# An e*X*tended *M*odel *B*ased *D*evelopment (XMBD) methodology
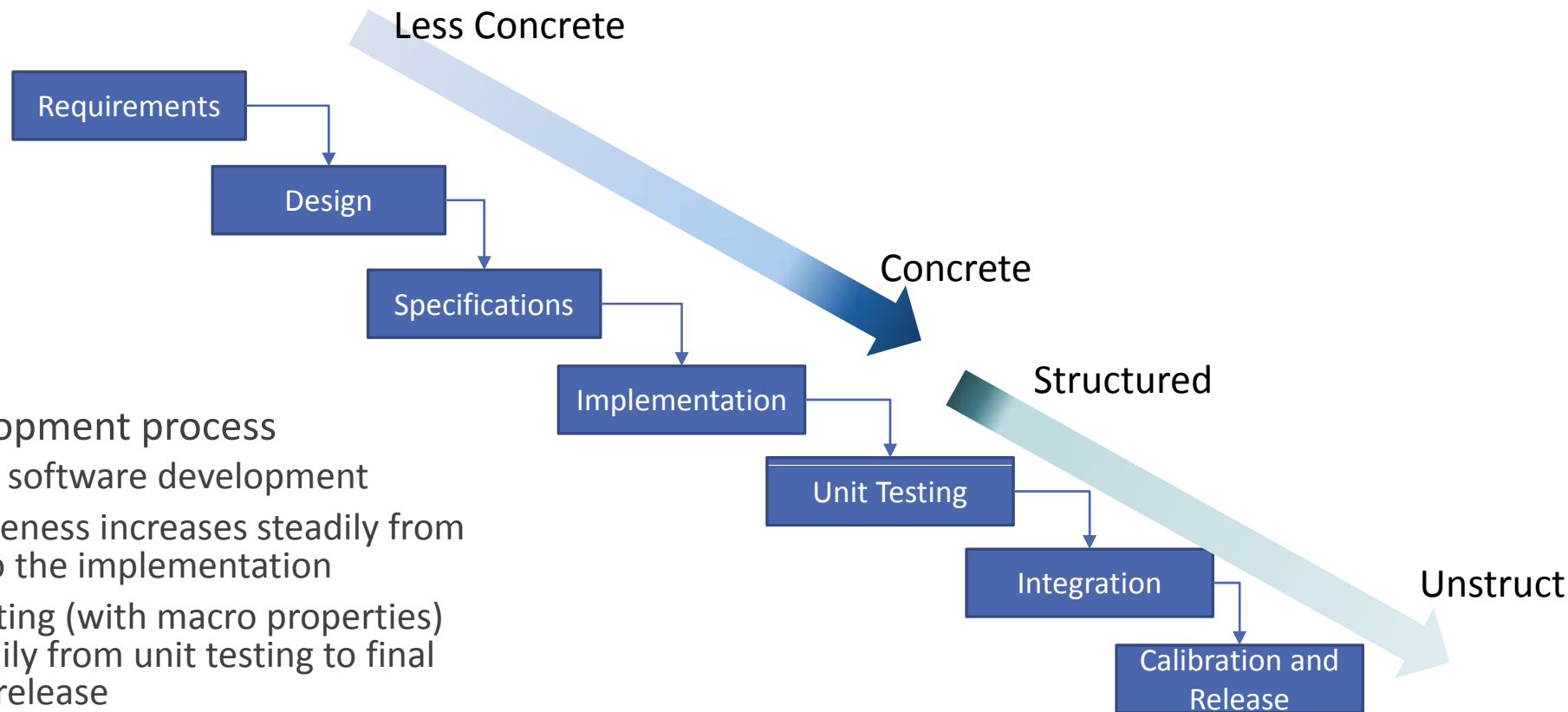
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MBD中部コンファレンス 2014/12/18

# Product Development Process
# The "Rational Model" – Waterfall approach

Less Concrete

Requirements

Design
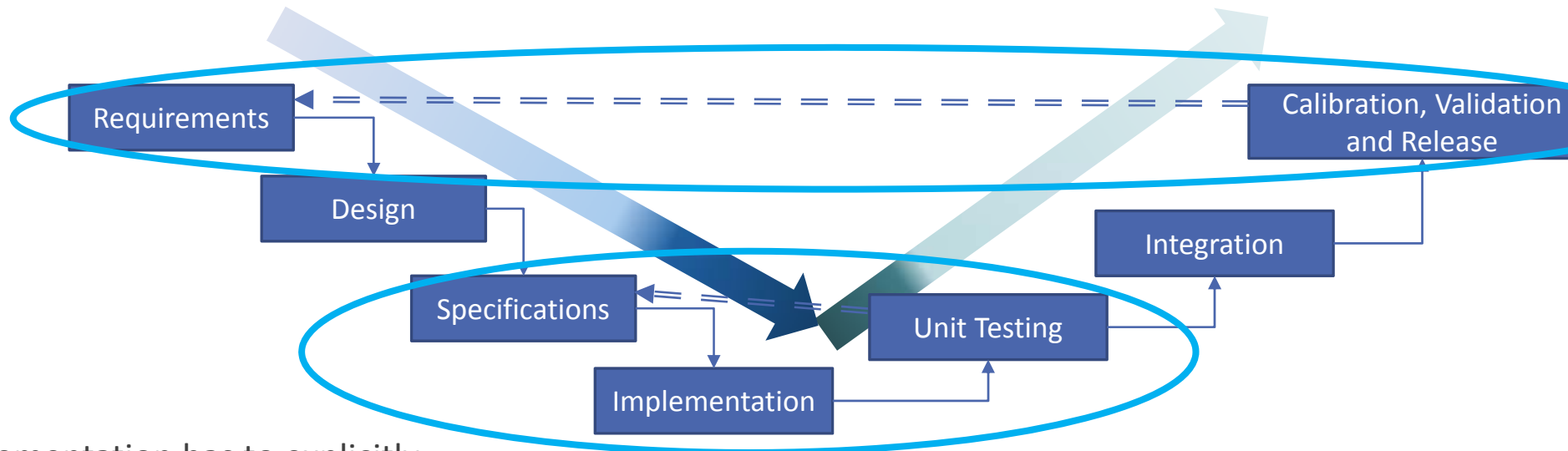
Specifications

Concrete

Implementation

Structured

**Structured development process**

- borrowing from software development
- Level of concreteness increases steadily from requirements to the implementation
- Structure of testing (with macro properties) decreases steadily from unit testing to final calibration and release

Unit Testing

Integration

Unstruct

Calibration and Release

# Product Development Process
## The "Rational Model" – The V-process (folded Waterfall)



**Key idea: Implementation has to explicitly satisfy the Specifications**

- Make Specifications as concrete as possible
- Focus on unit testing against specifications
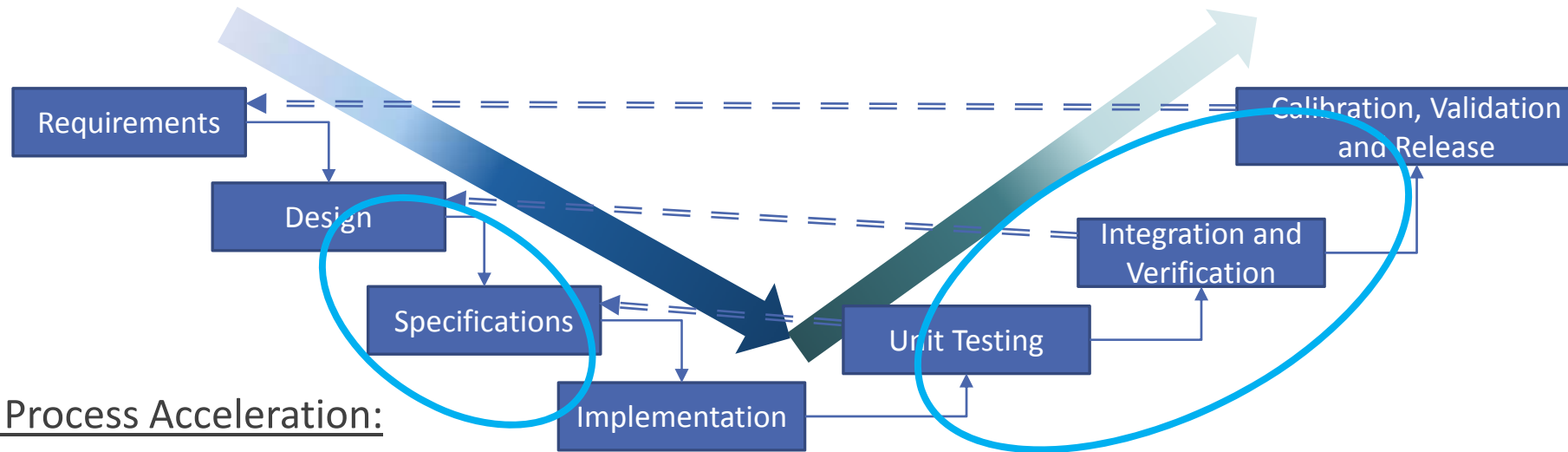- Coverage of unit tests relative to implementation and specifications

(also borrowed from software engineering)

Ultimately, the mechatronic system has to satisfy the product goals (captured as requirements)

- Validation against requirements
- Calibrations (adjustments) as needed

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# Product Development Process
# The "Rational Model" – MBD V-process (folded Waterfall)



**Requirements** → **Design** → **Specifications** → **Implementation** → **Unit Testing** → **Integration and Verification** → **Calibration, Validation and Release**

## Key Idea: Design Process Acceleration:

Use of "Models" for physical system and controls

- Design Solutions becomes more concrete also
  - *But NOT Design Rationale*
- Blurring the distinction between Design and (Executable) Specifications
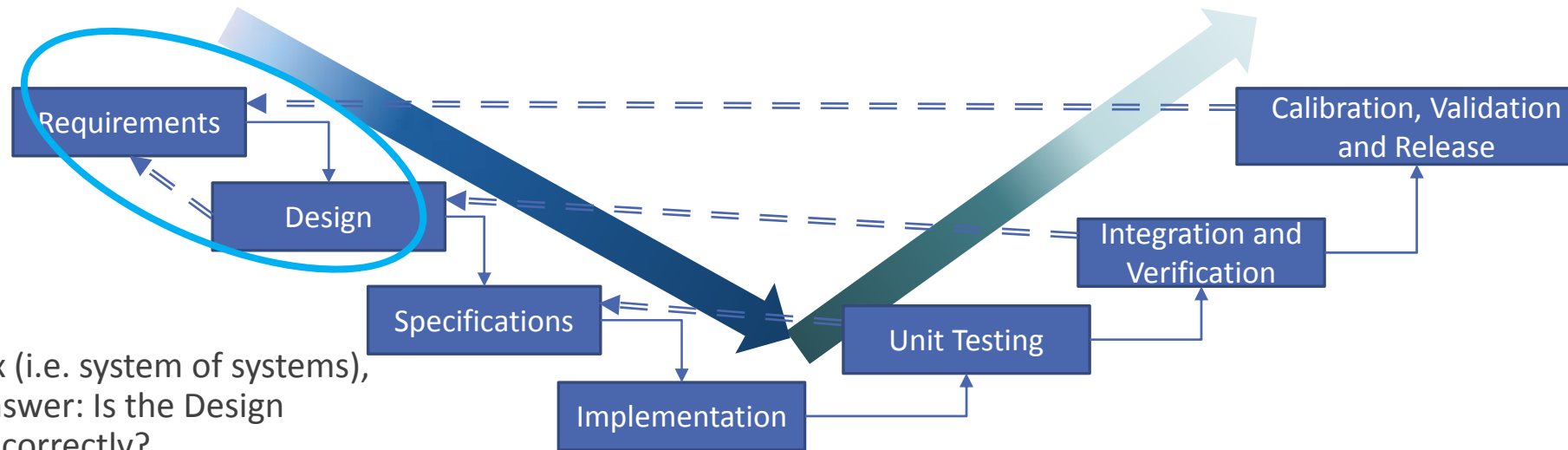- Automatic Implementations (Auto Code)

Upfront Virtual Testing through use of MIL, SIL and HIL simulations

- Reduced actual tests on prototypes
- Increased test scope and variety

"Preliminary" Calibration using Virtual Simulations

# Product Development Process
## The "Rational Model" – MBSE V-process (folded Waterfall)



systems became complex (i.e. system of systems),
important question to answer: Is the Design
turing the requirements correctly?

Attempt to make requirements more concrete

Structured Requirements Analysis
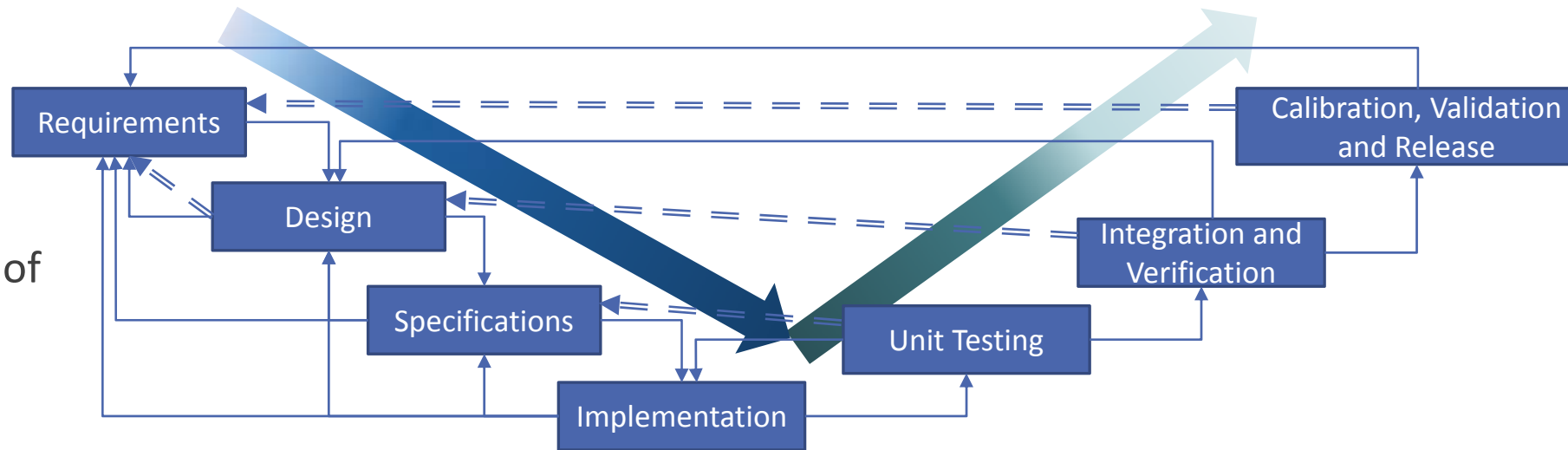
Upfront Design verification against requirements

This is the "State of the Art" today
◦ Tools and Processes are built around this paradigm

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# Product Development Process
## The "Empirical Model" – Design-Requirements-Iterative Process



ut, this is the "State of
he Practice" today

Requirements are NOT the starting point – any part of
the process can be: Code, Models, Design Ideas are
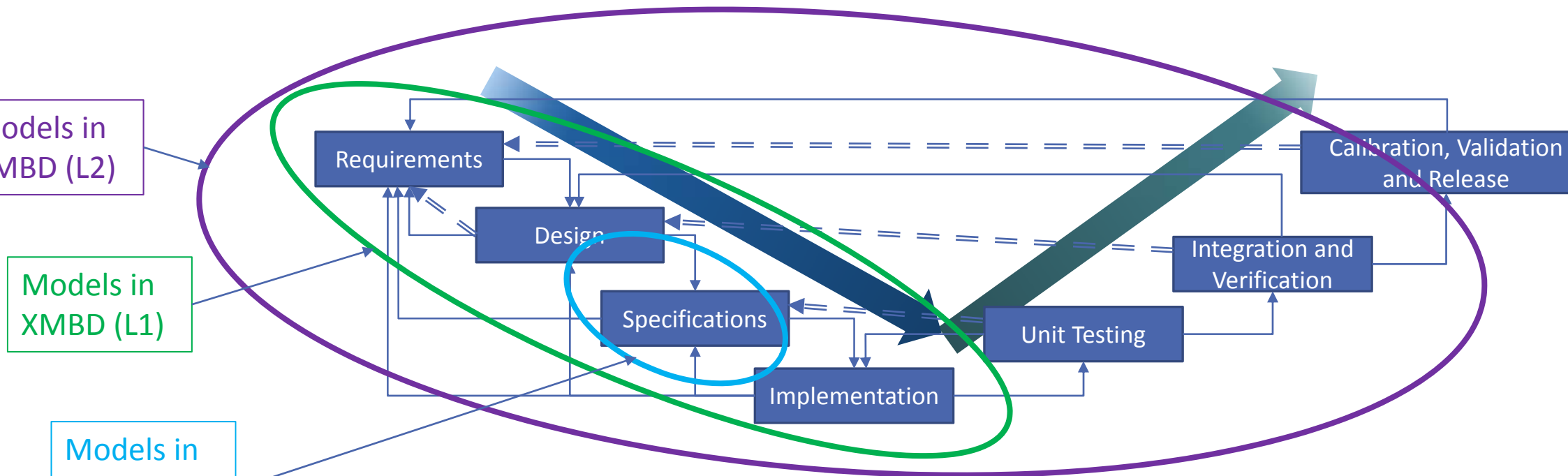equally valid starting points

Development is iterative, with Requirements
impacting and impacted by Design, Implementation,
etc

◦ Requirements derived from Design, Implementation, Testing, …

We need tools and processes that are aligned
with "State of the Practice"

# Product Development Process
## The "Empirical Model" – Design-Requirements-Iterative Process



- Models in XMBD (L2)
- Models in XMBD (L1)
- Models in Traditional MBSE

Requirements
Design
Specifications
Implementation
Unit Testing
Integration and Verification
Calibration, Validation and Release

◦ Multi-directional dependencies needs to be captured – requires an "eXtended / eXtreme" modeling framework that includes more than just physical system and control strategy

  ◦ Requirements need to be made more concrete

  ◦ Tests (Unit, Verification, Analysis, Validation) need to be made more structured

  ◦ Models for requirements, conceptual design, executable specifications, software, tests, analysis, ...

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# eXtended Model Based Development

An eXtended Modeling framework where all relevant assets are Modeled:

◦ Requirements

◦ Design (Design Decisions, Design Assumptions, Functional partitioning, algorithm)

◦ Implementation (Software, Software Specs, Executable Algorithm Specifications)

◦ Verification and Validation

A Continuous Iterative environment where traceability and iterations are supported between any of the relevant assets

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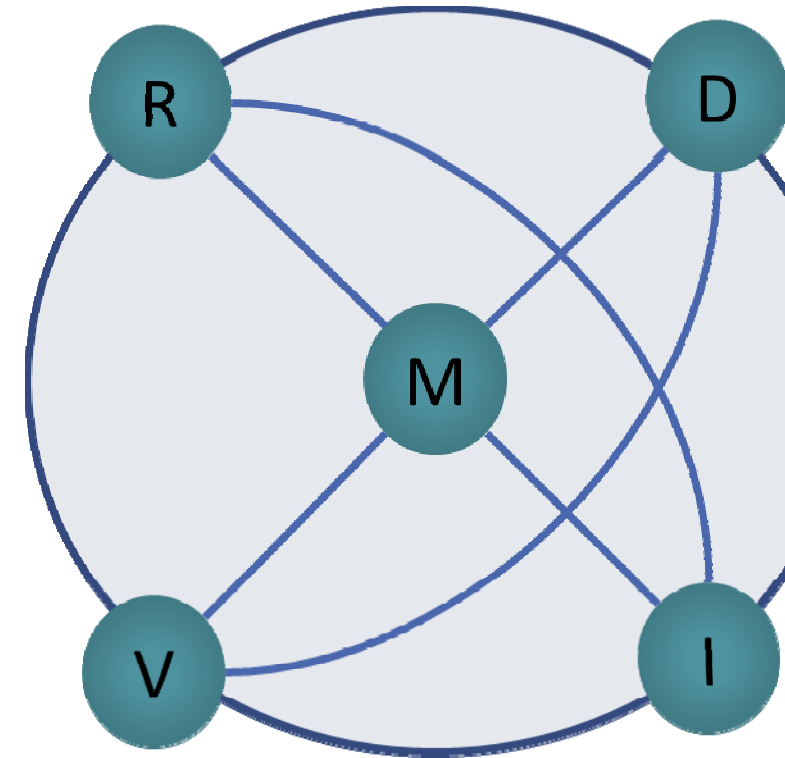
# Conclusions

"State of the Art" proposes a "Requirements Driven Approach"

"State of Practice" illustrates an Iterative environment for Design, Requirements, Implementation and Testing

We Propose an eXtended Model Based Development (XMBD) approach to align with the "State of Practice"

What is Needed for XMBD?

◦ Common framework for abstracting / modeling of relevant assets such as requirements, design, etc.
  ◦ Intuitive and non-burdensome to the practicing engineer
  ◦ Flexible to allow for evolving understanding
  ◦ Providing state of the art process support for the practicing engineer
◦ New tools and environment that understand and facilitate a "Design-Requirement Iterative Process"