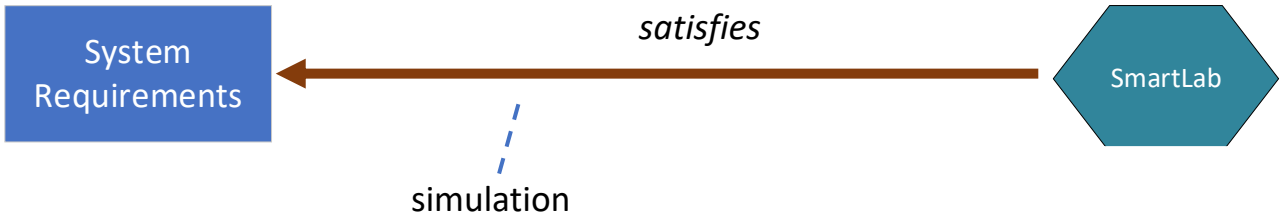
Supporting the Engineering of Multi-Fidelity Simulation Units with Simulation Goals

João Cambeiro, Julien Deantoni and Vasco Amaral

MPM4CPS 2021 Fukuoka

CPS Development



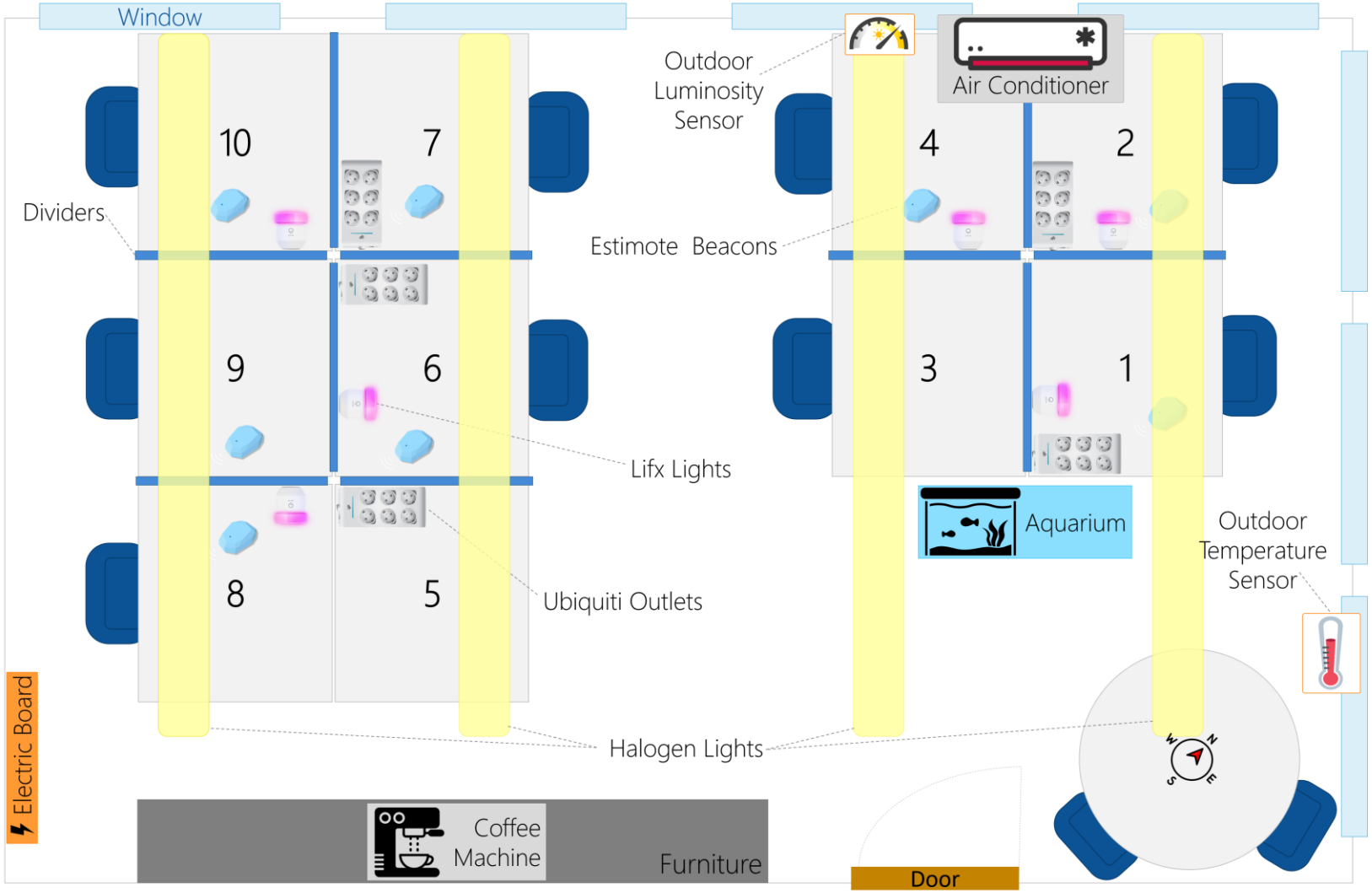
Smartlab CPS

Goals:

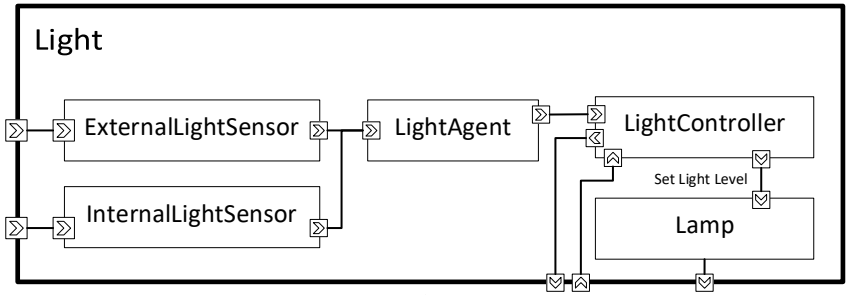
- Maximisation of user comfort while reducing energy costs

At each workstation it is possible to monitor the:

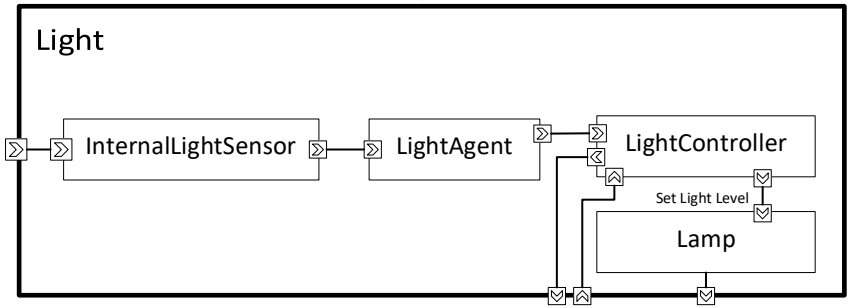
- Visible light level
- Temperature
- Power consumption



CPS Development



$\neq$ *fidelity levels*



System Requirements

satisfies

simulation

SmartLab

Computation

Plant

IoT Platform

Building Structural Elements

Lab users (Human-in-the-Loop}

Sensors

Actuators

Controller

Light

Temperature

AC Unit

Lights

Power Sockets

Simulation Unit 1

virtually implemented by

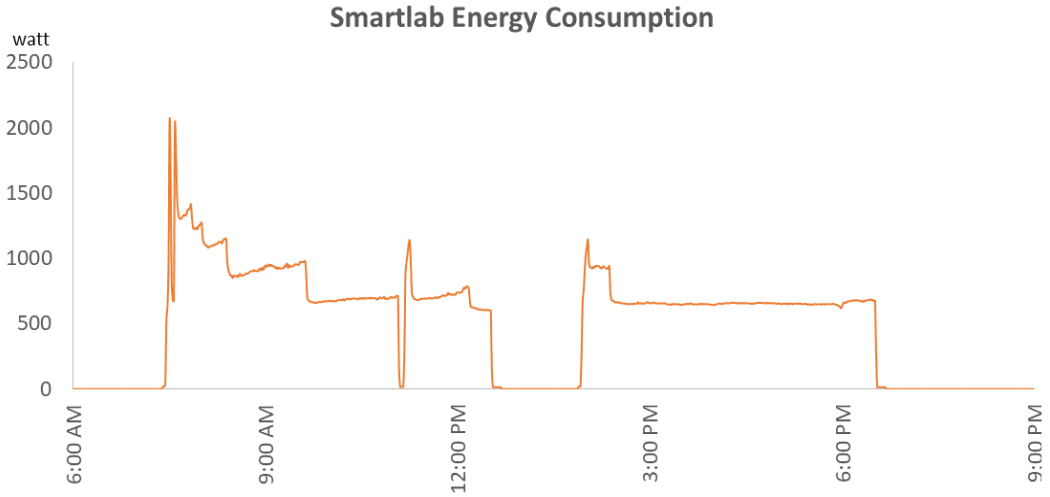
$\neq$ *fidelity levels*

Simulation Unit 2

Goal is to mimic the behaviour of its system counterpart

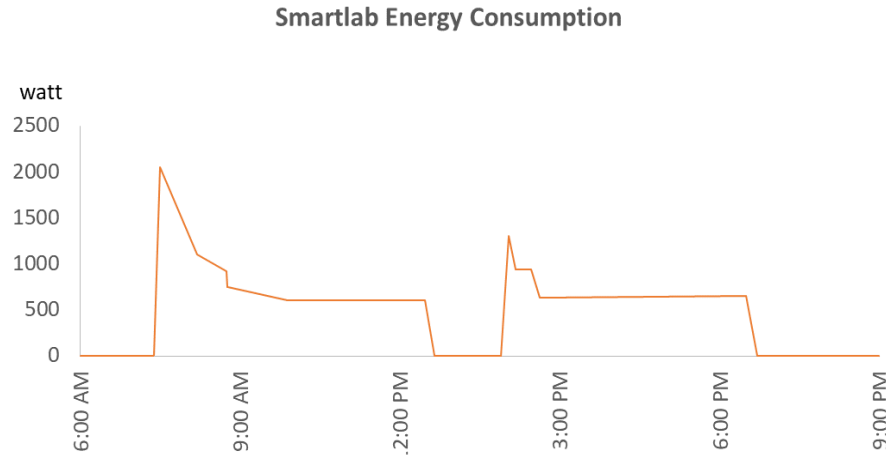
Fidelity

"The fidelity of a model is determined by how accurately it can reproduce the properties of the system under Study"*



Reality

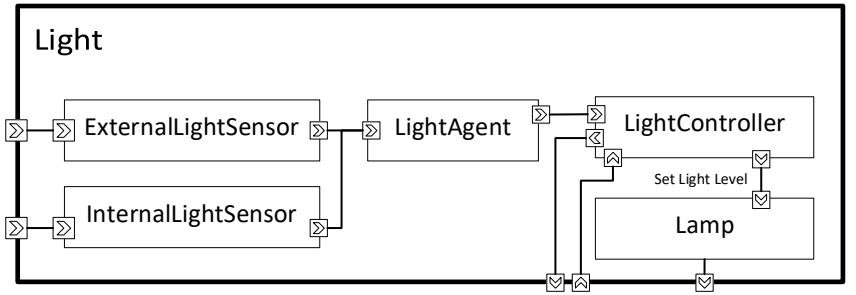
Approximates



Simulated Reality

* E. A. Lee and S. A. Seshia, Introduction to embedded systems: A cyber-physical systems approach. Mit Press, 2017.

CPS Development



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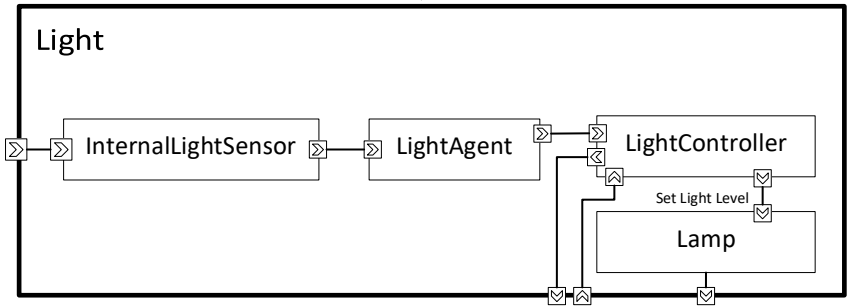

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Simulation Unit 1

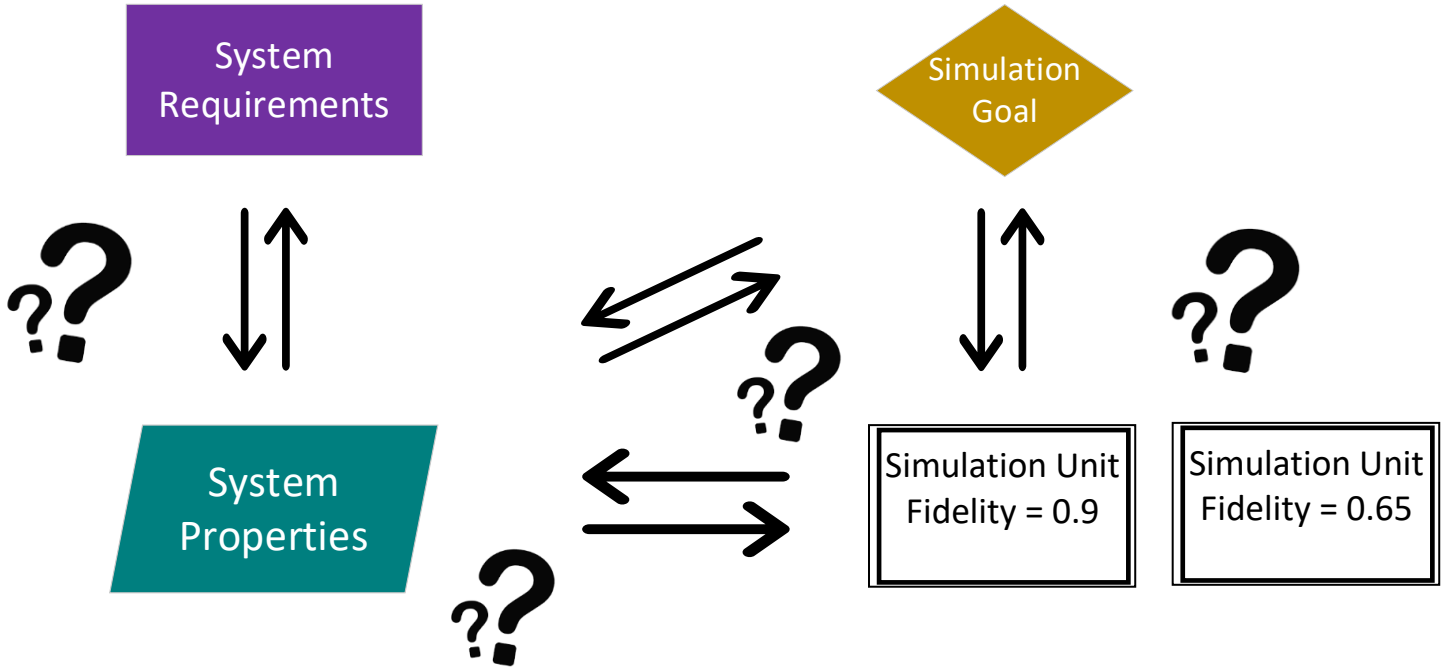
virtually implemented by

$\neq$ *fidelity levels*

Simulation Unit 2

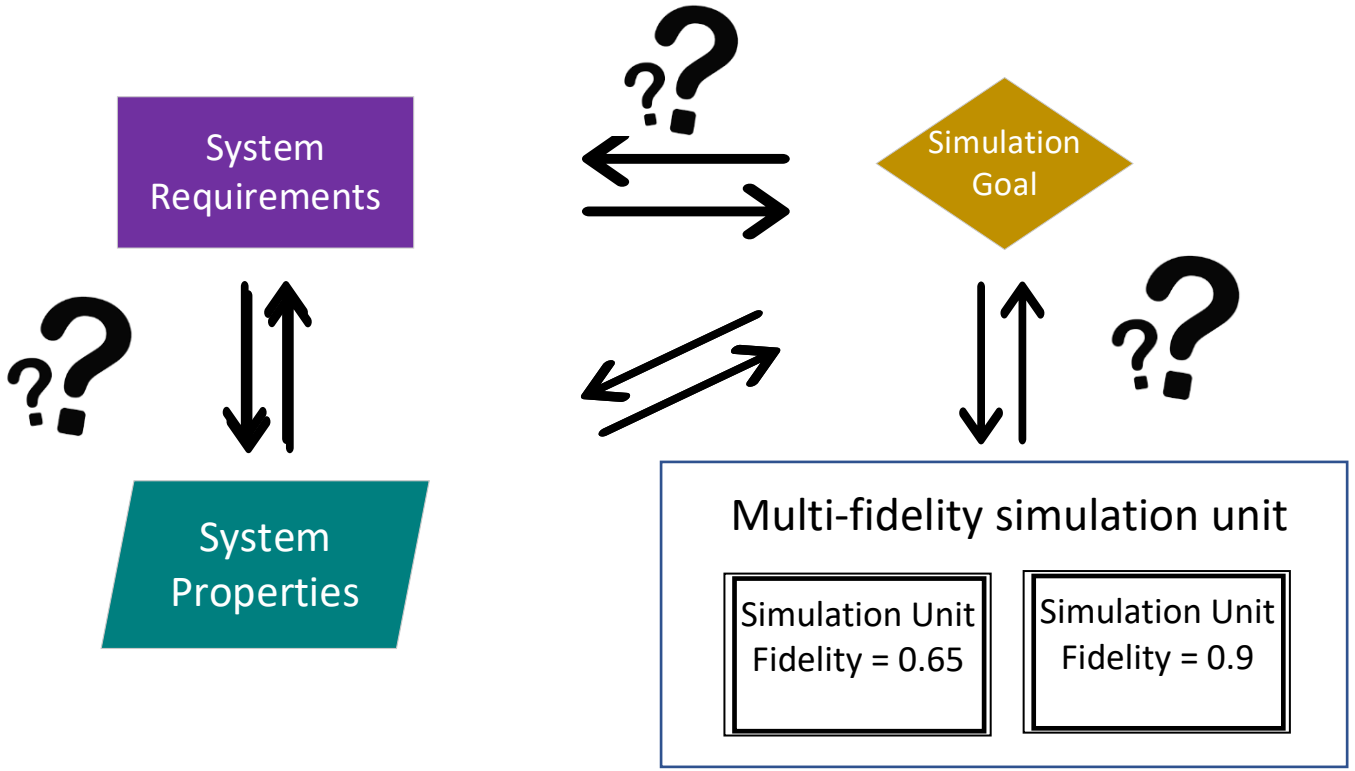
Problem

Currently, the relationships between the system requirements, the system properties, the simulation goals, and the choice of the appropriate simulation units to use on a simulation are usually left implicit or managed in an ad-hoc manner.



Our proposition

A framework that will automatically determine the simulation units at an adequate fidelity level suitable for answering a specific simulation goal.

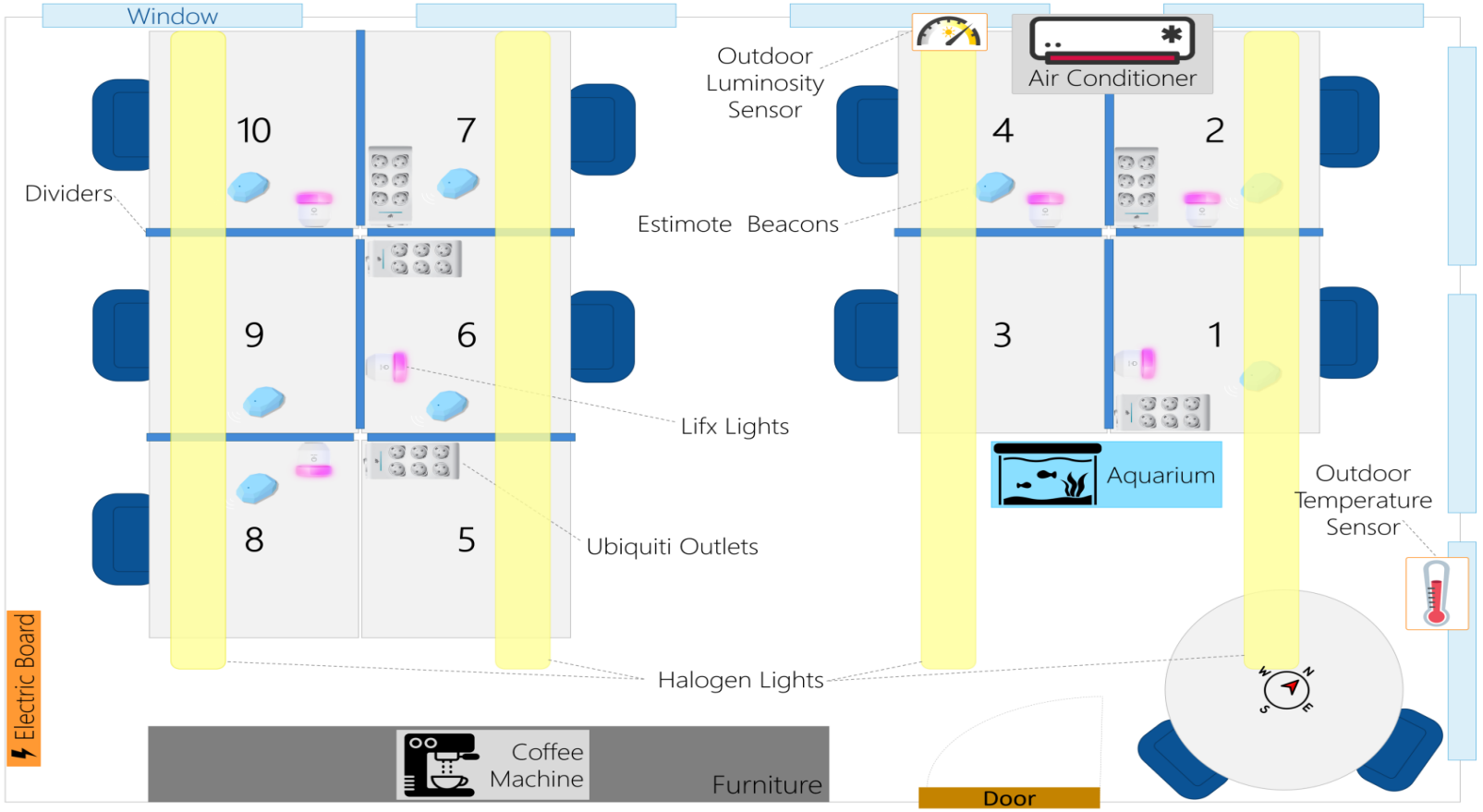


System properties

System properties are differentiating factors that can be measured or computed.

Examples:

- Visible light
- Energy consumption
- Room temperature



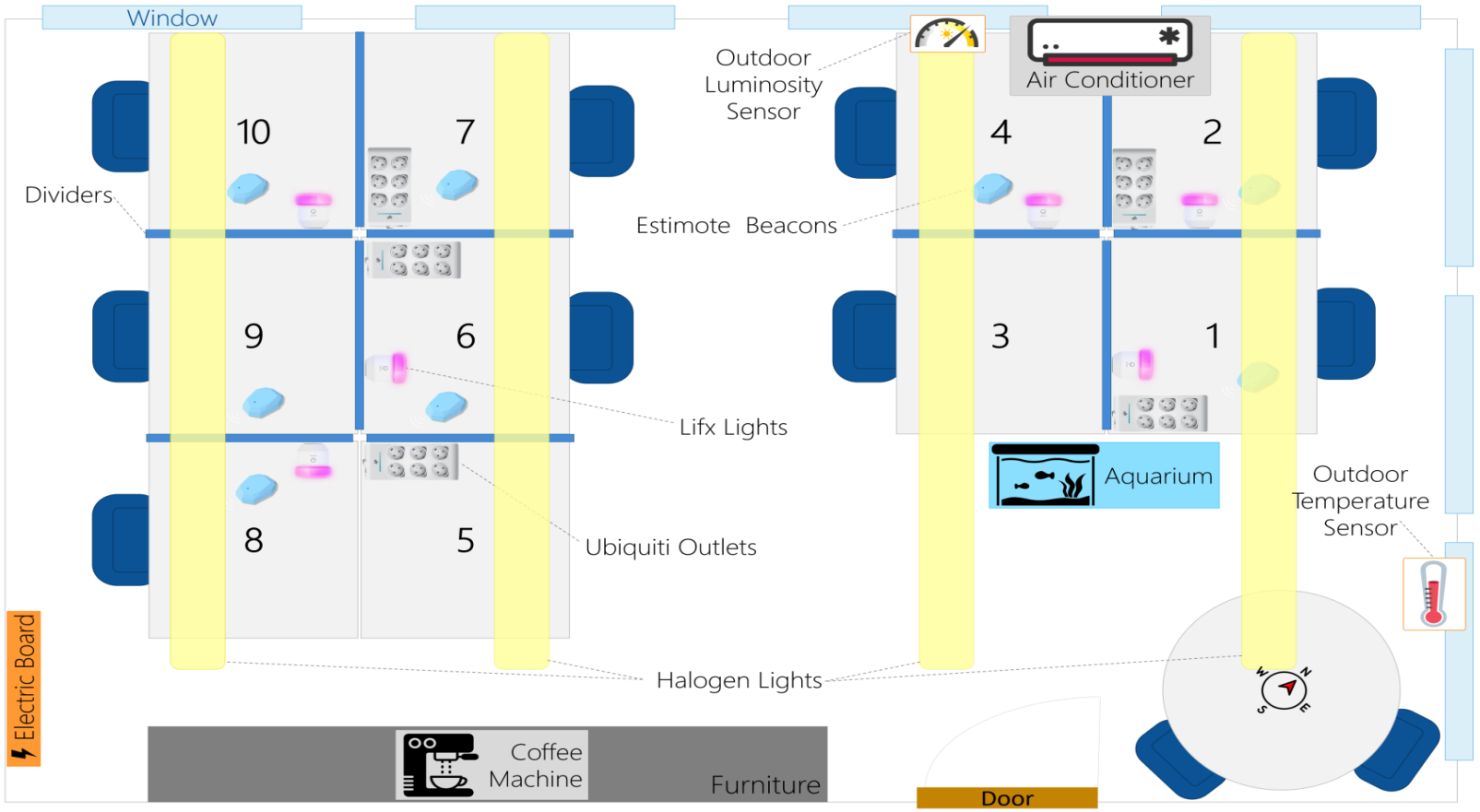
System properties – Multi-Representations

System properties are differentiating factors that can be measured or computed.

$$Visible\ light = \begin{bmatrix} 60 \\ 37 \\ 45 \\ 102 \\ 71 \\ 45 \\ 78 \\ 57 \\ 92 \\ 49 \end{bmatrix} in\ lux$$

OR

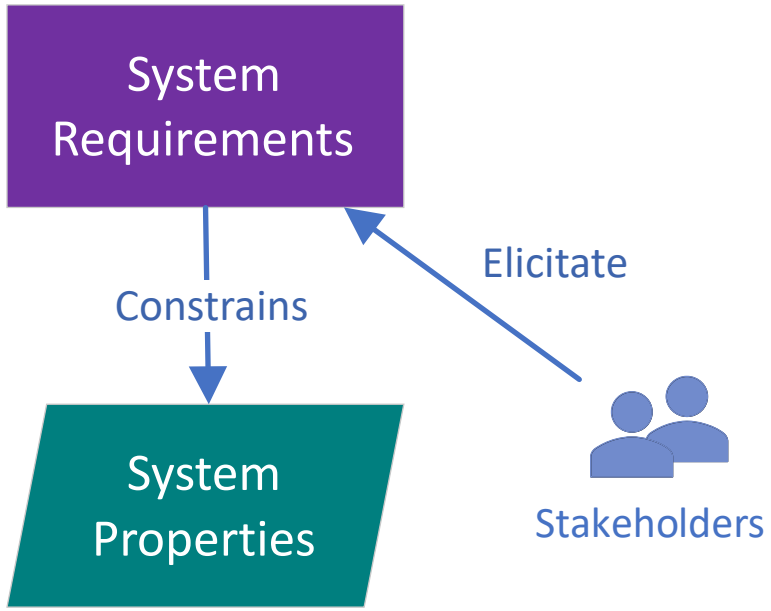
$Visible\ light$ = 63 *lux*



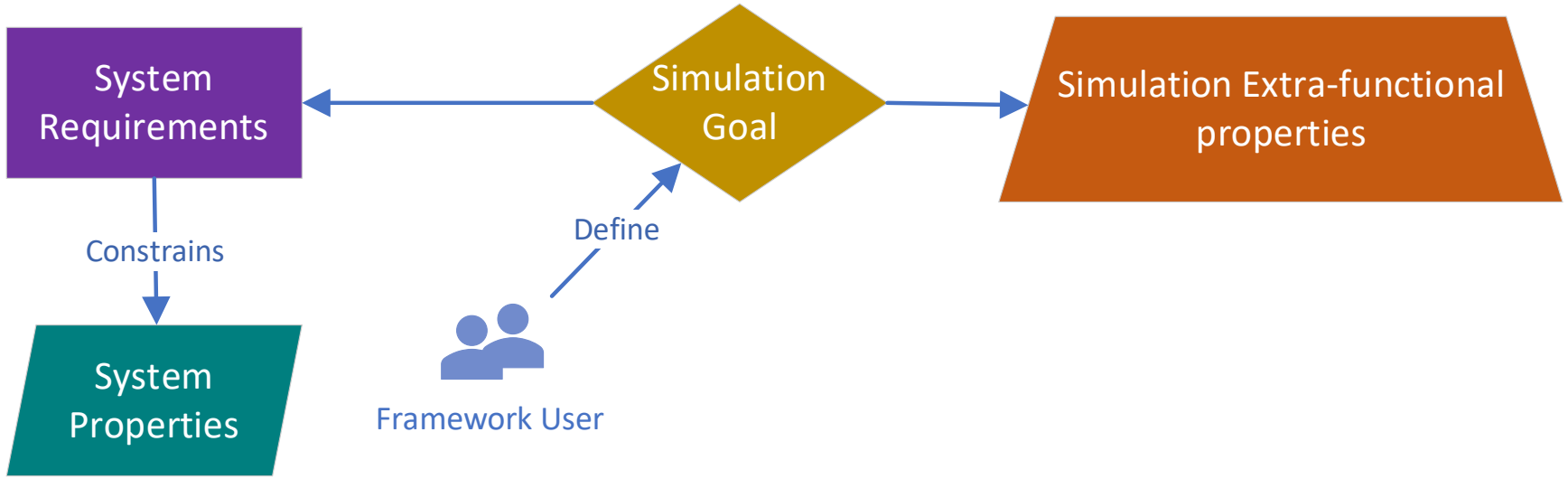
Requirements

A system requirement is a valuation of a system property that can be satisfied or not.

Ex: The minimum visible light level measured at an occupied workstation is 75 lux.

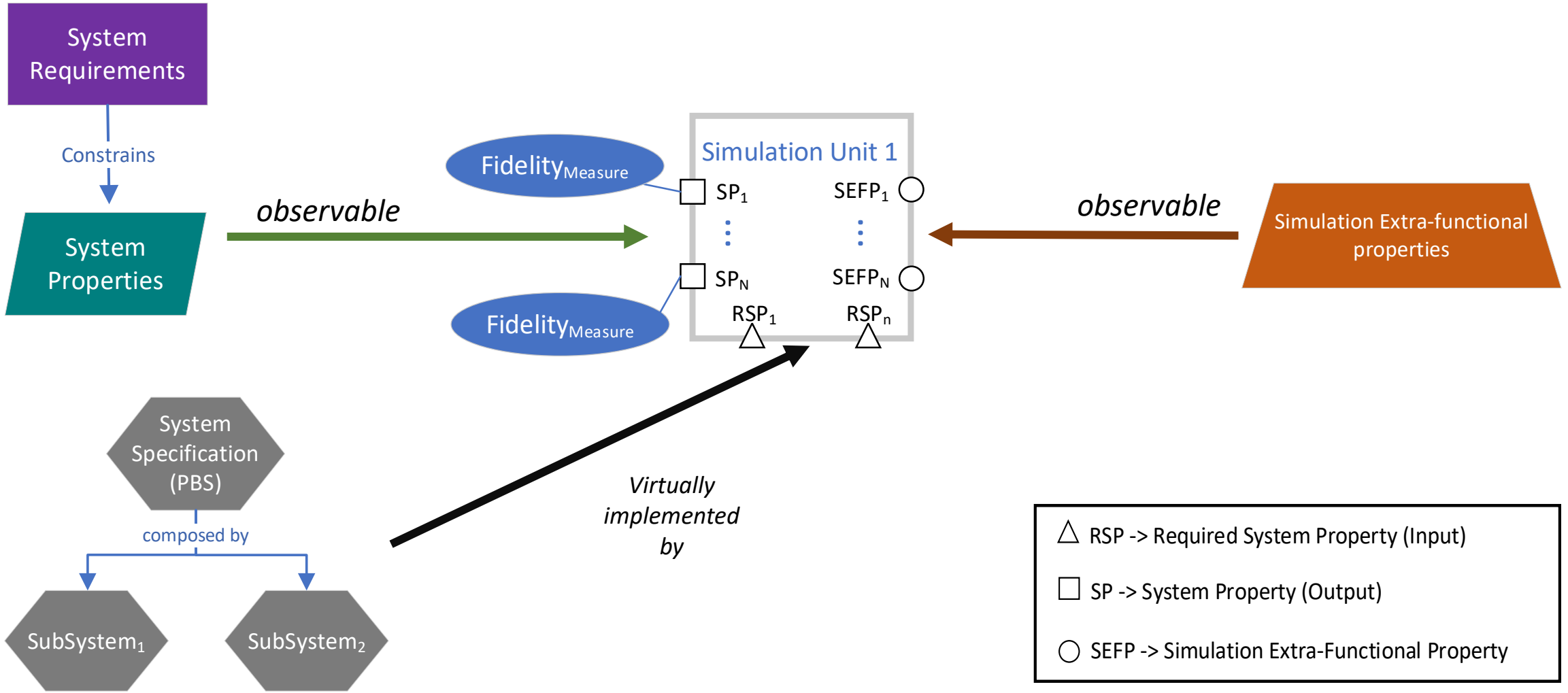


Simulation Goal

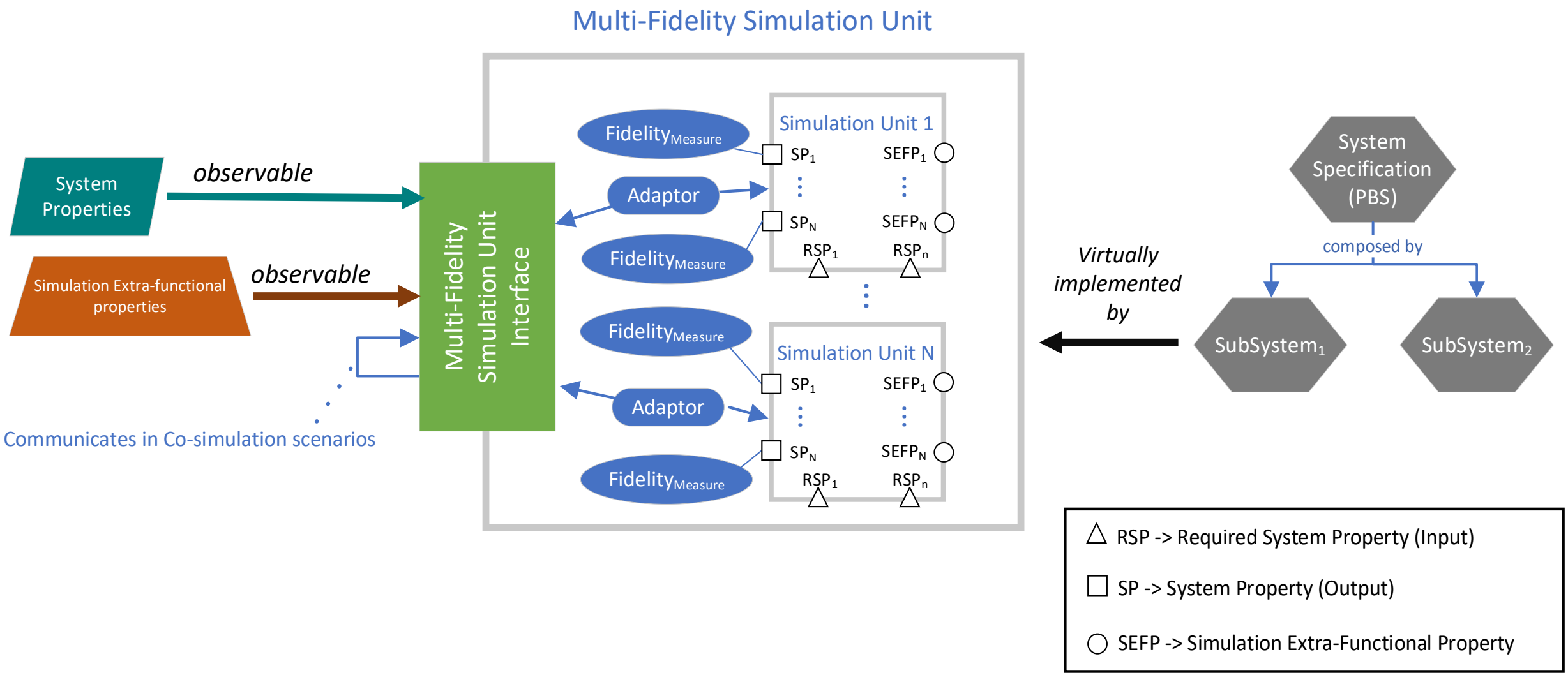


Ex: Simulation Goal -> “Verify that over the period of one week that the minimum visible light level measured at an occupied workstation is 75 lux with an accuracy of 2 lux and the simulation time required is less than 2 minutes”

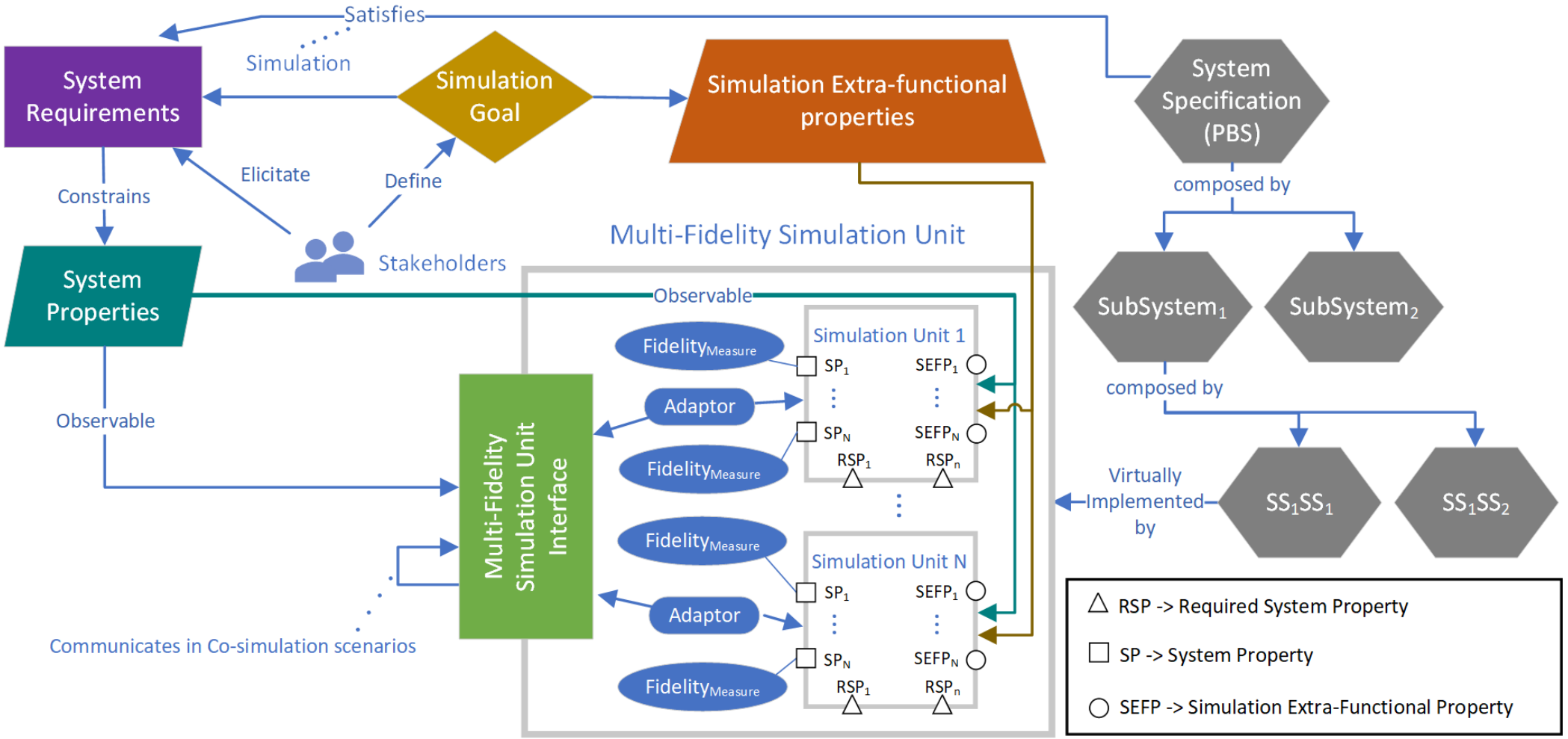
Simulation Unit adapted to a fidelity context



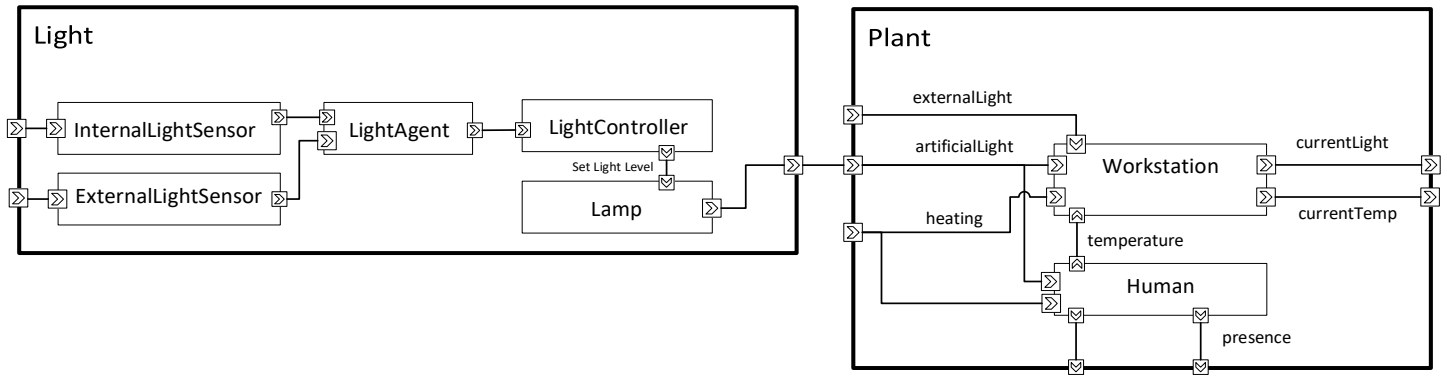
Multi-Fidelity Simulation Unit



Framework overview

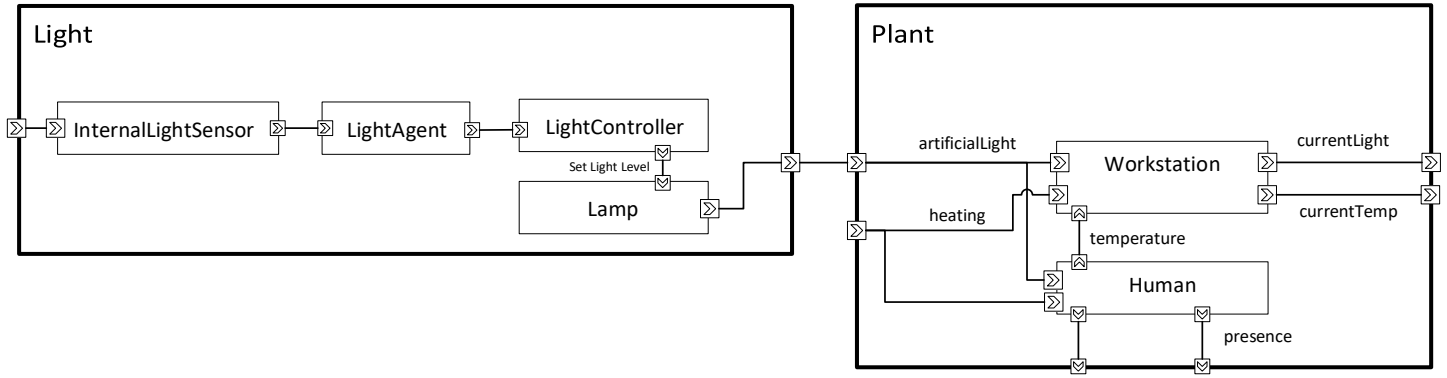


Framework application example



Accuracy workstation visible light level = 2
Simulation time = 1,7 minutes

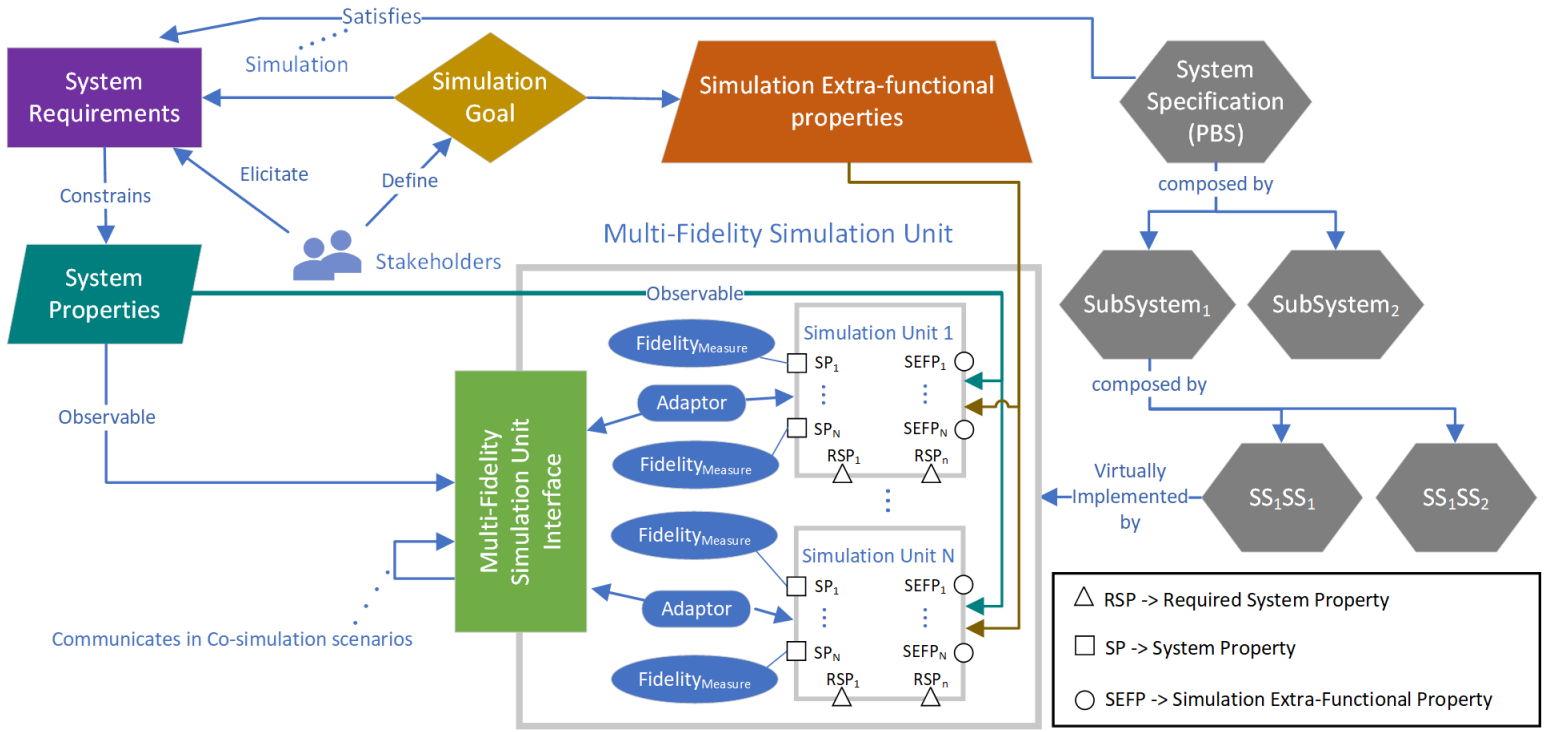
Simulation Goal -> “Verify that over the period of one week that the minimum visible light level measured at an occupied workstation is 75 lux with a maximum accuracy of 2 lux and the simulation time required is less than 2 minutes”



Accuracy workstation visible light level = 10
Simulation time = 1 minute

Conclusions

- The outcome of this framework is a way to automatically determine the simulation units at an adequate fidelity level suitable for answering a specific simulation goal.



Open Questions – Ongoing work

- Any links missing in the framework?
- How does a change in the fidelity of an input change the fidelity of an output?
- We need to reach a treatable fidelity definition. Can it be represented by bonds, an average, a distribution?
- What about simulation timing errors, and specificities of cyber simulation units?
- How to characterize the Multi-fidelity unit interface?

THANK YOU