Dependability in the Context of Human-in-the-Loop Cyber-Physical Systems

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Outline

- Human-in-the-Loop Cyber-Physical Systems (HiL-CPS)
  - Definition and Directions
  - Sample Research and Development
- Dependability in the context of HiL-CPS
  - Availability
  - Reliability
  - Safety
  - Integrity
  - Maintainability and Fault Tolerance

HiL-CPS – A definition

- "… a loop involving a human, an embedded system (the cyber component), and the physical environment. Basically, the embedded system **augments** a human's interaction with the physical world."
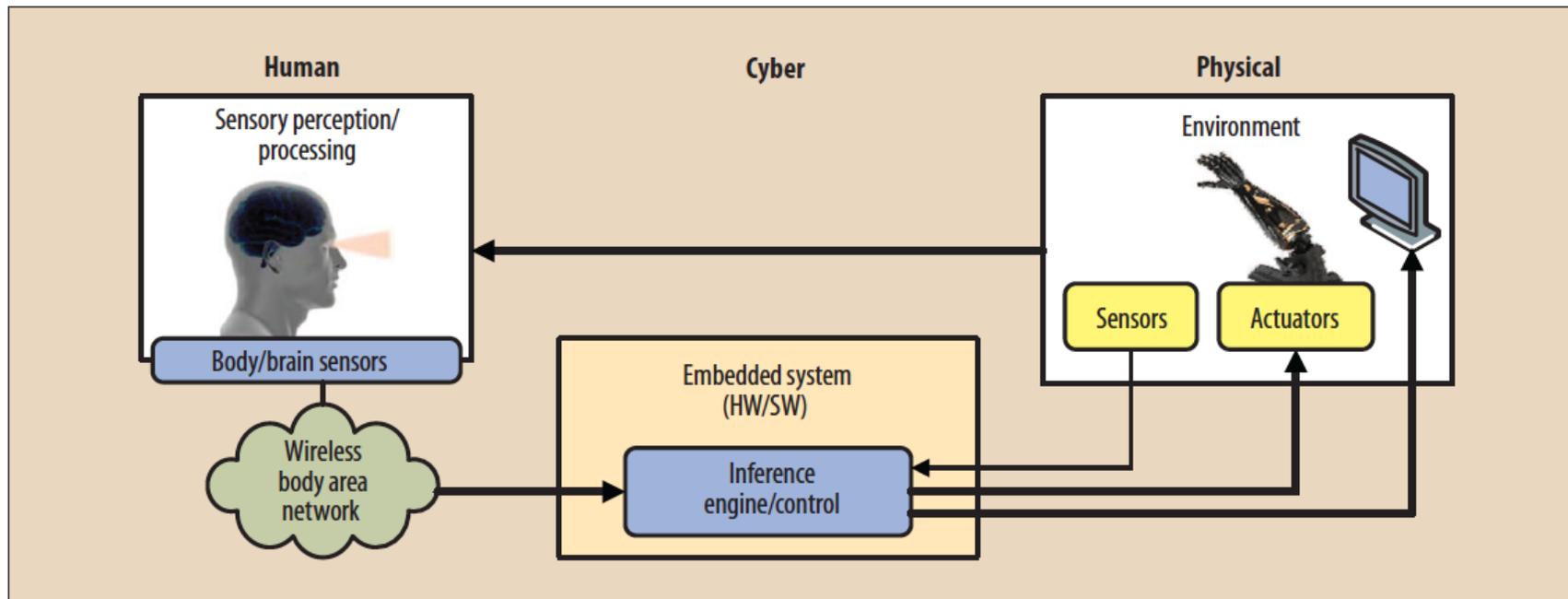
HiL-CPS Directions

- Humans, being in the loop, are the key decision makers
- Sensors gather data
  - From the human (BCI, EEG, EMG, ECG…)
  - From the environment (myriad of sensing technologies)
- Networked and distributed processing: Inference Engine
- Artificial intelligence via machine learning and big data processing
  - Make sense of the human and physical environment data
  - Present options to the human, who makes the final decision
- Actuators
 - Act upon the human's decision

HiL-CPS Sample Research

- HiL-CPS to aid patients with locked-in syndrome
  - Body/Brain Computer Interface
  - Embedded Systems
  - Robotics

SSVEP-controlled Robot \Wheelchair
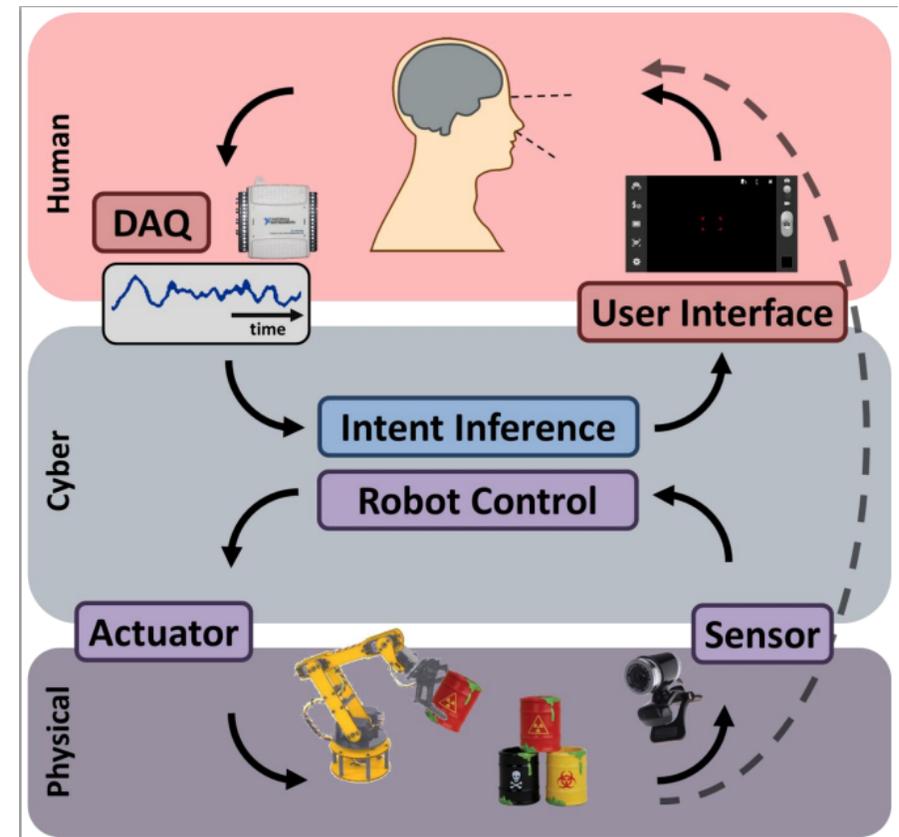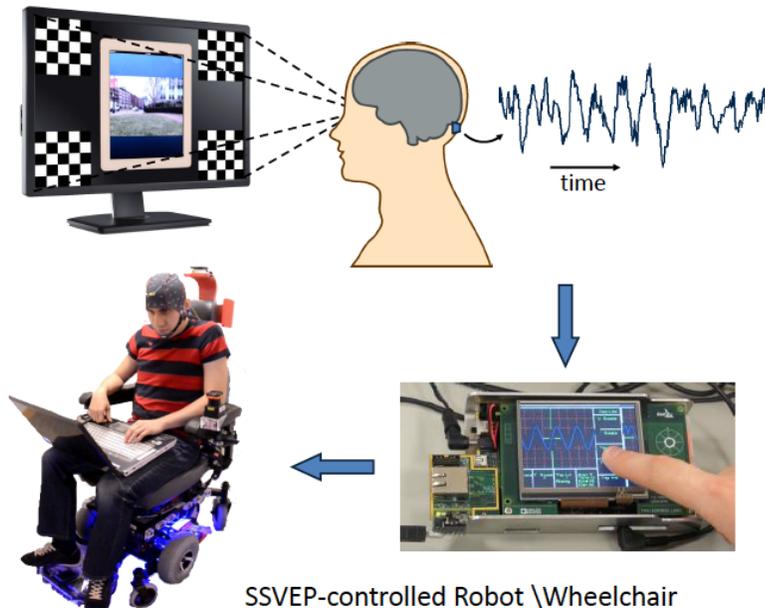
# Adaptive HiL-CPS for Telemedical Applications
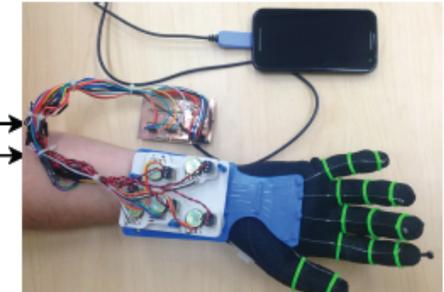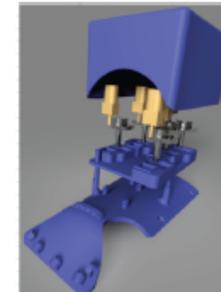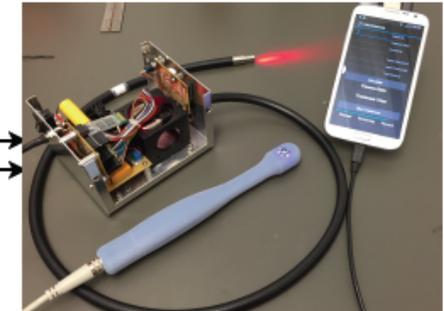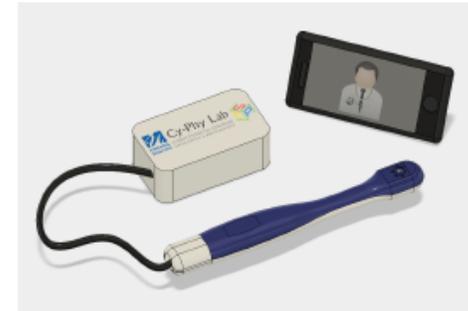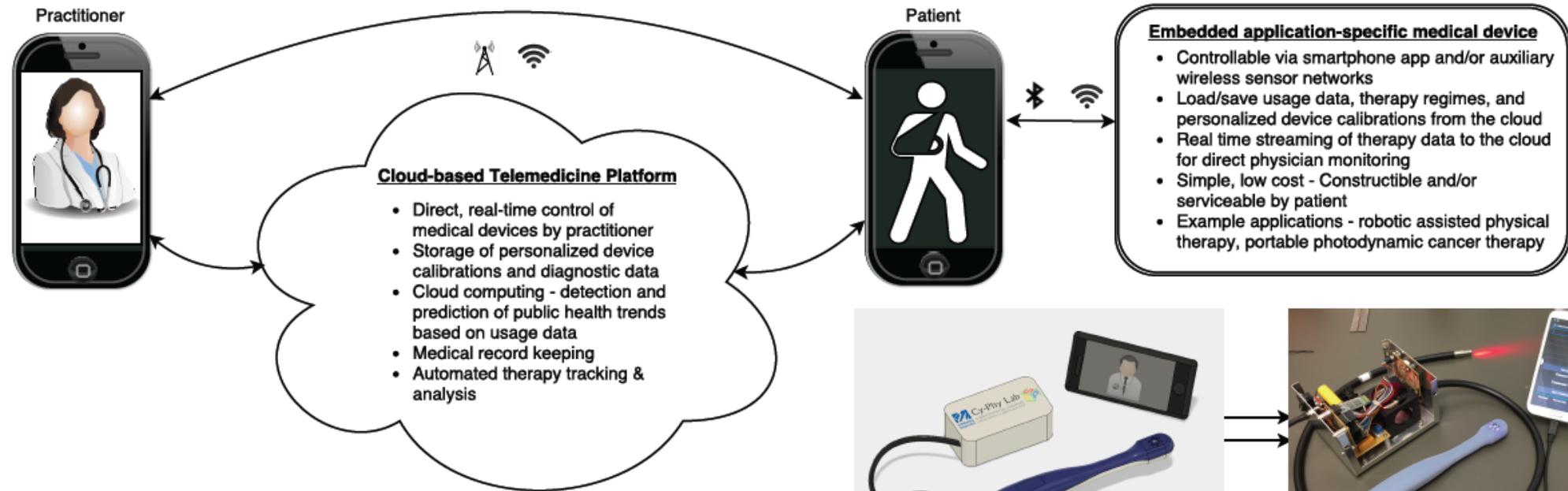
Dependability of HiL-CPS

- A key factor considering the safety of humans is paramount
- Considering:
  - Availability
    - On-demand real-time distributed computing
  - Reliability
    - Context-sensitive human decision inference engine
  - Safety
    - Human-CPS isolation/insulation
    - Robust models for human-CPS interaction
  - Integrity
    - System-level design
  - Maintainability and Fault Tolerance
    - Graceful failures may be catastrophic

HiL-CPS Availability

- Computing, Sensing, Networking:
  - On-demand
  - Real-time
  - Distributed
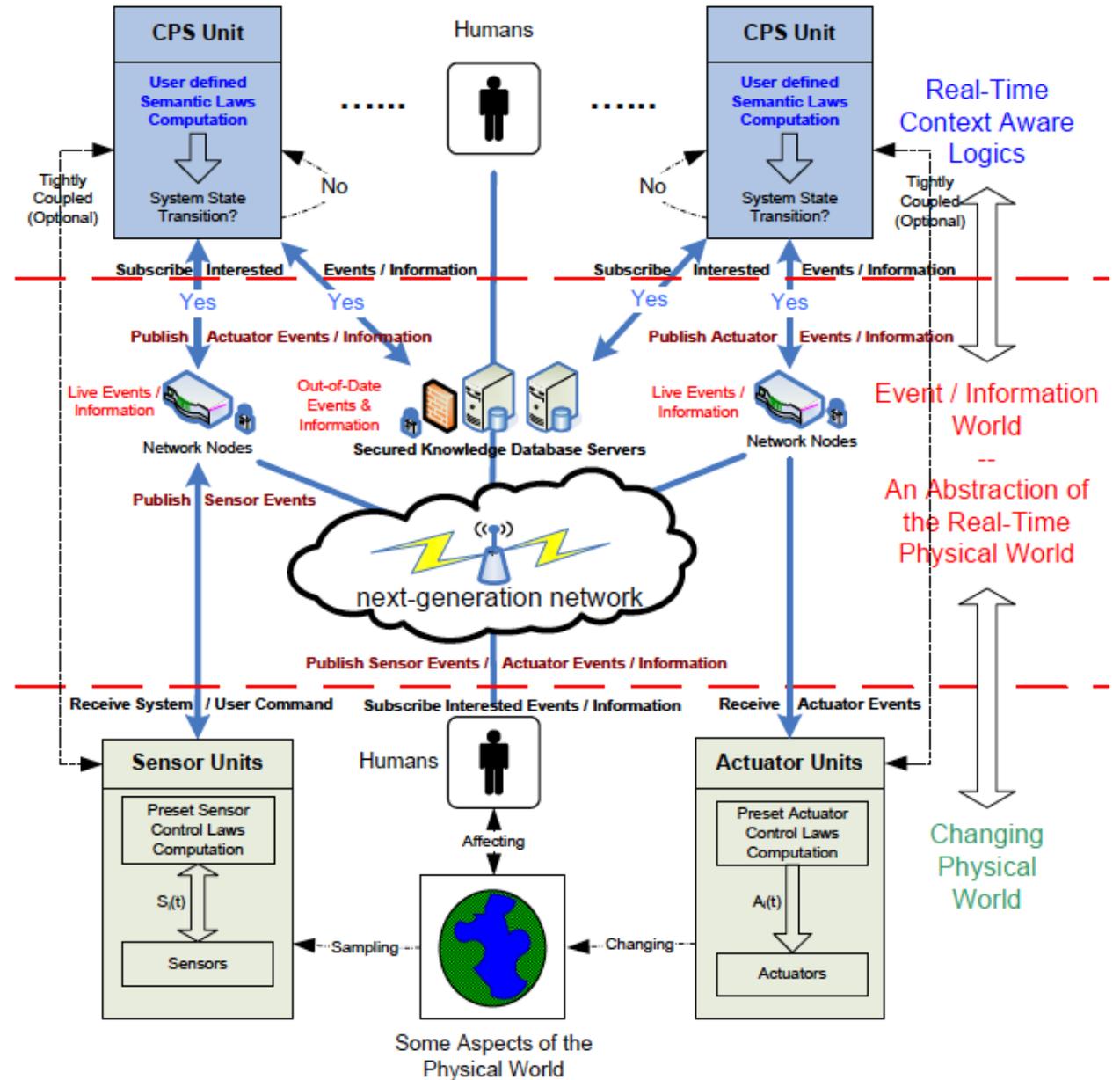
Source: Ying, Goddard, Perez. "A prototype architecture for cyber-physical systems." *ACM Sigbed Review* 5.1 (2008): 26.

HiL-CPS Reliability

Decisions made by humans are not always correct/desirable

Context-sensitive human decision inference engine

Decisions made by algorithms are not always correct/desirable
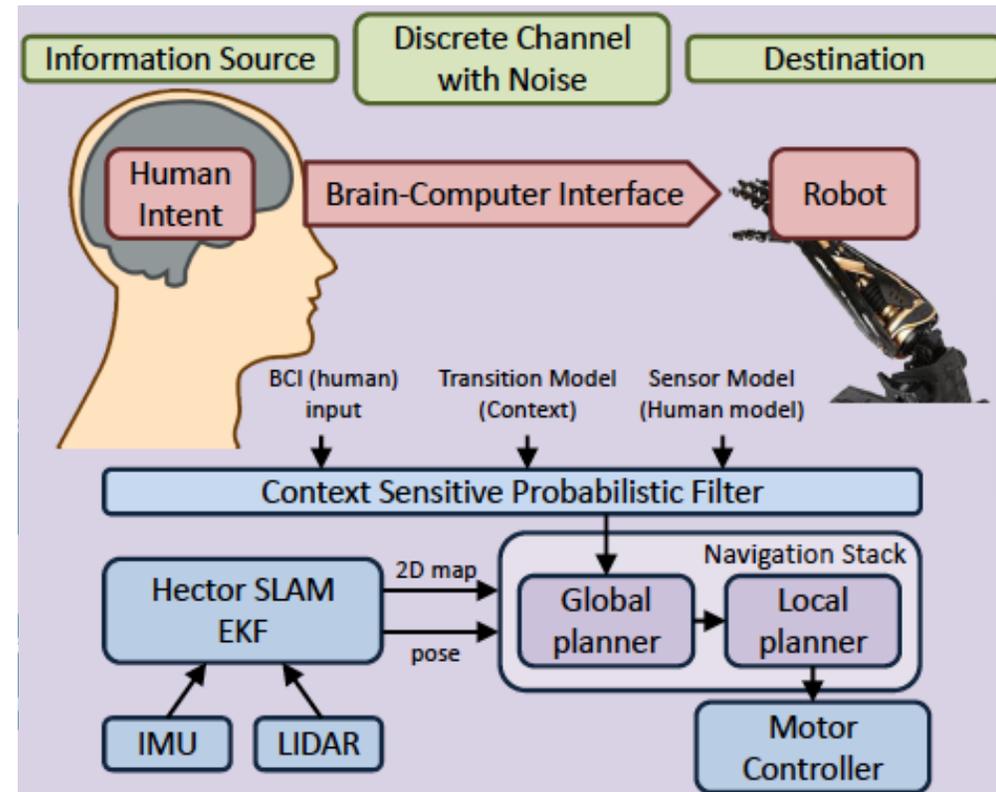
Source: Northeastern Embedded Systems Lab

HiL-CPS Safety

- Human-CPS isolation/insulation
  - Electrical and medical standards
  - Physical Human-to-CPS safety buffer
- Robust models for human-CPS interaction
  - Human models
  - Mechatronic models
  - Interaction models
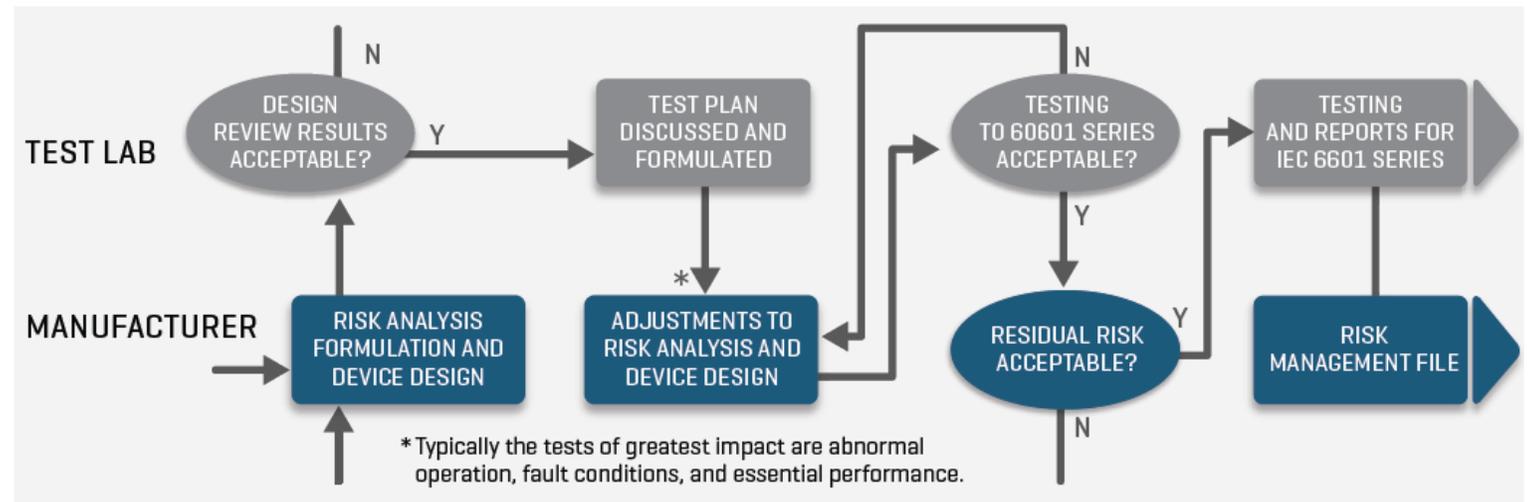
Source: International Electrotechnical Commission - IEC 60601-1 medical design standards

HiL-CPS Integrity

- ## System-level design
  - ### Abstraction
  - ### Automation
  - ### Realization
- ## Standardization of CPS
  - ### Components
  - ### Interfaces
  - ### Comm. Protocols

Abstraction layers define platforms

Platform mapping

Abstractions are linked through refinement relations

Platform mapping

Abstraction layers allow the verification of different properties
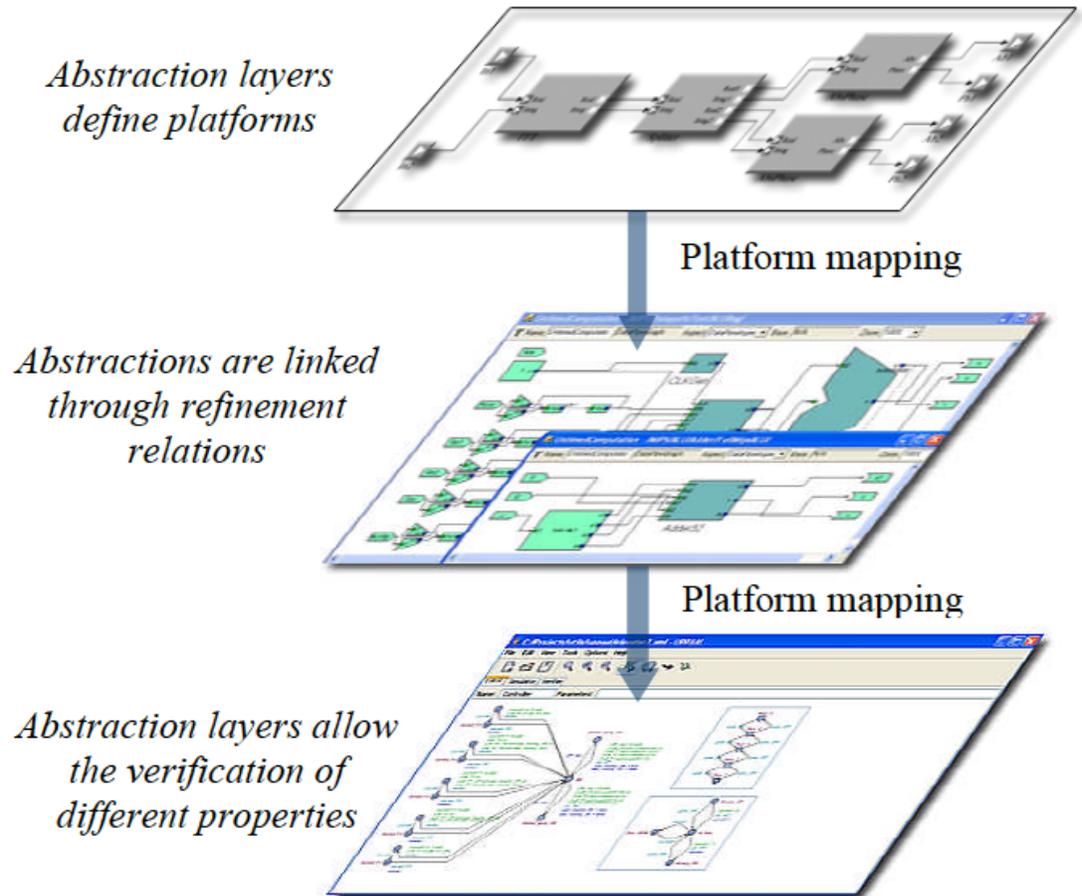
Source: Jianhua, et al. "A survey of cyber-physical systems." *Wireless Communications and Signal Processing (WCSP), 2011 International Conference on*. IEEE, 2011.

Maintainability and Fault Tolerance

- Graceful failures may be catastrophic and are therefore unacceptable
- The keystone to dependability
- Present more questions, and directions

- Thank you!