# Using Digital Twins to Tame the Testing of AI

20TH ANNUAL ACQUISITION RESEARCH
SYMPOSIUM
MAY 10-11, 2023

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Research Question - How can we effectively apply Digital Twin techniques to Train and Test (T&T) Cognitive EW systems?

Cognitive EW systems using AI/ML have potential for –

Radically increasing performance in dense, complex threat environments

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Ability to handle 'novel' and changing threats and environments effectively
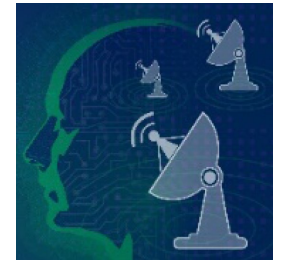
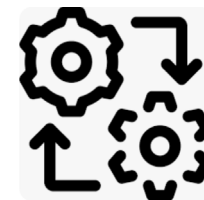## Cognitive EW T&E Challenges

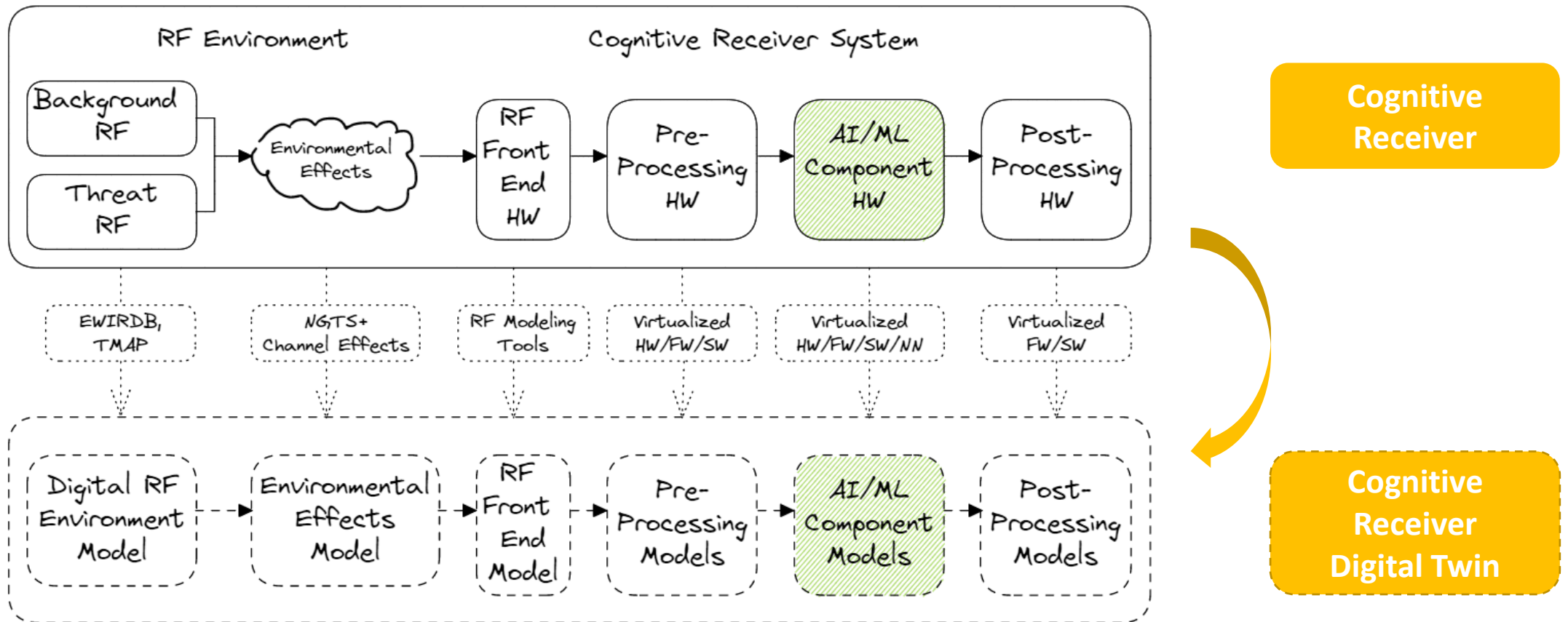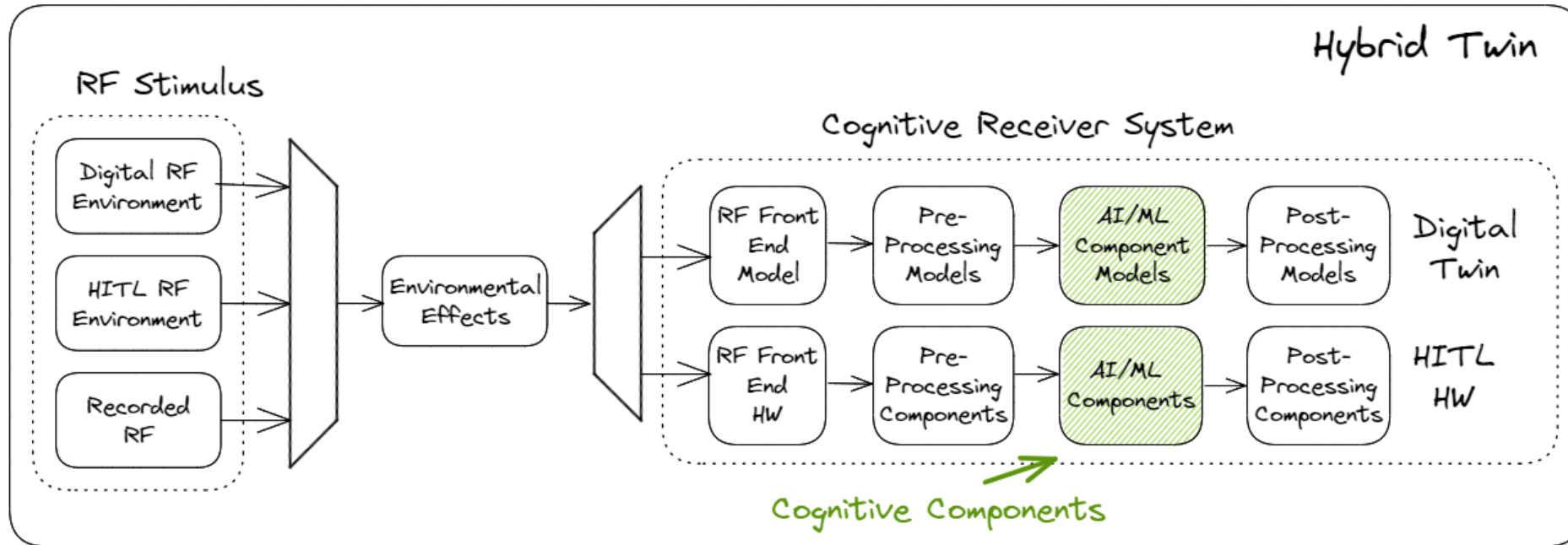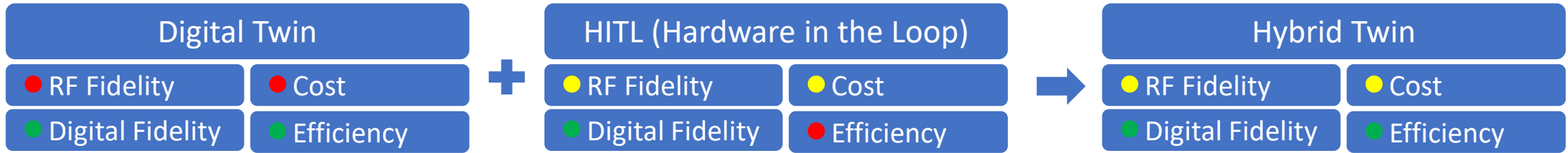| Test Infrastructure	Test Design
• Coverage Space • Data Generation • Continuous T&T	• Unique Quality parameters • New Adversarial Exploits • Trust – assurance case testing

? → Digital Twin

Digital Twin - Virtual representation of a real-world system, synchronized with the physical twin at a specific fidelity and frequency

**Digital Twin addresses Coverage Space, Data Generation, Continuous T&T challenges ...
With limitations - Fidelity vs Cost/Efficiency tradeoff + Complex RF stimulus and receiver interaction**

3

Hybrid Twin – Digital Twin + HITL testbed

Digital Twin		HITL (Hardware in the Loop)		Hybrid Twin	
🔴 RF Fidelity	🔴 Cost	🟡 RF Fidelity	🟡 Cost	🟡 RF Fidelity	🟡 Cost
🟢 Digital Fidelity	🟢 Efficiency	🟢 Digital Fidelity	🔴 Efficiency	🟢 Digital Fidelity	🟢 Efficiency

Hybrid Twin allows selective use of HITL/DT components for T&T:
- **Use HITL where more fidelity required**
- **Use DT where lower fidelity acceptable and efficiency important**
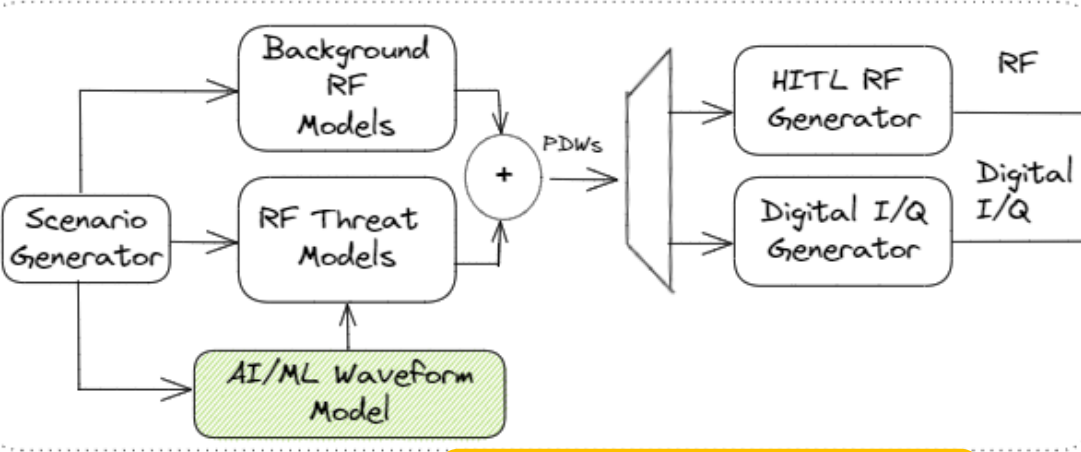
Hybrid Twin – T&T Dataset Generation

RF stimulus adds realism:
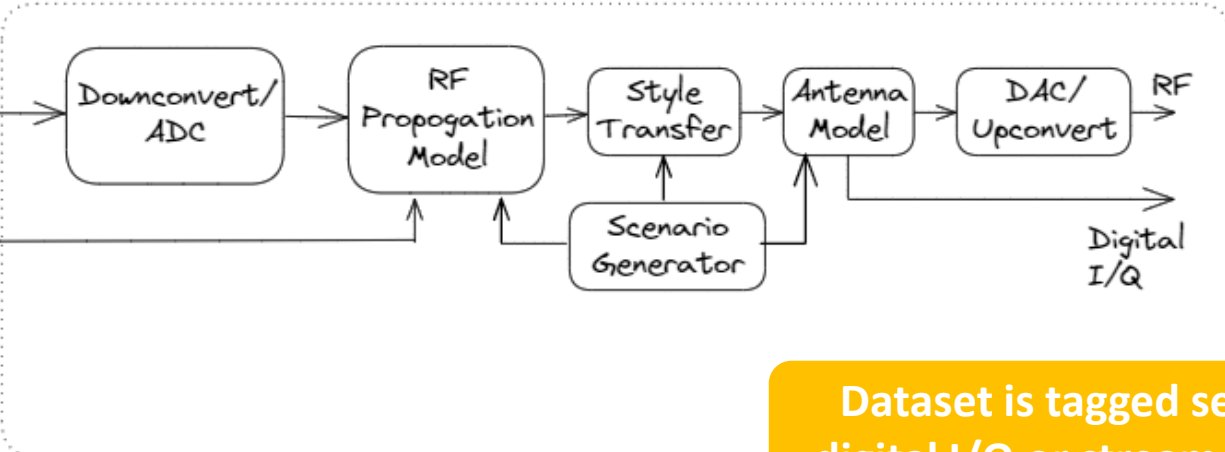HW or synthetic threat-based RF adds to realism
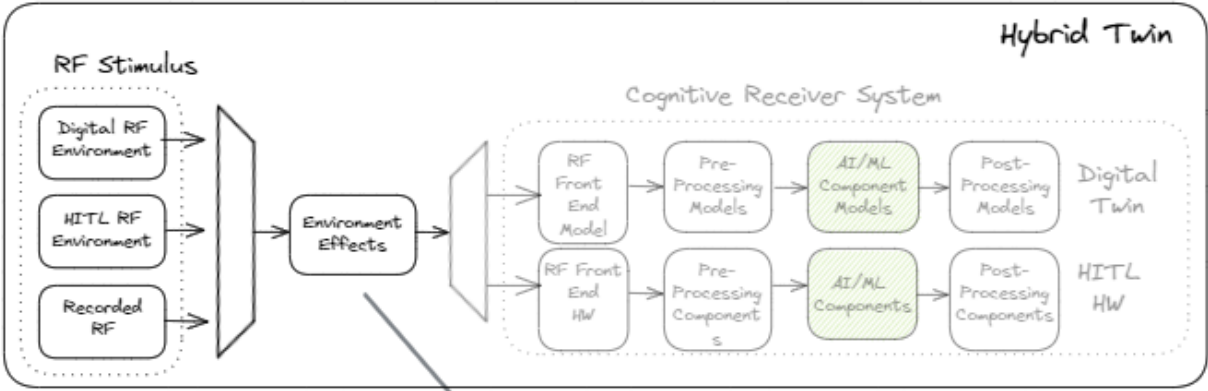
Environmental Effects add realism via dynamic scenario:
- Delay, Gain, Doppler
- Style transfer - other environmental effects
- EW system antenna effects

Dataset is tagged set of digital I/Q or streamed RF
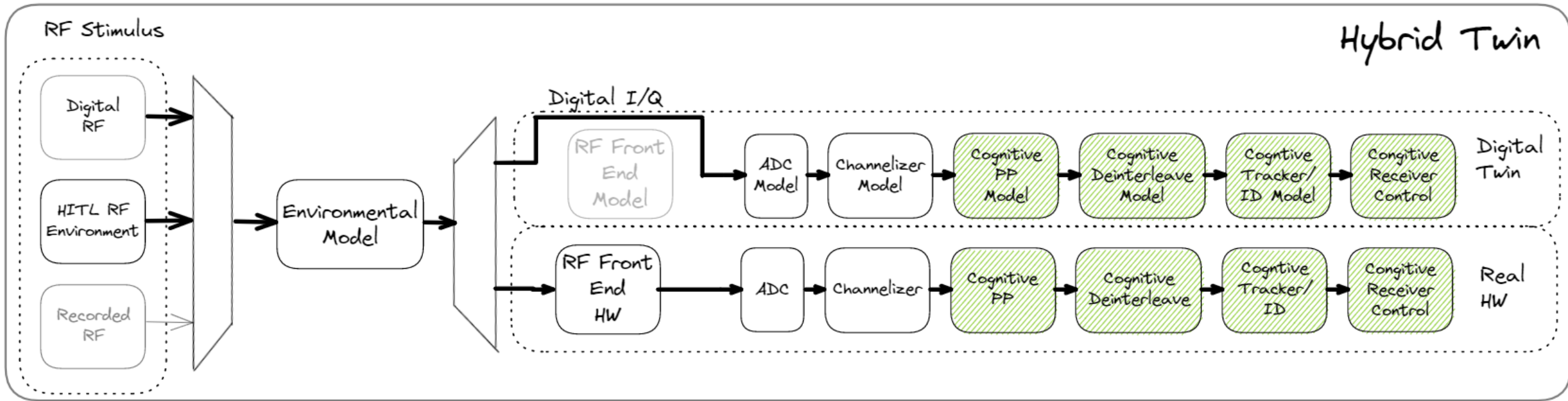
Models need to be developed here ...

Hybrid Twin - Isolated Component Training and Testing

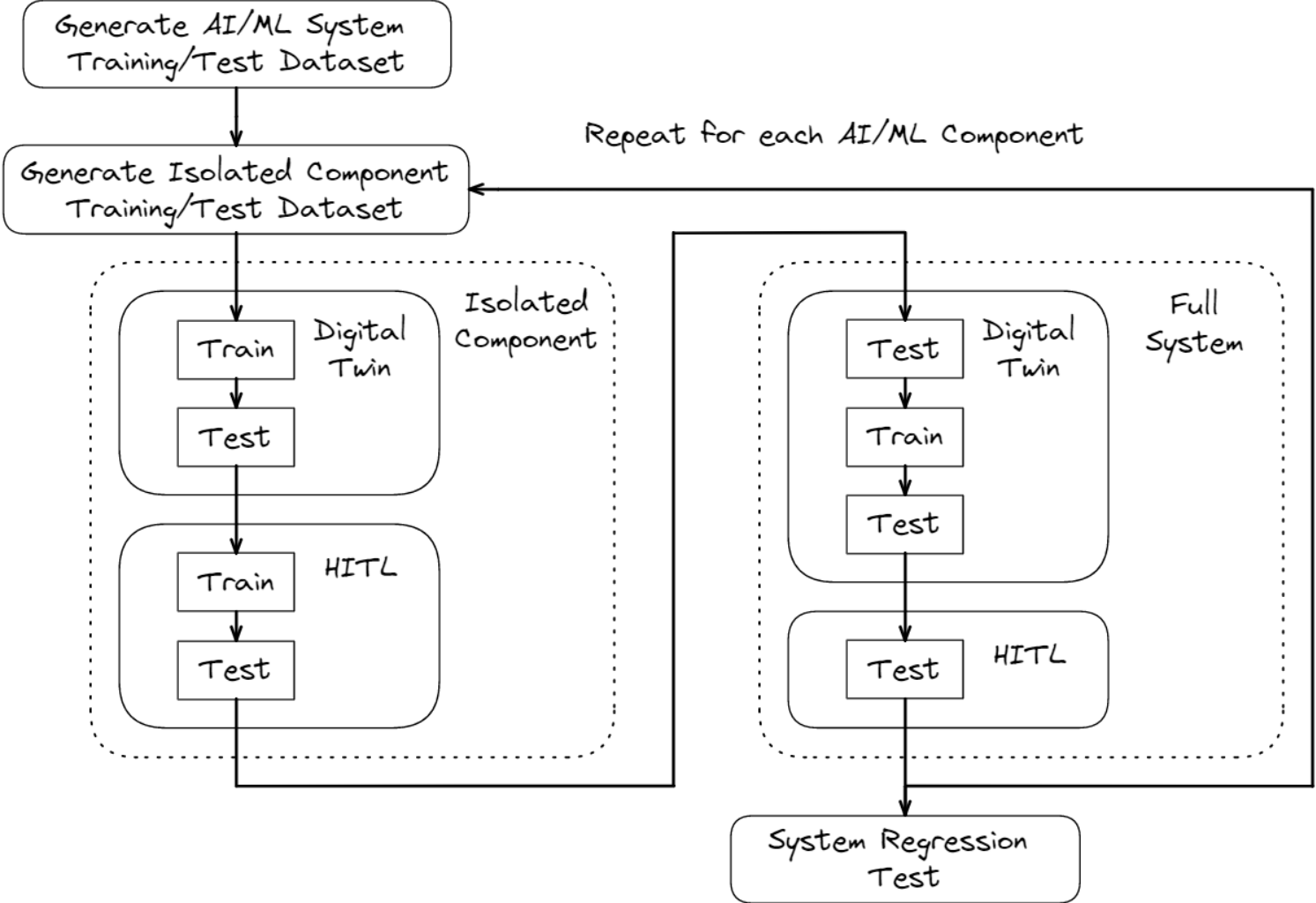**Need ability to directly drive component inputs and observe outputs for early T&T**

Start with DT for initial T&T and refine with HITL

Playback data generated during dataset generation
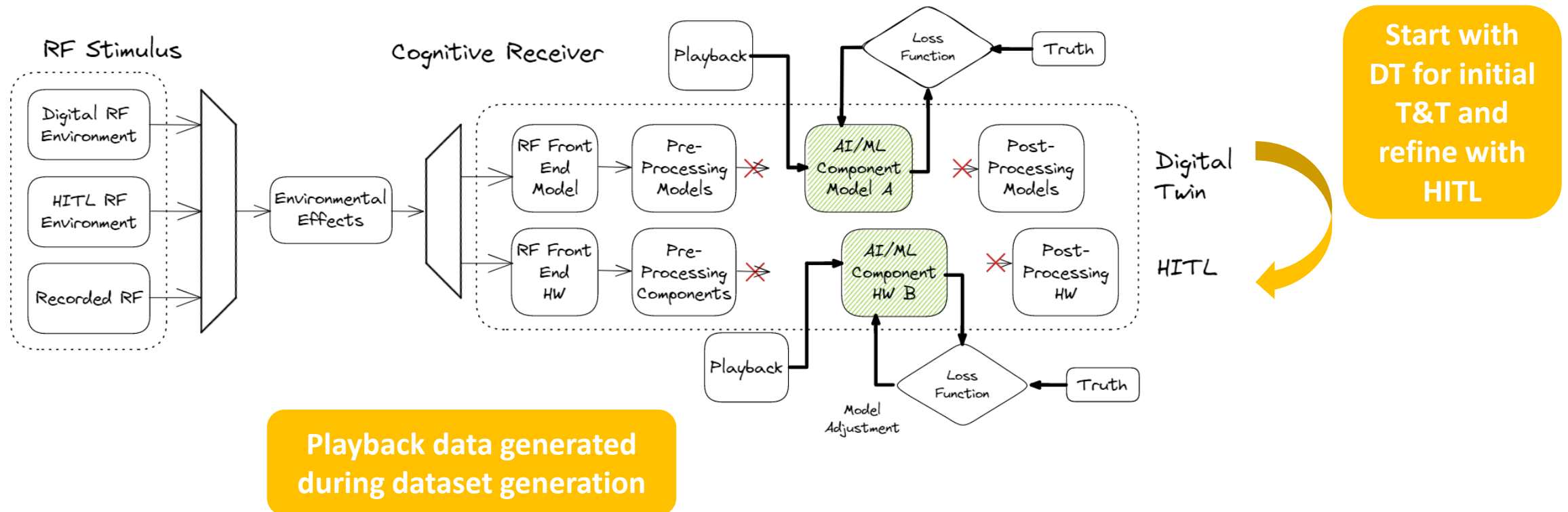
Hybrid Twin - Full System Training and Test

Hybrid Twin - Training and Testing Process

Generate AI/ML System Training/Test Dataset

Generate Isolated Component Training/Test Dataset

Repeat for each AI/ML Component

Isolated Component

Digital Twin
- Train
- Test

HITL
- Train
- Test

Full System

Digital Twin
- Test
- Train
- Test

HITL
- Test

System Regression Test

If process is used in DevSecOps pipeline it addresses continuous T&T challenge
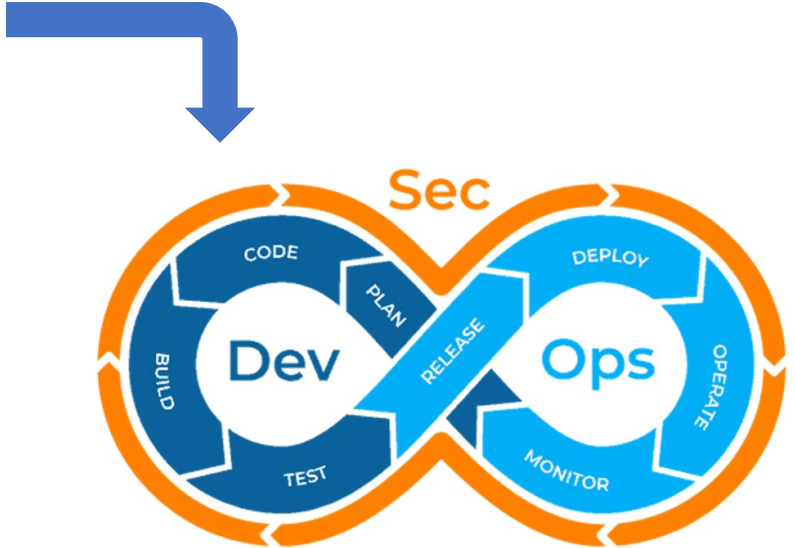
Hybrid Twin - Validation
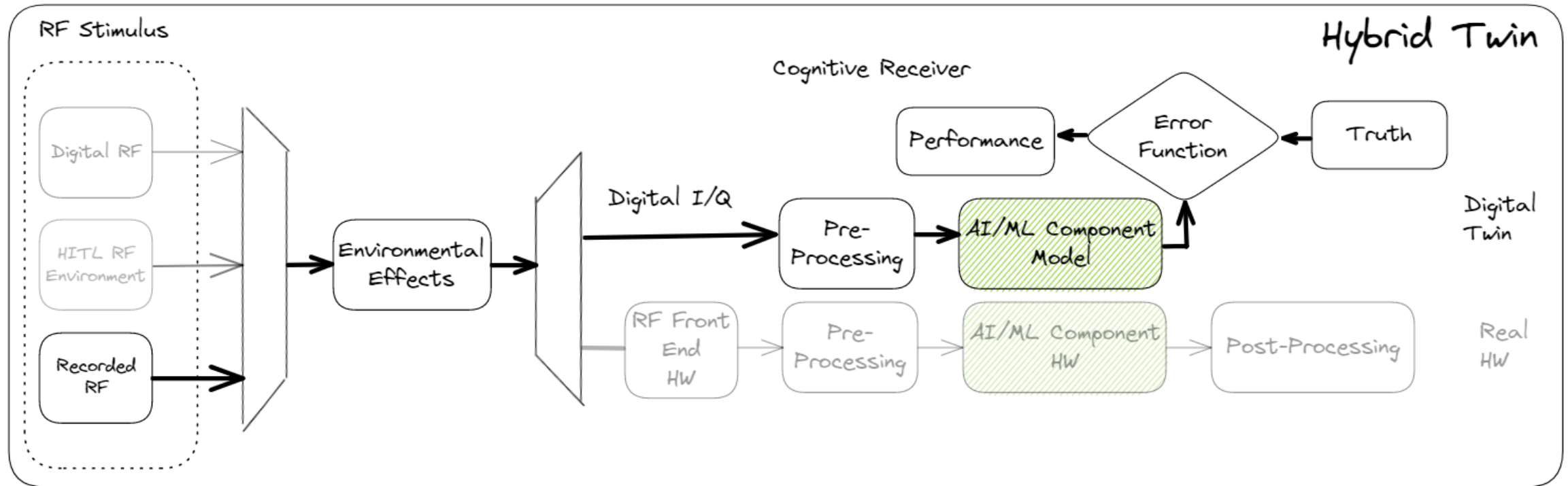
- **Validate with real data from ISTF, Open-air testing**
- **Continuous process over life of system**

9

Hybrid Twin - Implementation Challenges

- **No 'One-size-fits-all'** – solution is EW system specific. More complex systems involving component feedback (EA systems) more challenging.

- **RF stimulus requires significant investment** to achieve realism. Good candidate for community investment due to re-use potential.

- **Efficient DT update process required** – EW system HW/FW/SW will change frequently over life of system – should be part of DevSecOps pipeline.

Determining Feasibility

- Develop detailed reference architecture
- Investigate existing modeling frameworks for suitability
- Investigate availability of COTS components/existing solutions for RF stimulus
- Develop prototypes

Ultimate goal

Re-usable T&T architecture that can be adapted for a variety of Cognitive EW systems

Questions ??