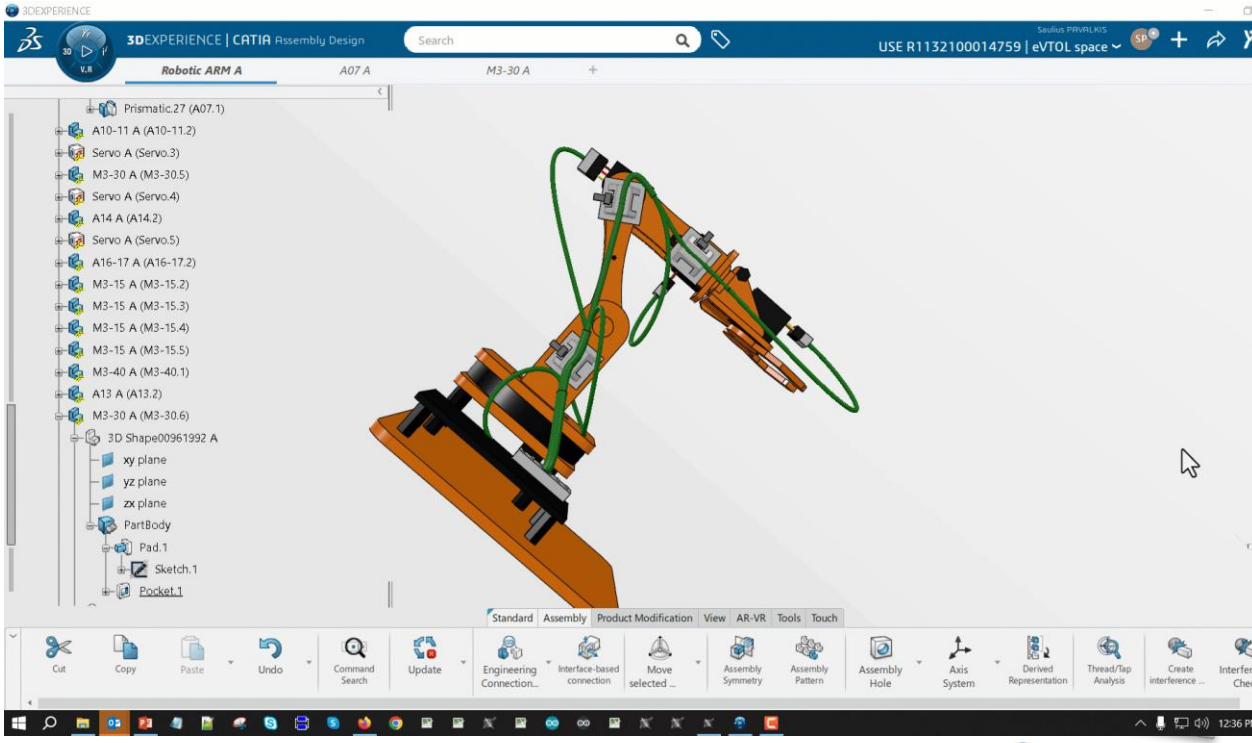
Electrical 3D Design

- Role: Electrical 3D and Manufacturing Engineer

- Create routed harness segments in 3D
- Use logical to physical assistant allocate wires and cables into 3D harness segments

- SE impact:
  - Behavior requirements compliance on system movement freedom





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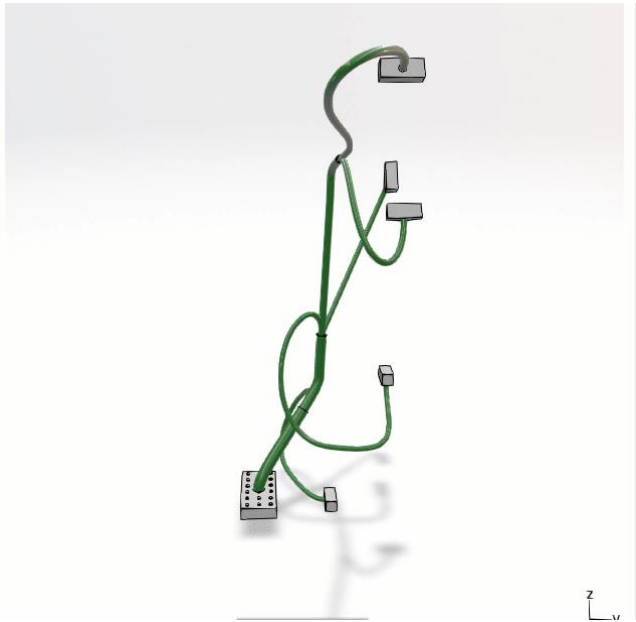
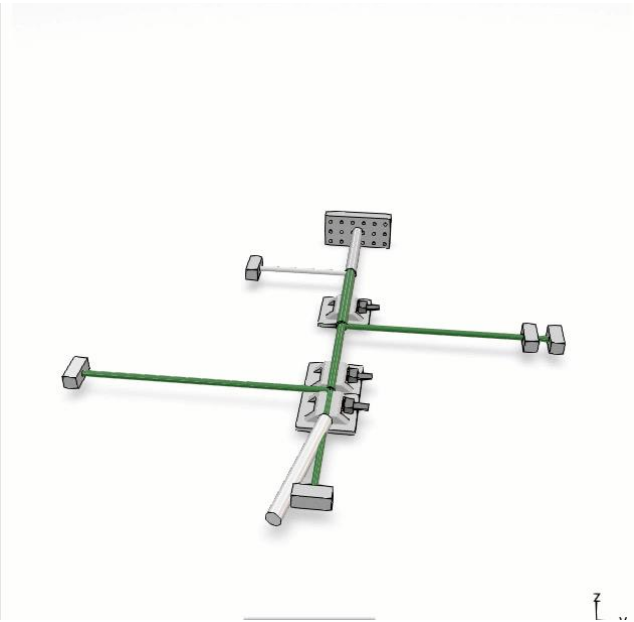
TRANSITIONING TO FLATTENED HARNESS AND MANUFACTURING





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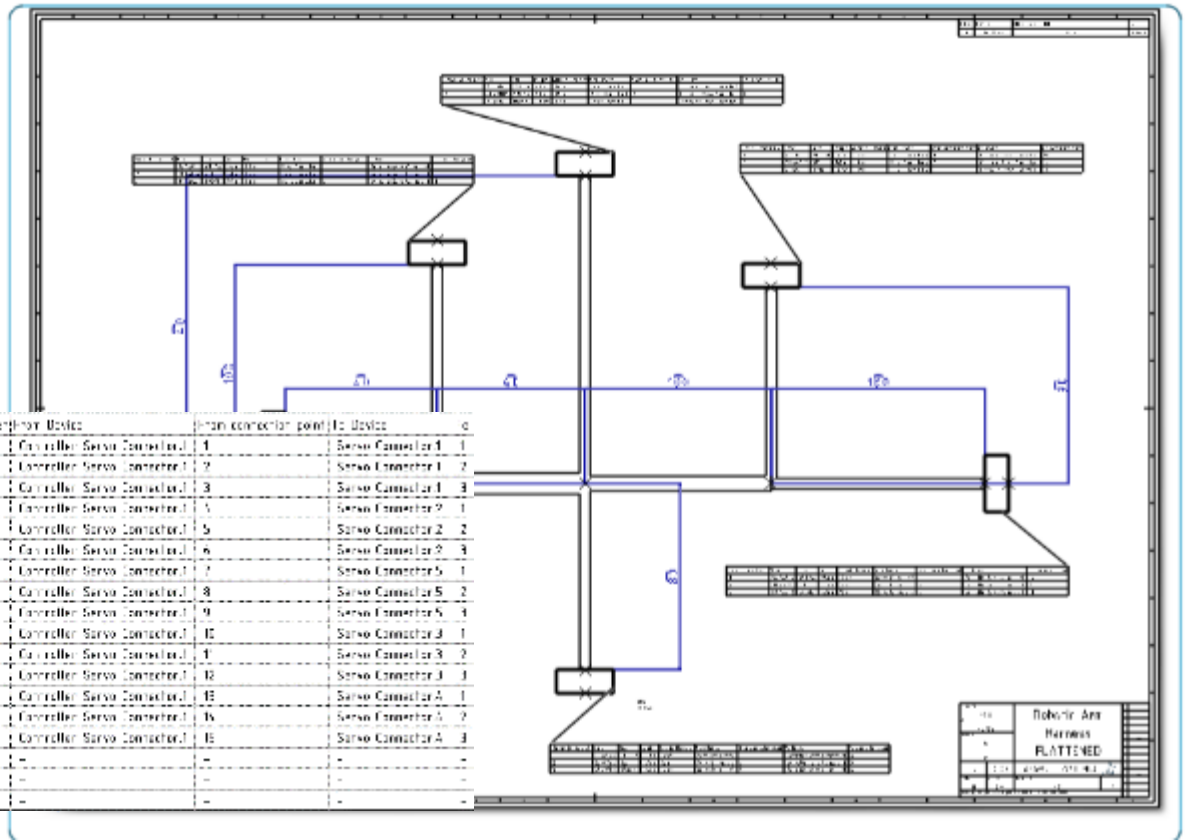
MANUFACTURING – FLATTENED HARNESS

Electrical Manufacturing Preparation

- Role: Electrical 3D and Manufacturing Engineer
- Flattened 3D Wire harness for manufacturing
- Absolute or algorithmic scale
- Full product specification

- SE impact:
  - Behavior requirements compliance on system movement freedom
  - Power requirements compliance on system mission



Controller Servo Connector.1	Name	Color	Length	Outside Diameter	From Device	From connection point	To Device	To
1	28 AWG.1	YELLOW	1140mm	1.2mm	Controller Servo Connector.1	1	Servo Connector 1	1
2	28 AWG.10	RED	1140mm	1.2mm	Controller Servo Connector.1	2	Servo Connector 1	2
3	28 AWG.2	BROWN	1140mm	1.2mm	Controller Servo Connector.1	3	Servo Connector 1	3
4	28 AWG.4	YELLOW	965mm	1.2mm	Controller Servo Connector.1	4	Servo Connector 2	1
5	28 AWG.3	RED	965mm	1.2mm	Controller Servo Connector.1	5	Servo Connector 2	2
6	28 AWG.6	BROWN	965mm	1.2mm	Controller Servo Connector.1	6	Servo Connector 2	3
7	28 AWG.7	YELLOW	1223mm	1.2mm	Controller Servo Connector.1	7	Servo Connector 5	1
8	28 AWG.11	YELLOW	1223mm	1.2mm	Controller Servo Connector.1	8	Servo Connector 5	2
9	28 AWG.8	BROWN	1223mm	1.2mm	Controller Servo Connector.1	9	Servo Connector 5	3
10	28 AWG.10	YELLOW	1362mm	1.2mm	Controller Servo Connector.1	10	Servo Connector 3	1
11	28 AWG.13	RED	1362mm	1.2mm	Controller Servo Connector.1	11	Servo Connector 3	2
12	28 AWG.12	BROWN	1362mm	1.2mm	Controller Servo Connector.1	12	Servo Connector 3	3
13	28 AWG.15	YELLOW	1362mm	1.2mm	Controller Servo Connector.1	13	Servo Connector 4	1
14	28 AWG.14	RED	1362mm	1.2mm	Controller Servo Connector.1	14	Servo Connector 4	2
15	28 AWG.15	BROWN	1362mm	1.2mm	Controller Servo Connector.1	15	Servo Connector 4	3
16	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-

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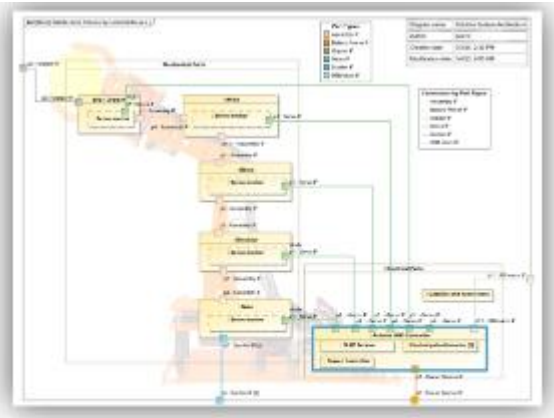
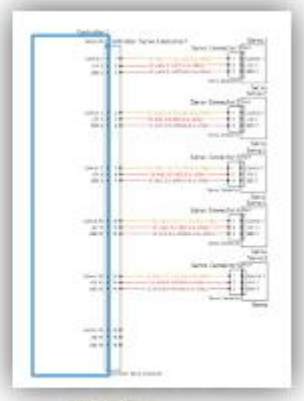
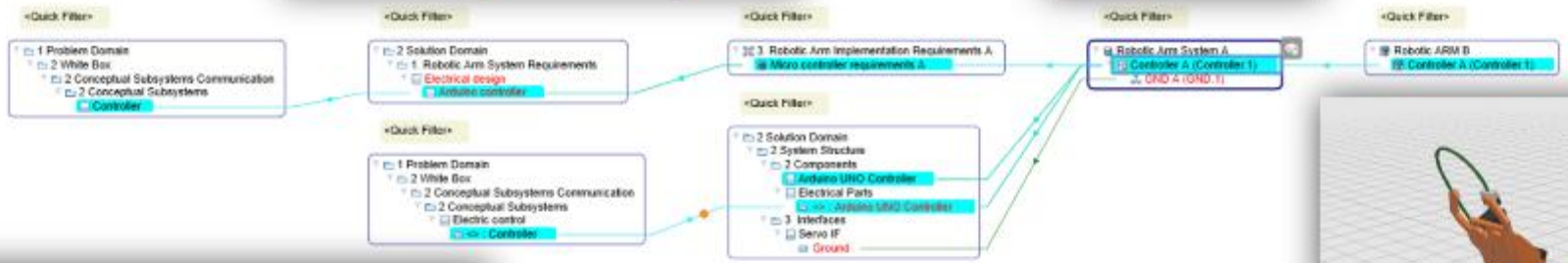
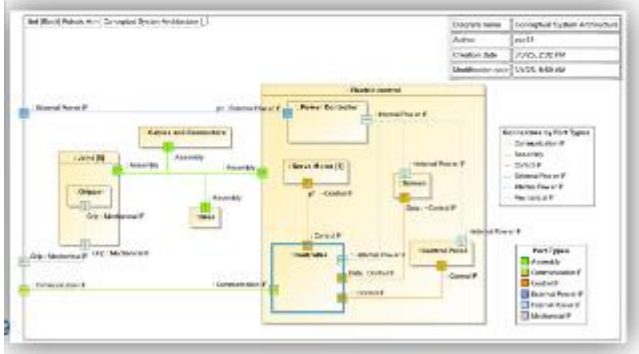
TRACEABILITY

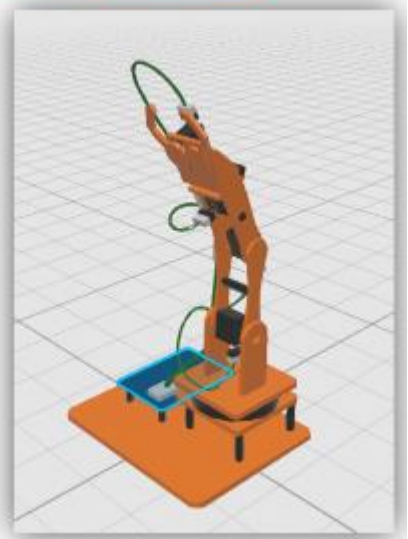
Systems Traceability











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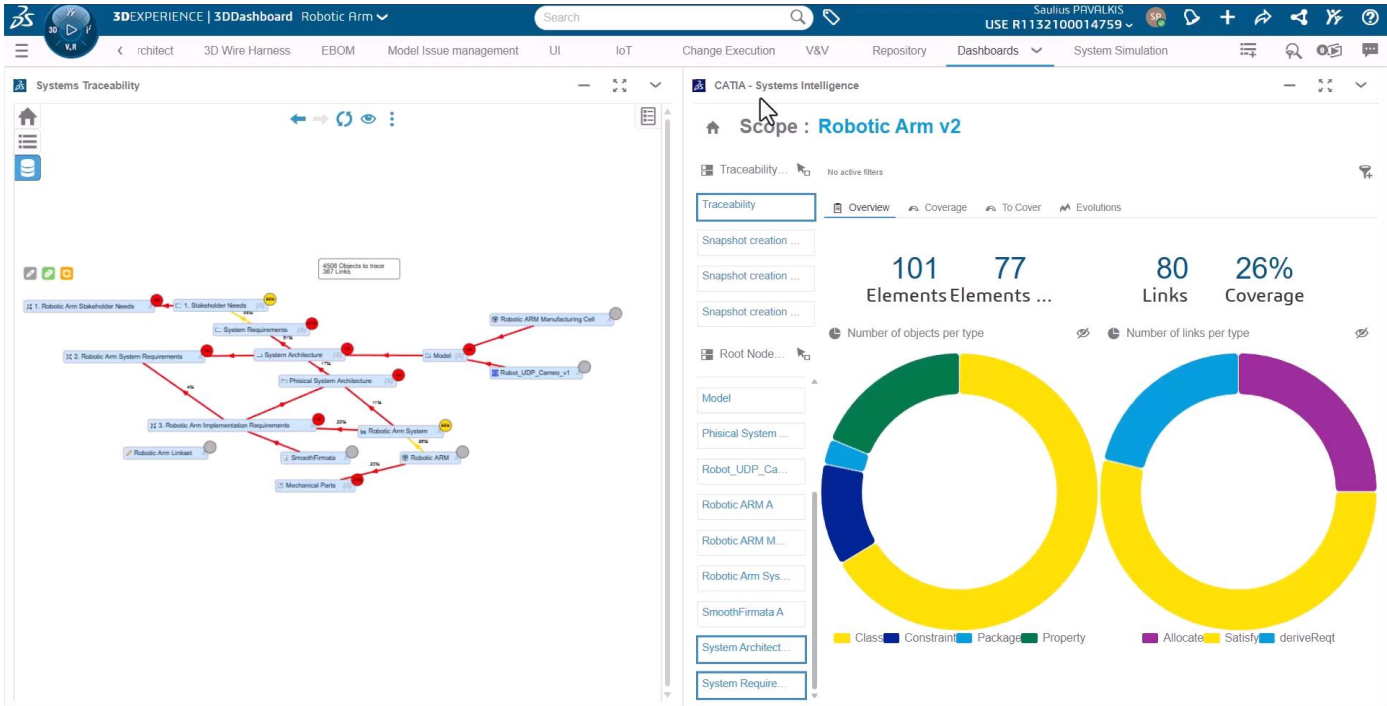
DASHBOARDS

Systems Intelligence

- Role: Project, product manager
  - Project status tracking: number of elements, number of relations, missing relations, change between snapshots

- SE impact:
  - Traceability summary, metrics at system model level extending to full engineering lifecycle.



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CHANGE MANAGEMENT: PROCESS

User need: longer arm to reach specimen.

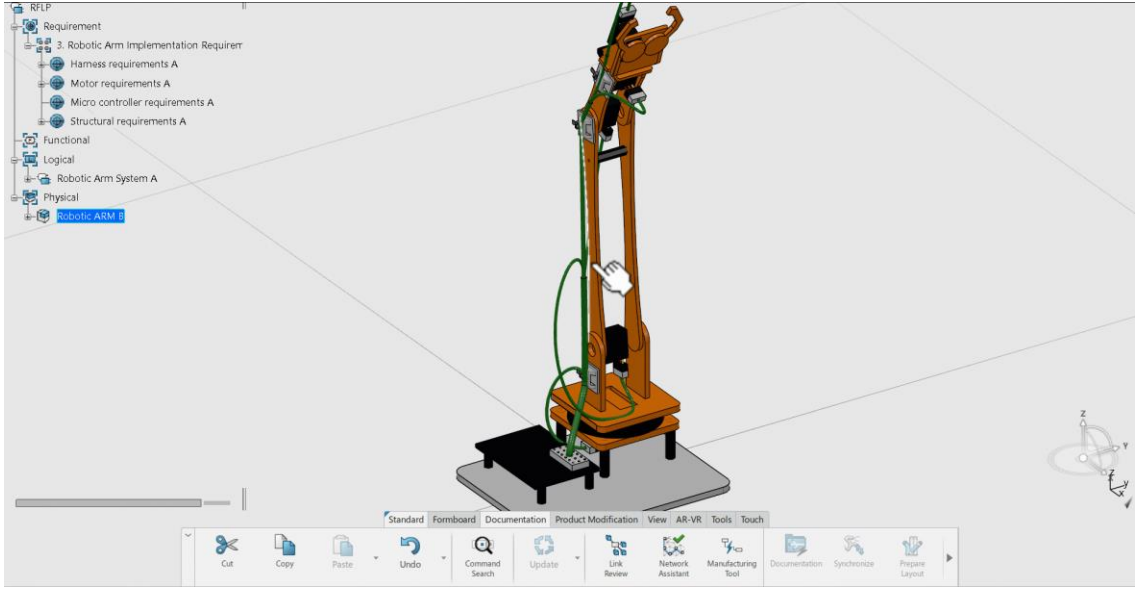
Assumptions:

- Robotic arm is in operational stage
- Virtual twin is fully released
- Issue identified based on changed in user needs

Goal: demonstrate a full change management using a capabilities of 3DX platform in context of model based DE and full engineering lifecycle.

Change process:

1. Create issue:
    1. feasibility study,
    2. approve
2. Create change action:
    1. Describe context
    2. Attaching artifacts to be changed
    3. Approval process
3. Implement changes:
    1. Increment artefact revision
    2. Go through release process



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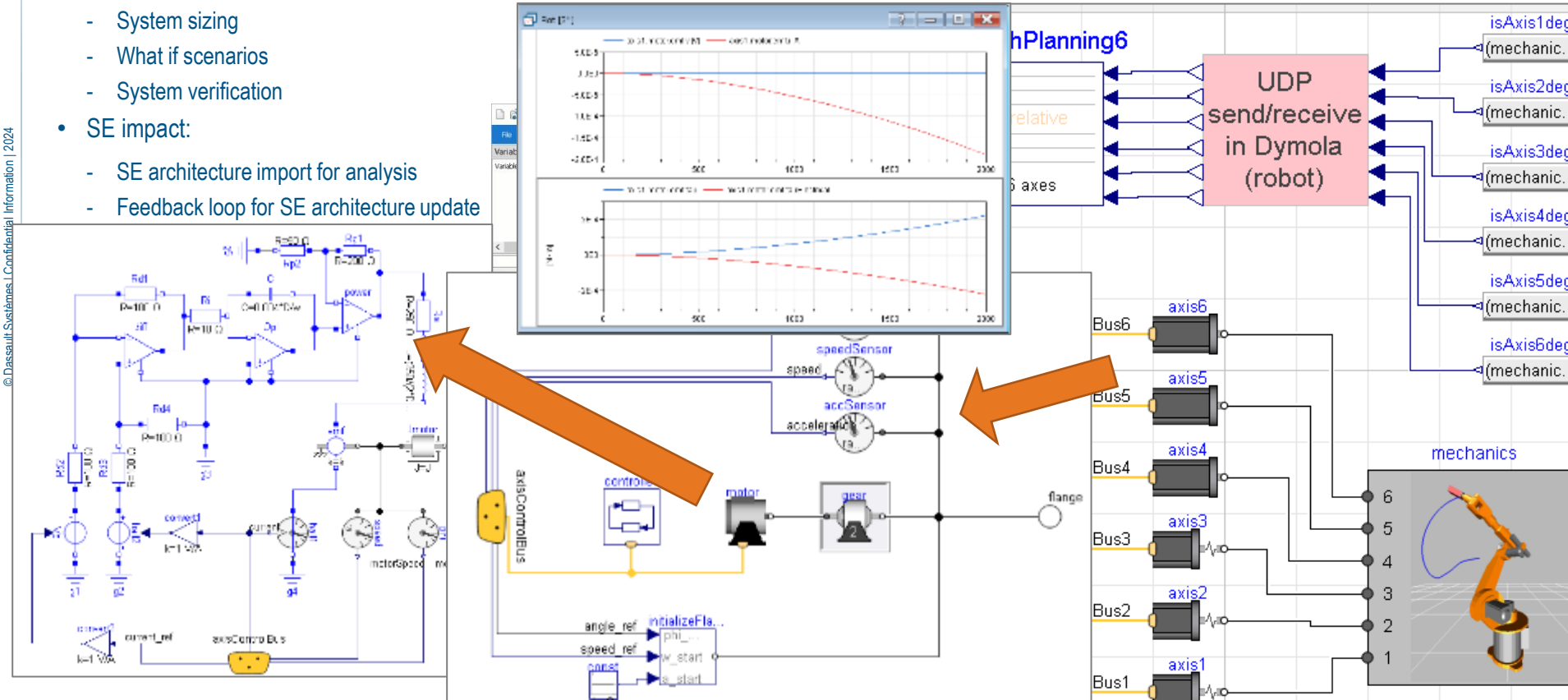
MULTIPHYSICS SIMULATION

Dymola

- Multiphysics analysis of system behavior based on custom and predefined libraries
  - System sizing
  - What if scenarios
  - System verification
- SE impact:
  - SE architecture import for analysis
  - Feedback loop for SE architecture update



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ROBOTICS SIMULATION

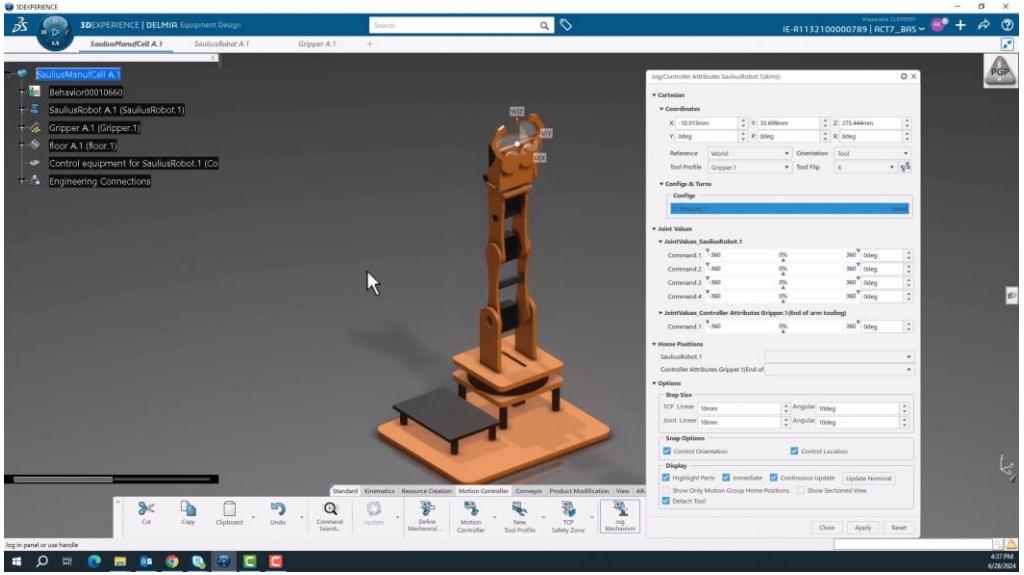
Takes 1h from CAD to Connected Virtual Robot!

Robot Virtual Commissioning

- Role: Fabrication Robot Work cell Programmer
  - Use cases: transitioning from CAD to 3D moving robot, ergonomic and robot logic development, kinematics, motion planning, collision detection, OLP, virtual commissioning
- DELMIA offers comprehensive robotics simulation capabilities:
  - Robot Simulation & Analysis:
    - Simulate robot movements realistically.
    - Conduct a thorough analysis of robotics factors, including accessibility, reachability, and singularity avoidance.
  - Motion Planning & Optimization:
    - Utilize an integrated motion planner to define and refine robot movements.
    - Adjust key parameters such as motion type, tool profiles, accuracy profiles, and speed for optimal performance.
  - Collision Detection & Avoidance:
    - Determine the swept volume of the robot task to identify potential collisions.
    - Leverage powerful tools to detect and diagnose faulty parameters (e.g., collision, travel limits).
    - Assist in analyzing and resolving collision issues effectively.

SE impact:

Ergonomics and logic requirements compliance, Virtual V&V, fast prototyping with system context



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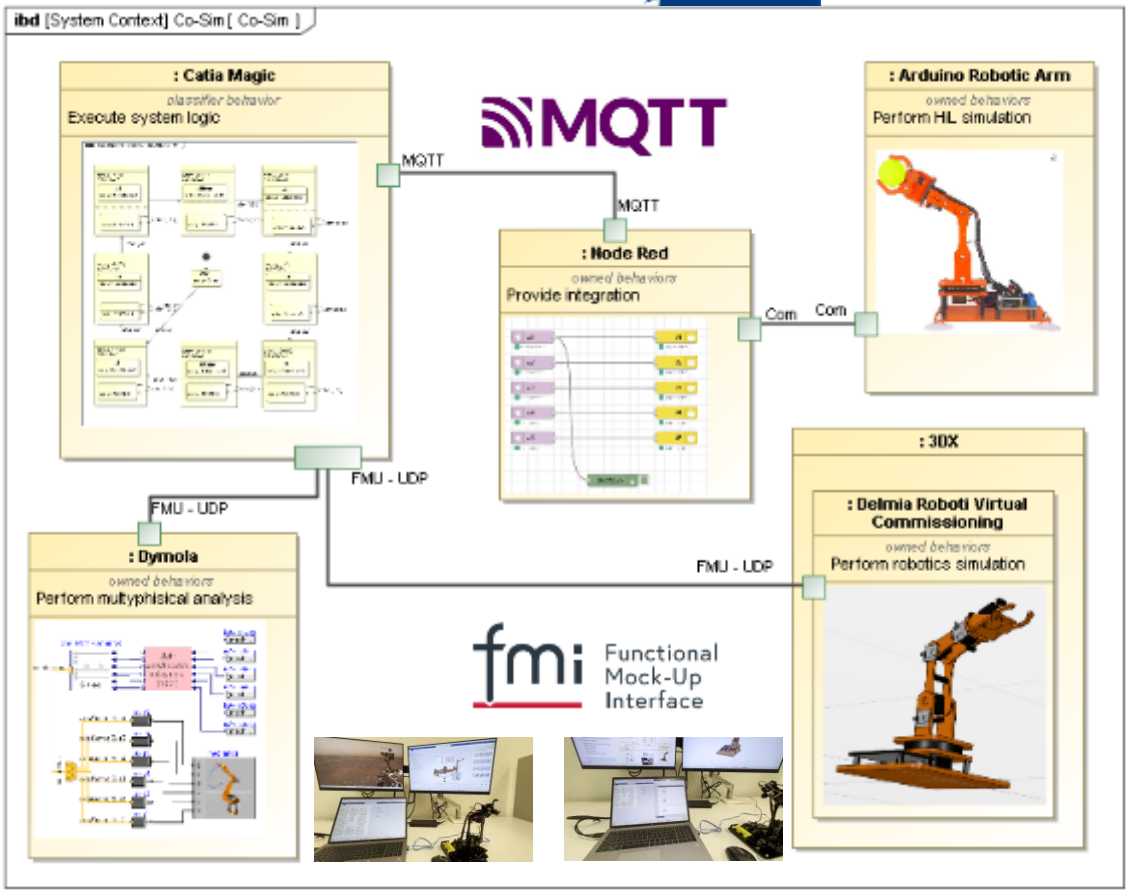
CO-SIMULATION ARCHITECTURE

VIRTUAL TWIN AS DESIGNED, AS SIMULATED AND IN OPERATION

Magic Model Analyst (MSI)

- Leveraging out-of-the-box open standards for connections: FMU, MQTT
- Integrating internal and external application for co-simulation:
  - Catia Magic – system architecture, system reqiurements
  - Dymola – multiphysics simulation
  - Robotic Virtual Commissioning – visual robot simulation
  - Hardware in the Loop – physical prototyping
- SE impact and benefits:
  - Transitioning form descriptive to executable system architecture
  - Rapid prototyping
  - What if scenarios
  - System requirements compliance

- How to demo on out-of-the-box co-sim interface - https://youtu.be/va4hLYiGf2c?si=P1mtwb_zD-54OSIE



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FACTORY FLOOR VISUALIZATION

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