Simulation Interoperability Standards Organization

"Simulation Interoperability & Reuse through Standards"

Simulation of Autonomous Systems: From Digital Twins to the Future Battlespace

SIM-2026-Presentation-017

Andy Fawkes, Thinke Company, United Kingdom

Stefan Sandberg, Remograph, Sweden

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Simulation of Autonomous Systems: From Digital Twins to the Future Battlespace

The Rise of the Machines… and their Digital Twins

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Andy Fawkes, Thinke Company, United Kingdom

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Outline

- Digital Twin Basics
- Comparing Humans and Machines
- The Rise of the Machine and its Simulation
- A Digital Twin Case Study - Västervik Drone Science Park
- Simulation Standards Challenges
- Looking Back to Look Forward

What is a Digital Twin?

"A Digital Twin is a Virtual Representation of a Connected Physical Asset"

(AIAA and adopted by NMSG MSG-205)

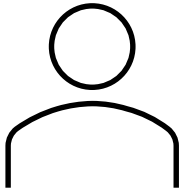
- Persistent
- Dynamic
- With the physical asset and/or remote
- AI might be considered their brain

References:

- **Digital Twin: Definition & Value – An AIAA and AIA Position Paper 2020 (American Institute of Aeronautics and Astronautics)**
- **Skinner & Pena Regueiro, STO-MP-AVT-369-29, NATO STO/MSG-205;**
- **Maglione et al., STO-MP-MSG-207-20, NATO STO/CMRE, 2023**

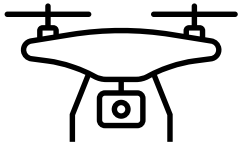
Humans & Machines

- As a human you are either in the real world, or in a virtual simulation. We also have skill fade and forget, and we exist in real time.



- A machine with a persistent digital twin can be in both, simultaneously, continuously comparing notes with itself, learning, reacting to its environment, and it remembers everything.

- A machine can train 24/7 in a simulation, faster than real time, across many parallel scenarios at once.



- And unlike a human training pipeline, this is not learn once then deploy once, it's a loop, real data constantly retesting the digital twin.

What This Means Now

- **Strategic shifts:**
  - **Control is shifting human → machine**
  - **Simulation shifting episodic → persistent**

- **Together a "battlespace digital twin" simulation is not only an episodic training aid, but always-on developmental and operational infrastructure**

- ***Have our simulation standards been tailored to episodic events with humans in the loop, whilst we are now moving towards persistent simulations with machines (and humans) in the loop?***

Why Should this Matter?

- Machines are Transforming Warfare
- Machines Are Multiplying
- Machines Are Rapidly Evolving
- Humans are Organising around Machines
- A Complex and Evolving World of Sim/C2/Non-Defence Standards
- Simulation as a Competitive Advantage

Machines Are Transforming Warfare

REPORT OF USF GROUPING

12:18:47 Thu 03.09.2026 | September | Since USF creation (11.06.2025 - now)

511 807	191 570	1 261 595	1 115 555	132 460	68 644	63 816
targets hit	incl. destroyed	strike missions	recon missions	enemy personnel	incl. killed	incl. wounded

	hit	incl. destroyed
Enemy personnel	132 463	68 649
Drone launch positions	16 332	492
Antennas	26 430	15 524
SAMs, SPADs PPOpad	201	33
Aircraft and helicopters	18	3
Vessels MoLoCHKa	283	0
Power hubs Crimea switch off	362	1
Radars, ELINT, comms (systems) PPOpad	117	13
EW (system) PPOpad	33	8
EW and Radars (mounted & portable)	5 518	2 229
Enemy fixed-wing UAVs	55 718	54 003
Shaheds and Gerberas	9 941	9 543
Tanks	940	161
AFVs (APCs, IFVs)	1 599	367

	hit	incl. destroyed
Guns, howitzers	5 978	433
Self-propelled artillery	411	54
Mortars	440	108
MLRS	328	83
Logistics, Engr. & special vehicles, refuelers etc.	27 548	6 076
Motorcycles and military buggies	14 251	4 365
Ammo, fuel and equipment depots	5 366	3 042
Strategic infrastructure	TOP SECRET	TOP SECRET
Tactical infrastructure	691	47
Shelters and dugouts	176 083	6 247
Network equipment and cameras	4 702	1 856
Enemy multirotor drones	16 198	15 186
Enemy UGVs	1 037	347
Other	8 423	2 695

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Ukraine Unmanned Systems Forces (as Sep 3rd)



August 2026 (Russian MoD via X)
Ukraine drone deployed an UGV with an anti-tank mine behind enemy lines

The Economics of Warfare

UAE's defence against Iran's 28 Feb barrage:

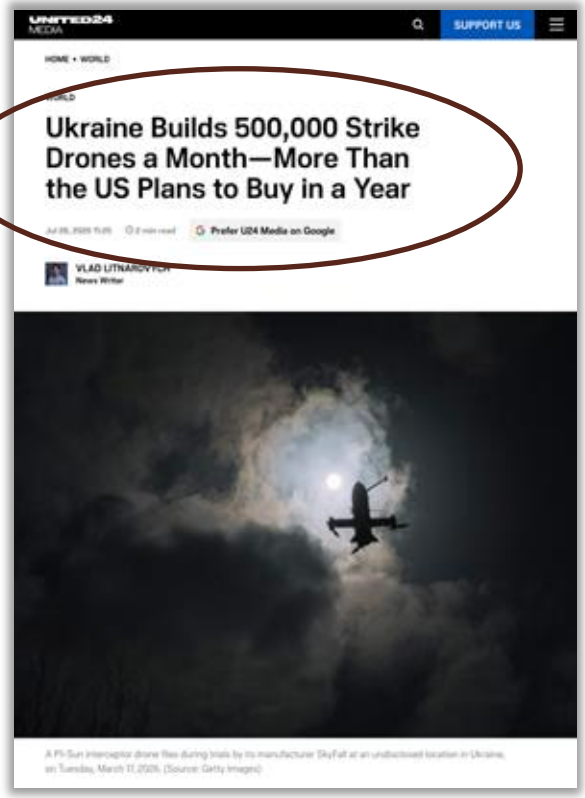
- **Iran fired 165 ballistic missiles, 2 cruise missiles, 541 Shahed drones**
- **UAE intercepted 92%+**
- **For every $1 Iran spent on uncrewed, the UAE spent ~$20-28 shooting them down**
- **PAC-3 Patriot missiles take around 2 years to manufacture, Shaheds do not**



March 27, 2026 - USAF E-3 Sentry ~$500m

Source - Kelly Grieco, Senior Fellow, Stimson Center (US Non-partisan)

Machines Are Multiplying



Also reported by Reuters July 2026

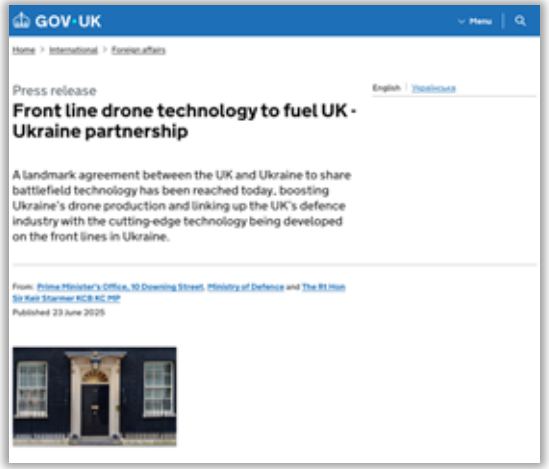


Collaborative Combat Aircraft, aka Loyal Wingman

> 500 USAF CCA in service by 2032 (Sep 14th)

Machines Are Rapidly Evolving

- Iteration in weeks, not years
- Previously expensive tech going cheap, eg:
  - fibre-optic guidance was tried and abandoned in 1990s for an anti-tank weapon, now costs $50-100 for a $400 drone
  - terrain-matching guidance, once exclusive to cruise missiles, is a similar story
- It is not all "AI", it is rapid agile engineering and COTS exploitation



No 10 Downing Street, 2025

‘drone technology evolving, on average, every 6 weeks’

Swarms are Coming

- Human Remote control
- Cameras
- + $3,500 MESH Modem Relays forming a chain
- + AI for some targeting

- **Interception rate 90% ↓ 60%**
- **Russia making 3,000/month ↑**

August 2026



Sources includes - www.rferl.org/a/russia-ukraine-jet-powered-drones-shahed-geran/33841747.html

Humans are Organising Around Machines



- Unmanned Systems Forces of Ukraine
- Est. 11 June 2024
- Size 40,000 – 80,000



- General Denis Lyamin
- New Head of Russian Unmanned Systems Forces
- Est. August 2026

en.wikipedia.org/wiki/Unmanned_Systems_Forces_of_Ukraine

Humans are Organising Around Machines







Ukraine Independence Day
24 August 2026

Credit - Ukrainian President's Office

A Complex and Evolving World of Standards

Standards for how uncrewed systems connect to real command and control (not simulation standards). Each domain seems to be building a rulebook:

- Air: STANAG 4586, UCI, OMS (UCI & OMS also cover manned aircraft, not uncrewed only)
- Land: Army IOP, built on JAUS, the Joint Architecture for Unmanned Systems
- Maritime: STANAG 4817, known as CATL, the Collaborative Autonomy Tasking Layer

None of these appear to automatically and easily connect to C2SIM/simulation environment

NATO's own maritime research centre had to create bespoke bridge between HLA and CATL, as no standard worked for them

Maglione, G.L. et al., "Digital Twin: a bridge between simulation and real world in the Maritime Environment," STO-MP-MSG-207-20, NATO STO/CMRE, 2023

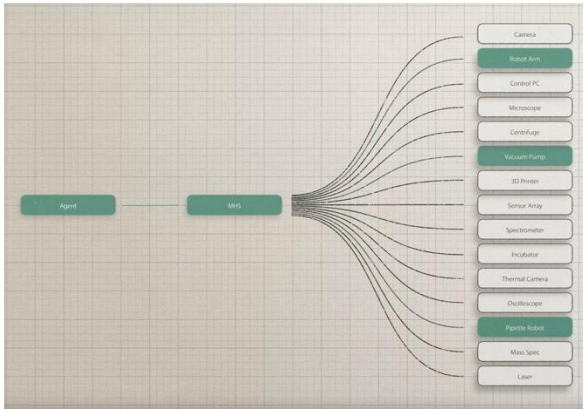
DELTA: Ukraine may solve multi-domain interoperability but built outside standards bodies

(COTS) Software-Defined Warfare is Coming?

- **27 August 2026: Anthropic released the Model Hardware Standard (MHS), a universal protocol (like MCP) letting AI agents read and write commands to physical hardware plus a device's limits safety file (*not defence for now*)**

- **MHS, or something like it, applied to a battlespace:**
  - Mismatched hardware from different manufacturers commanded as one, plug-and-play swarms
  - Ad-hoc, disposable, even 3D-printed hardware flown immediately, no custom code

- **Whoever builds the defence-grade version of MHS might become the connective wiring of the future battlespace**

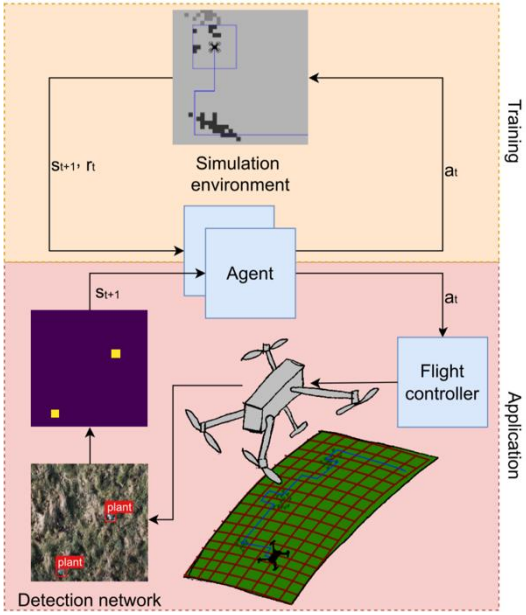


Agent MHS Physical Entities

Simulation as a Competitive Advantage

- Shield AI: part of $2B 2026 raise to acquire Aechelon (simulation)
- Anduril: acquired ExoAnalytic (M&S, space domain)
- Helsing: vertically integrating air/sea/space, bought Grob Aircraft
- Potential Consequence: every vendor validating in its own closed sim, means no shared way to know systems work together in coalition ops

- Counter-example: Auterion's Skynode, an open, vendor-agnostic autopilot and mission-control stack designed to work across different drone manufacturers



arXiv:2505.09278v2

Case Study







Västervik Drone Science Park, VDSP

- One of Europe's largest civilian UAS testbeds.
- Strategic location and role in European defense and commercial innovation.

VDSP – Physical Test Environment

Placed around Västervik Airport (ESSW)

Founded in 2024 for civilian use, now 50% military 1800 square km R-areas, Nordic terrain with forests, archipelagos and open sea

Critical infrastructure like power lines, railways and windmills for automated inspections and specialized missions

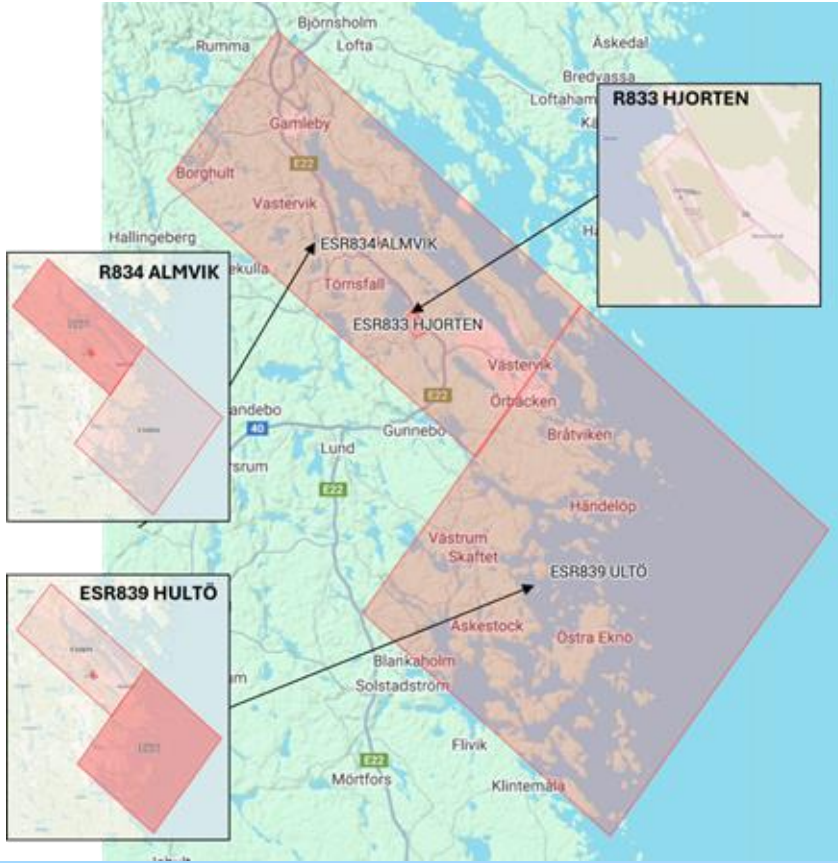
Multi domain

Air, Land Sea, UxV

Collaboration

Academia, Industry, Government

Defense and Civilian applications



VDSP - Synthetic Test Environment, Digital Twin

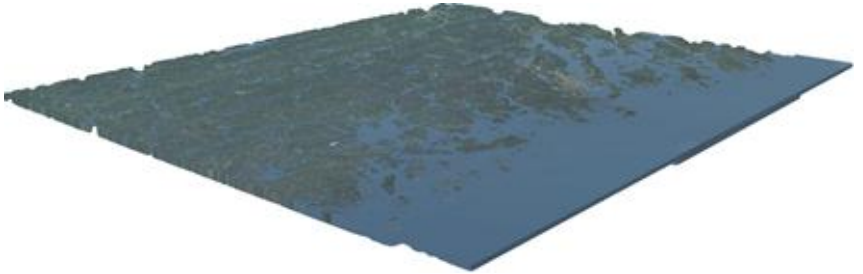
Mapping of a real-world environment into a high fidelity 3D Digital model

2600 km²

Automatically generated from geospatial data

High-resolution drone captured insets

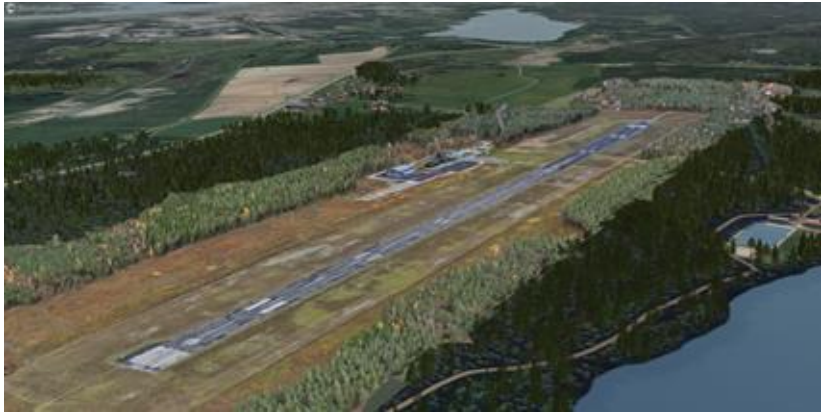
Available through a standard web browser



Integration of Real-World Data

Feeding live sensor and operational telemetry into the digital twin.

Closing the feedback loop: Virtual simulation - Physical deployment - Model refinement



VDSP – Digital Twin

Improved Development & Validation

Validation of autonomous behaviors in a persistent virtual environment, accelerating the development cycle

Training of AI models

Introducing simulated effects such as EW and air traffic in the real world

Improved Operator Proficiency

Provides a bridge between human cognitive bandwidth and machine speed by training drone operators in scenarios they may not have encountered in traditional flight training

Risk Mitigation

Allows for the testing of drone swarms and complex maneuvers in a risk-free digital environment before physical hardware is even ready for field testing



Mega Trends

Proliferation of Rapidly Evolving Uncrewed Machines

More Autonomous and Cooperating Machines

Episodic to Continuous Development and Deployment

Simulation Essential in Support of Uncrewed Machines

Complex Evolving Uncrewed Machine Standards

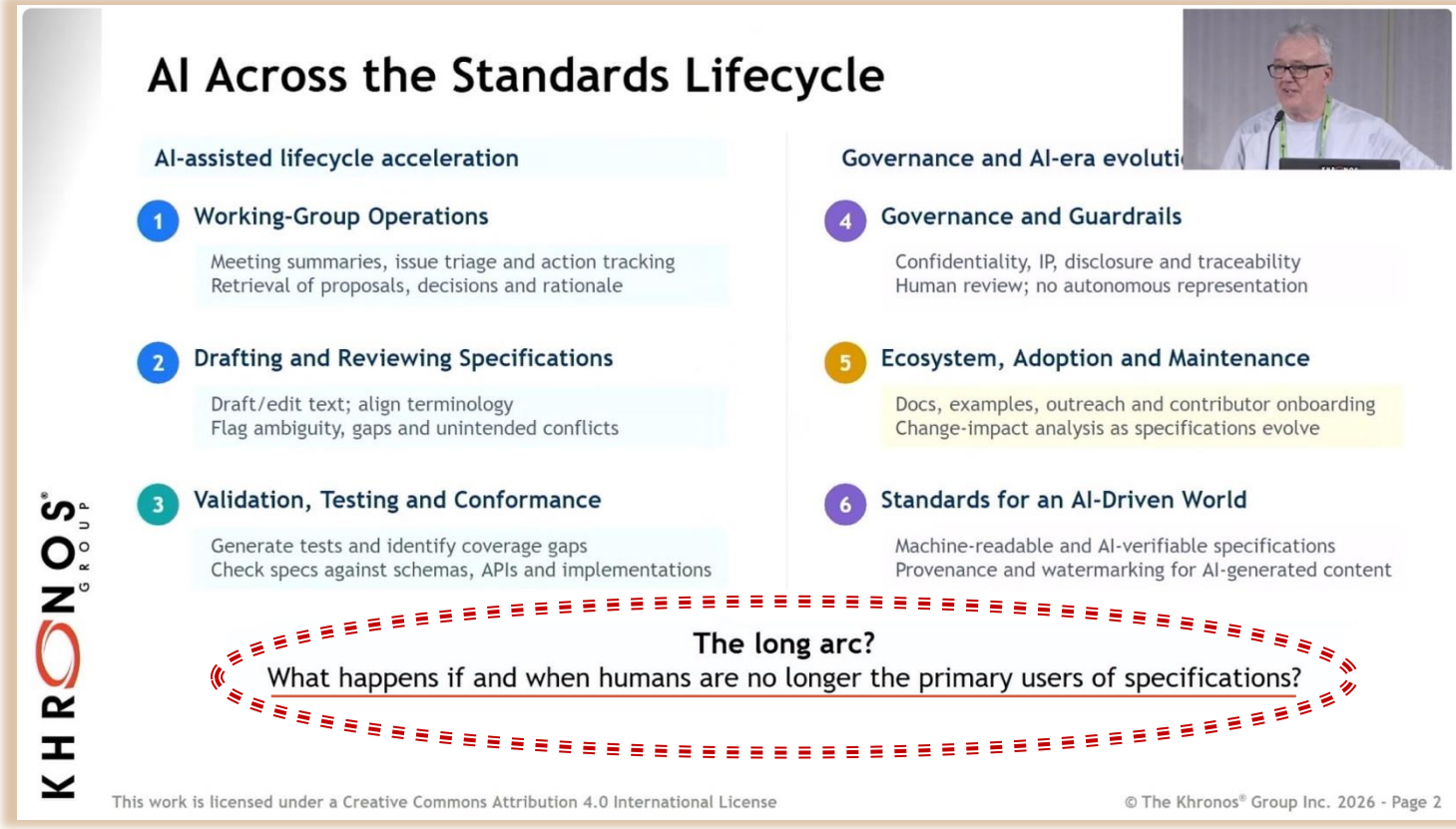
What About Simulation Standards?

- **C2SIM sits on a critical boundary**

- **The Cross Border Challenge - "I'm a Portuguese drone manufacturer. I want to know my system works within German doctrine. How do I convince the Germans?"**
- **Not one simulation? Not many disconnected unique ones?**
  Many sovereign sims, validated against one shared baseline?

- **Three ways forward for standards/SISO:**
  - **Adopt** (eg. OpenXR, 3D content already addressed outside defence)
  - **Extend** (eg. HLA for persistence)
  - **Bridge** (eg. C2SIM gateways to operational C2)

Looking to Other Standards Bodies for Inspiration



SIGGRAPH 2026
August 4th

AI Powered Standards

https://youtu.be/Zd0Rk_u2_qc?si=wvOaikJ0oy-u5bgw

Khronos Group creates and maintains open standards such as glTF, OpenXR, and OpenGL

Looking Back to Look Forward

USAF Capt Jack Thorpe's White Paper (1978)



1
Enemy aggression detected by overhead sensor



2
Planning a response using the holographic electronic sand table



3
Air crews rehearse the plan and planners assess suitability

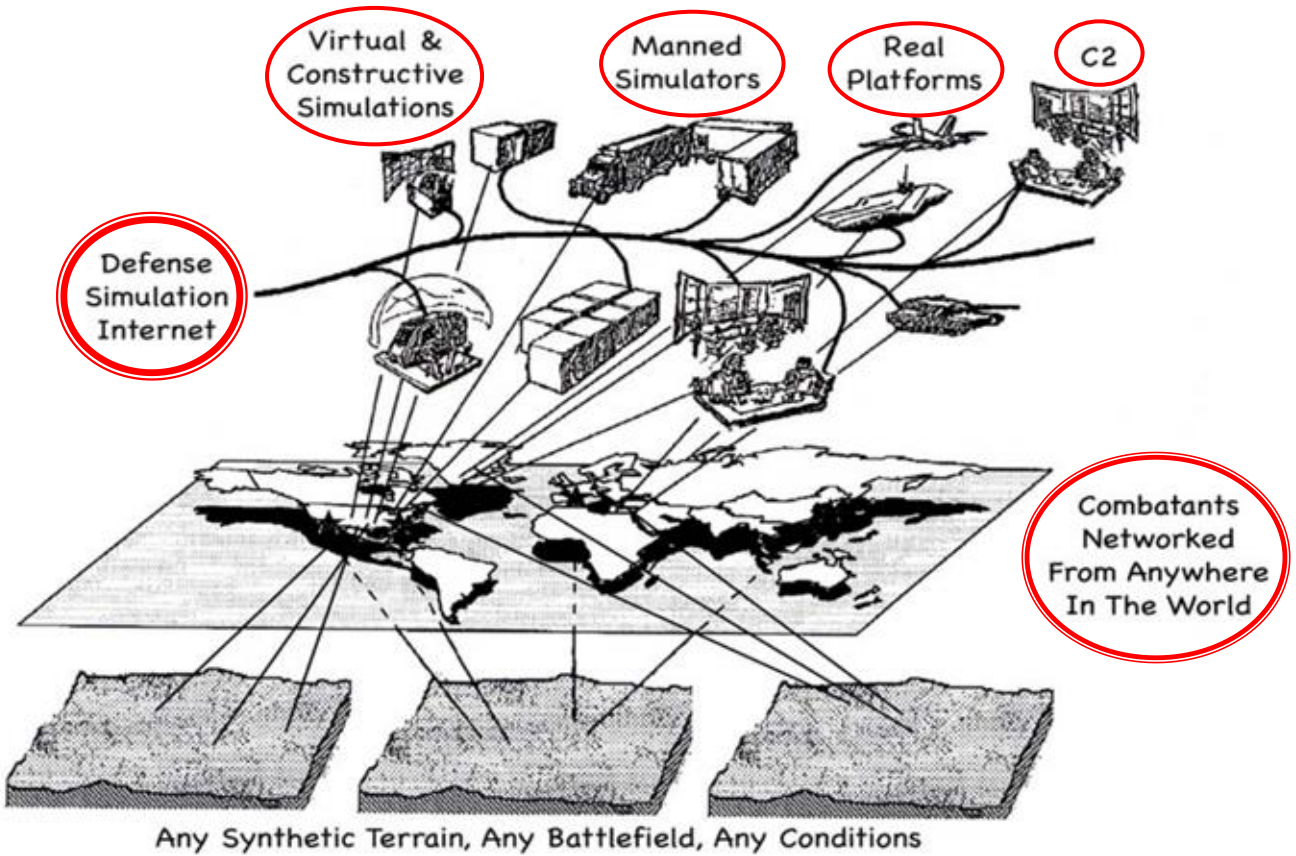


4
Mission execution with real time observation

Tight Integrated ISTAR-Planning-Training-Operational Loop ⟶ For Humans

Ref. I/ITSEC 2010 "Trends in Modelling, Simulation and Gaming: Personal observations about the past 30 years and speculating about the next 10" Jack Thorpe PhD & SIMNET: An Insider's Perspective: Neale Cosby - March 1995

Thorpe's SIMNET Distributed Simulation Vision (early 1990s)



Ref. I/ITSEC 2010 "Trends in Modelling, Simulation and Gaming: Personal observations about the past 30 years and speculating about the next 10" Jack Thorpe PhD

Going Back to SIMNET

SIMNET, 1980s - DARPA/US Army 1983-1990

260 simulators across 11 sites showed what's possible connecting human training simulators together



SIMNET simulators at Fort Knox, KY.
(www.jimmillar.net/BBN.html)

Direct foundation for our lineage: SIMNET → DIS (IEEE 1278) → HLA

Key question:

do we now need a SIMNET of the 2020s, one that connects uncrewed and crewed system simulators ?

Something to Think About?

SIMNET 2020s

a modernised ”SIMNET" to serve as a collaborative testbed where AI agents, humans, crewed and uncrewed platforms can be developed, tested, prepared for operations, and learn from them, within a connected, multi-domain battlespace digital twin simulation infrastructure

Ender’s Foundry?

Something to Think About?

SIMNET 2020s

a modernized ”SIMNET" to serve as a collaborative testbed where AI agents, humans, crewed and uncrewed platforms can be developed, tested and prepared for operations within a connected, multi-domain battlespace simulation infrastructure

What War(s) Are We Preparing For, And What Simulation And Standards Do We Need?



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QUESTIONS

Abstract

The rise of uncrewed systems has fundamentally transformed modern warfare, shifting the focus from manpower-heavy operations to software-driven production challenges. In the future battlespace, military success will be defined by the speed of AI-enabled decision-making and the seamless integration of autonomous platforms. Consequently, simulation has evolved from a traditional training tool into a continuous feedback loop where autonomous systems are forged, tested, and retrained using real-world operational data before they ever enter the physical world. This presentation explores the Västervik Drone Science Park (VDSP) in Sweden as a primary use case for this convergence. As one of Europe's largest civilian UAS testbeds, VDSP provides a 1,800 km^2 geo-zone featuring diverse Nordic terrains, including forests, archipelagos, and open sea. To maximize the utility of this facility, a high-fidelity digital twin of the Västervik drone center and its surrounding areas has been developed.

This digital twin serves as a persistent virtual environment designed to support the development, test, and evaluation (DT&E) of autonomous drones and swarms. By "simulating before building, " engineers can validate complex autonomous behaviors and software-defined capabilities in a risk-free digital space. Furthermore, the digital twin is utilized to train drone operators, bridging the critical gap between human cognitive bandwidth and the accelerating speed of autonomous systems. This integrated approach demonstrates how digital environments are now essential for certifying both the machines and the professionals who operate them in the future battlespace.