BOSTON METAL

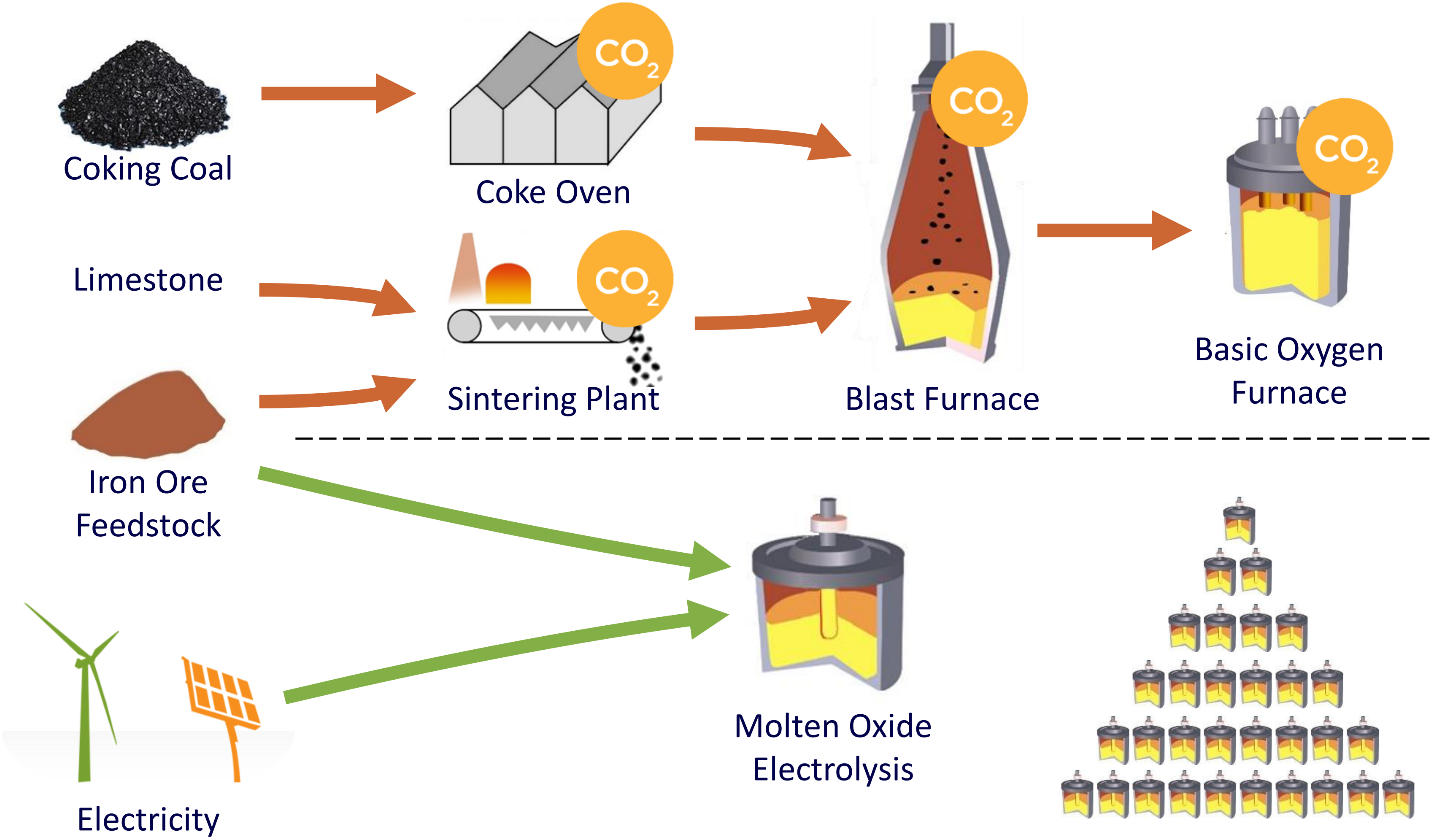
Lessons in applying Model-Based Design for systems and controls engineering in alternative energy startup environment

Igor Braverman

(controls engineering team lead)

Boston Metal

Steel production is the largest source of the industrial CO2 – 7% of global emissions



Coking Coal

Coke Oven

CO_2

Limestone

Sintering Plant

CO_2

Iron Ore Feedstock

Blast Furnace

CO_2

Basic Oxygen Furnace

CO_2

Electricity

Molten Oxide Electrolysis

2.1

gigatons CO_2 per year

0

CO_2 per year

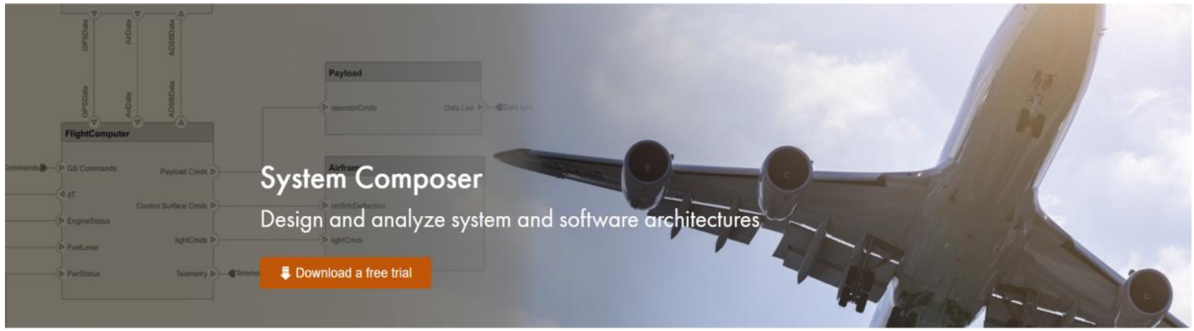
Engineering Startup Needs

Scale up technology quickly with limited resources

- Small engineering team
- Aggressive timelines
- Limited budget
- Uncertainty
- Complexity

Adopted Solution

Mathworks Model-Based Design for Systems and Controls Engineering

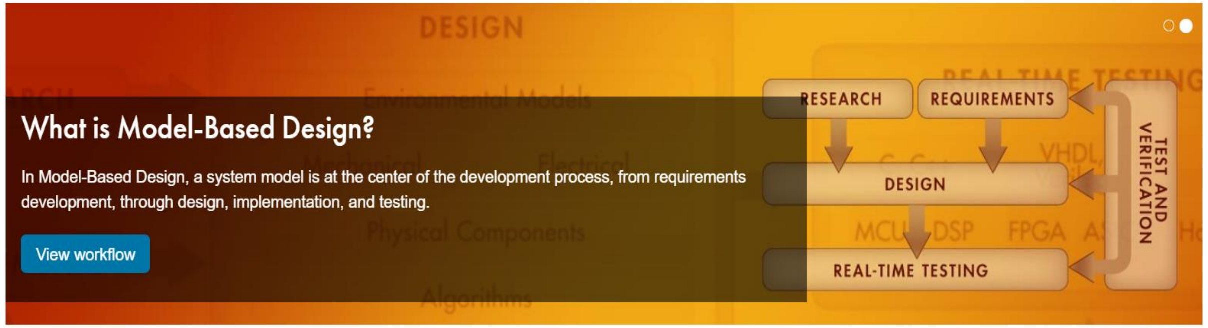


System Composer

Design and analyze system and software architectures

Image credit: Mathworks website – System Composer product page

- Facilitate communication between highly specialized functional teams
- Handle system complexity and reduce requirements uncertainty
- Perform trade space analysis for concept selection



What is Model-Based Design?

In Model-Based Design, a system model is at the center of the development process, from requirements development, through design, implementation, and testing.

Image credit: Mathworks website – Model-Based Design page

- Adopt agile methodologies for control system development, automate!
- Minimize building expensive hardware prototypes through “virtual prototyping”, perform continuous verification, find defects early
- Build insight into system behavior, perform “what-if” analysis, inform system design

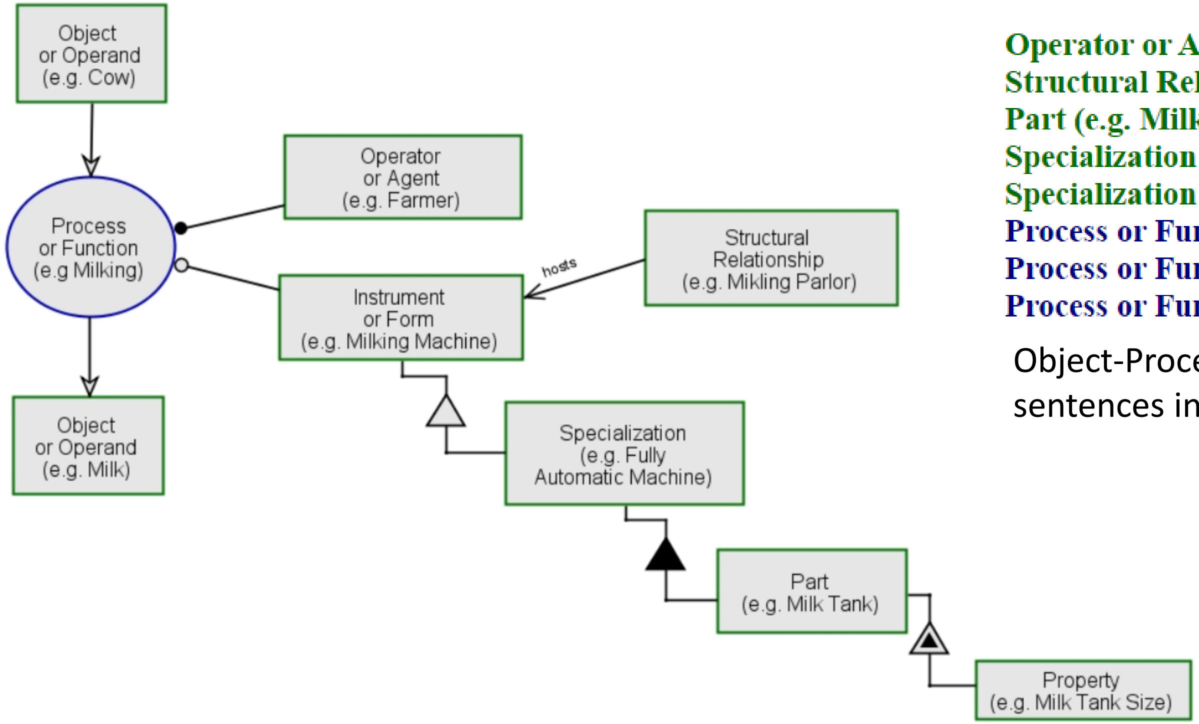
How do I systematize the use of various Mathworks MBD tools?

Apply systems thinking to product / controls development process with Mathworks MBD tools

- Treat product / controls development process with Mathworks MBD tools as a system - a set of interrelated entities
- Identify the MBD system entities form and function and their interaction with each other
- Create the MBD system model to map form onto function and demonstrate the process
- Use Object-Process Methodology for MBD system modeling

What is Object-Process Methodology (OPM)?

OPM is a conceptual modeling language for capturing knowledge and designing systems

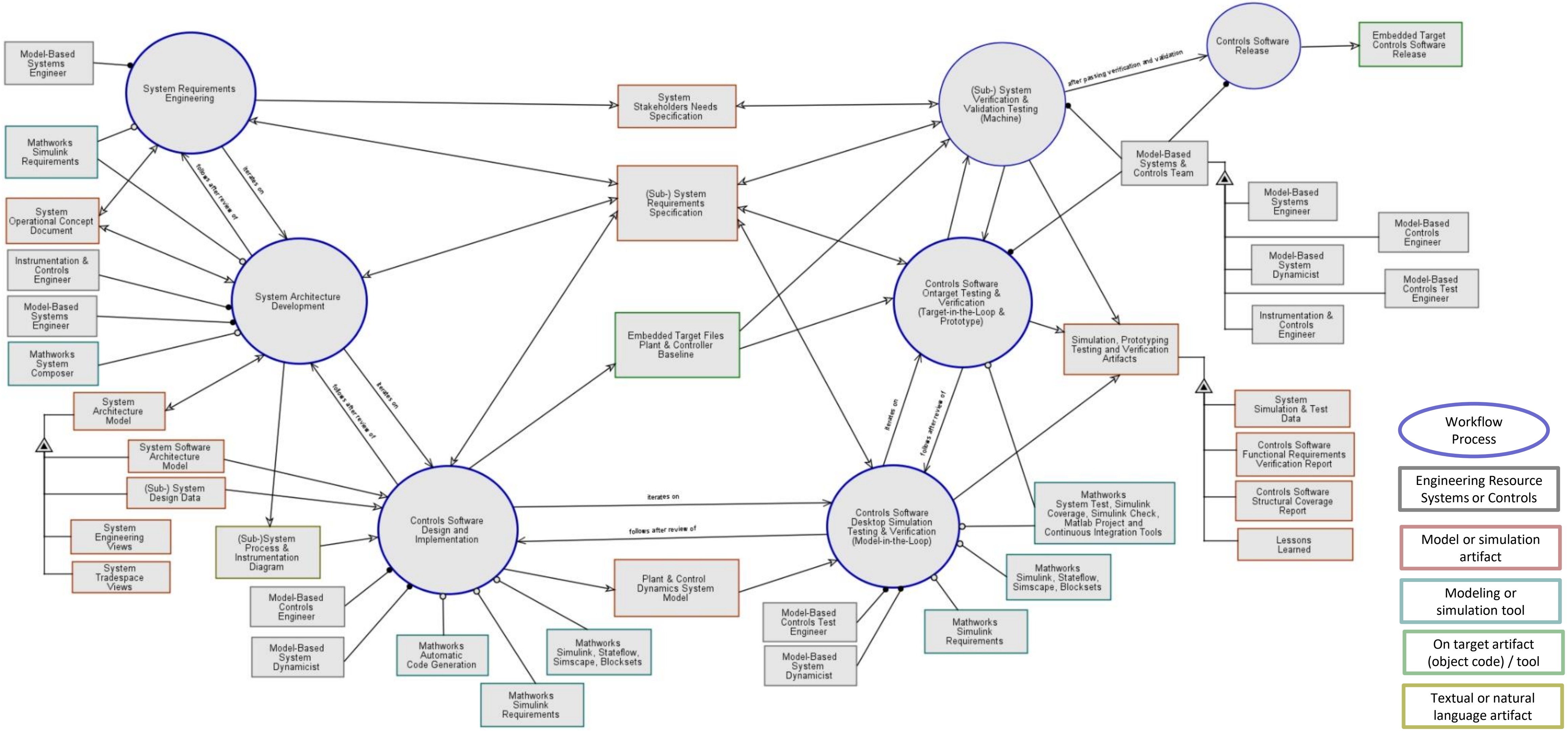


Object-Process Diagram (OPD): formally capturing function, structure and behavior of the system

Operator or Agent (e.g. Farmer) handles Process or Function (e.g Milking).
Structural Relationship (e.g. Mikling Parlor) hosts Instrument or Form (e.g. Milking Machine).
Part (e.g. Milk Tank) exhibits Property (e.g. Milk Tank Size).
Specialization (e.g. Fully Automatic Machine) is an Instrument or Form (e.g. Milking Machine).
Specialization (e.g. Fully Automatic Machine) consists of Part (e.g. Milk Tank).
Process or Function (e.g Milking) requires Instrument or Form (e.g. Milking Machine).
Process or Function (e.g Milking) consumes Object or Operand (e.g. Cow).
Process or Function (e.g Milking) yields Object or Operand (e.g. Milk).

Object-Process Language (OPL): a set of automatically generated (from OPD) sentences in a subset of English

Mathworks MBD System Object-Process Model



Model-Based Systems Engineer

System Requirements Engineering

Mathworks Simulink Requirements

System Operational Concept Document

Instrumentation & Controls Engineer

Model-Based Systems Engineer

Mathworks System Composer

follows after review of

iterates on

System Architecture Development

System Architecture Model

System Software Architecture Model

(Sub-) System Design Data

System Engineering Views

System Tradespace Views

(Sub-)System Process & Instrumentation Diagram

follows after review of

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Controls Software Design and Implementation

Model-Based Controls Engineer

Model-Based System Dynamicist

Mathworks Automatic Code Generation

Mathworks Simulink Requirements

Mathworks Simulink, Stateflow, Simscape, Blocksets

System Stakeholders Needs Specification

(Sub-) System Requirements Specification

Embedded Target Files Plant & Controller Baseline

Plant & Control Dynamics System Model

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Controls Software Ontarget Testing & Verification (Target-in-the-Loop & Prototype)

(Sub-) System Verification & Validation Testing (Machine)

after passing verification and validation

Controls Software Release

Embedded Target Controls Software Release

Model-Based Systems & Controls Team

Model-Based Systems Engineer

Model-Based Controls Engineer

Model-Based System Dynamicist

Model-Based Controls Test Engineer

Instrumentation & Controls Engineer

Simulation, Prototyping Testing and Verification Artifacts

System Simulation & Test Data

Controls Software Functional Requirements Verification Report

Controls Software Structural Coverage Report

Lessons Learned

Workflow Process

Engineering Resource Systems or Controls

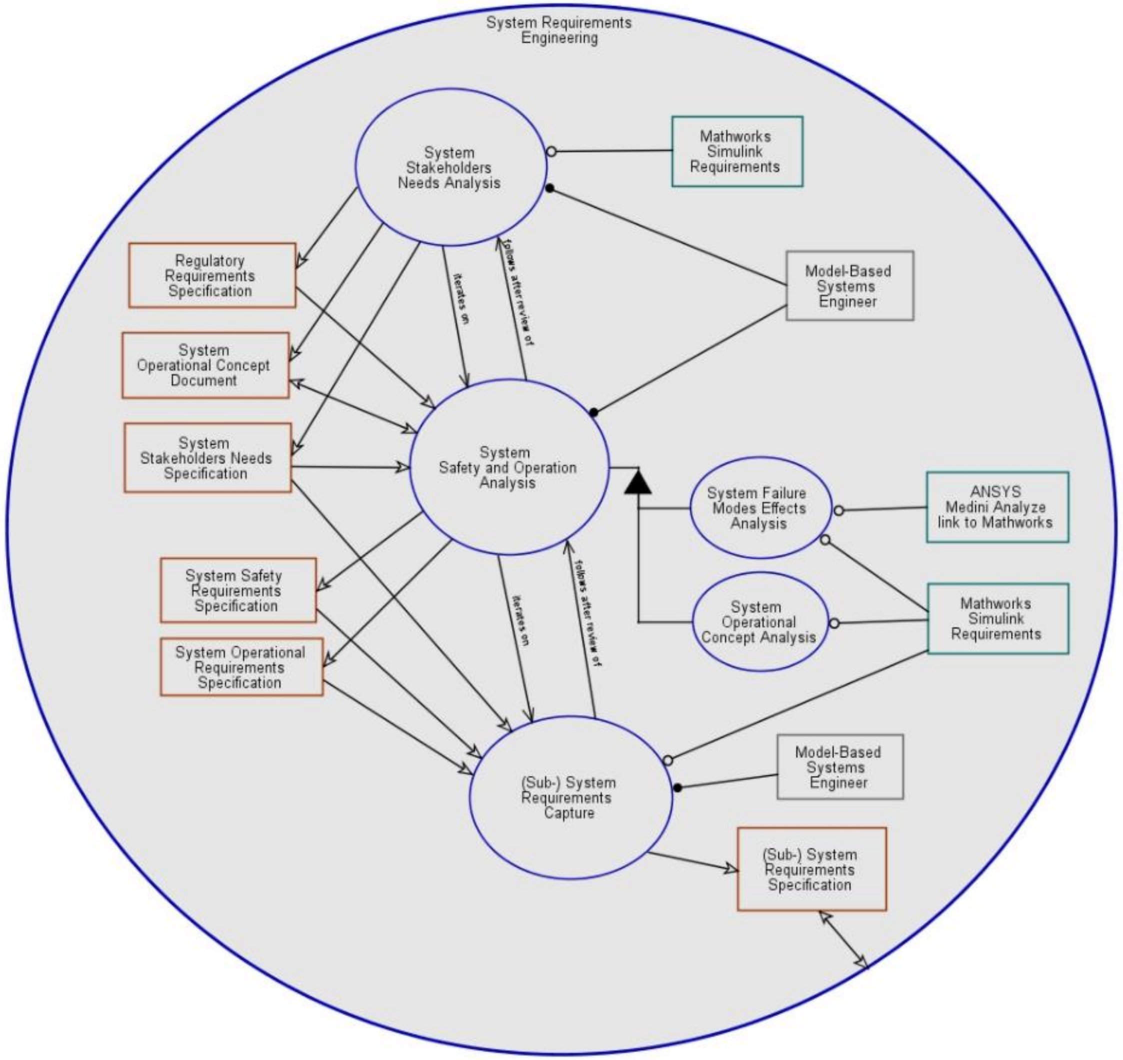
Model or simulation artifact

Modeling or simulation tool

On target artifact (object code) / tool

Textual or natural language artifact

System Requirements Engineering - OPM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System Safety and Operation Analysis
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ANSYS Medini Analyze link to Mathworks
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(Sub-) System Requirements Capture
Model-Based Systems Engineer
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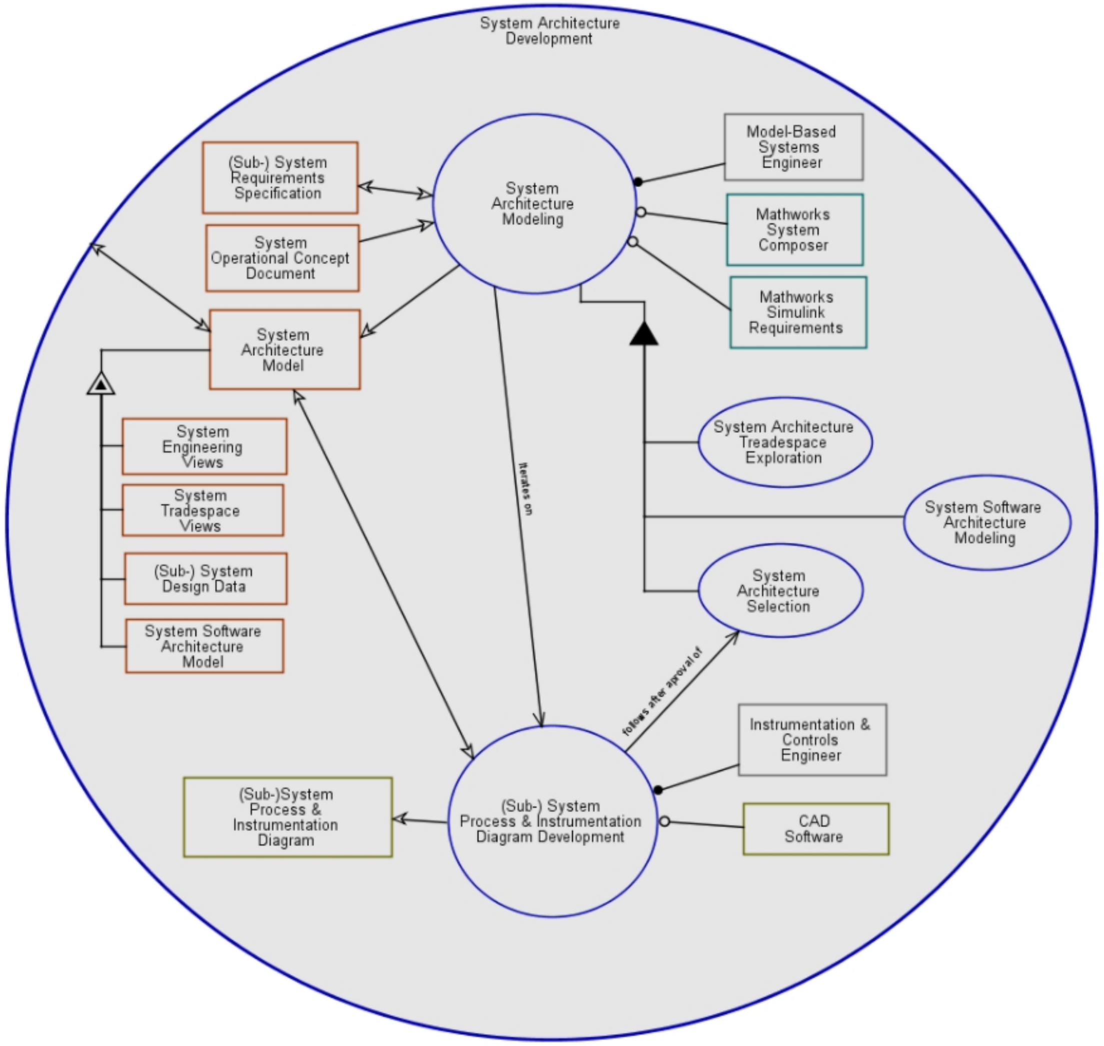
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System Software Architecture Modeling
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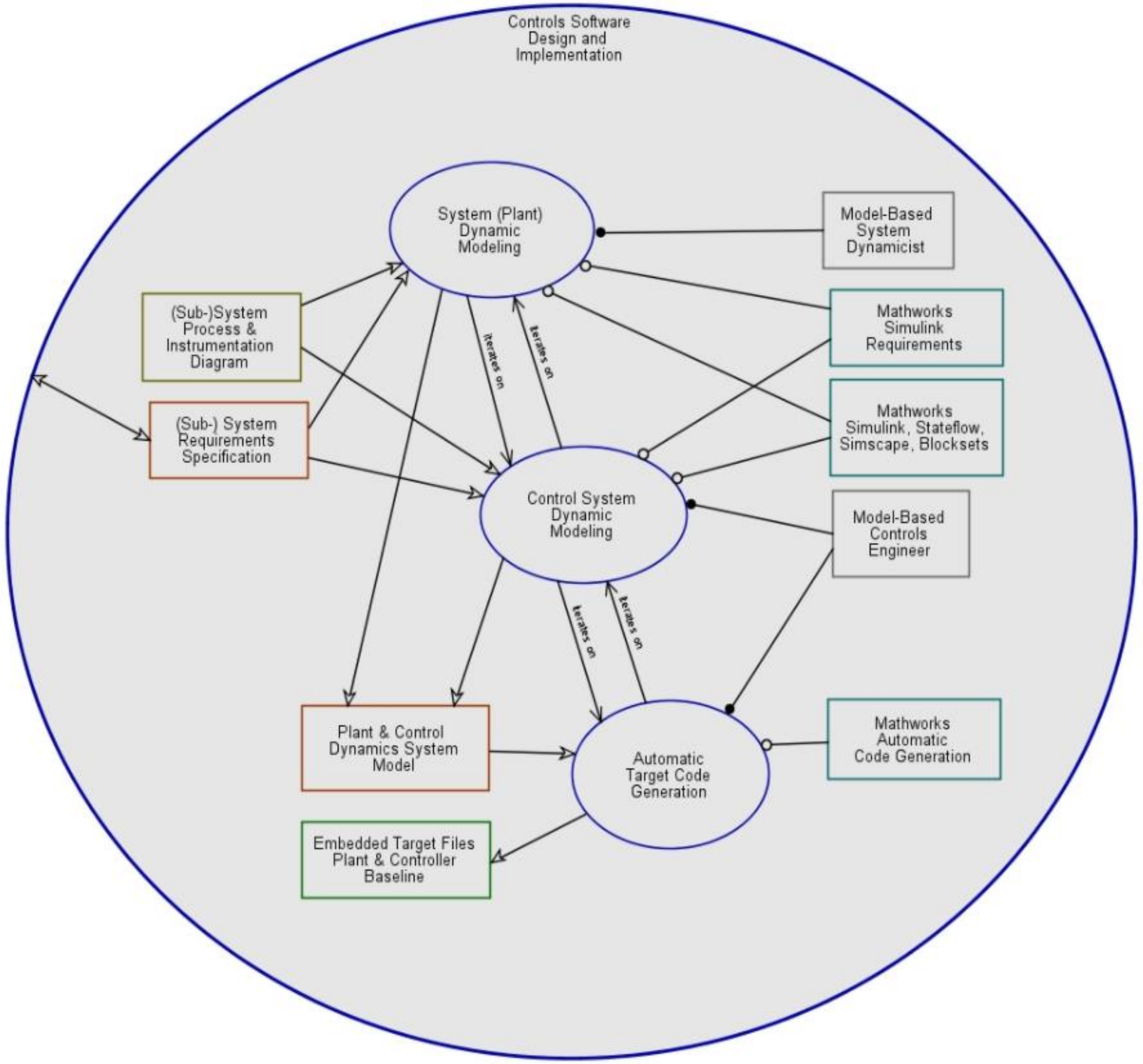
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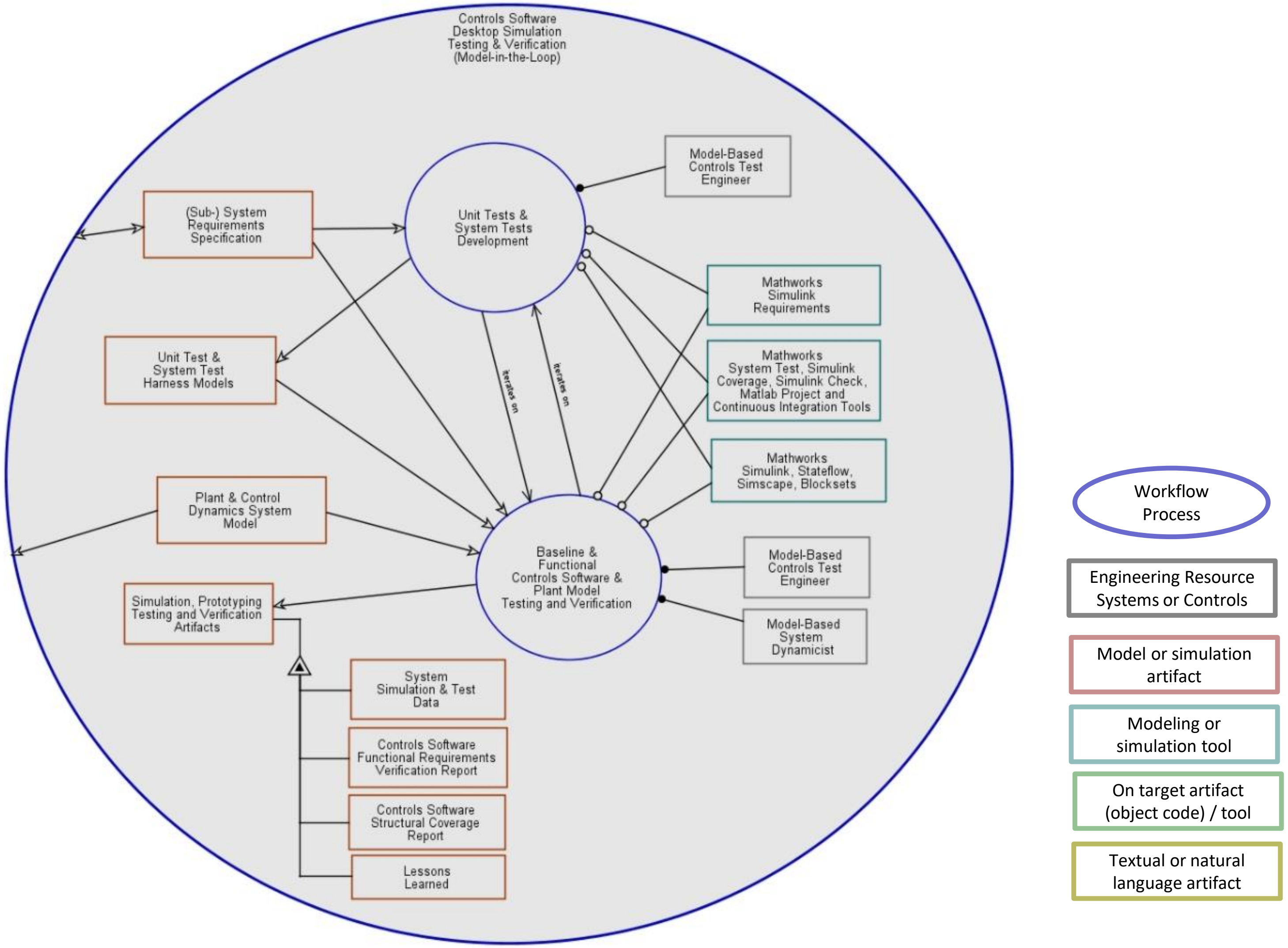

Controls Software Desktop Simulation Testing & Verification (Model-in-the-Loop)

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Plant & Control Dynamics System Model

Baseline & Functional Controls Software & Plant Model Testing and Verification

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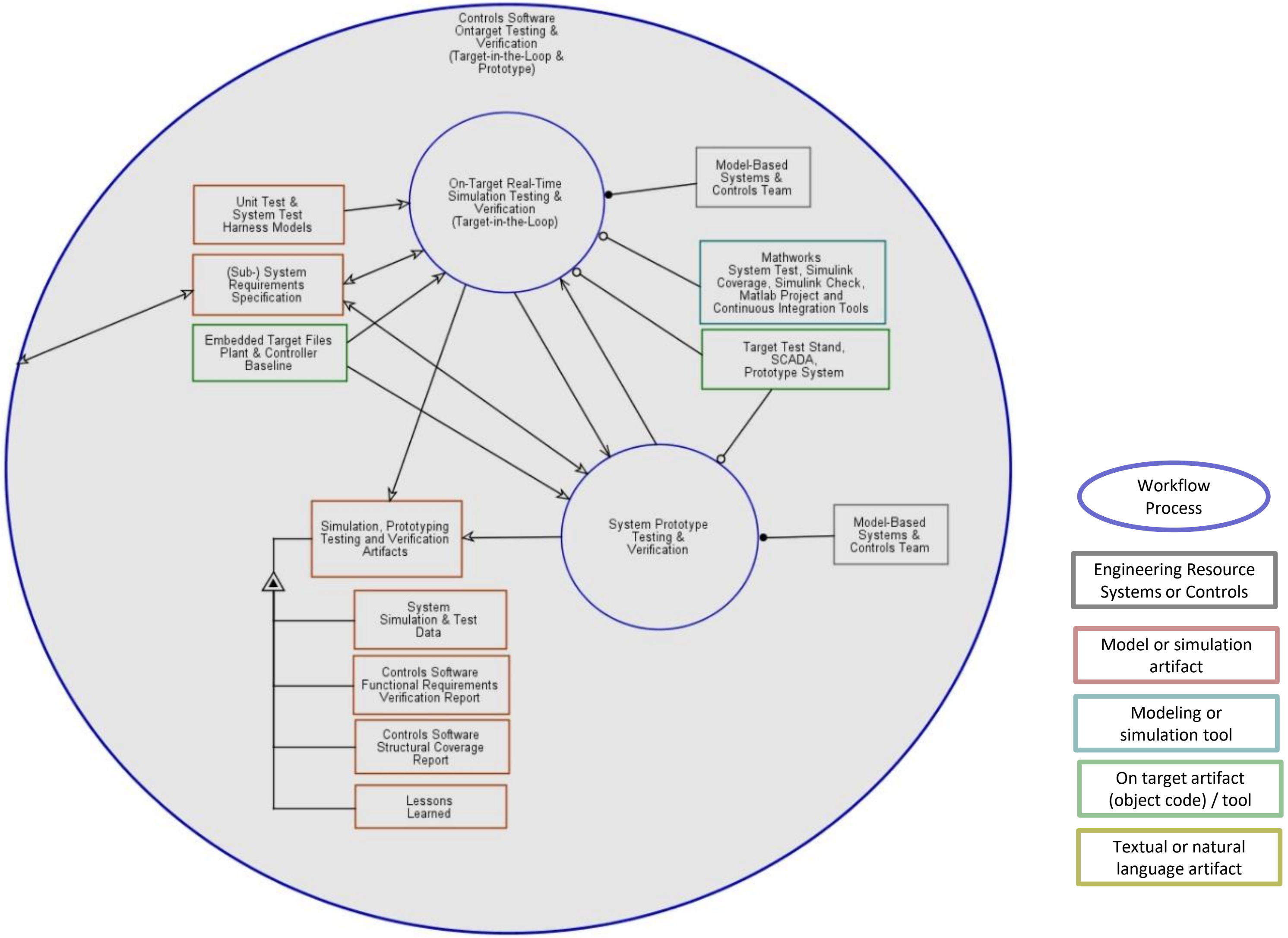

Controls Software Ontarget Testing & Verification (Target-in-the-Loop & Prototype)

On-Target Real-Time Simulation Testing & Verification (Target-in-the-Loop)

Model-Based Systems & Controls Team

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Target Test Stand, SCADA, Prototype System

System Prototype Testing & Verification

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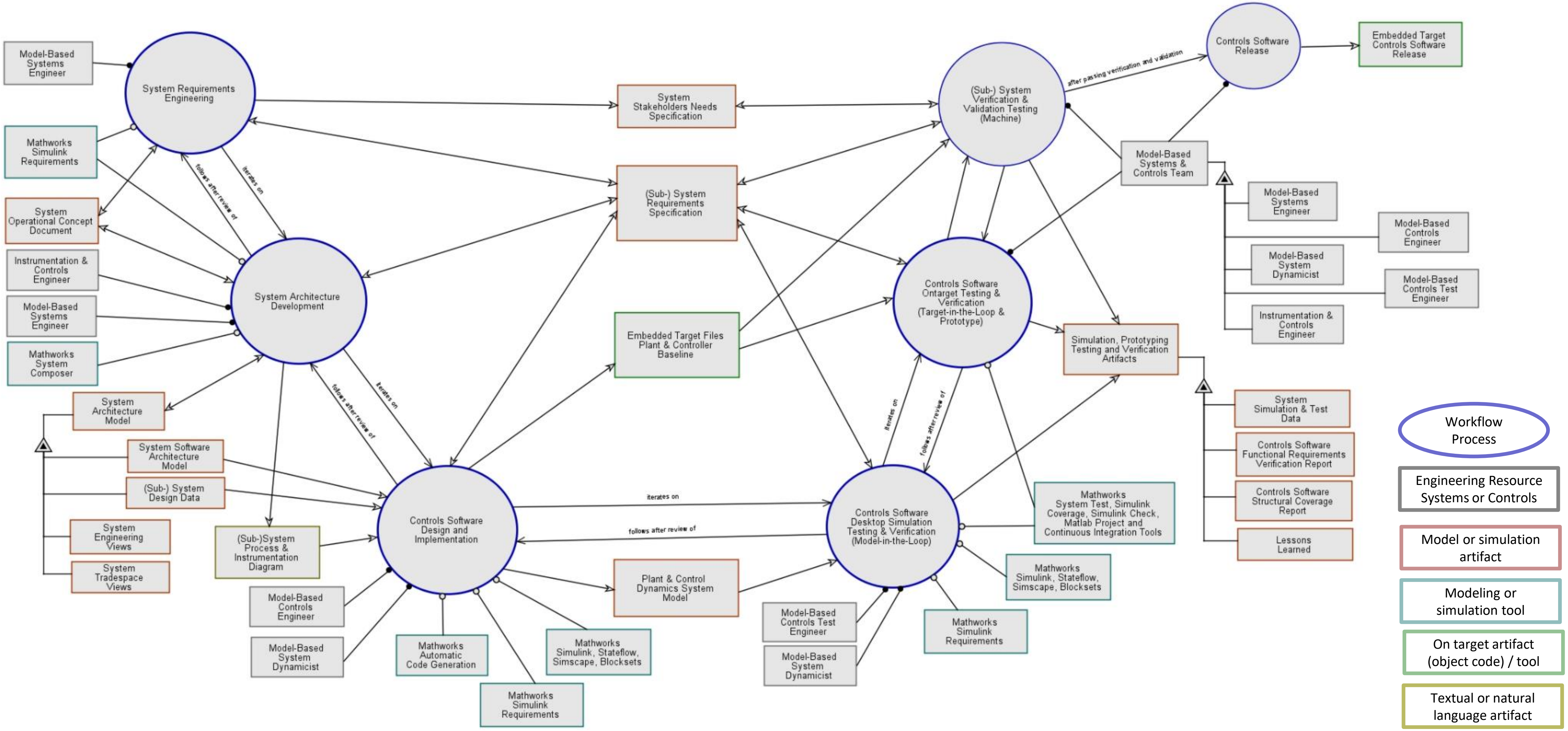
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Thank you!

Questions?