DEPENDABLE
COMPUTING

The Problem-Derived World-Situated Machine Model

M. Anthony Aiello
Dependable Computing
9 June 2015

DEPENDABLE COMPUTING

Systems of Systems
The Challenge of Reuse

- Reuse is a key feature of systems of systems
  - Systems — with prior missions — are reused to complete a new mission

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- Existing approaches struggle with both of these challenges

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We introduce a solution based on
Problem Frames, Real-World Types, and Argumentation

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The Problem-Derived World-Situated Machine Model

- A *reference model* for safety- and security-critical systems engineering
  - from the problem to be solved
  - into the world the solution will transform
- *What* must the system accomplish?
- *Where* must the solution take place?

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- *What* must the system accomplish? — Interface

- *Where* must the solution take place? — Context

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Why Do We Build Systems?

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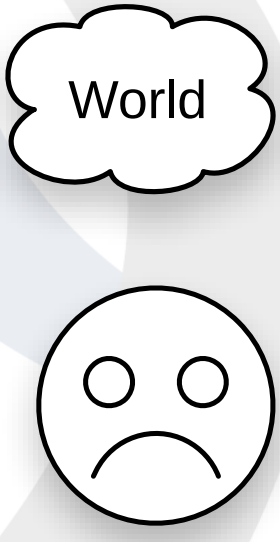

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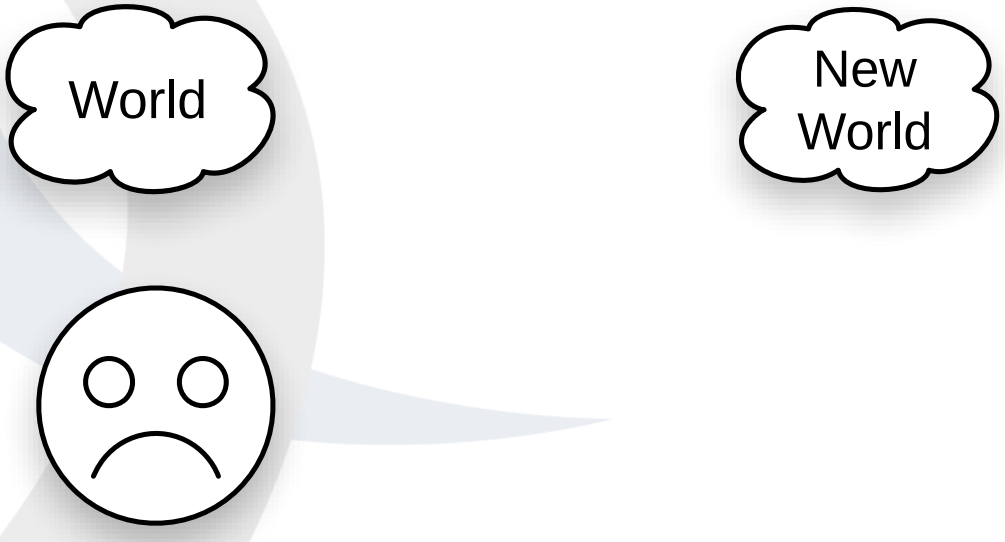

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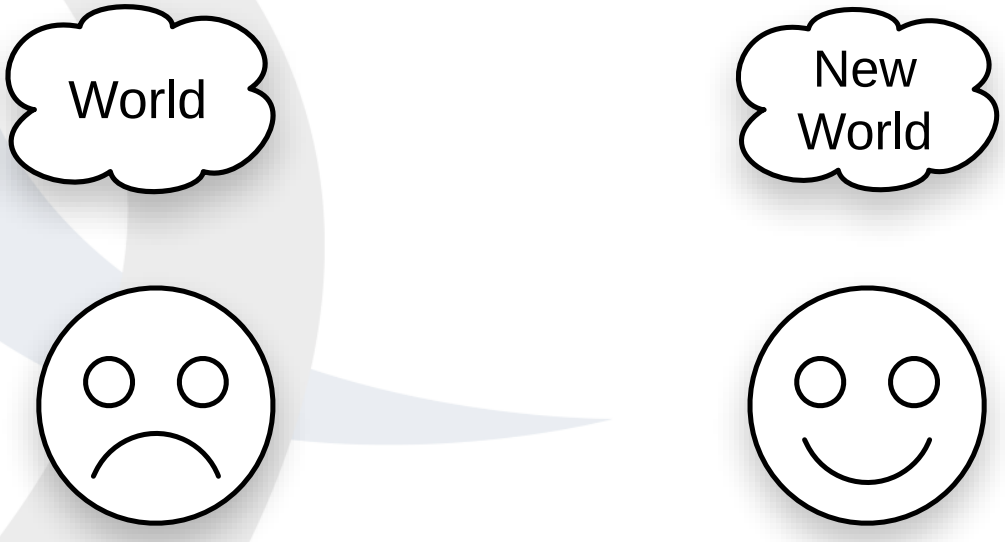

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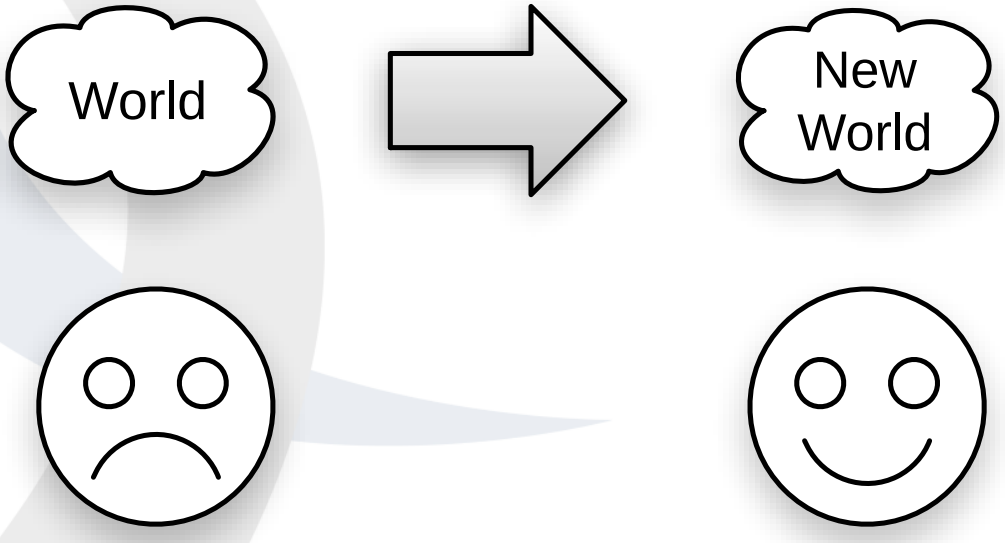

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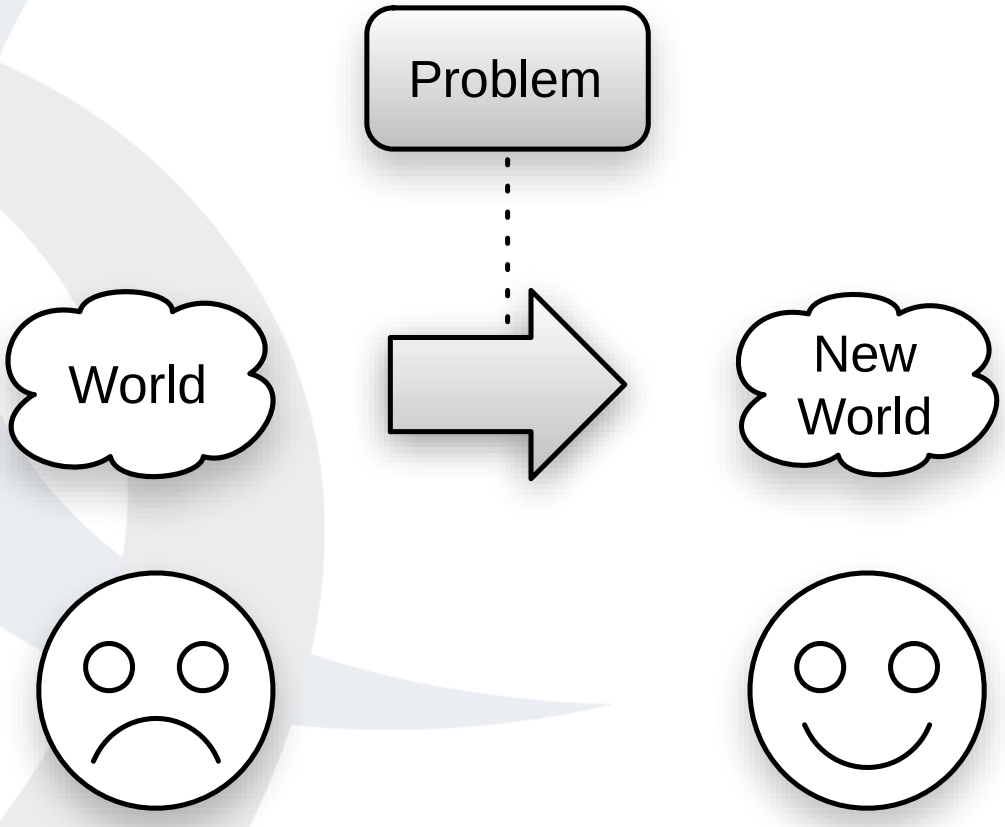

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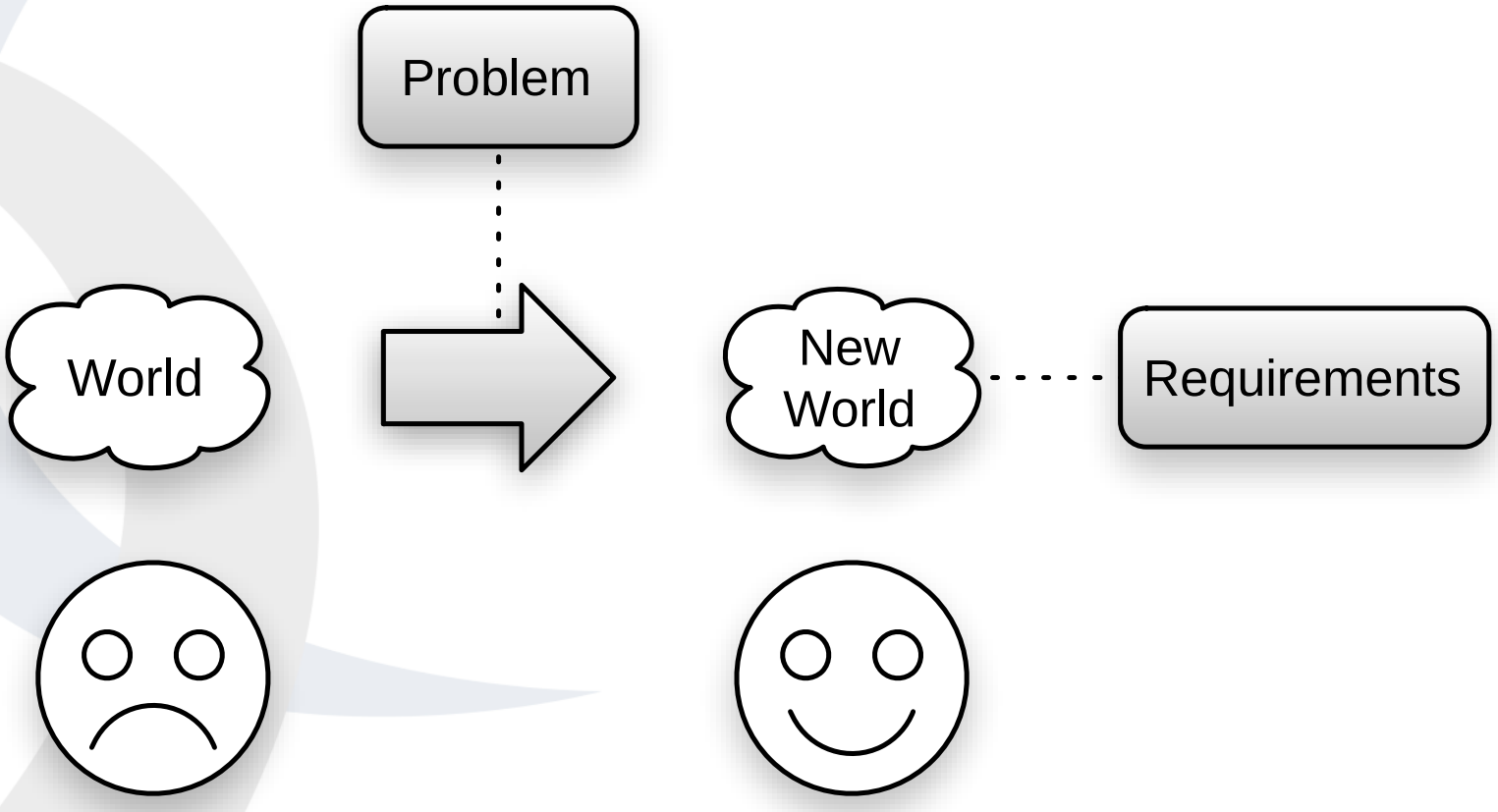

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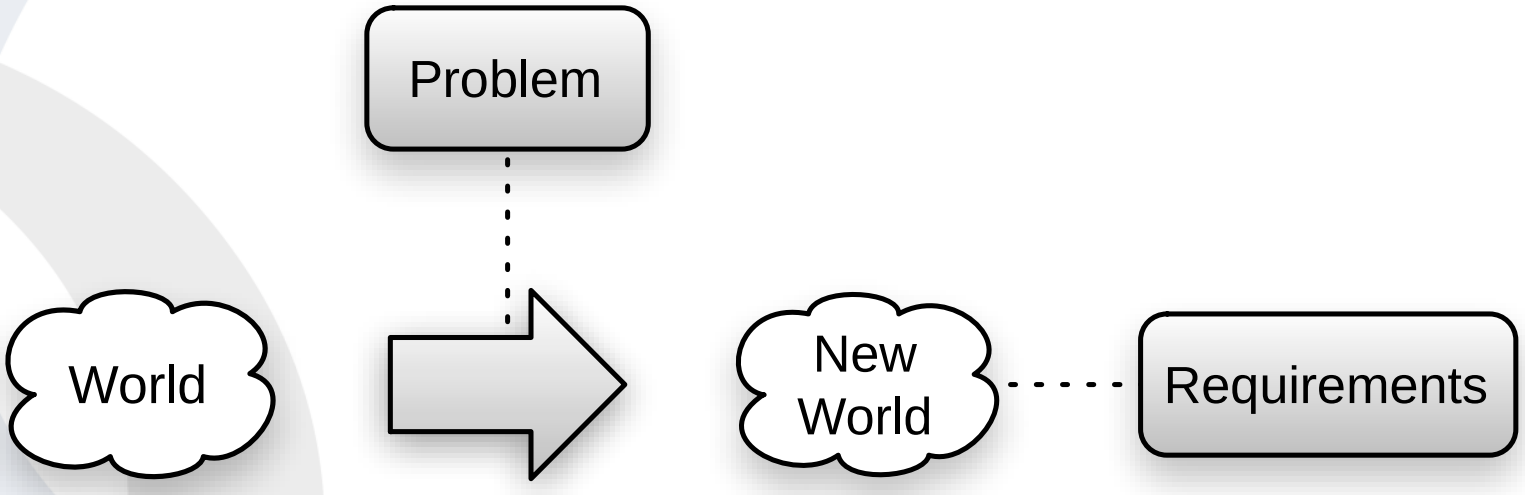

We build systems to solve a problem, thereby changing the world.

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How Do We Solve the Problem?

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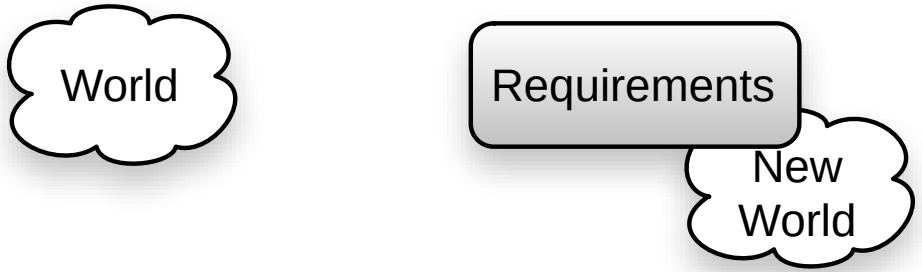

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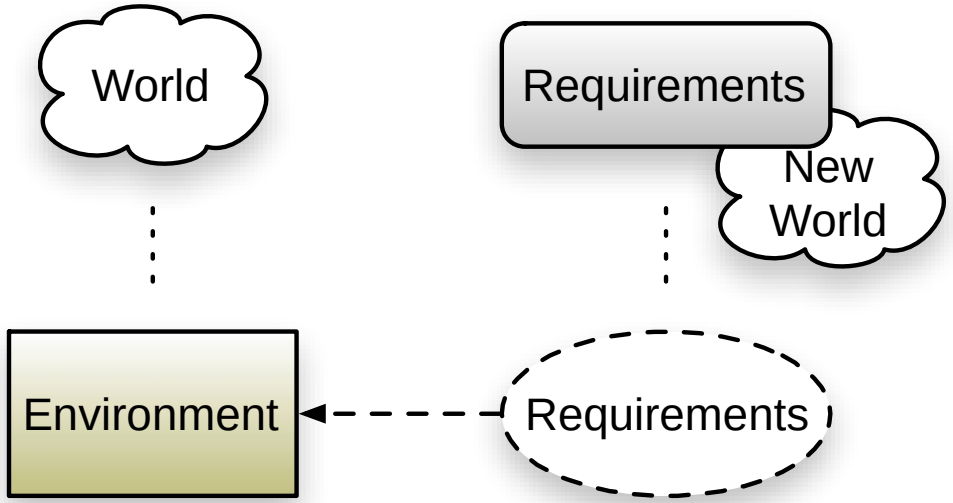

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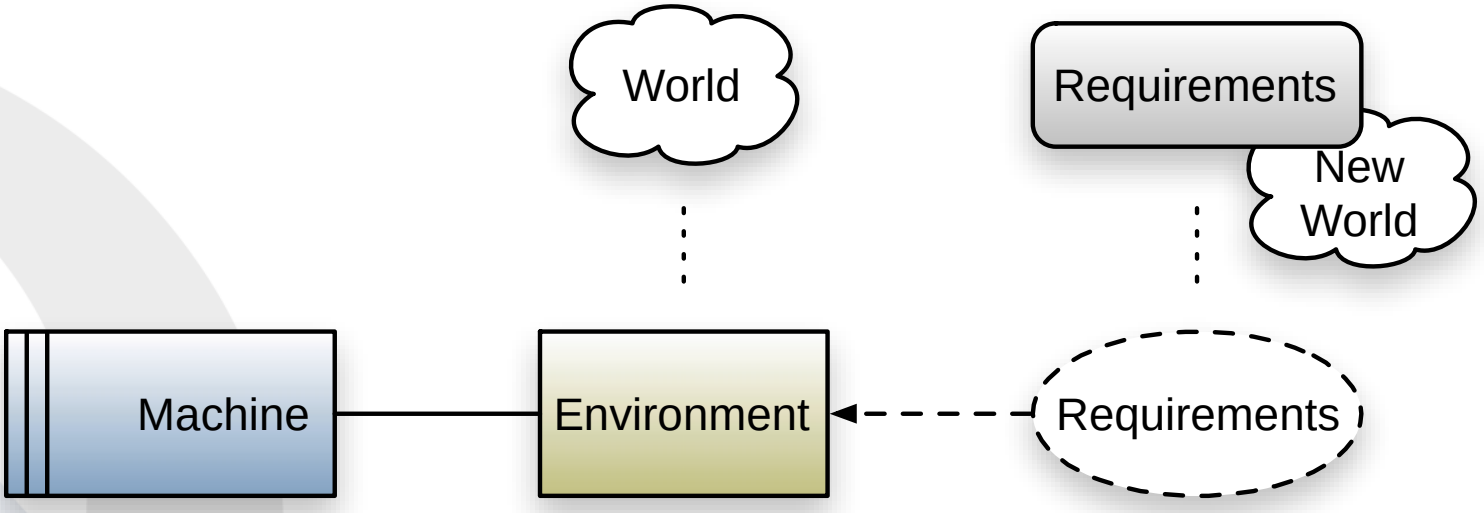

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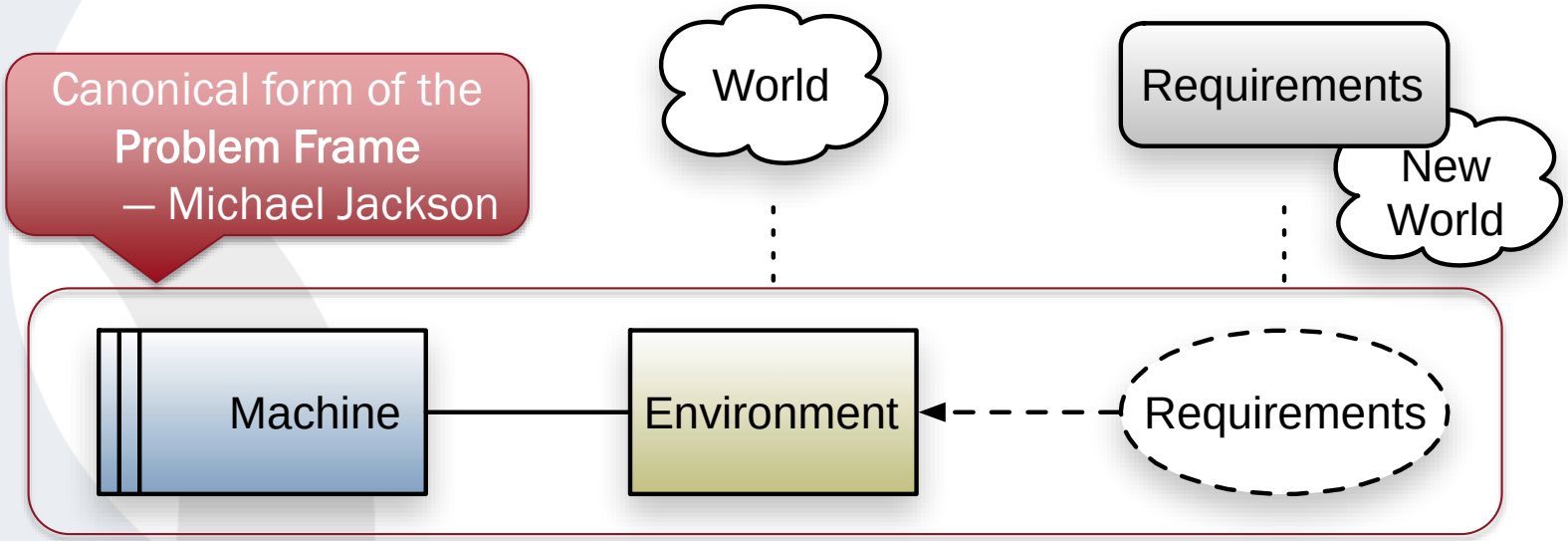

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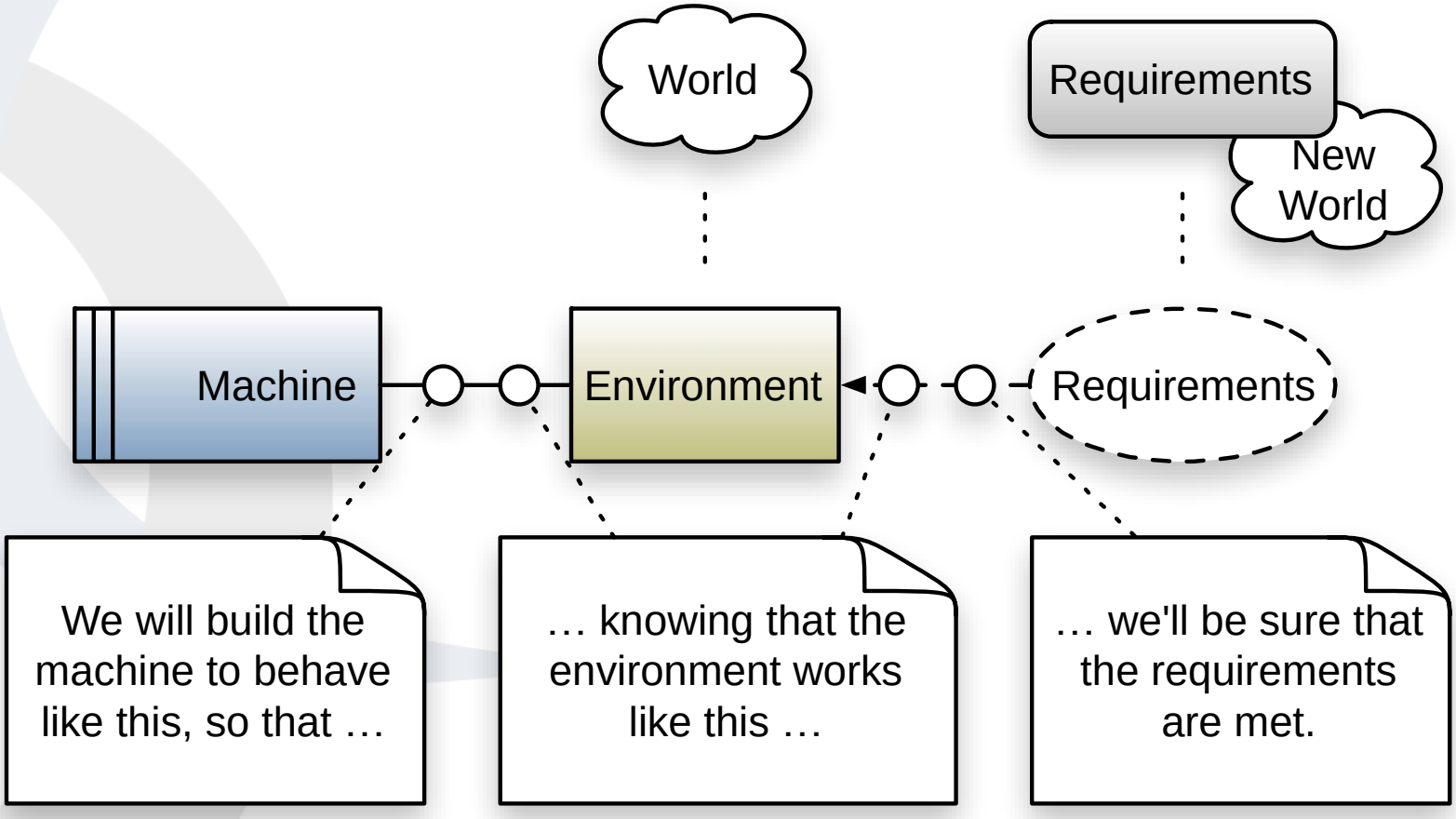

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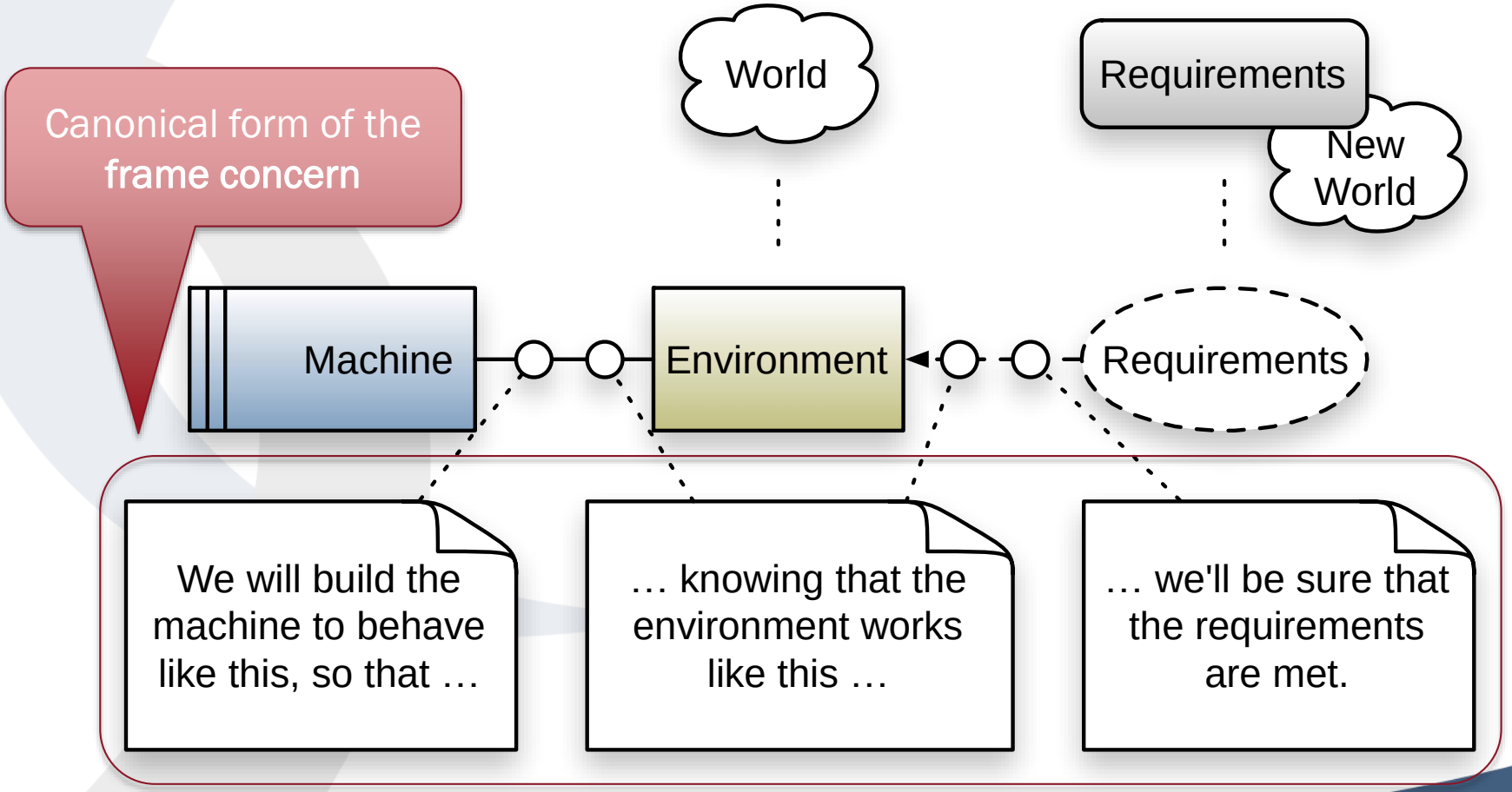

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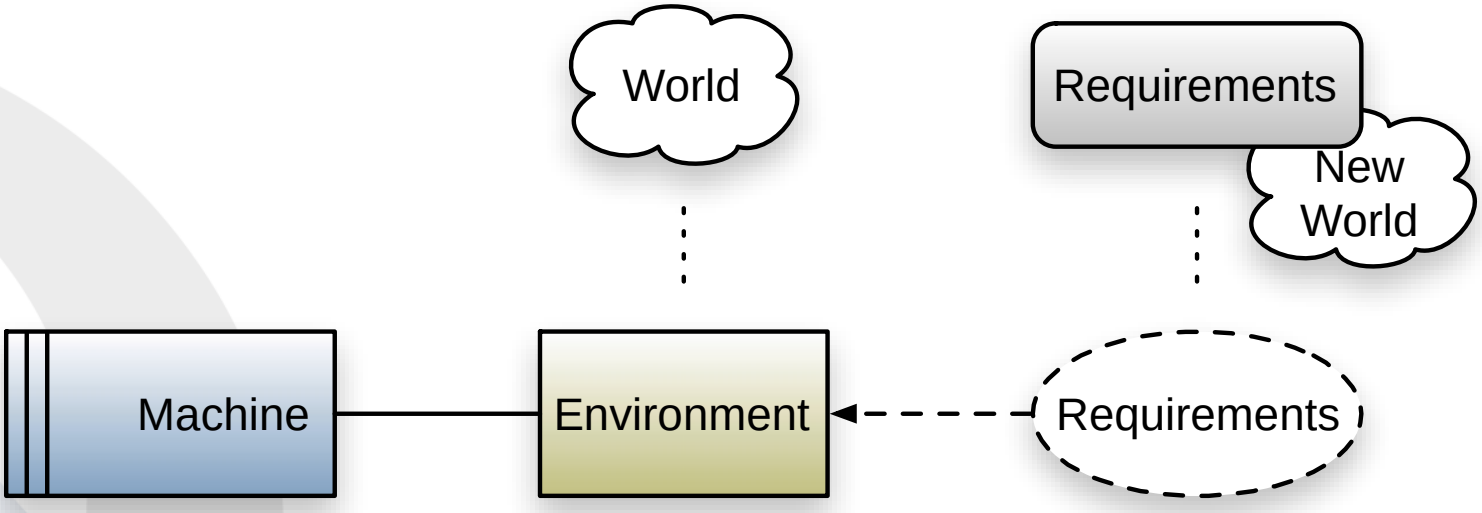

We solve the problem by satisfying the *frame concern*:

The Machine and the World satisfy the Requirements

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The Problem-Derived World-Situated Machine Model

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Problem

Explicitly identify the problem to be solved

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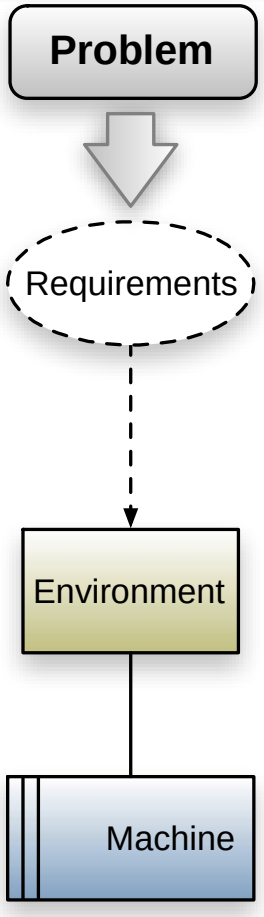

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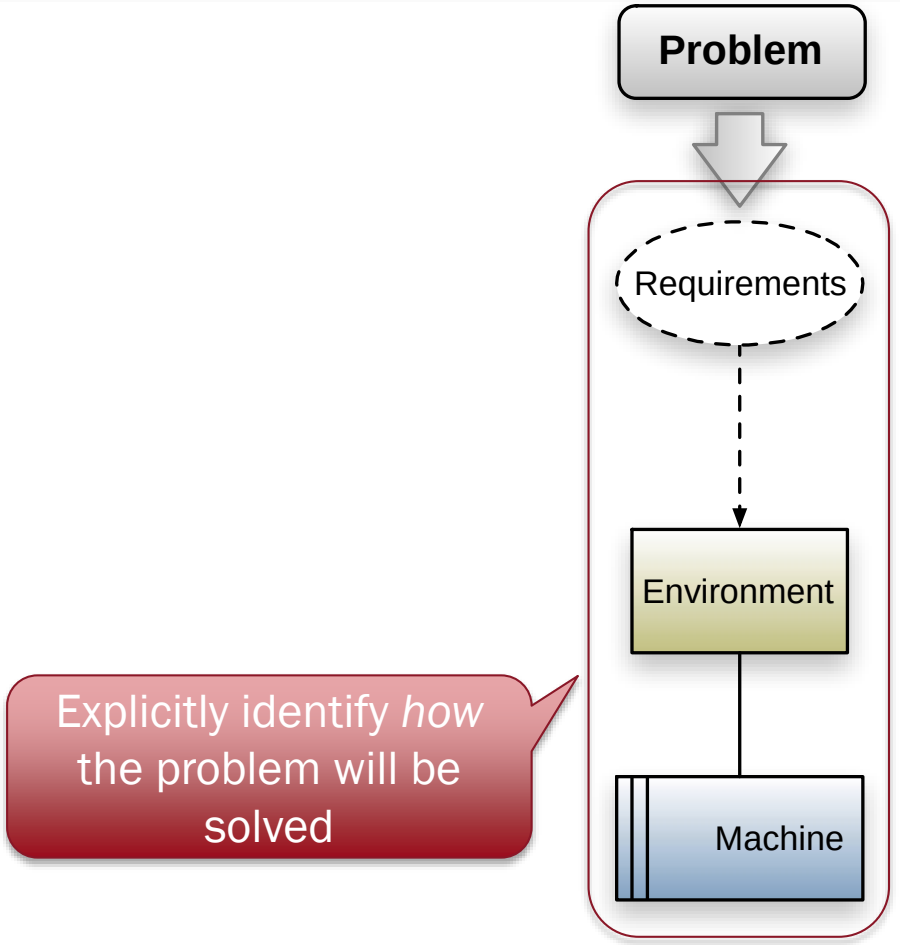

Explicitly identify *how* the problem will be solved

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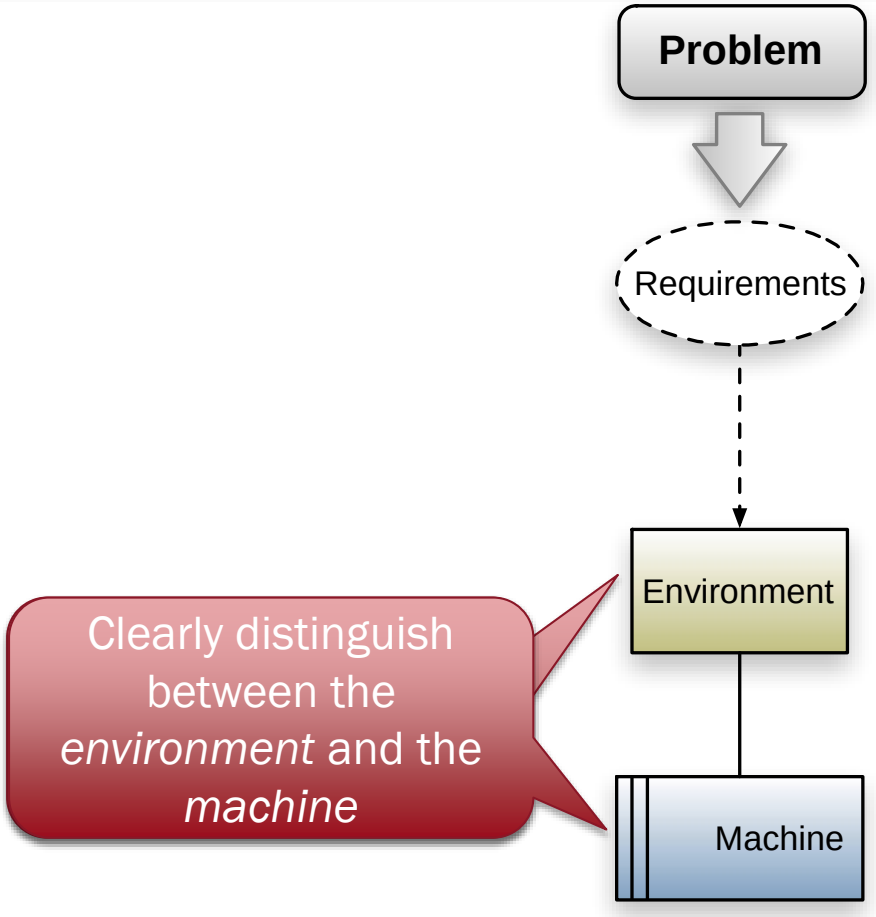

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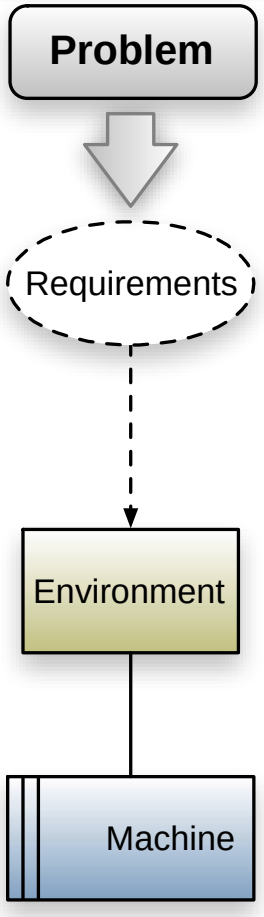

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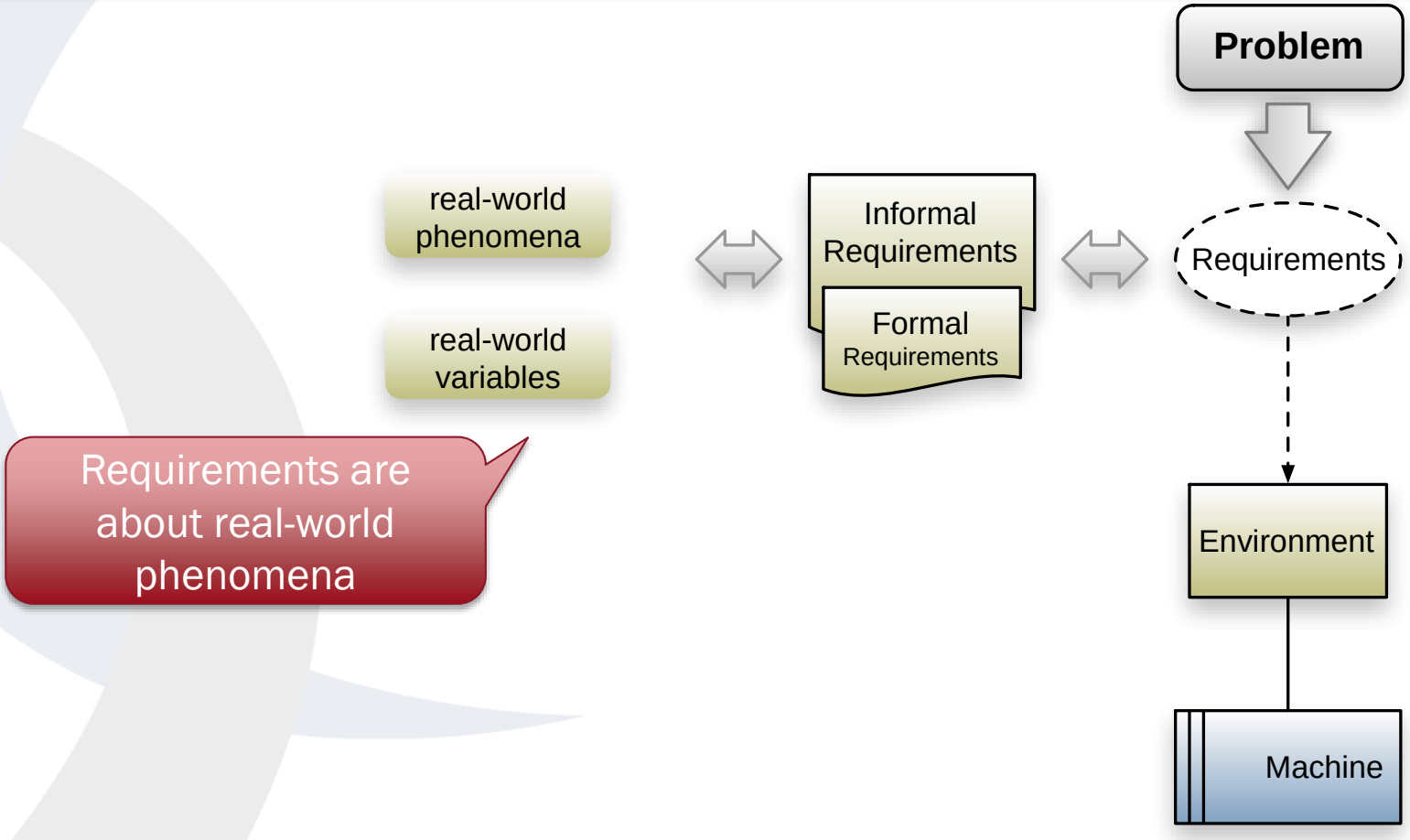

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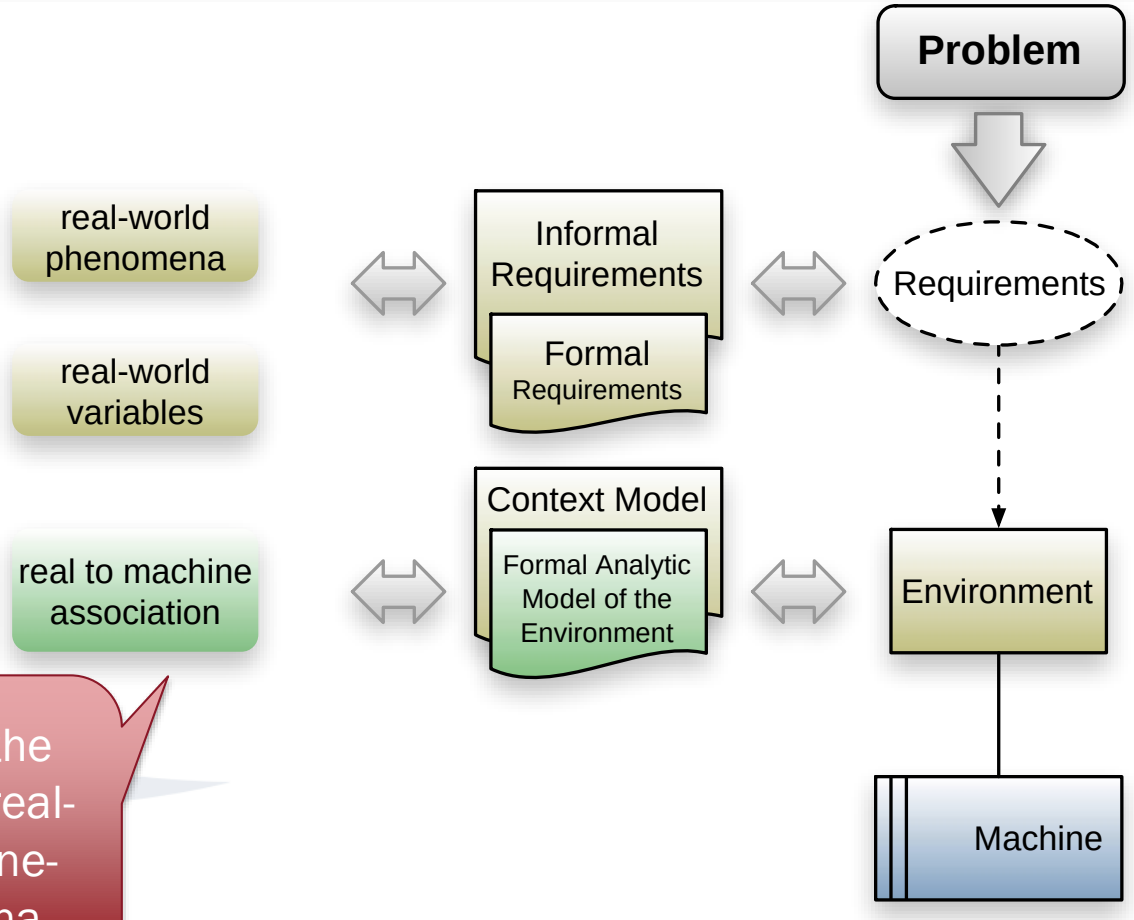

Model provides the linkage between real-world and machine-world phenomena

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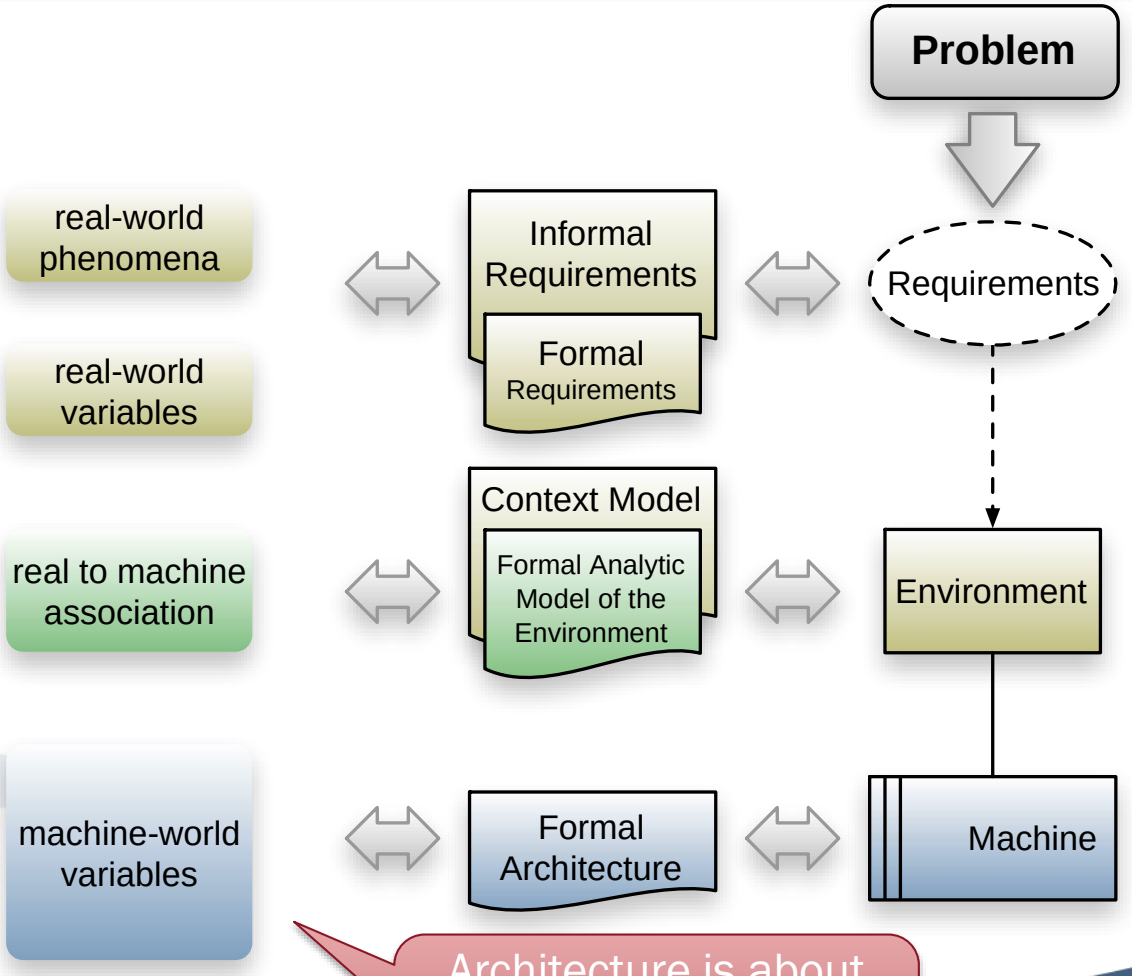

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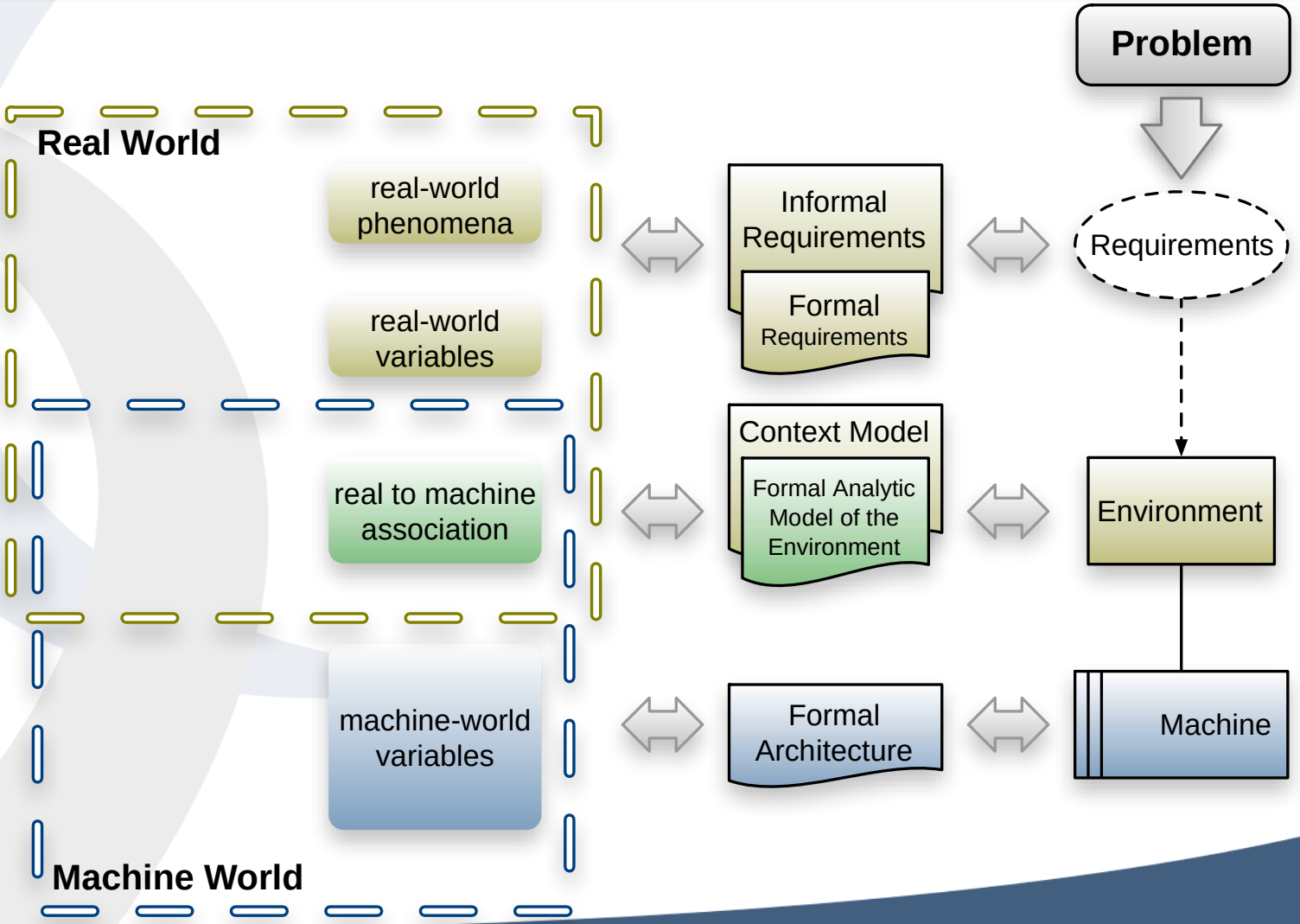

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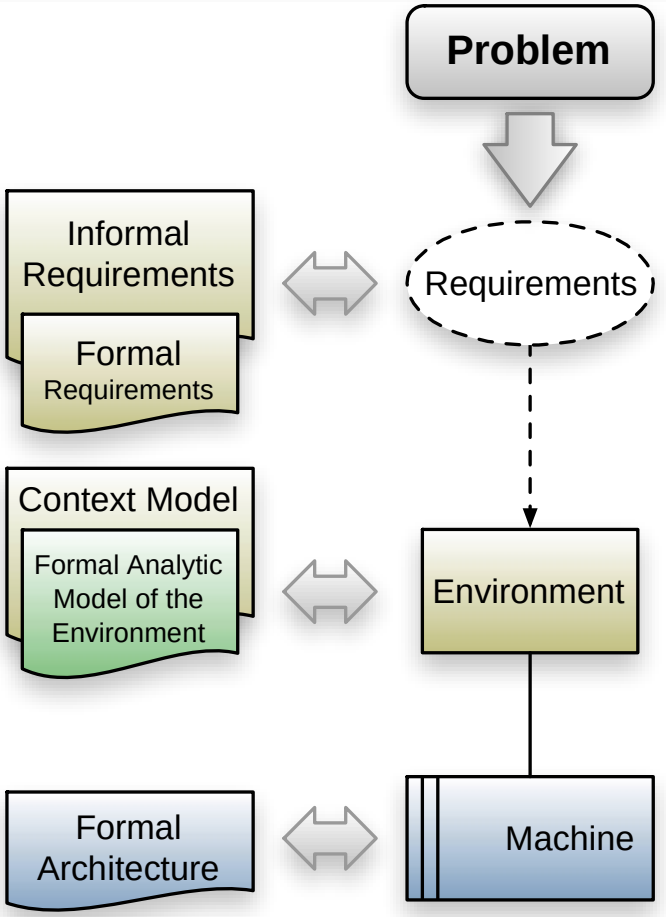
Satisfaction of the Frame Concern



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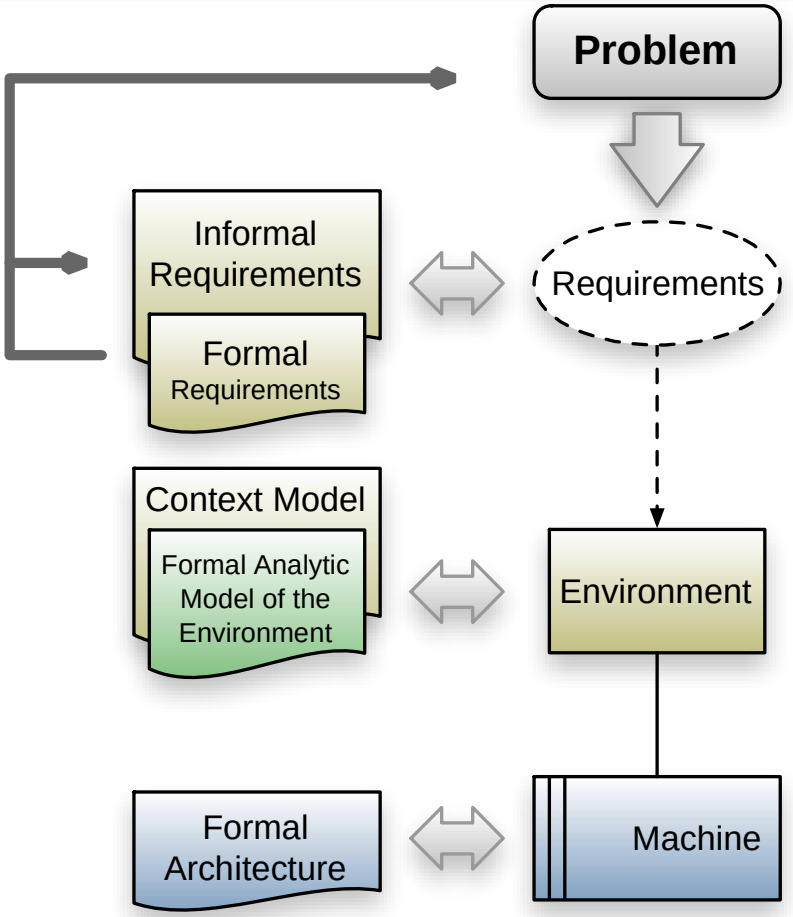
Satisfaction of the Frame Concern

- Informal Validation:
  - Formal properties "imply" informal requirements
  - Informal requirements solve the problem



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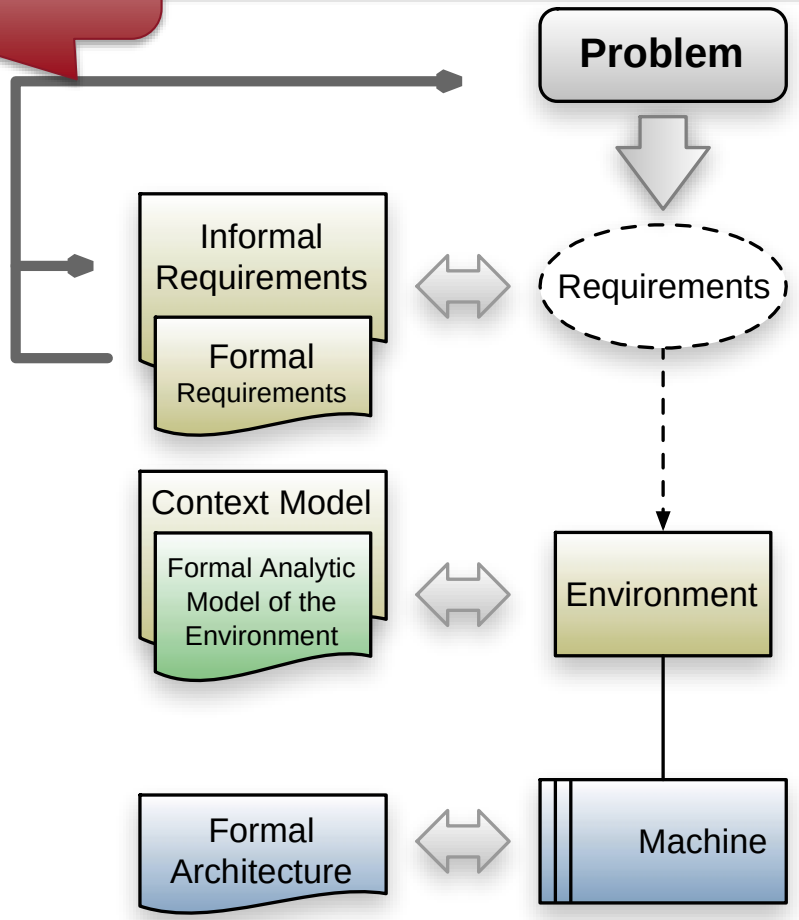

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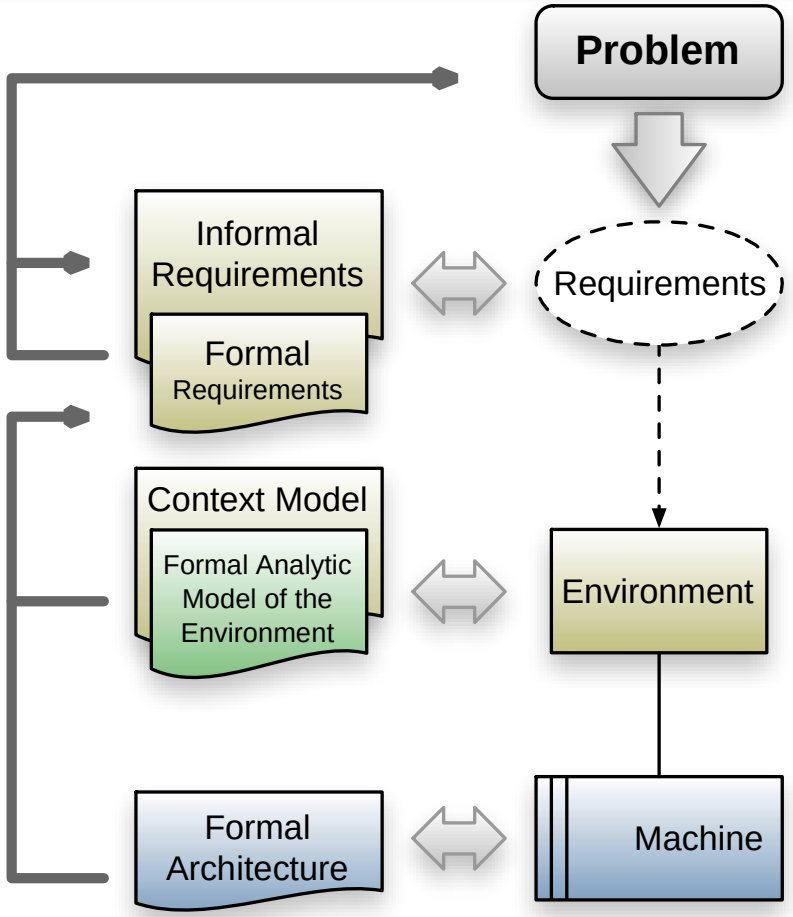

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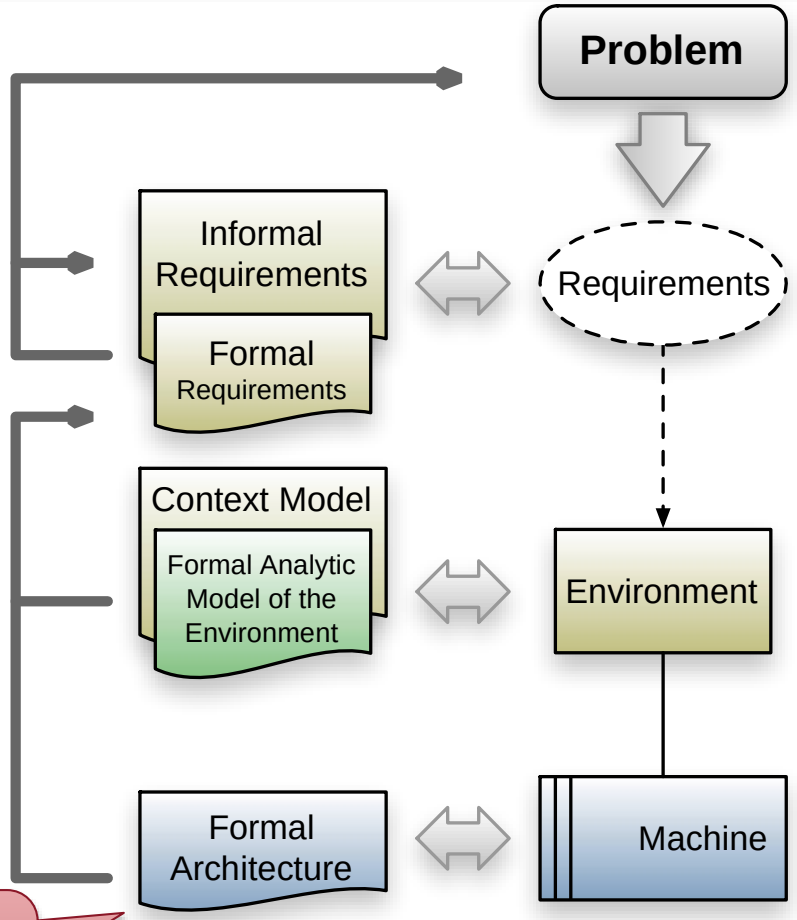

From **interfaces** through the architecture

DEPENDABLE COMPUTING

Satisfaction of the Frame Concern

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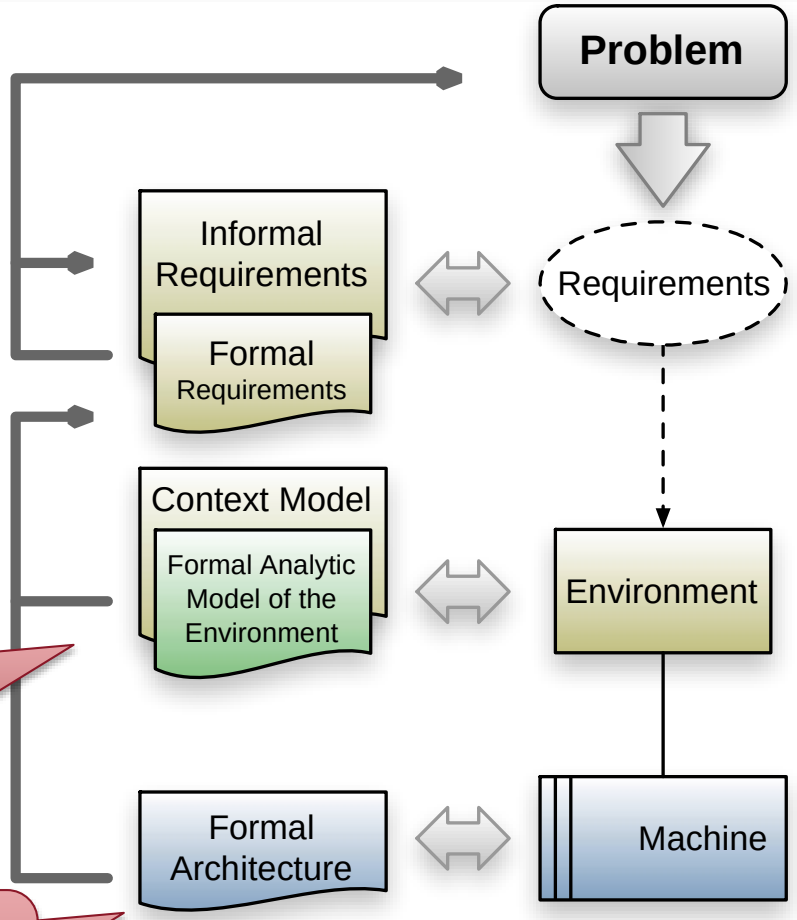

Given the **context** of the environment

From **interfaces** through the architecture

DEPENDABLE COMPUTING

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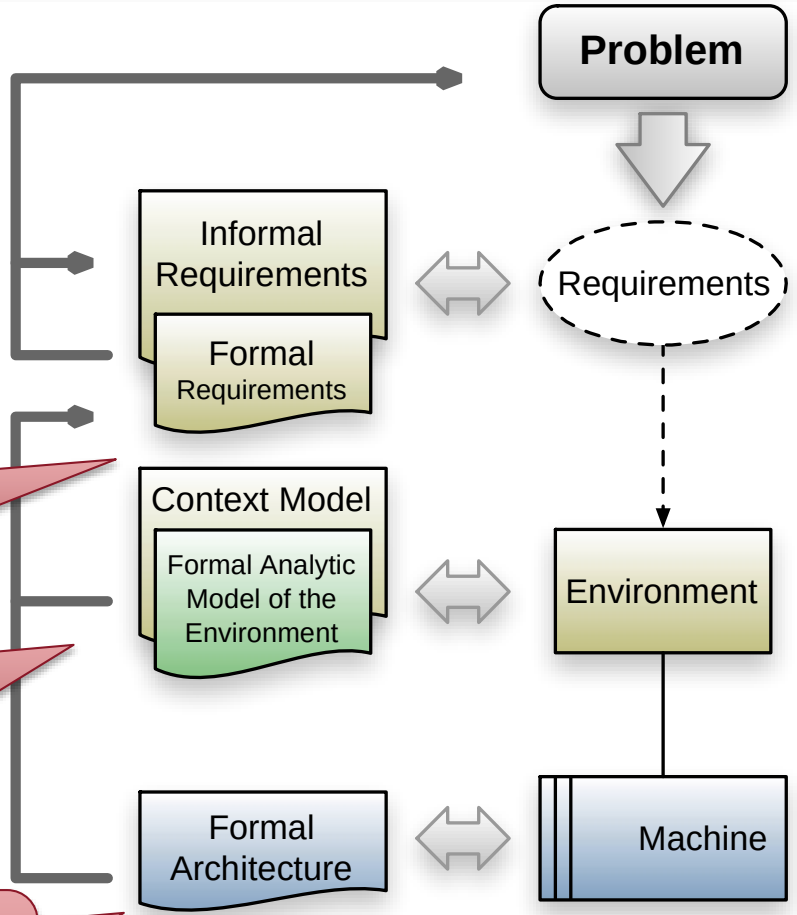
  - Info[illegible] solv[illegible]



Requirements are met

Given the **context** of the environment

From **interfaces** through the architecture

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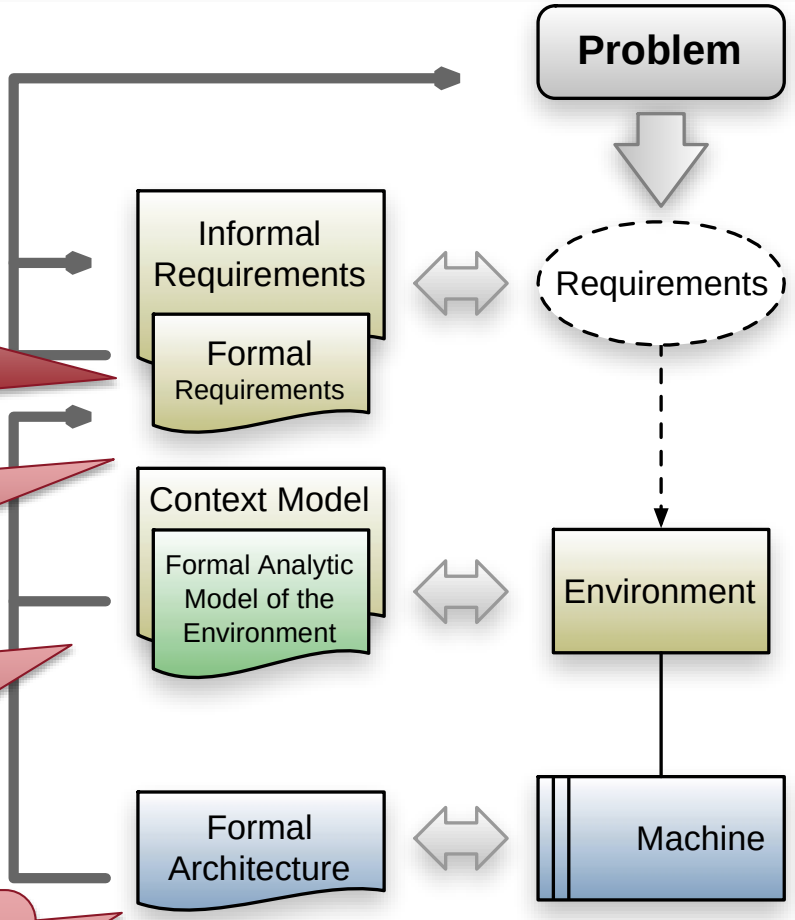

Interfaces at the next level up

Requirements are met

Given the **context** of the environment

From **interfaces** through the architecture

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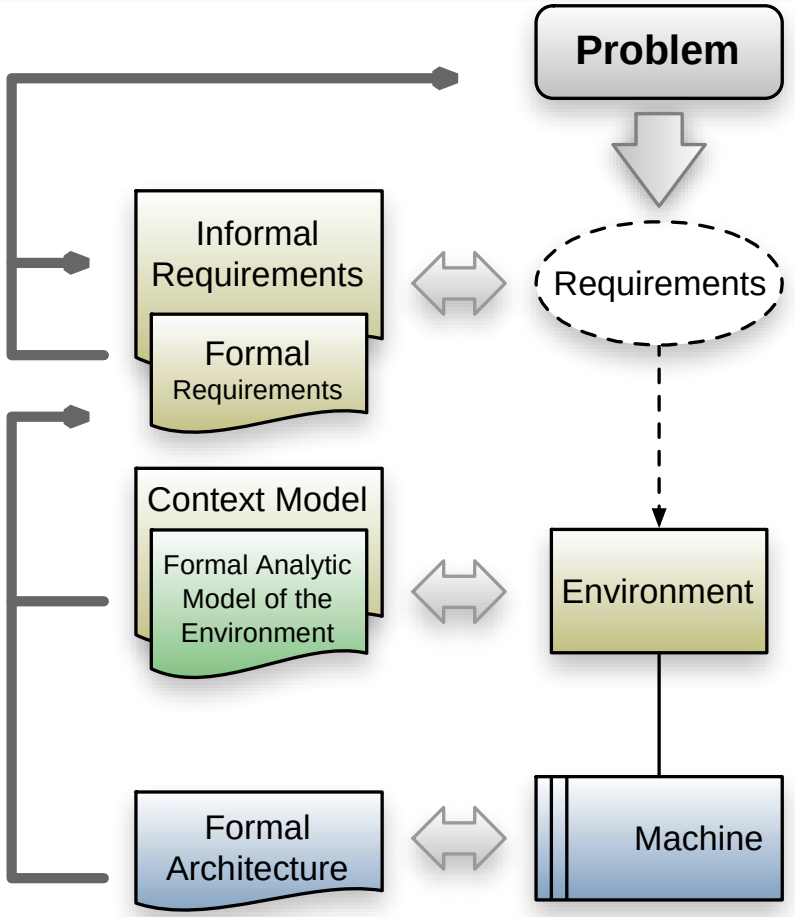
Proof

– "imply" informal requirements

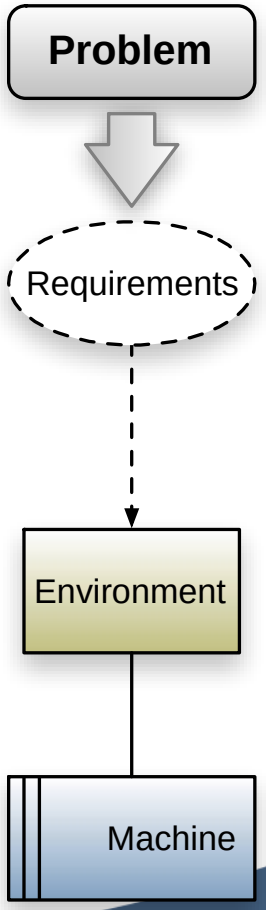
– Informal requirements solve the problem



DEPENDABLE COMPUTING

The Problem-Derived World-Situated Machine Model

- Composite model of the machine and its environment
- Separates the descriptions of
  - Machine with *machine-world* phenomena
  - Environment with *real-world* phenomena
- Clearly identifies
  - *Interfaces* at the requirements and machine
  - *Context* in the environment
- Enables **formal validation** and **assured reuse**



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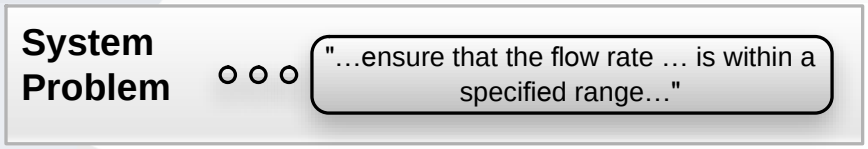
Liquid Tank: Problem Statement

System Problem

"…ensure that the flow rate … is within a specified range…"

DEPENDABLE COMPUTING

Liquid Tank: Problem Statement



A buffering tank is needed for a chemical processing application. Currently, a pump provides liquid at a constant flow rate for a subsequent stage of processing. However, the pump occasionally introduces gas or vacuum cavities into the liquid, reducing the efficiency of processing in the subsequent stage. By buffering the liquid in a tank, the cavities can dissipate, improving overall production efficiency.

[…]

1. The tank system must ensure that the flow rate for liquid leaving the tank is within a specified range, or zero.

[…]

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Liquid Tank: Requirements

System Problem

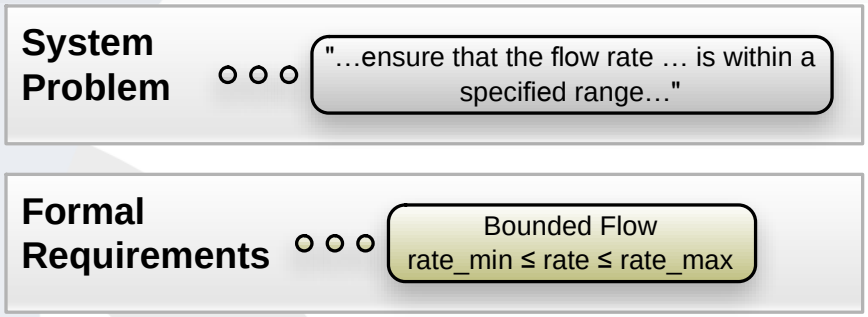
"…ensure that the flow rate … is within a specified range…"

Formal Requirements

Bounded Flow
rate_min ≤ rate ≤ rate_max

DEPENDABLE COMPUTING

Liquid Tank: Requirements



- **Invariant Requirements**
  - SI1: The tank system shall have two modes: normal and emergency.
  - […]
- **Normal-Mode Requirements**
  - SN1: The liquid outflow rate shall be between *rate_min* and *rate_max*.
  - […]
- […]

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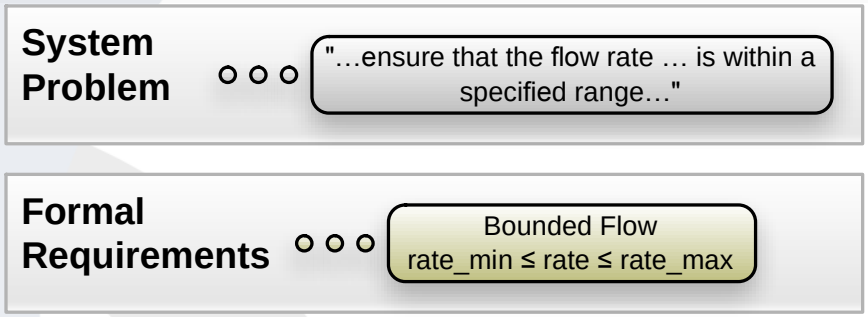
Liquid Tank: Requirements



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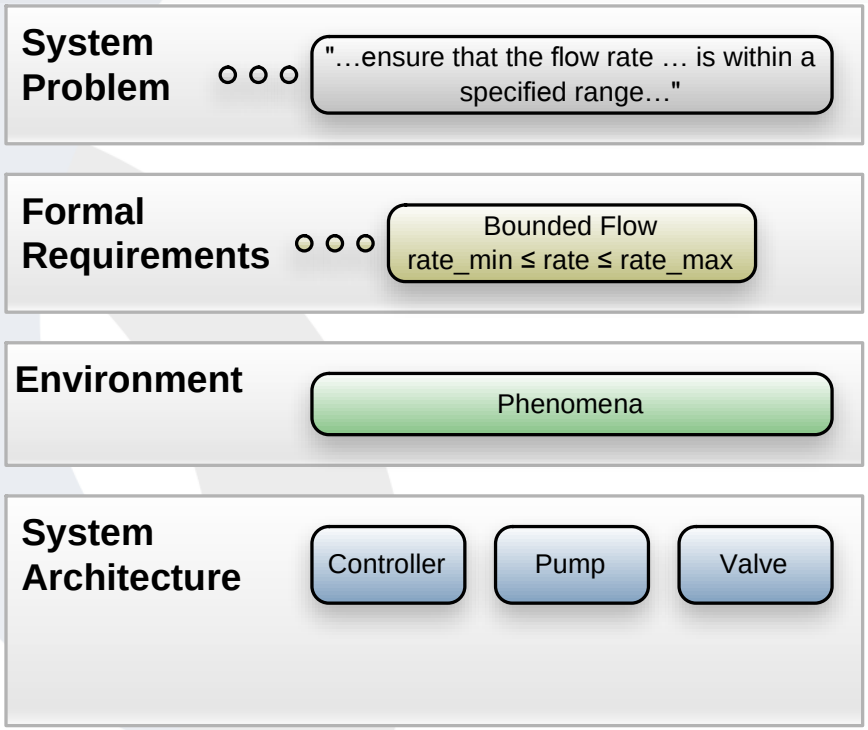
Liquid Tank: Architecture



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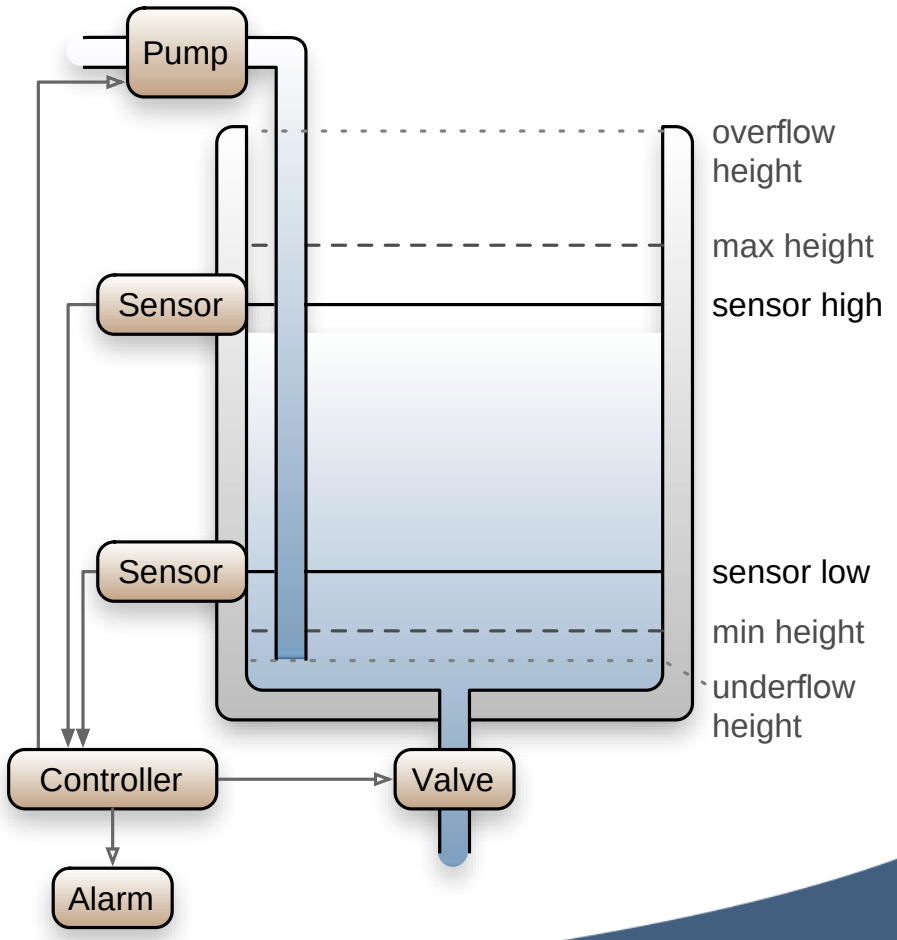
Liquid Tank: Architecture

System Problem "…ensure that the flow rate … is within a specified range…"

Formal Requirements Bounded Flow rate_min ≤ rate ≤ rate_max

Environment Phenomena

System Architecture Controller, Pump, Valve



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Liquid Tank: Architecture

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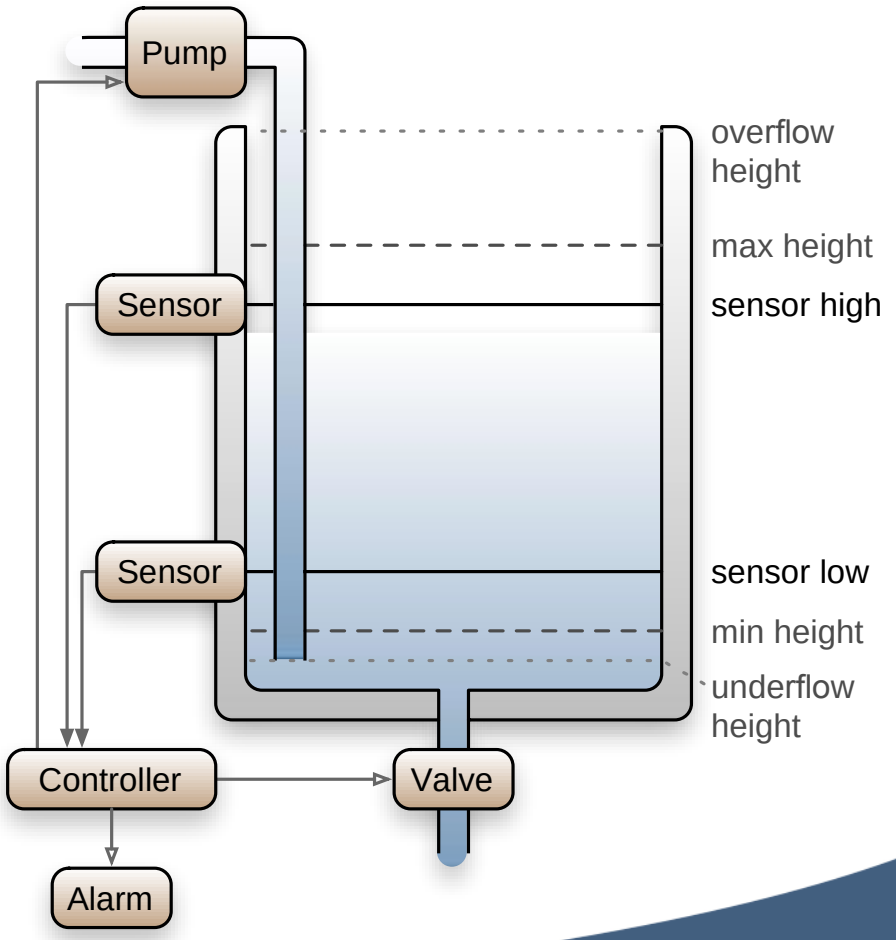
Formal Requirements Bounded Flow: rate_min ≤ rate ≤ rate_max

Environment Phenomena

System Architecture Controller, Pump, Valve

Controller Contract, Pump Contract, Valve Contract



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Liquid Tank: Architecture

System Problem

"…ensure that the flow rate … is within a specified range…"

Formal Requirements

Bounded Flow
rate_min ≤ rate ≤ rate_max

Environment

Phenomena

System Architecture

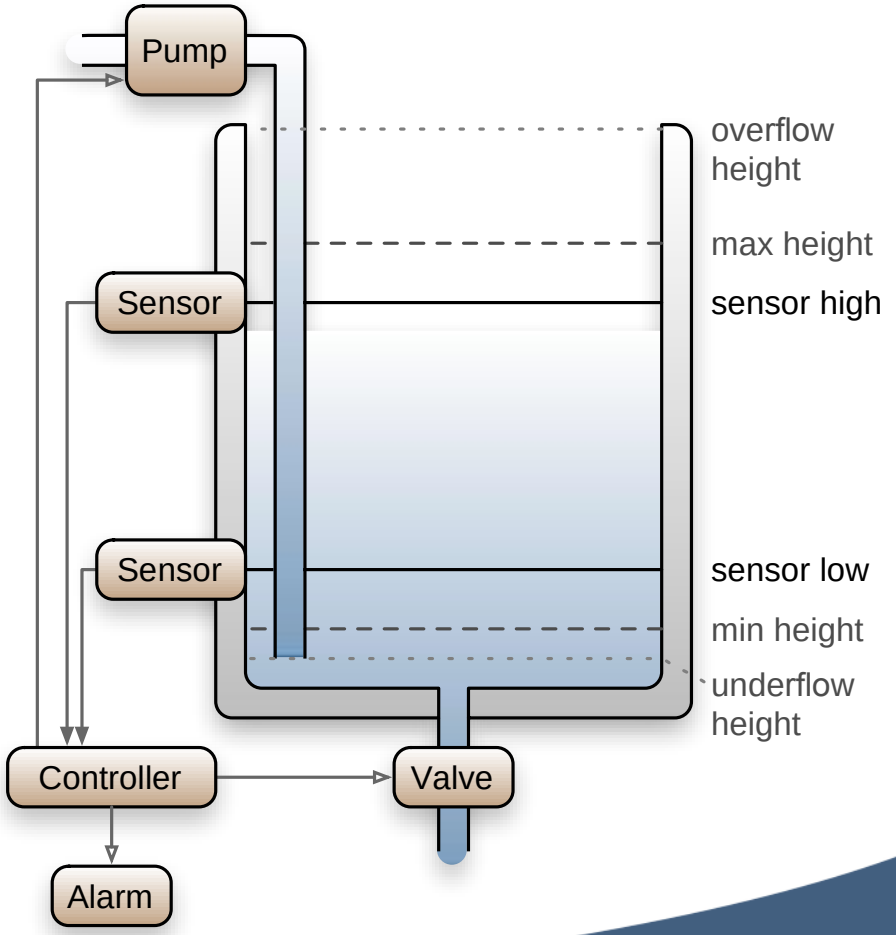
Controller | Pump | Valve

Controller Contract | Pump Contract | Valve Contract

Phenomena | Phenomena | Phenomena

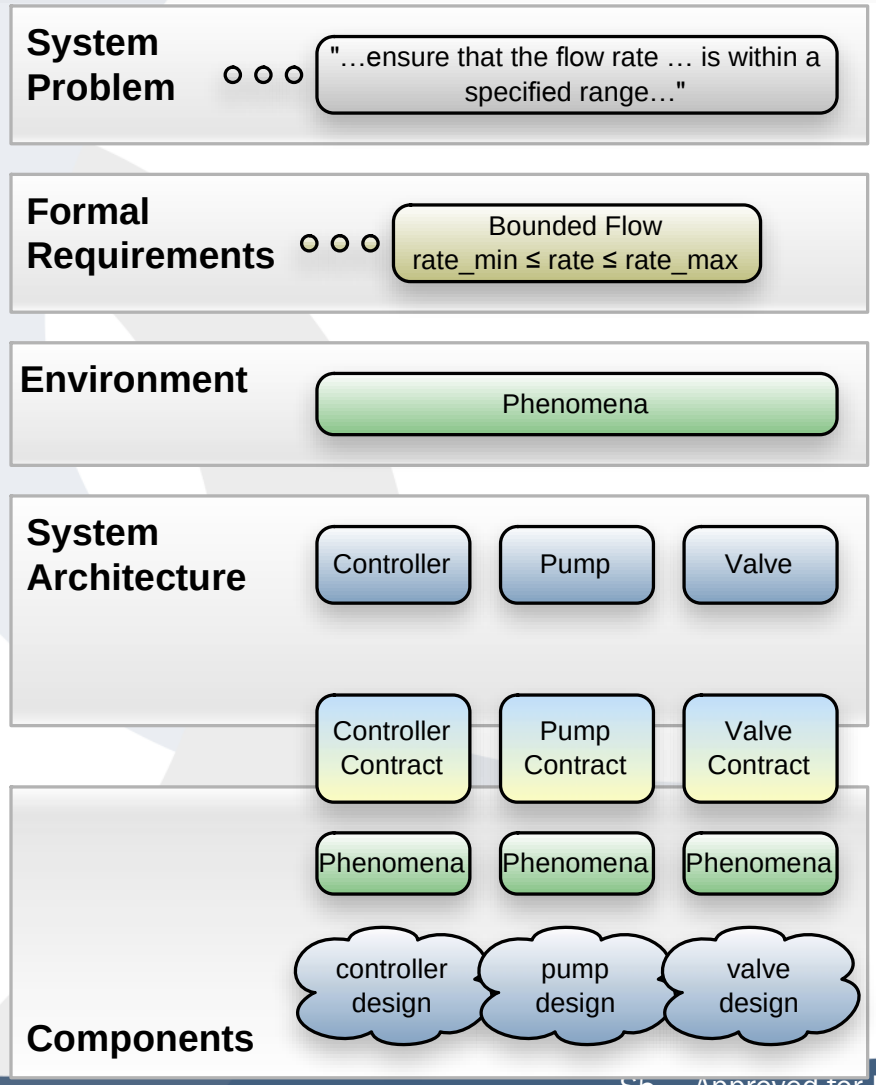
Components

controller design | pump design | valve design



DEPENDABLE COMPUTING

Liquid Tank: Validation



DEPENDABLE COMPUTING

Liquid Tank: Validation

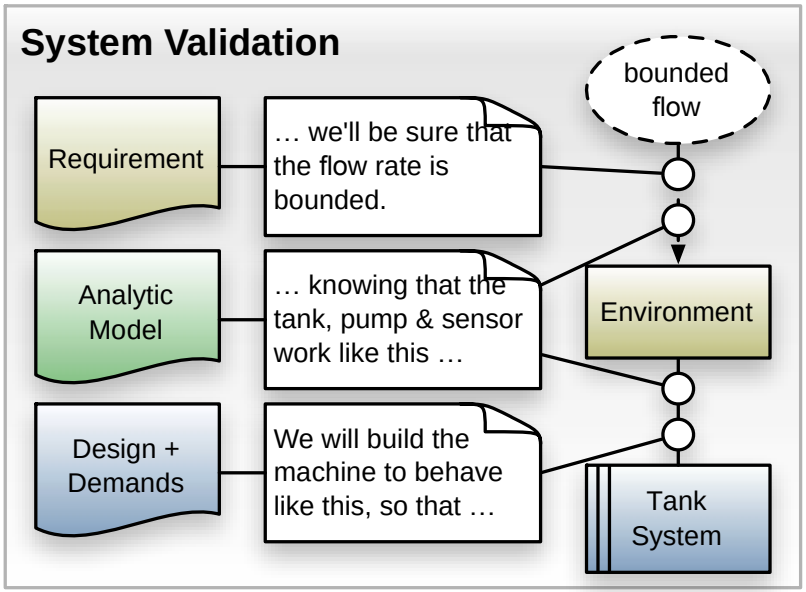
System Problem "…ensure that the flow rate … is within a specified range…"

Formal Requirements Bounded Flow: rate_min ≤ rate ≤ rate_max

Environment Phenomena

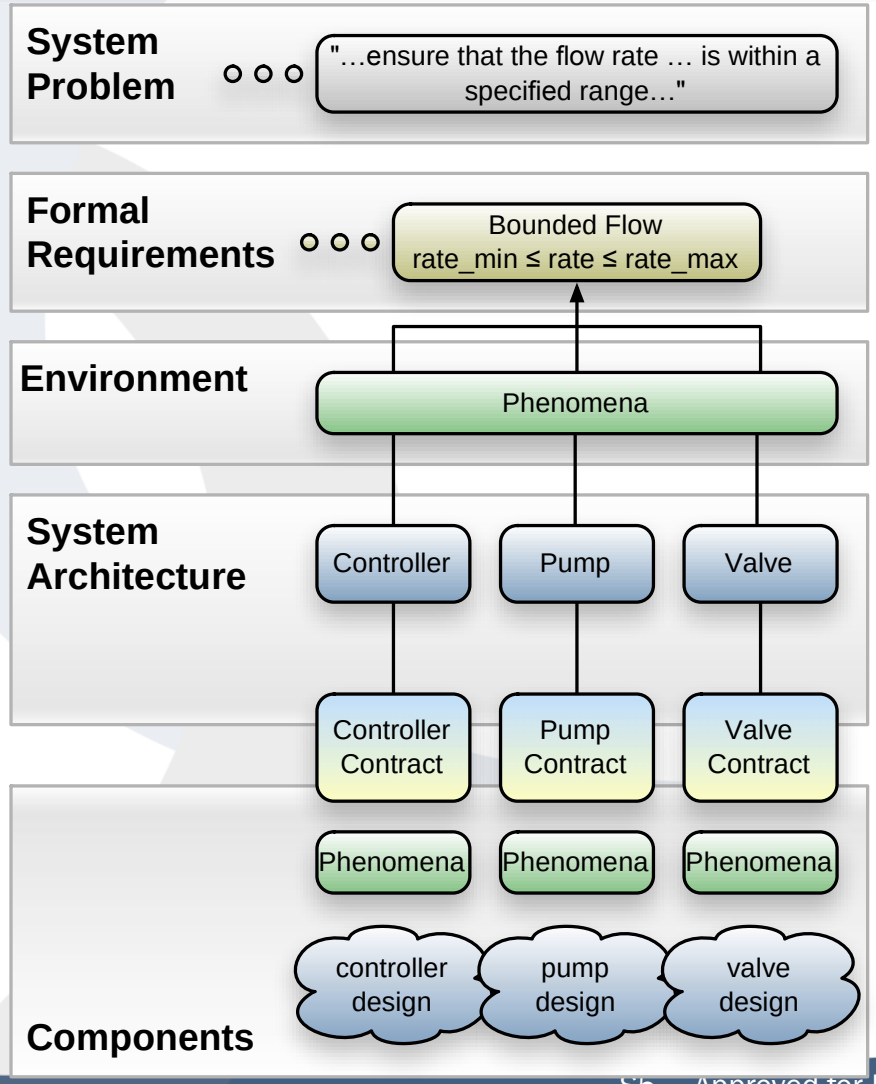
System Architecture Controller, Pump, Valve

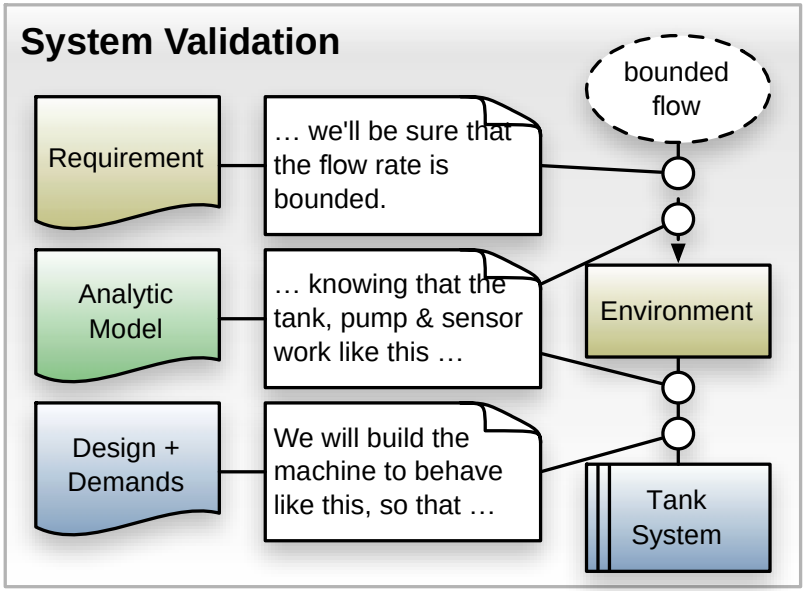
Components Controller Contract, Pump Contract, Valve Contract; Phenomena, Phenomena, Phenomena; controller design, pump design, valve design



DEPENDABLE COMPUTING

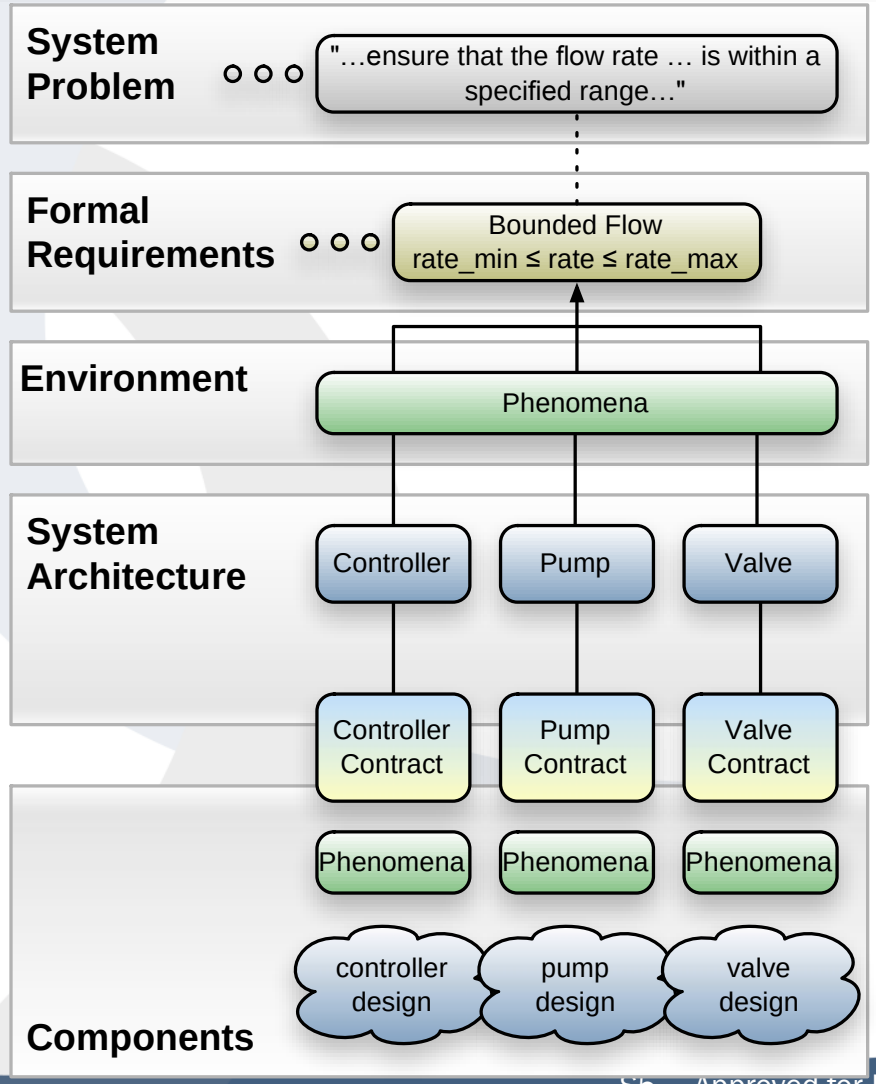
Liquid Tank: Validation

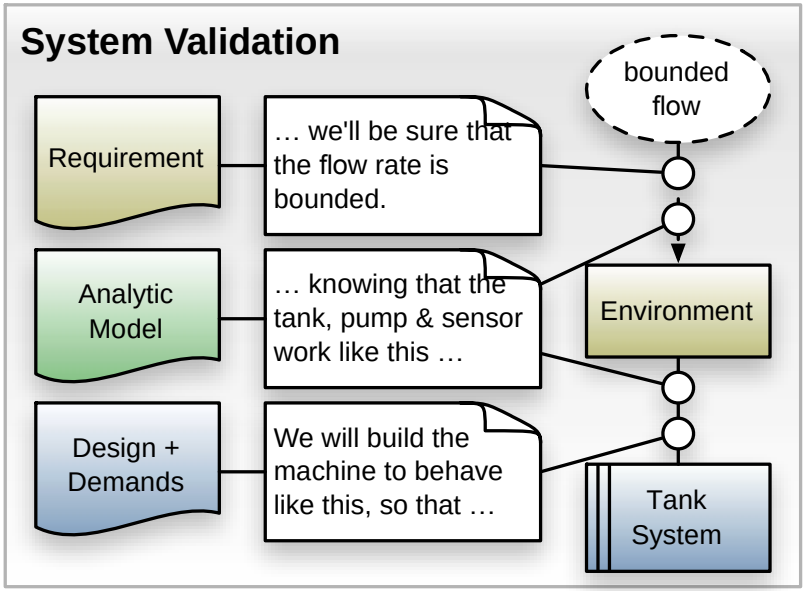




DEPENDABLE COMPUTING

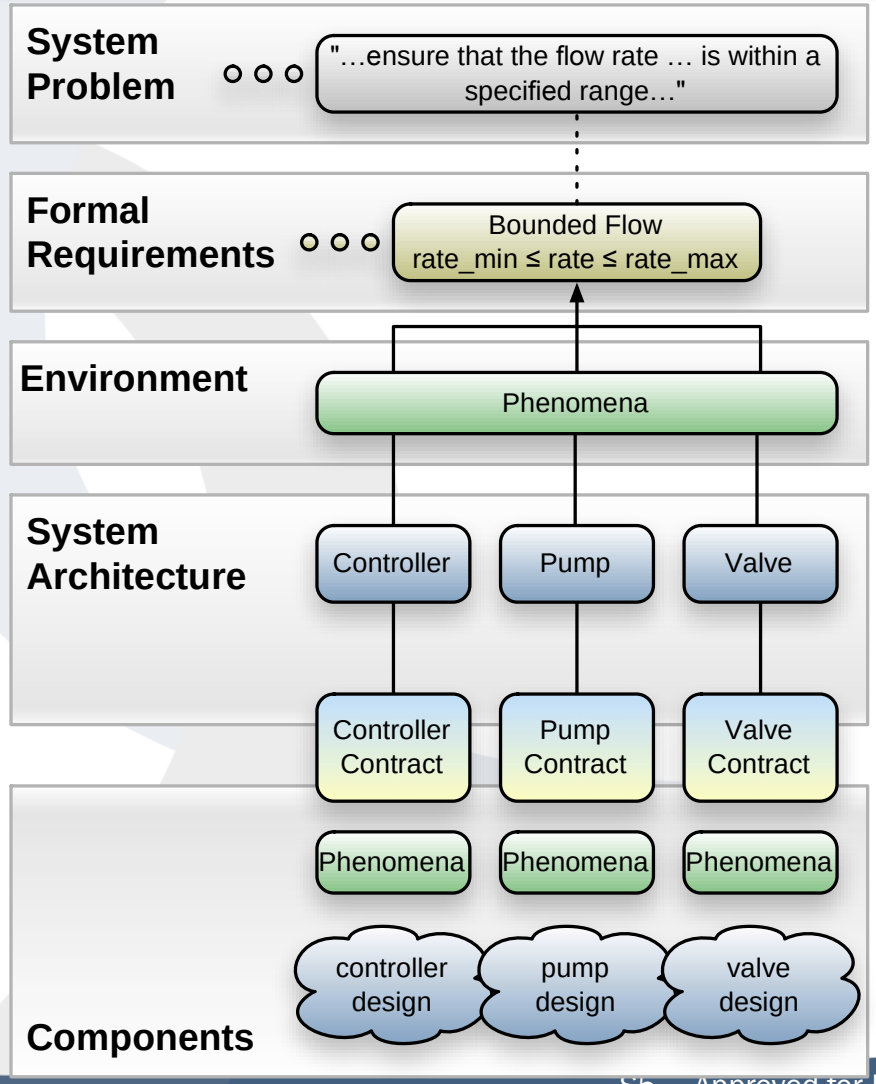
Liquid Tank: Validation

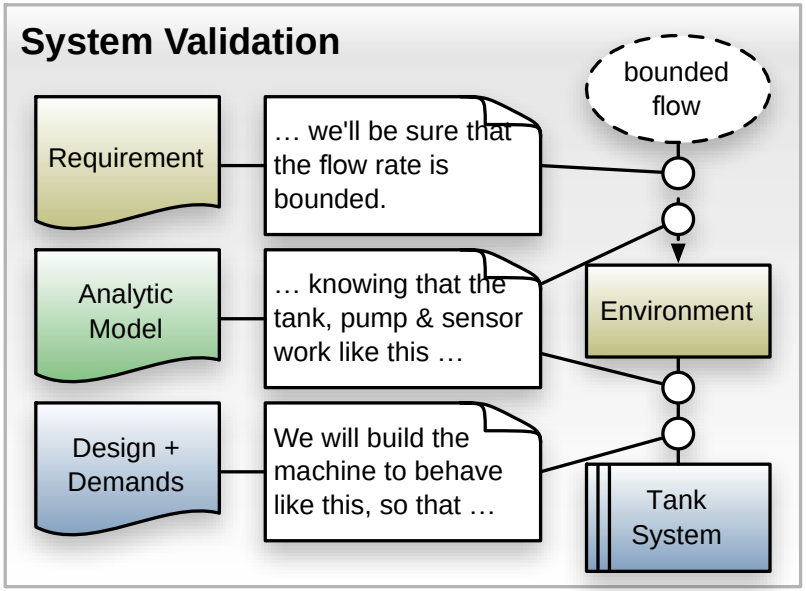




DEPENDABLE COMPUTING

Liquid Tank: Validation

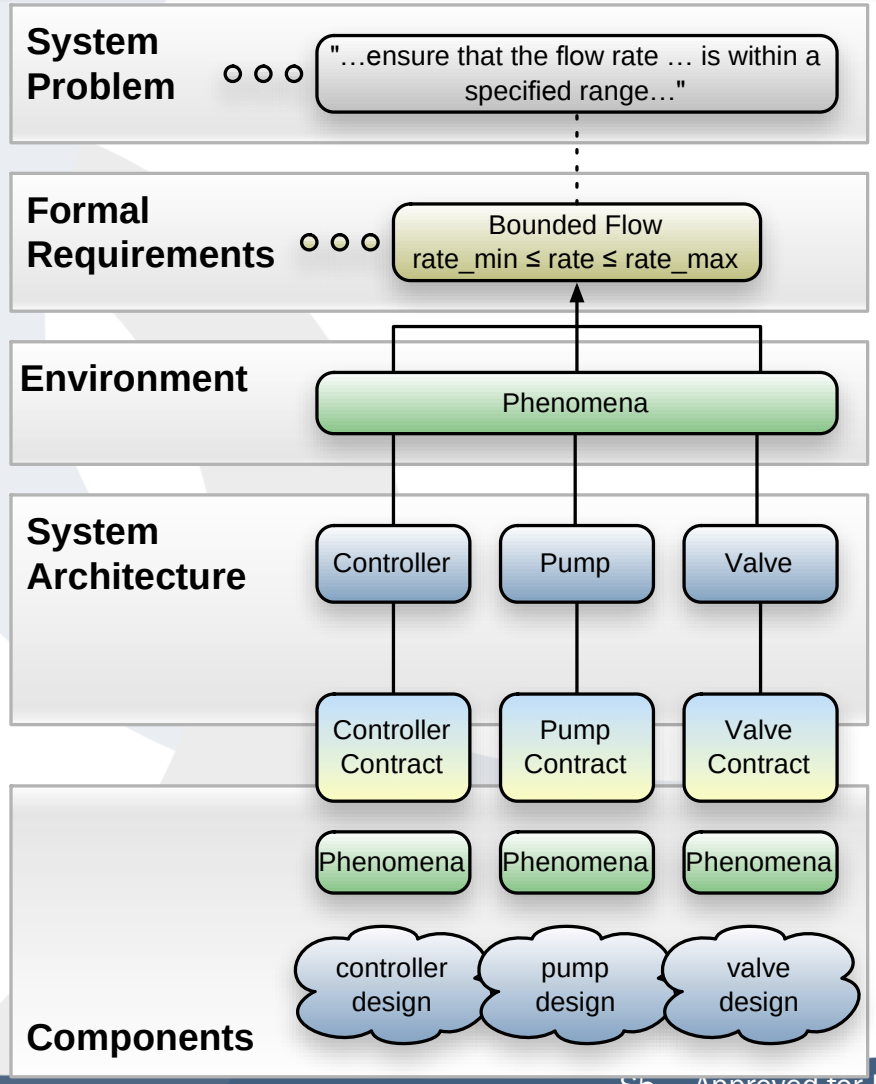


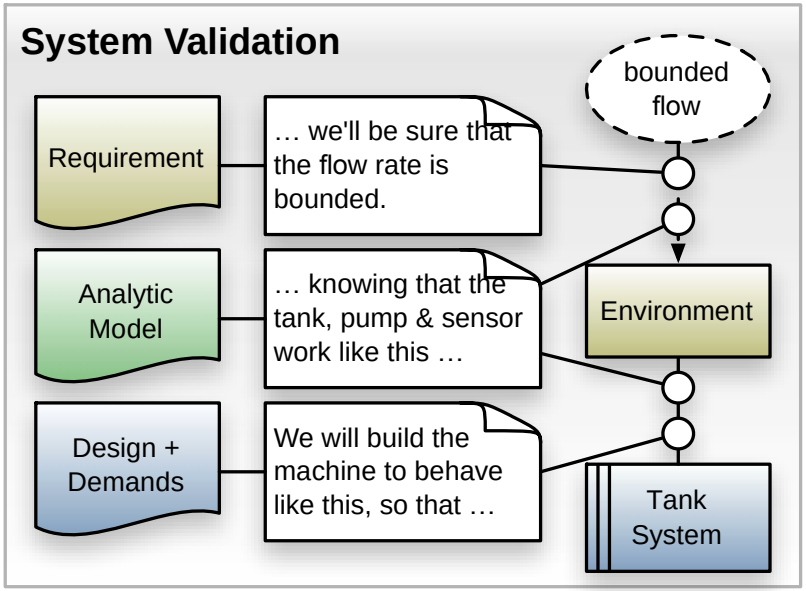


Analysis of Contract Fulfillment

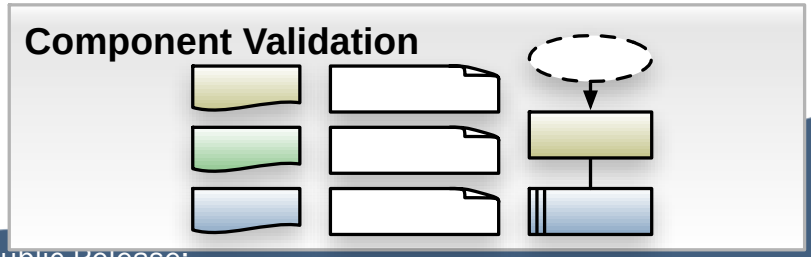
DEPENDABLE COMPUTING

Liquid Tank: Validation



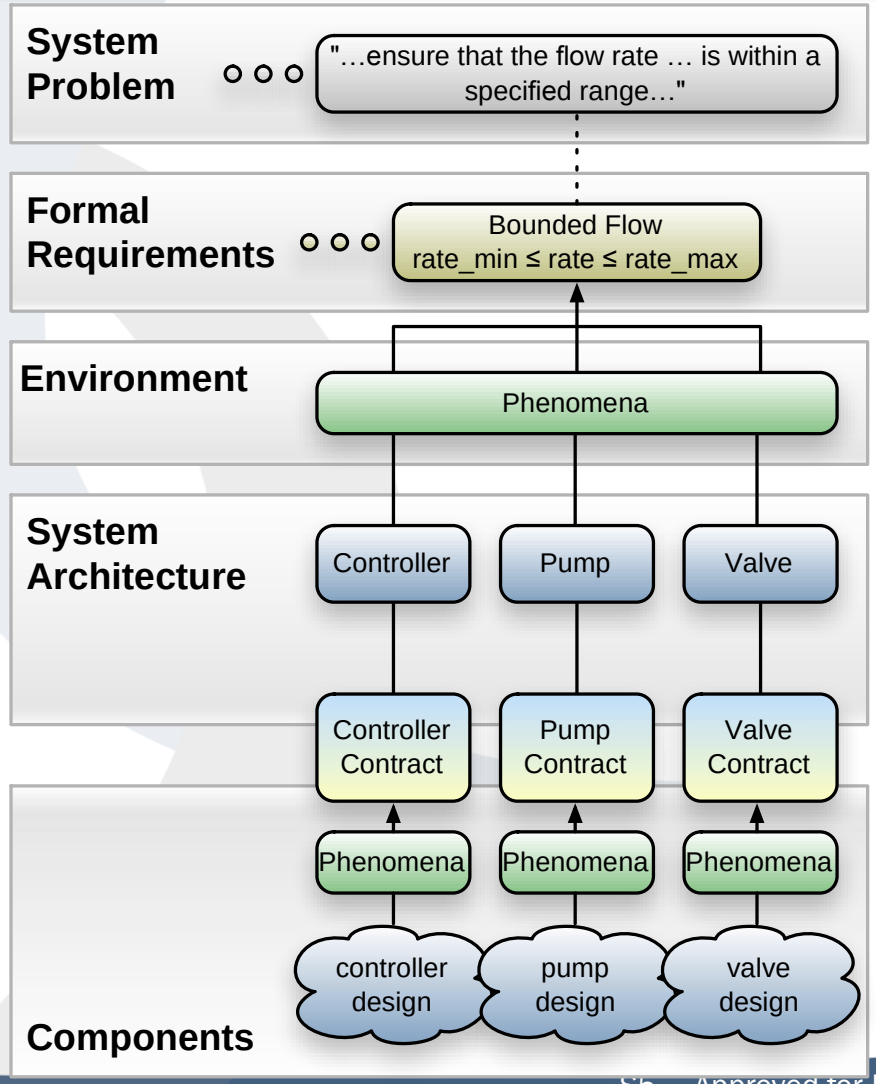


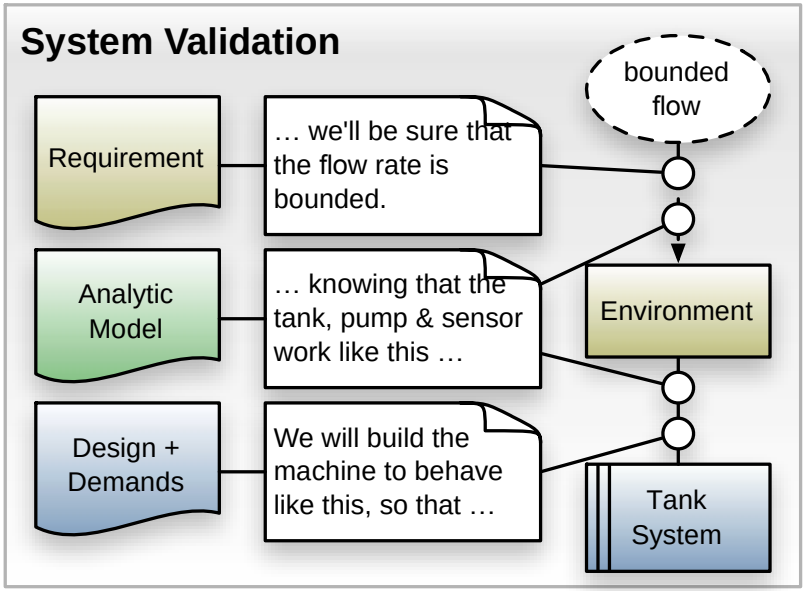
Analysis of Contract Fulfillment



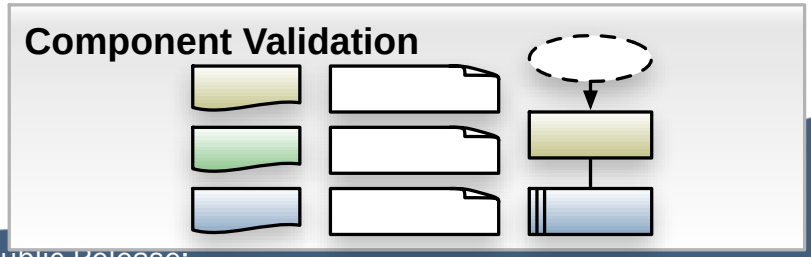
DEPENDABLE COMPUTING

Liquid Tank: Validation





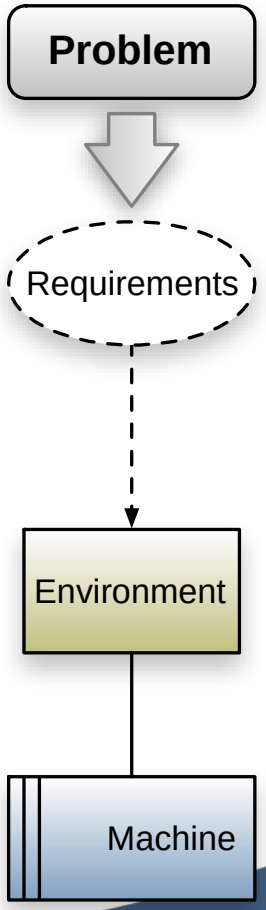
Analysis of Contract Fulfillment



DEPENDABLE COMPUTING

The Problem-Derived World-Situated Machine Model

- Composite model of the machine and its environment
- Separates the descriptions of
  - Machine with *machine-world* phenomena
  - Environment with *real-world* phenomena
- Clearly identifies
  - *Interfaces* at the requirements and machine
  - *Context* in the environment
- Enables **formal validation** and **assured reuse**



DEPENDABLE
COMPUTING

Questions?