

**MICROGRID
KNOWLEDGE™**
CONFERENCE

THE REVOLUTION IN ENERGY

APRIL 22-24, 2024
BALTIMORE, MD

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**MICROGRID
KNOWLEDGE™**

microgridconferences.com



Microgrid Knowledge

Typhoon HIL

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VP for Grid Modernization

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Typhoon HIL, Inc.

- ❑ Spun off from MIT and ABB, funded by Ray Stata (Analog Devices).
- ❑ Power Electronics testing genesis.
- ❑ Ultra-high fidelity **Hardware in the Loop** (HIL) Controller Hardware in the Loop (**HIL**) solution
 - Down to **50ns** simulation time step (typically 250ns), **3.5ns** digital oversampling
 - Vertically integrated technology stack Serving Power Electronics HIL customers for **10+ years**.
- ❑ **700+** drives, EV, and power electronics customers since **2009**
- ❑ **100+** employees across **7** offices



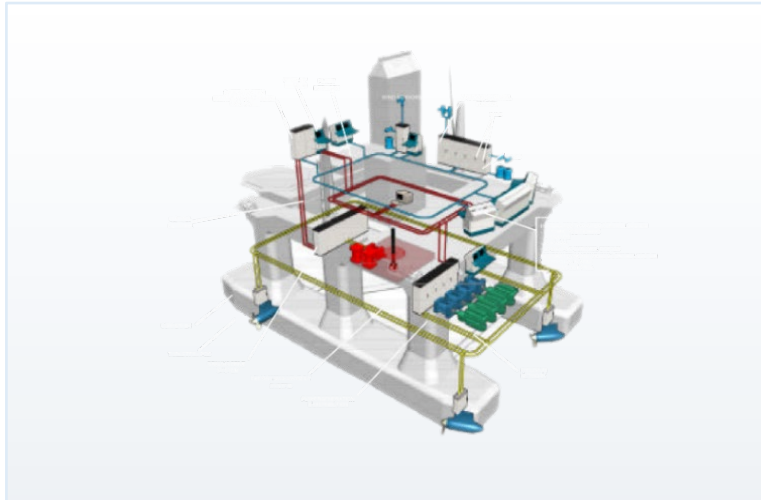
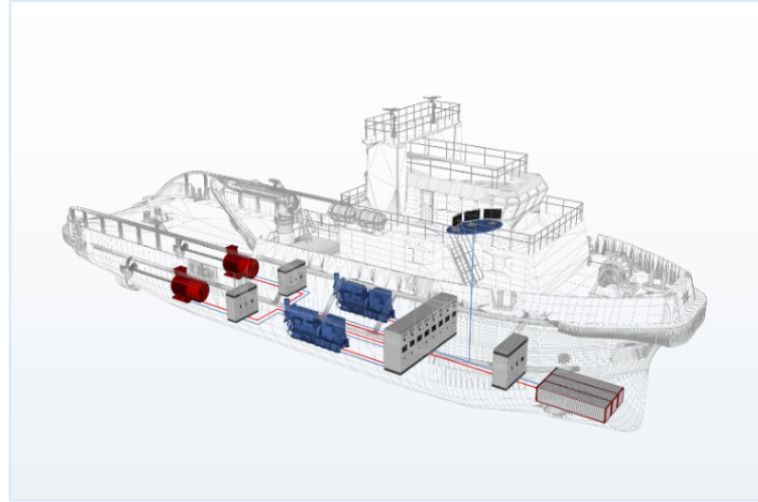
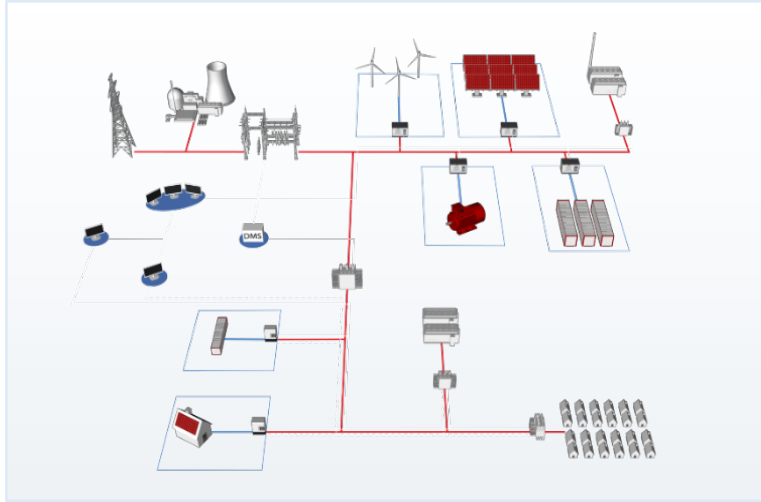
Agenda

- Set the stage:
 - **Why** you need Hardware in the Loop
 - **What** Hardware in the Loop
 - **How** to do it (joined by RTDS)
 - **Who, When and Where** examples (RTDS and IHI)



Why Hardware In the Loop?

Electrification and Digitalization...



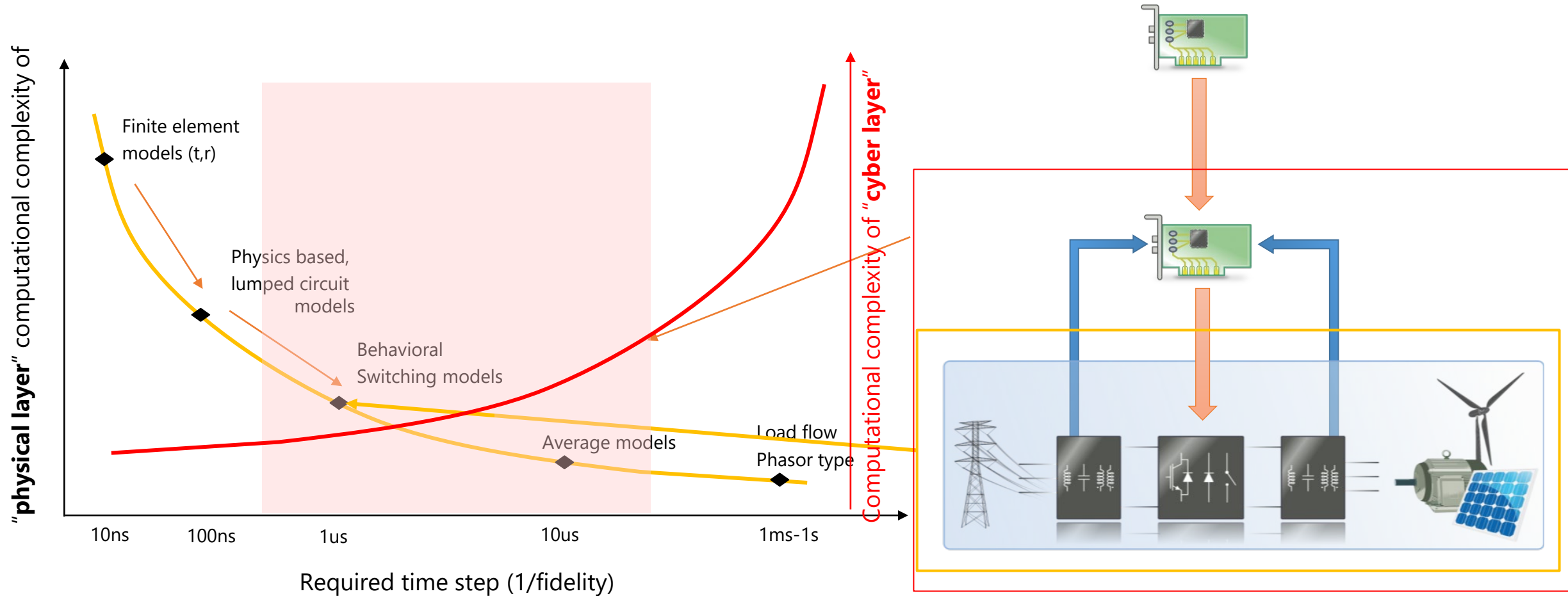
Problem: Lack of effective testing

- ❑ Ship as microgrid
- ❑ \$12 Billion to buy
 - Electromagnetic Catapults
 - Advanced Ammunition Elevators
 - Radar
- ❑ \$5 Billion to commission



Power Electronics are FAST

Model fidelity as a function of computational complexity

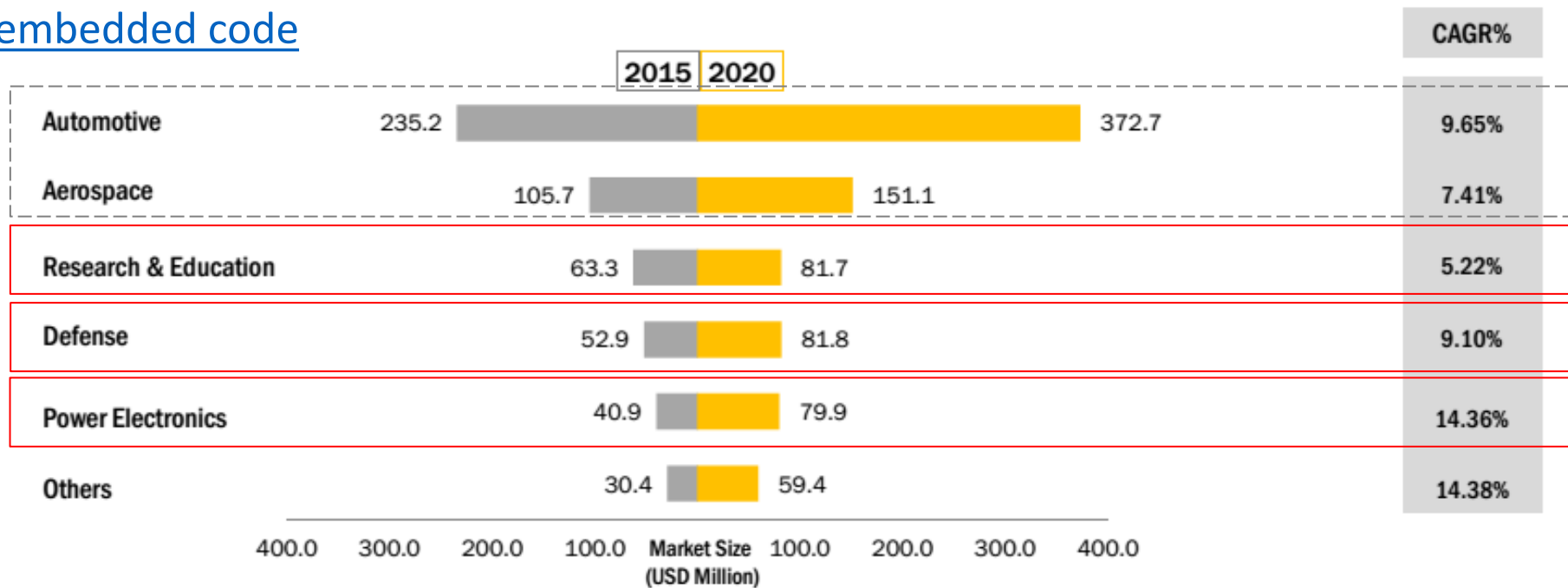
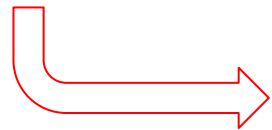


Distribution is software controlled

Hardware-in-the-Loop is broadly defined as “open loop” and “”

FIGURE 9 HARDWARE IN THE LOOP MARKET SNAPSHOT (2015–2020): APPLICATION IN AUTOMOTIVE SECTOR EXPECTED TO DOMINATE THE MARKET DURING THE FORECAST PERIOD

100M (SLOC) of embedded code

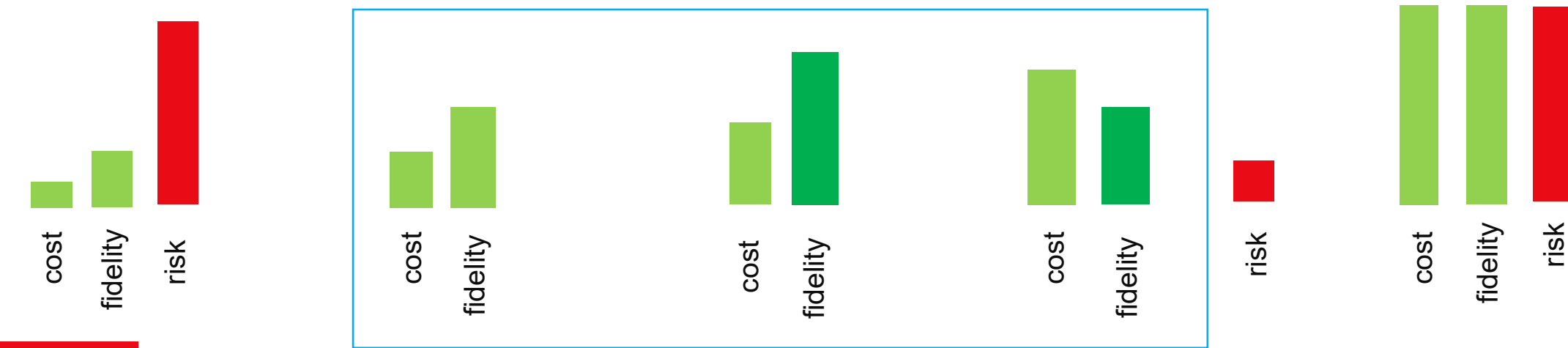
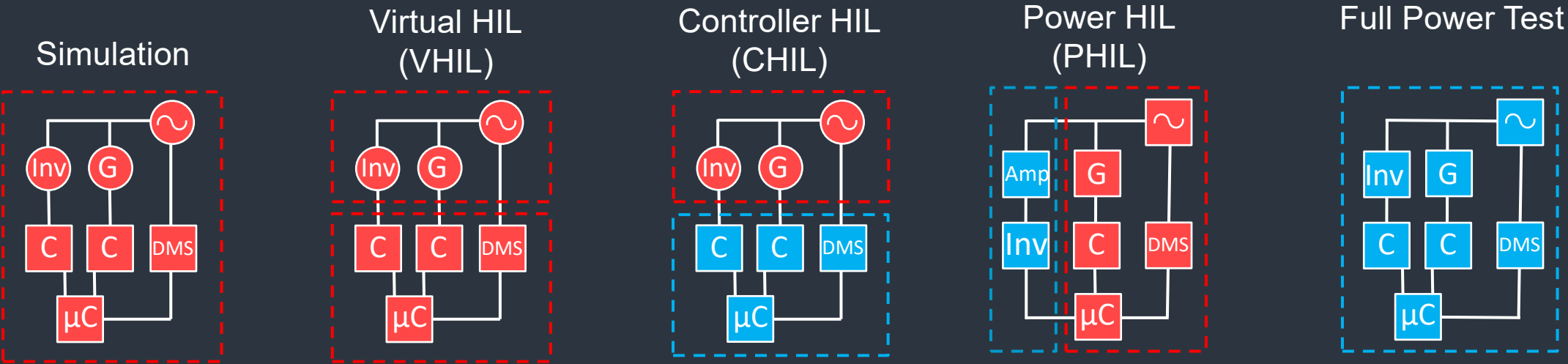


Source: Investor Presentations, Experts' interviews, and MarketsandMarkets Analysis



What is Hardware In the Loop?

Model Based Testing Methodologies



Model Types

VHIL – Idealized / Modeled control

Generic models

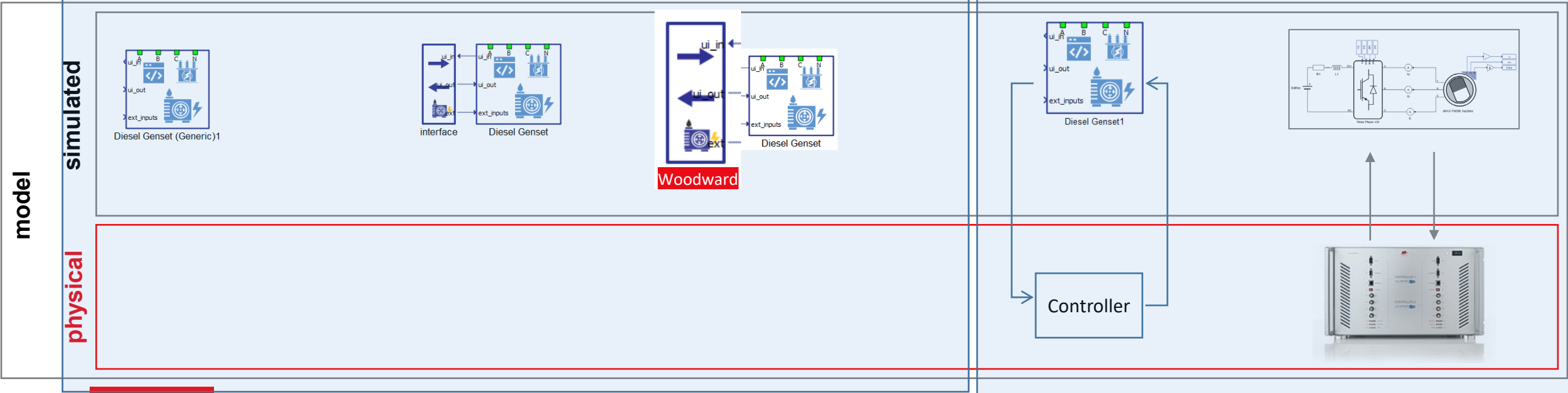
Generic W Comm Interface
Generic w/ accurate control interface using protocols like 61850

Generic OEM Models*
Generic models w/ Parameterized, OEM specific, registration and communications

CHIL – Actual / Real Controller

ACTUAL CONTROLLER with CHIL Model
For Validation and Verification

HIL Compatible Pkg
high-fidelity power stage model with actual controller



System Development Lifecycle

Acquisition Process



Project



Typhoon MBSE

0- Software Solutions

1- VHIL (Generic)

2- VHIL (Design)

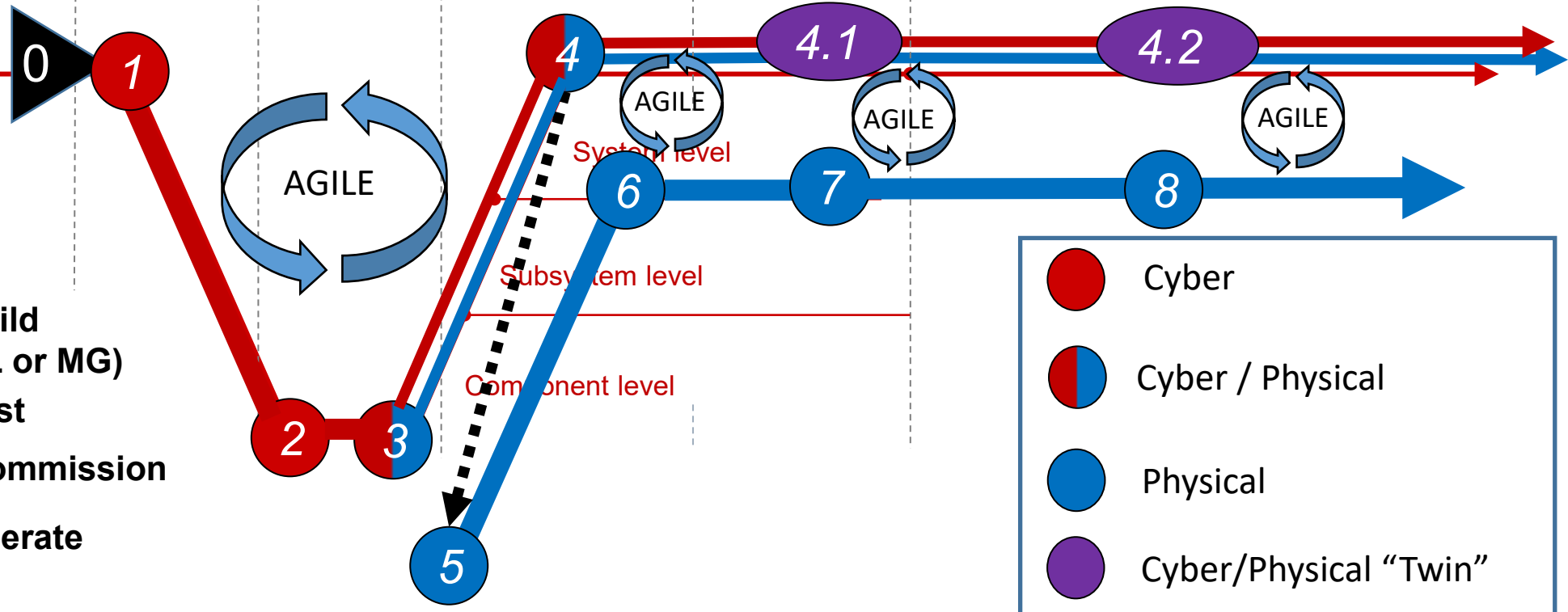
3- CHIL (Build)

4- CHIL (Test) → 5- Build (PHIL or MG)
→ 6- Test

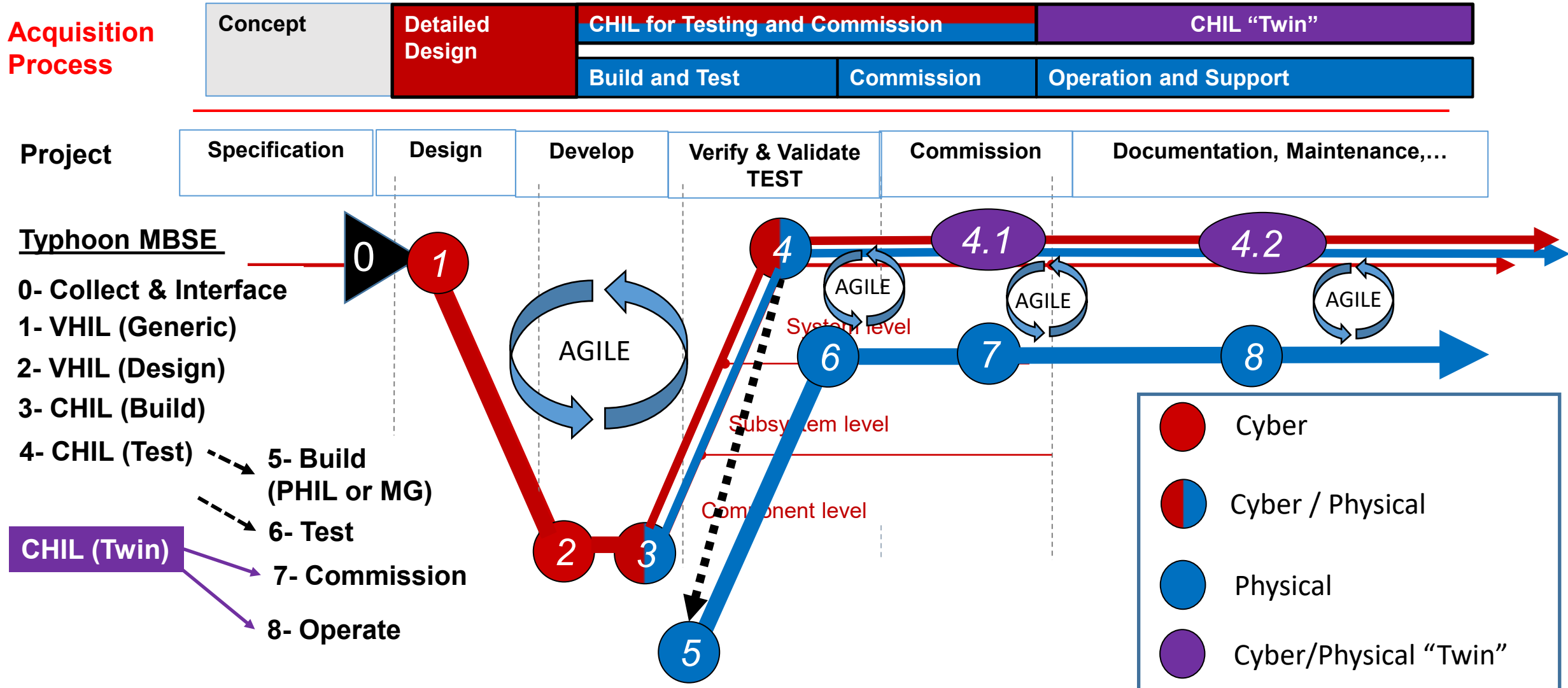
CHIL (Twin)

7- Commission

8- Operate



System Development Lifecycle





How Its Done



Typhoon HIL, Inc

services

- ☐ Expert engineering
- ☐ Technical support
- ☐ Development and Customization
- ☐ On/Off-Site training
- ☐ <https://HIL.Academy>

software

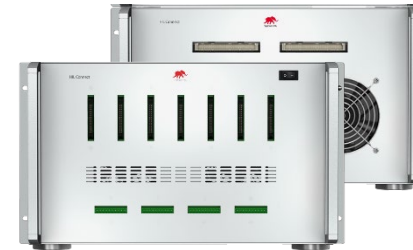
- ☐ Integrated.
- ☐ Graphical modeling
- ☐ Custom test interfaces
- ☐ Automated testing (Python Test)
- ☐ Guaranteed forward compatibility

hardware

- ☐ Highest Fidelity in industry



- ☐ Real Time Emulators



- ☐ HILConnect Interfaces



- ☐ HILCompatible Controllers



HIL Simulators



HIL402



HIL404



HIL604



HIL606

Model capacity

Detailed converter models (1ph/3ph)

8/4

8/4

16/8

16/8

Average converter models (3ph)

8

12

10

24

Distribution network simulation



Time resolution

Minimum simulation step

500 ns

200 ns

500 ns

200 ns

DI sampling resolution

6.2 ns

3.5 ns

6.2 ns

3.5 ns

I/O

Analog I/O per unit

16/16

16/16

32/64

32/64

Digital I/O per unit

32/32

32/32

64/64

64/64

Connectivity

USB



Ethernet



CAN



RS232



EtherCAT



SFP



Time synchronization (PPS and IRIG-B)



Paralleling

Up to 4 units

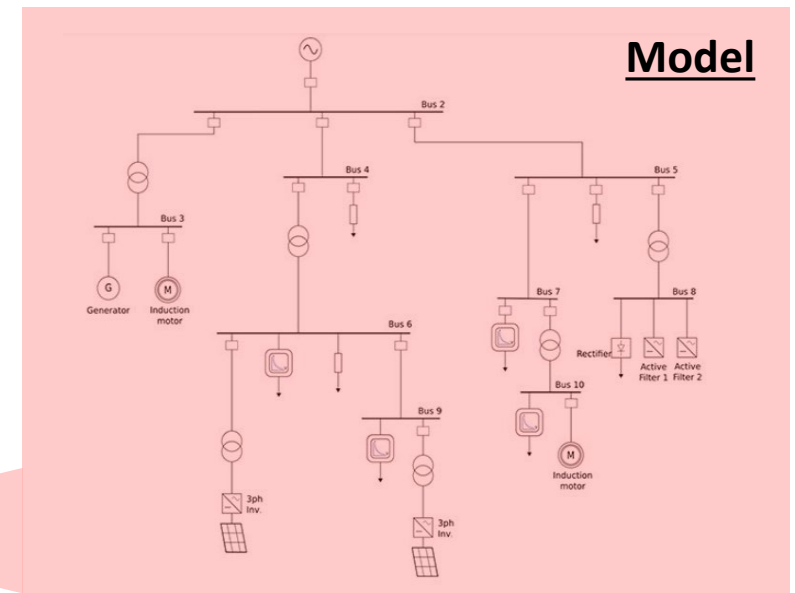
Up to 16 units

Up to 16 units

HILCompatible

1. Actual Controller
2. Interface*
3. Model

HILCompatible Package



Interface

“Modular HILConnect”

Actual Controllers

Connect to Modular HILConnect by cable harnesses



Type 1 -- Distinct



Type 2 -- Integrated

Integrated Interface and Actual Controllers
Power HILConnect”

HILCompatible Packages

Distribution

ABB	REF 615	Relay
ABB	RER 615	Recloser Control
Beckwith	M2001D	Tap Changer
Beckwith	M-6283A	3 Phase Digital Capacitor Controller
Eaton	CBC-8000	Cap Bank Controller
Eaton	CL-7	Voltage Regulator
Eaton	Form 7	Relay
Eaton	EDR-5000	Distribution Relay
S&C	Intellicap	Automatic Capacitor Controls
SEL	300	Generator Relay
SEL	311	Line Current Differential Protection
SEL	351	Protection, Automation and Bay Control System
SEL	421	Protection, Automation and Control System
SEL	451	Protection, Automation and Bay Control System
SEL	487	Transformer Protection Relay
SEL	651R	Advanced Recloser Control
SEL	700G	Generator Protection Relay
SEL	735	Power Quality and Revenue Meter
SEL	751	Feeder Protection Relay
SEL	787	Transformer Protection Relay
SEL	2411	Programmable Automation Controller
SEL	2414	Transformer Monitor
SEL	2240	Axion - Real Time Automation Controller
SEL	3555	Real Time Automation Controller

Microgrid (System)

Eaton
ABB
ETAP
ComAp
Fractal
SEL

Genset

Woodward
Deif
ComAp

Wind Turbine

Woodward

Inverter / Drive

Fronius
Rolls Royce
Schneider
Fimer
EPC Power
Dynapower
ABB
Hitachi Power Grid
Danfoss
Solar Turbines
AIT
Power Electronics
TMEIC
LS



Modular HILCONNECT

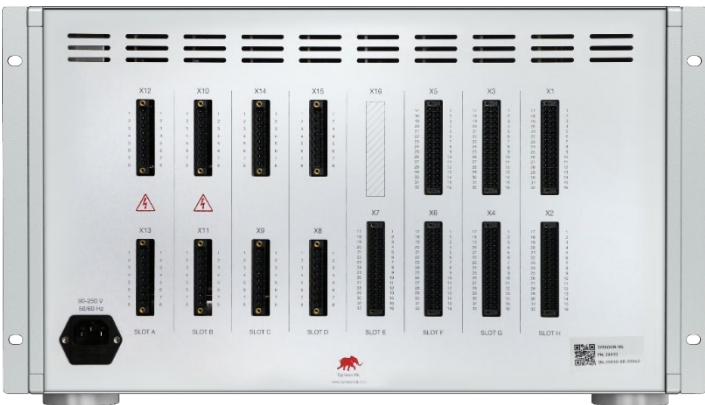


Analog output

Type	Range (peak)	Qty	Bandwidth	Accuracy	Comment
Analog Output	$\pm 10\text{ V}/\pm 20\text{ mA}$	32	DC-100 kHz	$0.1\% + 500\text{ }\mu\text{V}$ $0.1\% + 10\text{ }\mu\text{A}$	Load range: > 500 Ω < 500 Ω
High voltage	$\pm 183.3\text{ V}$	16	DC-10 kHz	$1\% + 10\text{ mV}$	1 mA output current
Current Output	$\pm 2\text{ A}$	16	DC-120 kHz	$0.1\% + 600\text{ }\mu\text{A}$	$\pm 2\text{ V}$ compliance

Analog input

Type	Range	Qty	Bandwidth	Accuracy	Input resistance	Comment
Current	$\pm 40\text{ mA}$	16	DC-100 kHz	$0.1\% + 10\text{ }\mu\text{A}$	249.5 Ω	$\pm 24\text{ V}$ continuous external voltage resistant
Voltage	$\pm 10\text{ V}$	16	DC-100 kHz	$0.1\% + 500\text{ }\mu\text{V}$	1 M Ω	



Digital output

Type	Logic	Qty	Output resistance	Rating	Comment
Voltage	Push-pull/ Open Drain	32	10 Ω /2.2 k Ω	3.3/5/15/24 V	Default: 24 V Push-Pull

Digital input

Type	Logic	Qty	Input resistance	Rating	Comment
Voltage	Fast IO	32	100 k Ω /1.8 k Ω	Logic High: 2.5..28 V Logic Low: 0..0.8 V	Default: Fast IO

IHI Energy Storage

Microgrid control & integration

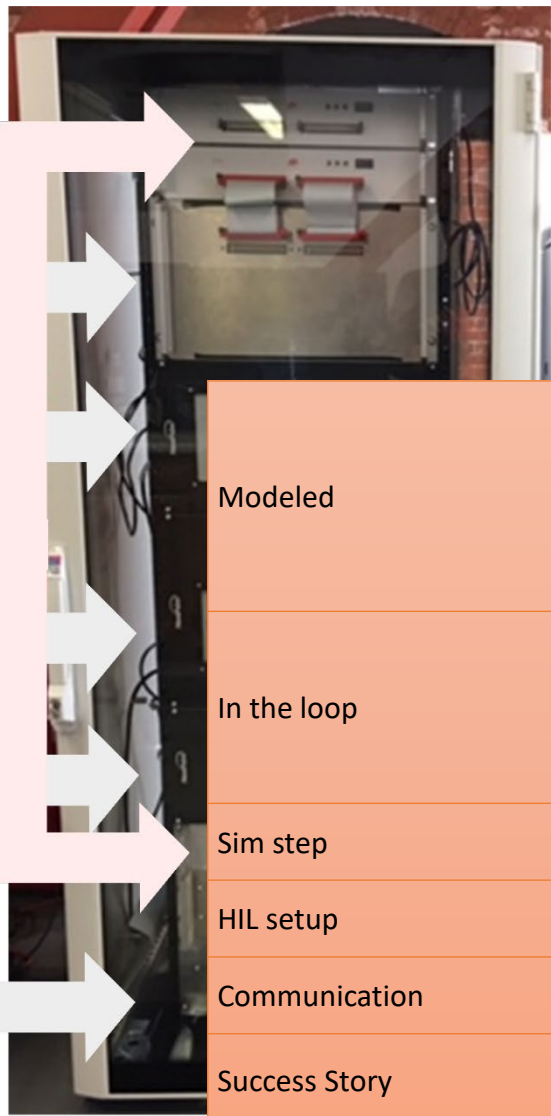
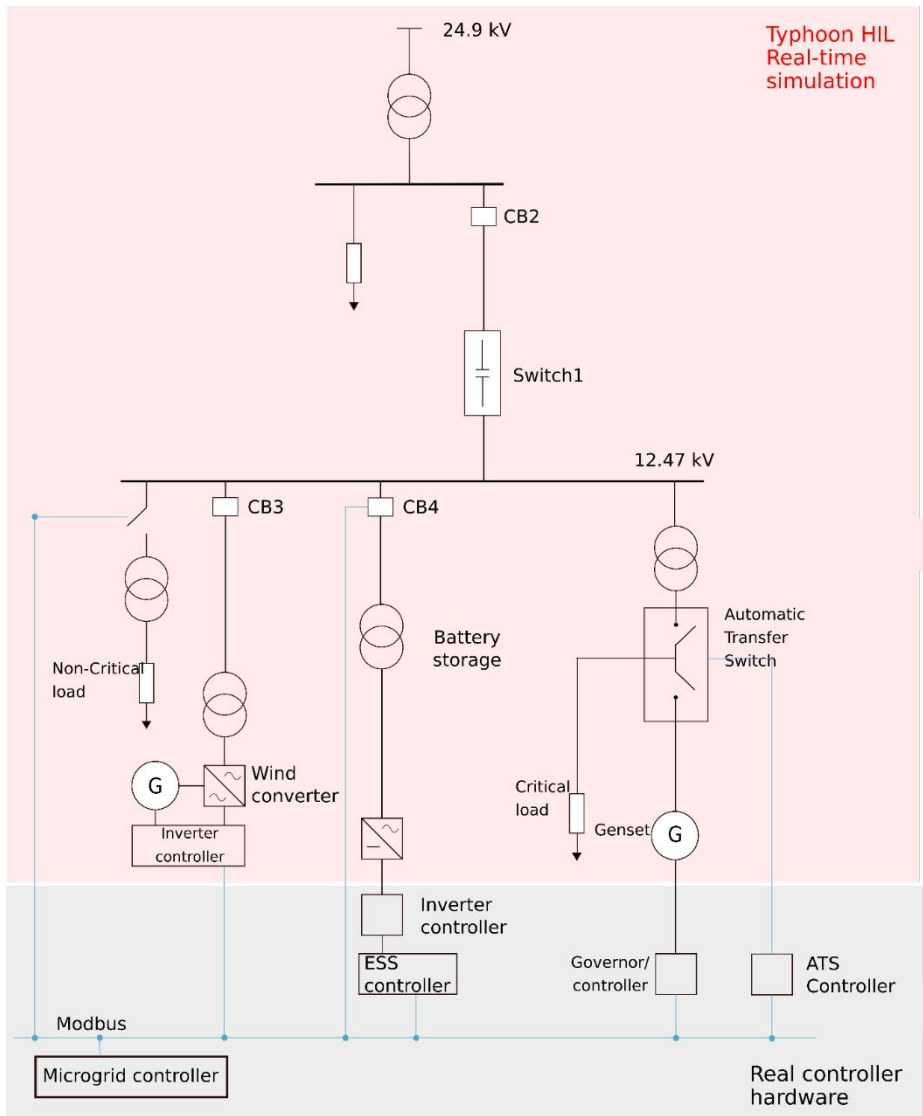


- ❑ Battery management system software testing
- ❑ Test automation for ESS controllers

Modeled	▪ Genset ▪ Inverters ▪ Batteries
In the loop	▪ 2xEPC Power Inverter Controller ▪ 2xSEL 751 Relay
Sim step	1μs
HIL setup	4xHIL604
Communication	▪ Modbus TCP
Success Story	▪ Test automation for utility storage projects

Raytheon

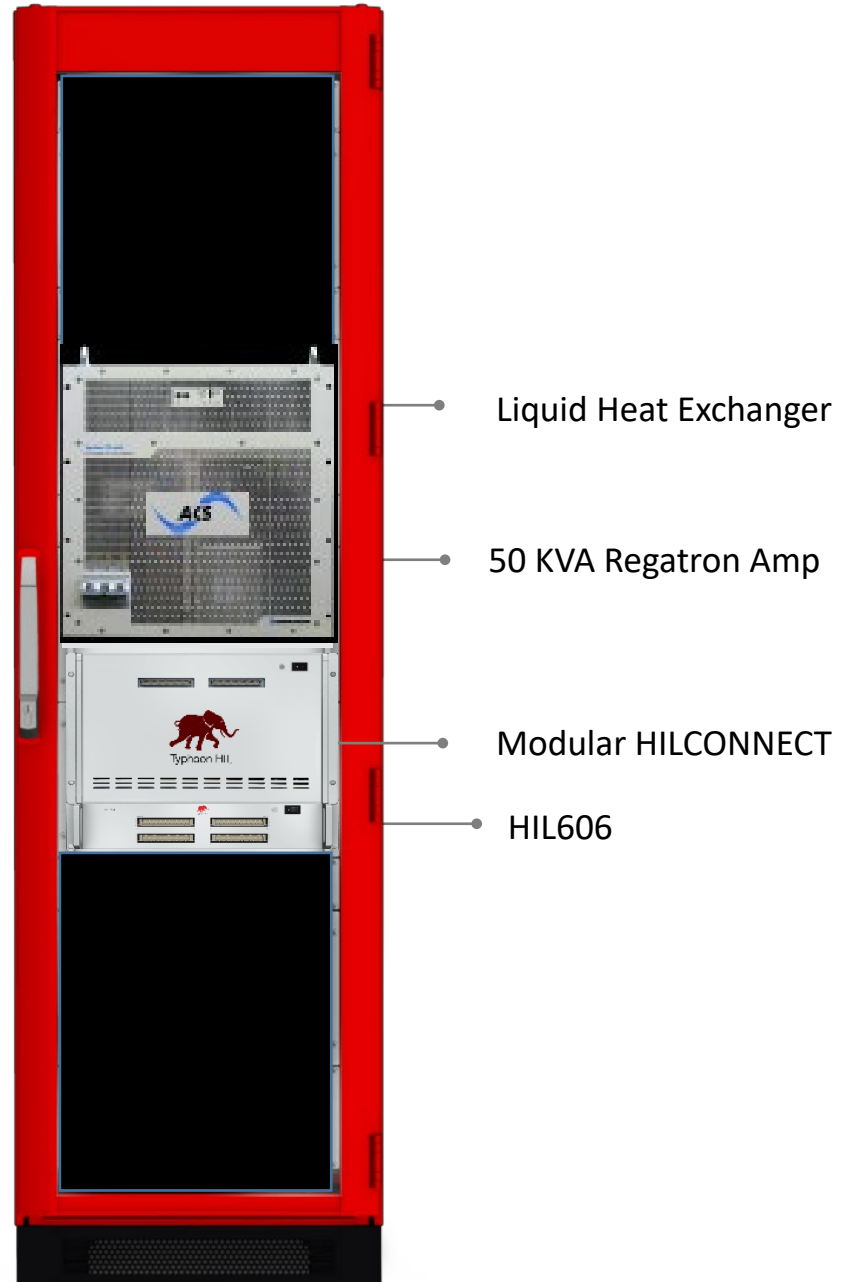
Tactical & FOB Microgrids



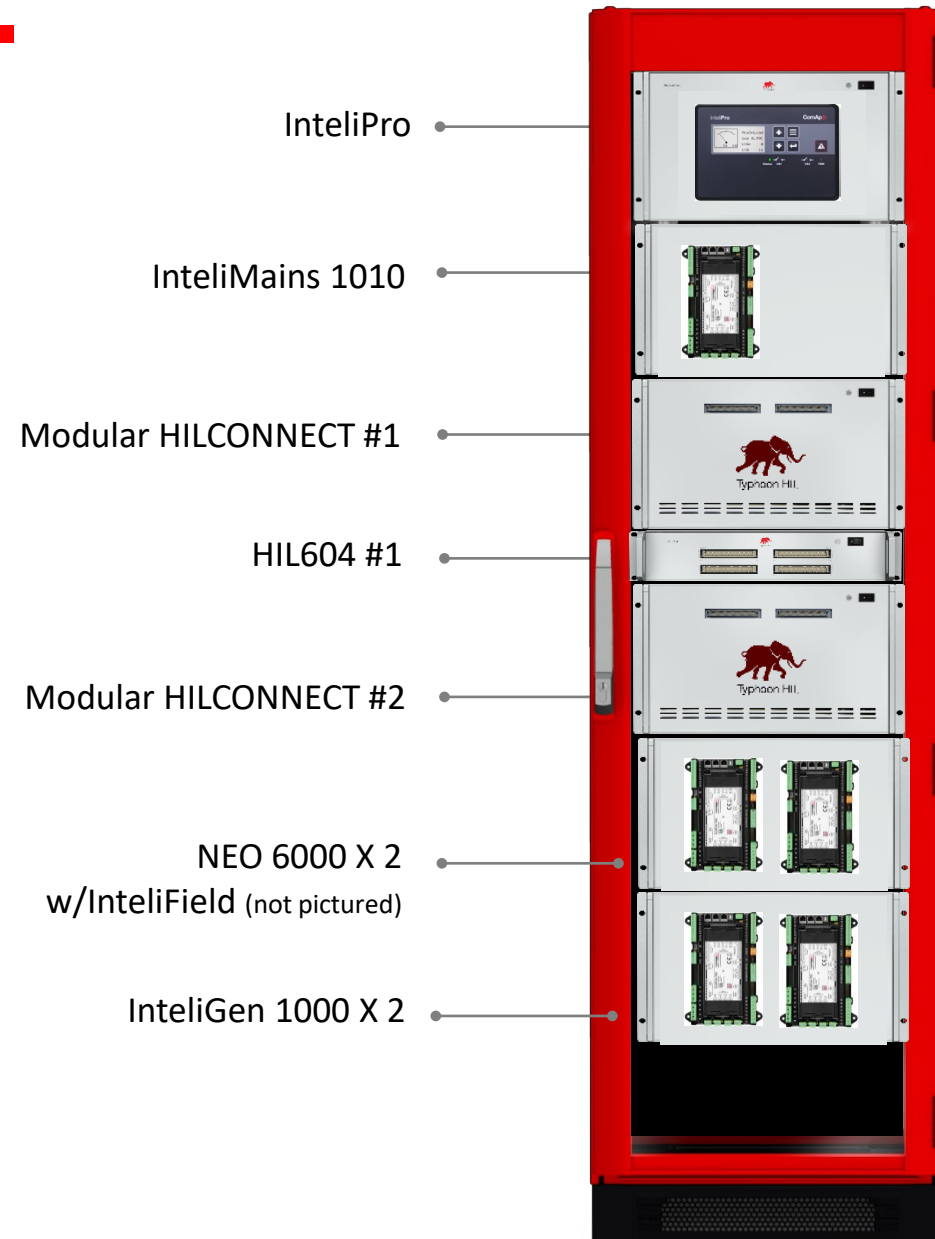
HIL603
HIL603
Soft Load Controller
Interface-HILConnect

Modeled	- Automatic transfer switch - Genset - Wind turbine inverter - BESS inverter - Controllable loads
In the loop	- ASCO Soft load controller - ASCO Group 5 transfer switch controller - ASCO power manager XP - Dynapower inverter controller
Sim step	2μs
HIL setup	3x HIL 603
Communication	Modbus TCP
Success Story	

PHIL RACK



ComAp MG Testbed Concept





Thank you for your attention!

Typhoon-HIL.com

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