Developing and Validating Defense Physical AI Systems through Agent-Assisted Digital Test Beds

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Short abstract: Defense forces increasingly rely on Physical AI systems capable of operating autonomously within complex and contested operational environments. The development and validation of such systems require the evaluation of communication reliability, sensor performance, mission behavior, environmental conditions, and AI-enabled decision processes across a large spectrum of operational situations. Physical experimentation alone cannot provide the required scale, repeatability, or coverage. This paper presents a Digital Test Bed (DTB) approach designed to support the development, training, testing, and validation of Physical AI systems through mission-level simulation, digital-twins, physics-based models, synthetic data generation, and virtual experimentation. The contribution further explores how AI-agent-assisted workflows can reduce the engineering effort associated with cloud-based infrastructure deployment, scenario preparation, mission variation definition, workflow orchestration, and validation analysis. Finally, the paper discusses scalable and sovereign deployment architectures enabling execution on customer-controlled infrastructures including on-premises and private-cloud environments. The proposed approach aims to accelerate the transition from mission concept to trusted operational evidence for next generation defense AI systems. The Digital Test Bed also enables rapid adaptation of Physical AI systems by accelerating learning from initial missions, supporting virtual retraining and validation, and enabling updated systems to be deployed with confidence in subsequent operations.

Proposed topic areas: Autonomous and Robotic Systems; Multi-Sensor Perception and Fusion; Mission Planning and Optimization; Qualification, Validation and Trustworthy AI; Resilience in Contested Environments.

Identification of Use Cases

Defense Physical AI systems must perceive, reason, communicate, and act in complex operational environments across air, land, maritime, space, and cyber domains. Their value depends on complete mission-system performance, including sensing, communications, platform dynamics, weather, terrain, electromagnetic conditions, adversarial effects, human supervision, and mission objectives.

The target use cases are defense-oriented development and validation workflows before deployment, during operational preparation, and after mission feedback. Examples include assessing autonomy under degraded communications, evaluating multi-sensor perception in harsh environments, testing replanning under contested scenarios, generating synthetic data for rare or hazardous situations, and validating updated AI behaviors before redeployment.

Physical experimentation alone lacks the scale, repeatability, coverage, and agility required for these situations. The Ansys Digital Test Bed, part of Synopsys, addresses this gap by enabling mission-level virtual experimentation and a continuous loop from concept definition to operational evidence, including system design trade-offs, learning from early missions, updated training data, renewed validation evidence, and deployment confidence.

Proposed Technical Approach

The proposed DTB framework supports the development, training, testing, adaptation, and validation of Physical AI systems throughout their lifecycle. Its core technology foundation combines mission-level simulation, digital twins, physics-based sensor and environment models, synthetic data generation, OpenUSD-based scene composition, and SimReady assets to create reusable, interoperable, and physically consistent virtual environments. This enables evaluation of complete mission systems rather than isolated AI components, including sensing, communications, autonomy, decision processes, human oversight, and mission outcomes.

The DTB workflow starts from an operational mission concept and translates it into executable scenarios. OpenUSD provides the shared scene-description backbone for composing environments, platforms, sensors, and mission context, while SimReady assets help accelerate the creation of simulation-ready content with consistent physical properties. Scenario variations then explore nominal, degraded, rare, and edge-case

conditions; results are analyzed to identify behaviors, failure modes, robustness limits, and evidence supporting qualification or operational-readiness decisions.

AI-agent-assisted workflows reduce engineering effort in infrastructure deployment, scenario preparation, mission variation, campaign orchestration, and validation analysis. Agents assist expert users by configuring studies, proposing relevant variations, automating repetitive steps, monitoring execution, and summarizing results, while human oversight remains central for operational judgement and validation authority.

The same environment supports rapid adaptation after operational feedback: mission observations can update scenarios, enrich synthetic datasets, retrain or tune AI-enabled functions, and re-run validation campaigns before subsequent deployment while preserving traceability, reproducibility, and confidence in updated behaviors.

Maturity Level and Deployment Perspectives

The contribution is positioned beyond concept stage: the DTB approach is entering deployment with selected early-adopter customers worldwide, supporting mission-level experimentation, simulation-asset integration, automated validation studies, and evidence generation for advanced AI-enabled systems. The paper will focus on deployment patterns and representative defense-relevant workflows while avoiding sensitive or classified operational details.

For defense adoption, deployment must be scalable and sovereign. The DTB is designed to run on customer-controlled infrastructure, including on-premises and private-cloud environments, so organizations can protect sensitive mission data, models, scenarios, and experimentation assets while benefiting from scalable execution and AI-assisted engineering workflows.

Expected Defense Benefits

The expected benefit is faster transition from mission concept to trusted operational evidence. By combining scalable virtual experimentation, OpenUSD interoperability, SimReady content, physics-based models, and AI-agent-assisted workflows, the DTB improves operational coverage, exposes failure modes earlier, reduces dependence on costly physical trials, and strengthens reproducibility and traceability for deployment in complex and contested environments.