

XR Data

Andy Fawkes | Reality Reimagined Expo 2025
Battlelab, Dorset | 26 June 2025

Outline

- **Context**
- **XR Data Framework**
- **XR Standards**
- **XR Security**
- **Looking Forward**

My XR Journey ...



201
9



XR Data Framework

Final Report

Prepared for: ACE C050.6 HORIZON SCANNING

Date: 30 November 2022

Authors: Andy Fawkes; Chris White; Nick Cheshire

Contact Details: andy.fawkes@vedetteconsulting.com

2022



SERAPIS SSE52 DELTA Call Off Task
WP3.2d
XR Standards & Security Report



Document Reference: QTSL-820-2569
Issue 1.2
04 December 2023

2023



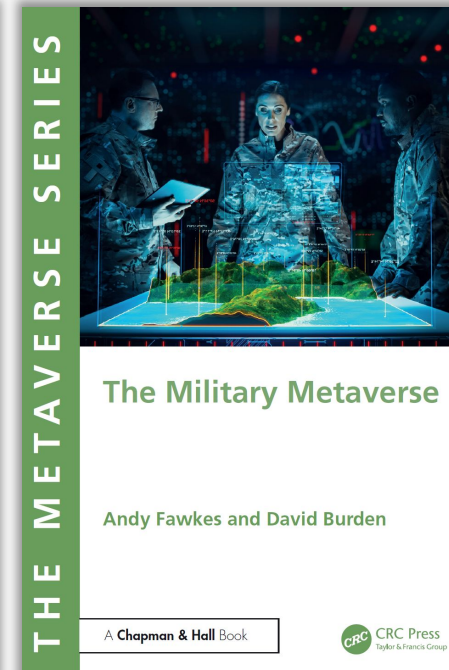
NORTH ATLANTIC TREATY ORGANIZATION

SCIENCE & TECHNOLOGY ORGANIZATION

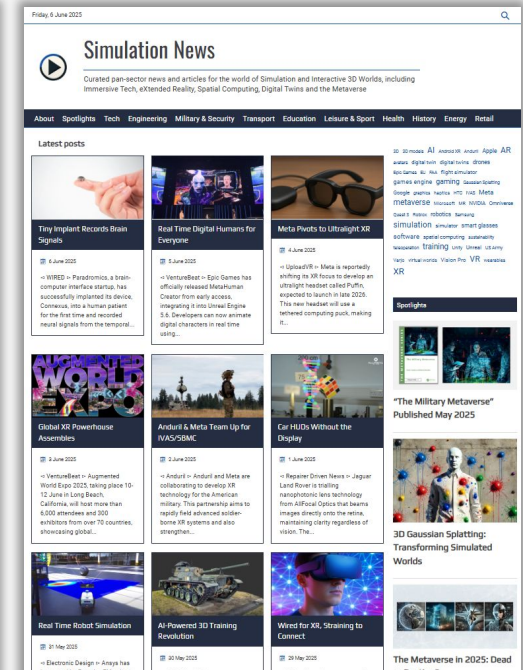
TECHNICAL ACTIVITY PROPOSAL

Panel/Group	MSG	Activity Title	
Reference Number	MSG-234	Training Data Analytics and Standards	
Activity Type	Research Task Group		
Panel Approval Date 22 Oct 2024	Board Approval Date	Activity Start Date 02 Dec 2024	Activity End Date 02 Dec 2027
Related Activity		MSG-ET-056	
Projected Meeting Location(s)		London, United Kingdom	
Lead Nation(s)		United Kingdom	
Team Leader(s)		Mr Andy FAWKES (United Kingdom) Mr Martyn HARVEY (United Kingdom)	
Panel/Group Mentor		LLOYD, Jonathan (Mr)	
NATO Nations/Orgs Invited to Participate		NATO Bodies	
Non-NATO Nations/Orgs Invited to Participate		PIP GP	
Nations/Orgs Committed to Participate		Germany, The Netherlands, United Kingdom, United States	
Security Classification Level or Marking of the Activity		Releasable to the Public	
Keywords		AI, Analytics, Data Standards, Feedback, Interoperability, Performance, Simulation, Training	
NATO and National Resources Required			

2025 ...



2025



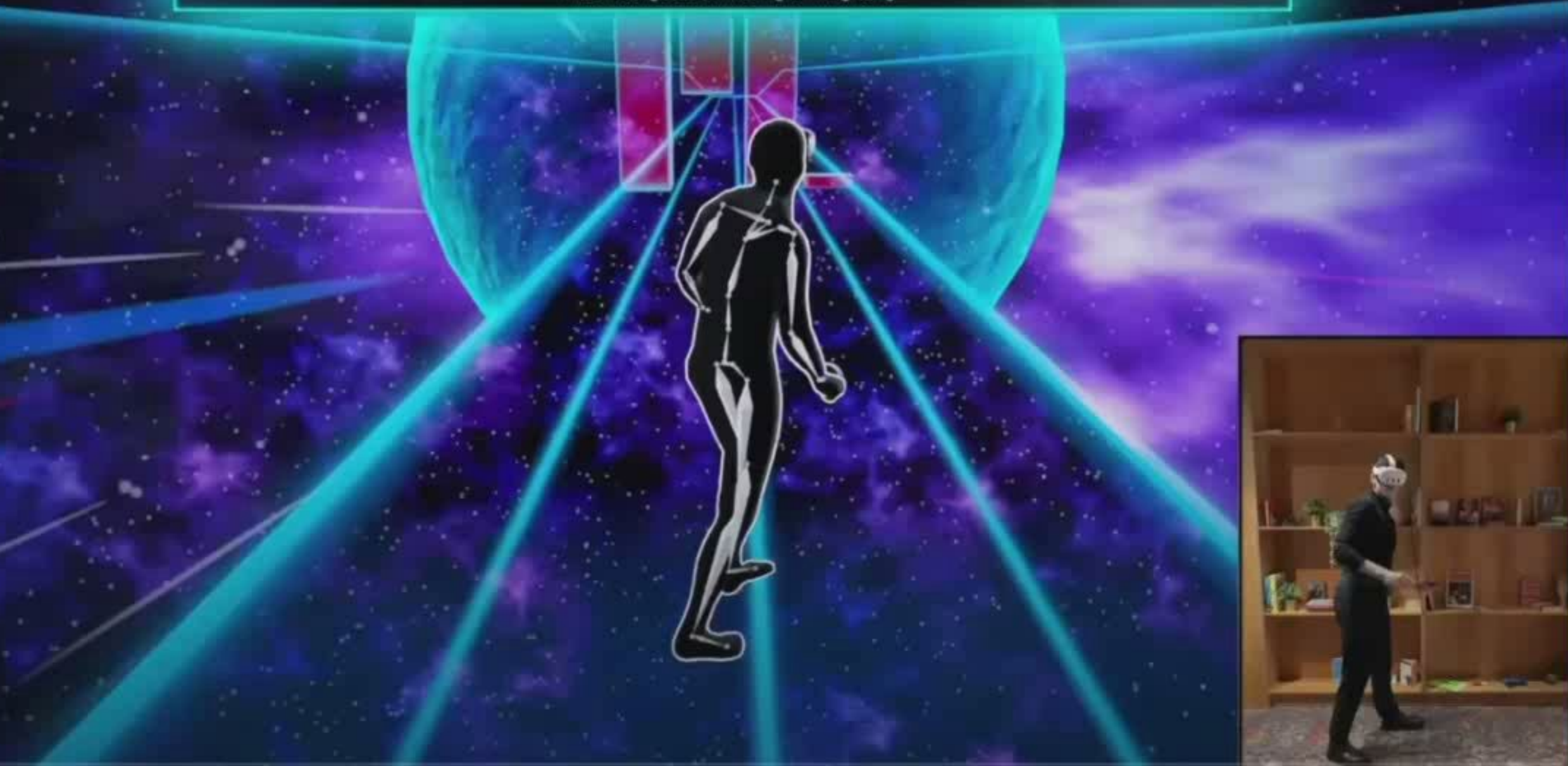
2025 ...

THINK



CATEGORICAL CODEBOOK MATCHING FOR EMBODIED CHARACTER CONTROLLERS

Sebastian Starke¹, Paul Starke¹, Nicky He¹, Taku Komura², Yuling Ye¹
Meta Reality Labs¹, University of Hong Kong²



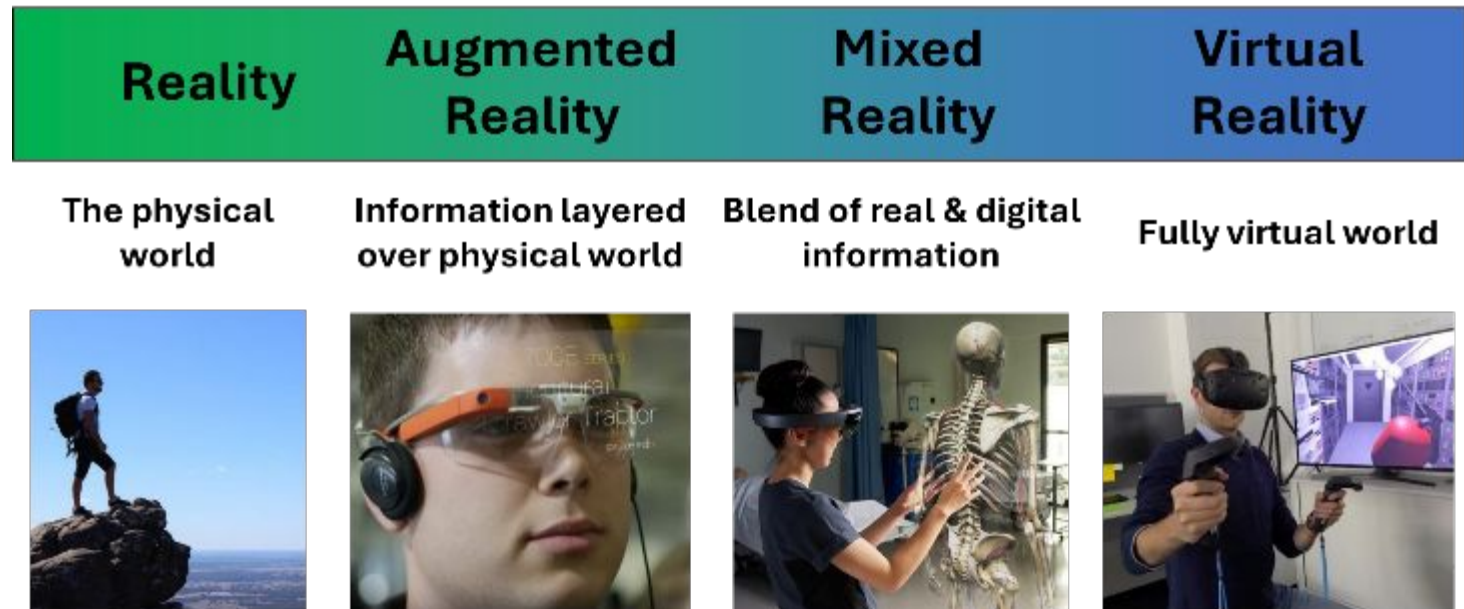


THINKE



XR Data Framework

XR and Simulation are (Prolific) Data Generators!



Inferred Data

Exploring the Unprecedented Privacy Risks of the Metaverse

Vivek Nair*
UC Berkeley
vcn@berkeley.edu

Gonzalo Munilla Garrido*
Technical University of Munich
gonzalo.munilla-garrido@tum.de

Dawn Song
UC Berkeley
dawnsong@berkeley.edu

Abstract—Thirty study participants playtested an innocent-looking “escape room” game in virtual reality (VR). Behind the scenes, an adversarial program had accurately inferred over 25 personal data attributes, from anthropometrics like height and wingspan to demographics like age and gender, within just a few minutes of gameplay. As notoriously data-hungry companies become increasingly involved in VR development, this experimental

possible pernicious intrusions into users’ most private activities [15]. Overall, the tendency is clear: each new technology has gradually expanded the scope of data attributes accessible to would-be attackers.

Virtual reality (VR) is well positioned to become a natural continuation of this trend. While VR devices have been around



Fig. 4: Estimating handedness from behavior.

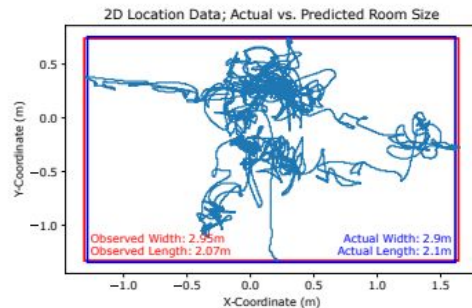


Fig. 8: Estimating room size from geospatial telemetry.

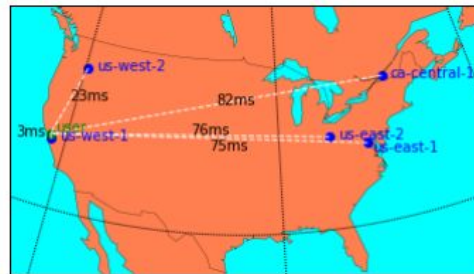


Fig. 9: Estimating user location from network latency.

Attribute	Type / Source	Precision	Accuracy	Attackers
Height	Primary Telemetry	1 cm	70% within 5 cm 100% within 7 cm	Privileged I-III Non-Privileged*
Longer Arm	Primary Telemetry	boolean	64% for ≥ 1 difference 100% for ≥ 3 cm difference	Privileged I-III Non-Privileged*
Interpupillary Distance	Primary Telemetry	0.1 mm	96% within 0.5 mm (Vive Pro 2) 87% within 0.5 mm (All Devices)	Privileged I-II
Wingspan	Secondary Telemetry	1 cm	86% within 7 cm 100% within 12 cm	Privileged I-III Non-Privileged*
Room Size	Secondary Telemetry	1 m ²	78% within 2 m ² 97% within 3 m ²	Privileged I-III Non-Privileged*
Geolocation	Primary Network	100 km	50% within 400 km 90% within 500 km	Privileged II-III
HMD Refresh Rate	Primary Device	1 Hz	100% within 3 Hz (Privileged Attacker) 81% within 60 Hz (Unprivileged Attacker)	Privileged I-II Privileged III* Non-Privileged*
Controller Tracking Rate	Primary Device	1 Hz	100% within 2.5 Hz	Privileged I-II Privileged III* Non-Privileged*
Device Resolution (MP)	Primary Device	0.1 MP	100% within 0.1 MP	Privileged I-II
Device FOV	Primary Device	10°	100% within 10°	Privileged I-II Privileged III* Non-Privileged*
Computational Power	Primary Device	0.1 GHz 10 Mh/s	CPU: 100% within 0.4 GHz GPU: 100% within 20 Mh/s	Privileged I-II
VR Device	Secondary Device	N/A	100%	Privileged I-III Non-Privileged*
Handedness	Primary Behavior	boolean	97% [†]	Privileged I-III Non-Privileged
Eyesight	Primary Behavior	boolean	70% (Hyperopia) 81% (Myopia)	Privileged I-III Non-Privileged
Color Blindness	Primary Behavior	boolean	100%	Privileged I-III Non-Privileged
Languages	Primary Behavior	boolean	88%	Privileged I-III Non-Privileged
Physical Fitness	Primary Behavior	boolean	90%	Privileged I-III Non-Privileged
Reaction Time	Primary Behavior	17 ms	88%	Privileged I-II Privileged III* Non-Privileged*
Acuity (MoCA)	Primary Behavior	1 point	81% within 1 point 90% within 2 points 100% diagnostic accuracy	Privileged I-III Non-Privileged
Gender	Inferred Classification	boolean	100%	Privileged I-III Non-Privileged
Age	Inferred Regression	1 yr	100% within 1 yr	Privileged I-III Non-Privileged
Ethnicity	Inferred Classification	categorical	100%	Privileged I-III Non-Privileged
Income	Inferred Regression	\$1k	100% within \$25k	Privileged I-III Non-Privileged
Disability Status [‡]	Inferred Classification	boolean	100%	Privileged I-III Non-Privileged

XR Data Framework

Principal XR Interface

Smart-glasses

Smart Contact Lens

Augmented Reality HMD

Mixed Reality HMD

Virtual Reality HMD

Neuro Reality

XR Interactivity Enablers

Handheld Devices

Limb-Worn Devices

Haptics

Movement Simulators

Electro-myography Devices/EEG

External 3D Capture Devices

Spatial Sound positioning/presence

Implants/Prosthetics

Sensors/Data

MR Cameras

Audio

LiDAR

Eye Tracking

Face Tracking

Hand Tracking

IR

Pulse

Voice

Body-suits

IoT

Presence

After Processing

Room Dimensions

User Body Dimensions

Inferred Data
e.g. Age, Gender, Fitness, Disability

Photorealistic User Avatars

User Avatar Dynamics

Biometrics

Biological Motion/Gait

Data Storage/Network

Volatile

On-Device

Local

Cloud

5G

XR (Data) Standards

Warfighter Data Here, There, Everywhere



“(Personal) Data is hard to access, technology is ageing, and processes and culture are not suited to the information age.

A fractured ecosystem has created the need for manual workarounds and interventions across the force

...

With many systems in play that either speak different data languages or are unable to communicate at all, there is no single view of data across the Armed Forces.”



Call for Action – Collect Data!

“ ... **Data analysis is essential** for us to understand how we change training in the future.

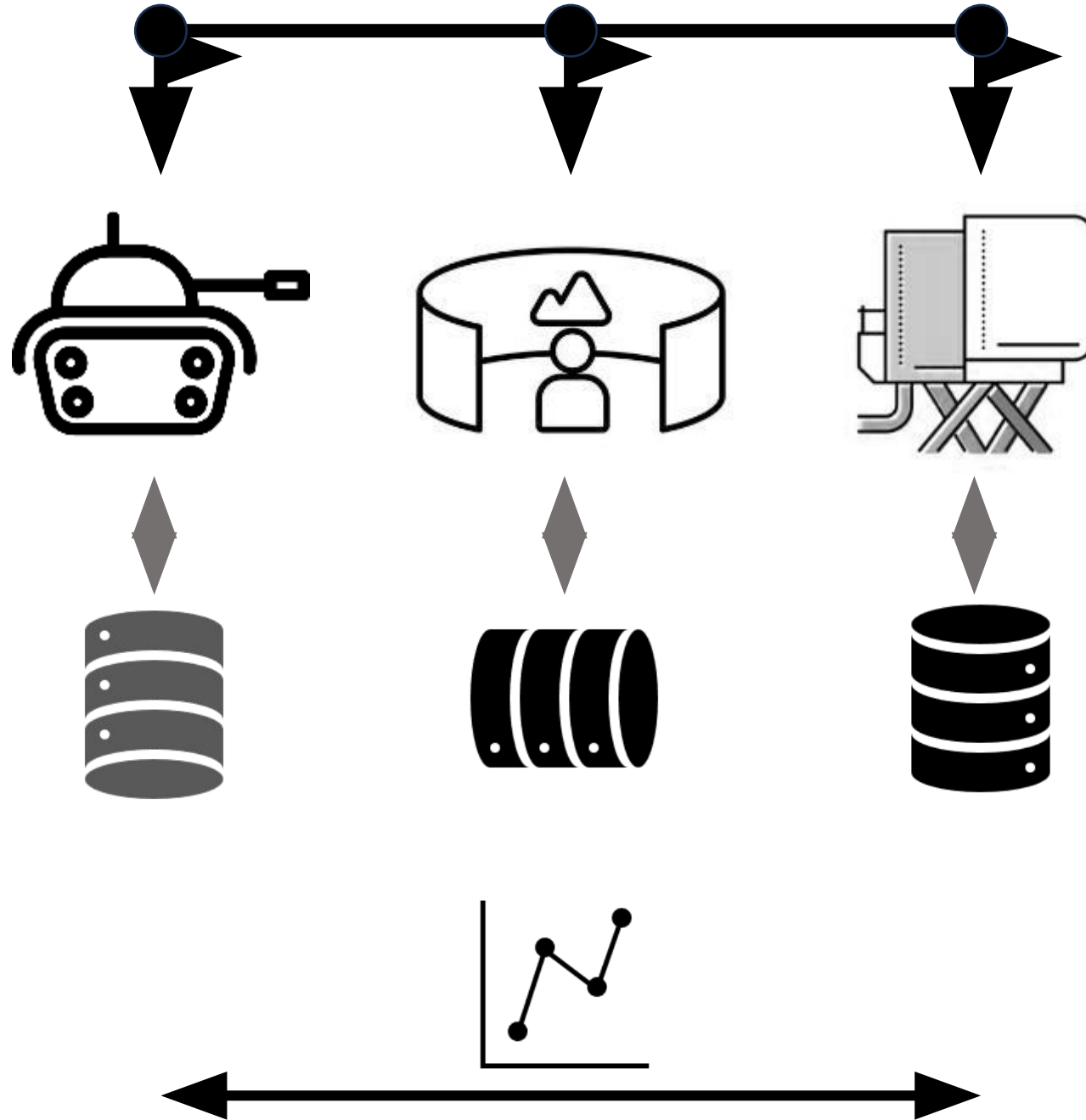
We need to be recording data in our training systems far more radically than we currently are.

If we had for the last 20 years recorded every single mission we've flown in a Typhoon simulator we could now use AI to analyse that data and think about for example how many times did the pilot make a particular manoeuvre? ... ”



IT2EC 2025 (Oslo)
AVM Ian Townsend,
Director of Training for
the UK RAF

Training Systems Interoperability



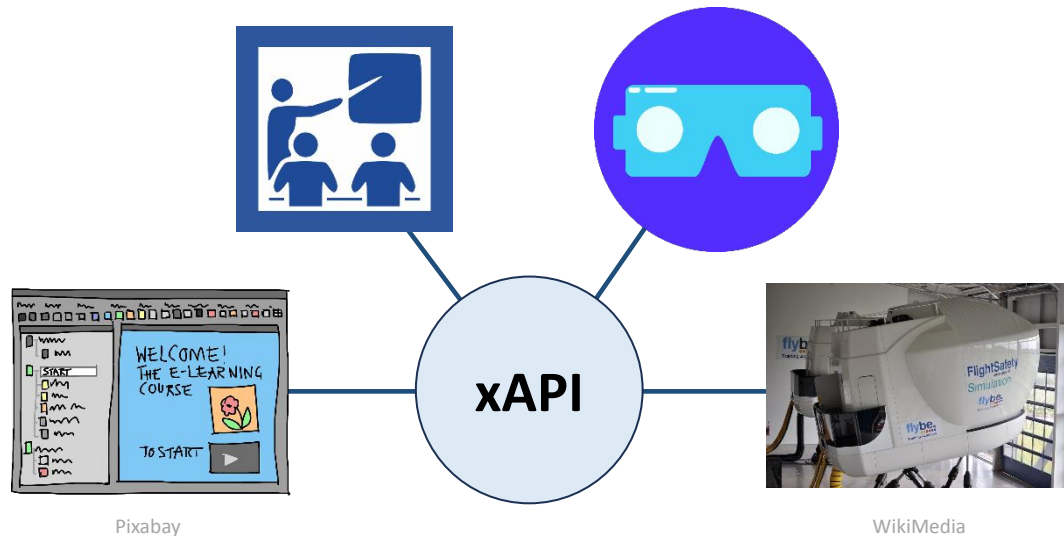
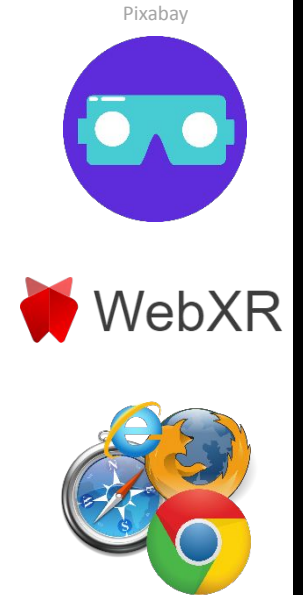
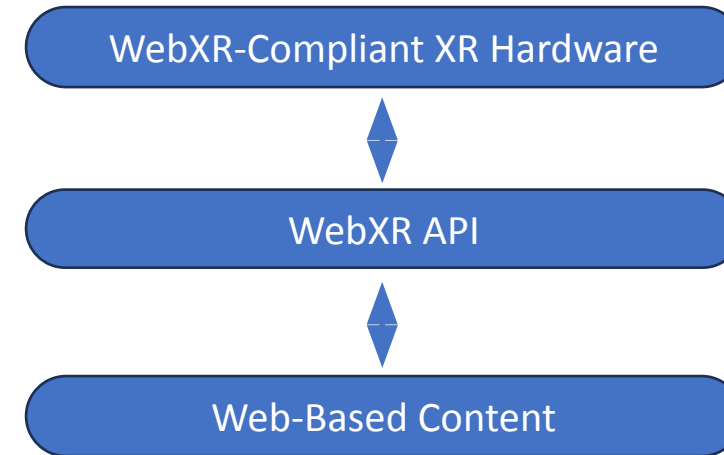
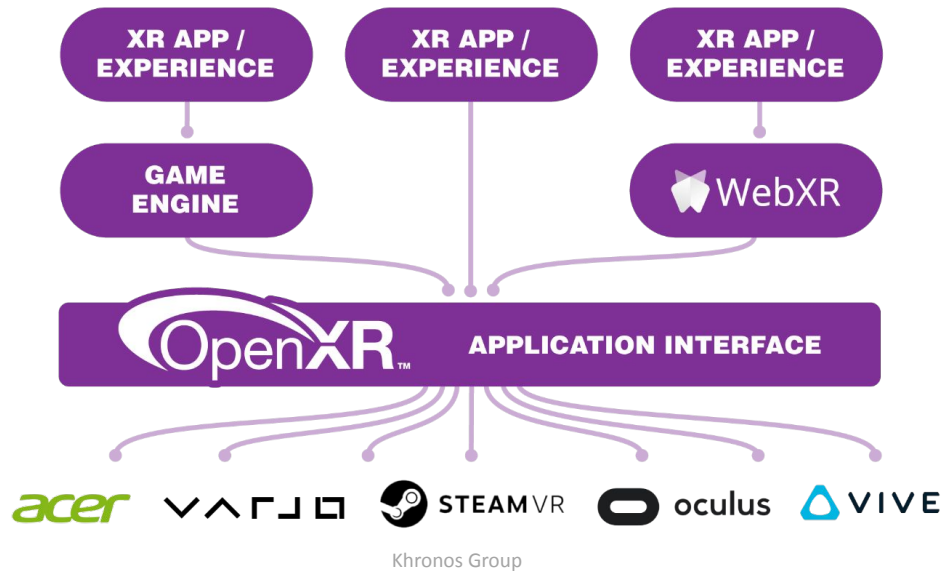
- Our Mission -





Uniting Human Data — Warfighter Digital Twins

XR Technology Standards

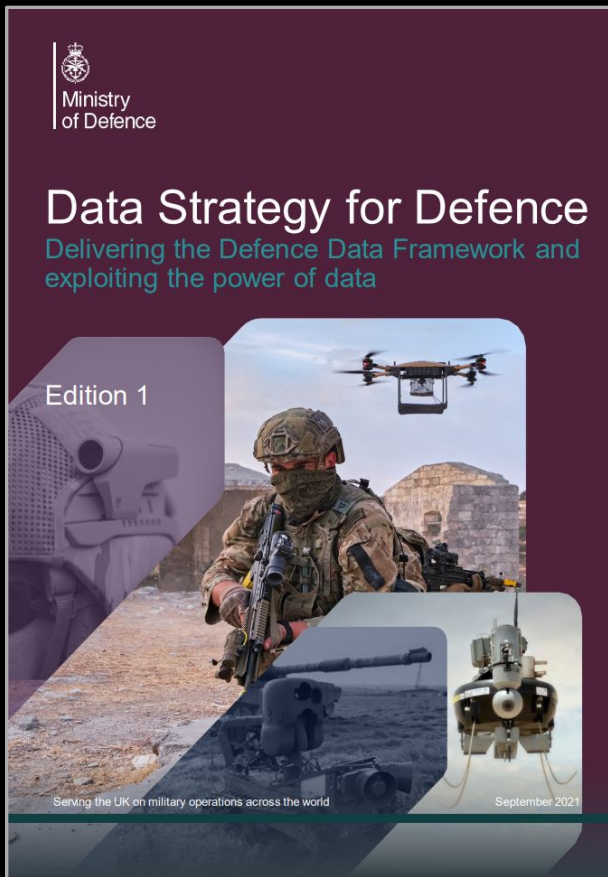


(XR/Metaverse) Enterprise Standards Framework

Theme	Sub-Themes	Example Standards
3D Content	Objects, Materials, Rendering	glTF, OpenUSD, OpenPBR, MaterialX, OpenFlight, Digital Twins
3D Worlds	Geospatial, Human-Built, Biomes	CDB, CityGML, 3D Tiles, BIM, ISO 19107, OGC API - 3D GeoVolumes
Sim-Sim Interoperability	Models, Comms	HLA, DIS, DSEEP, SpaceFOM, TENA
Sim-Others Interoperability	Software, Hardware	Cyber DEM, C2-SIM, CIGI, UCATT, Link 11/16, WebLVC, OpenXR, WebXR
Networking	Performance, Wireless, Security	5G/6G, WiFi 7, ISO/IEC 27033
User Experience	Safety, UX, Performance Tracking	ISO 45001, ISO/IEC 5927:2024, ISO 25010, xAPI, Caliper Analytics
Governance	Security, VV&A, Privacy, Ethics	ISO/IEC 27001, IEEE 1012, ISO/IEC 27701, GDPR, IEEE 7000

UK MoD

6 Data Rules

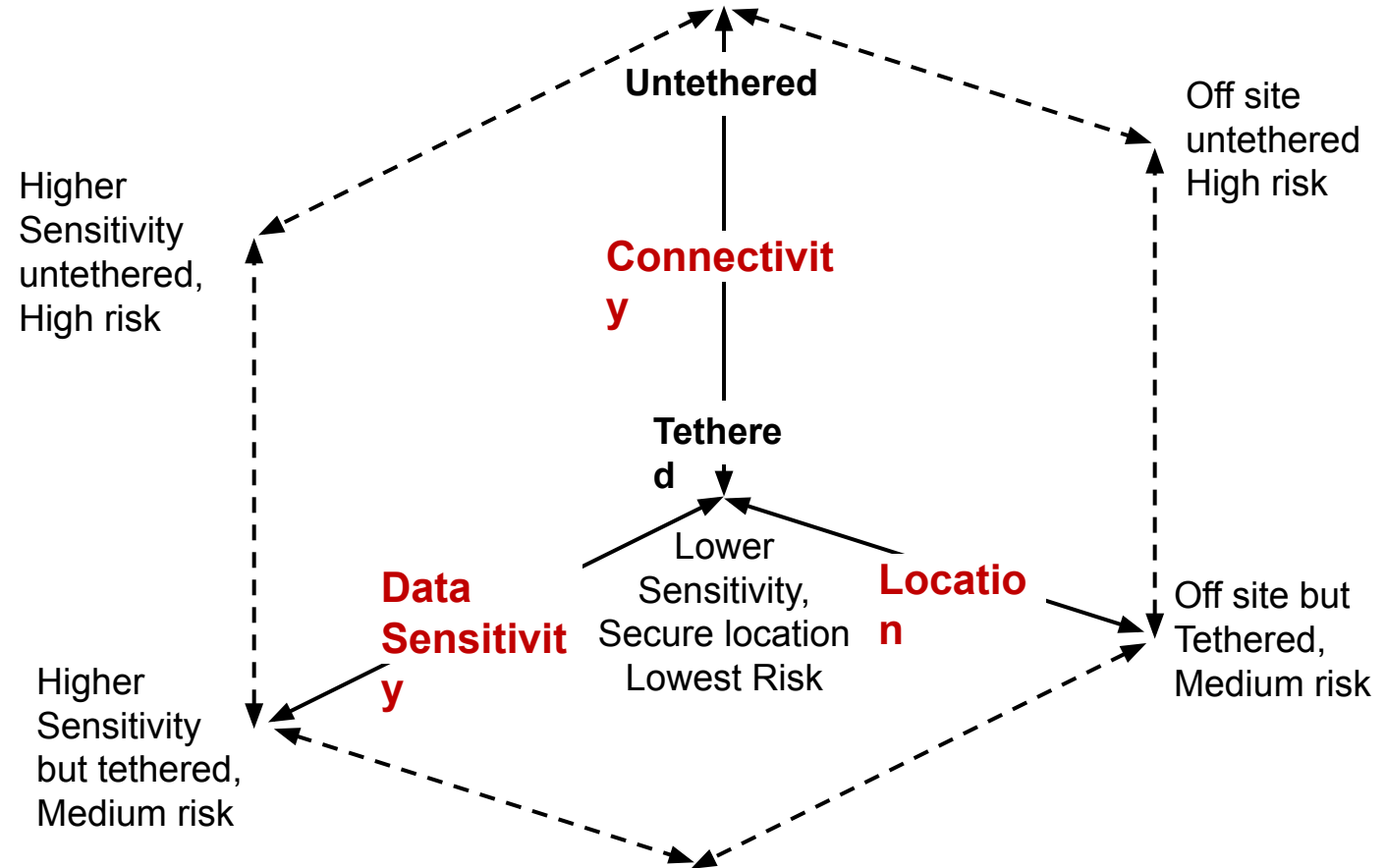


- Exercise sovereignty over data, including **accountability** and ownership
- **Standardise** data across the Defence landscape
- **Exploit** data at the most effective and relevant point in the value chain
- **Secure** digital data at creation, curation, when handling, storing and transmitting
- **Curate** data, ensuring it is assured, discoverable and interoperable
- **Endure** data as an asset beyond individual projects

XR Security

XR Security

3 Dimensions



Looking Forward

AI, Data and XR

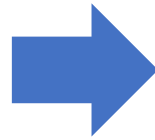
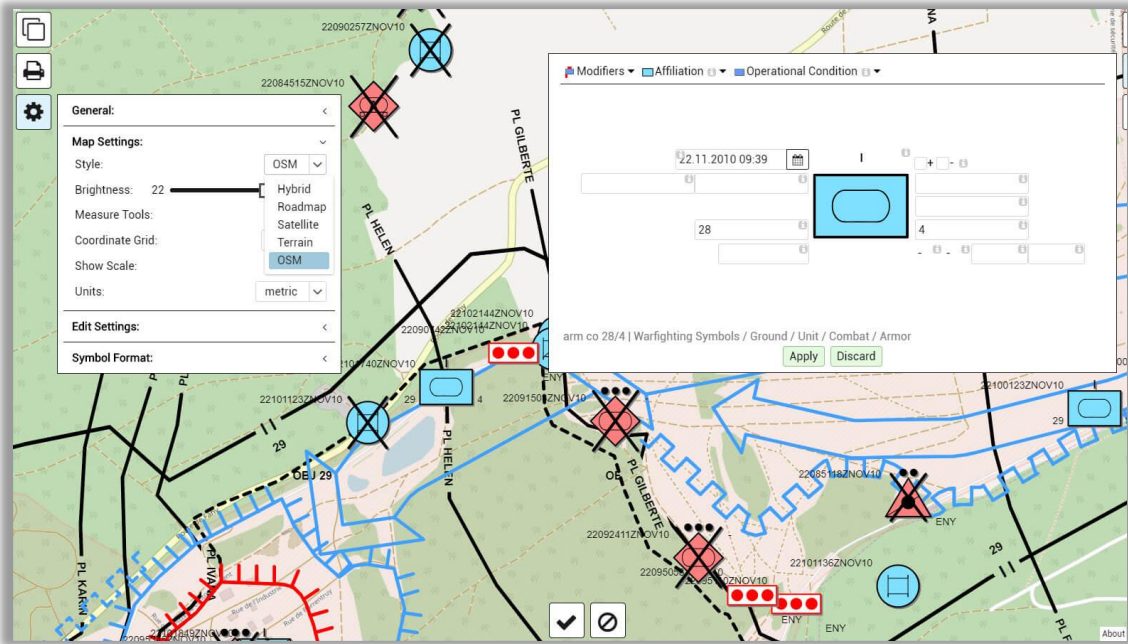
Data Category	AI Applications
Sensor & Tracking Data	Motion prediction, gaze-based rendering, gesture recognition, avatar animation
Environmental & Spatial Data	Scene understanding, spatial mapping, occlusion handling, environmental labeling
User State & Biometric Data	Adaptive interfaces, cognitive load estimation, stress detection
Behavioural & Usage Data	Personalisation, usage analytics, experience optimisation
Content & System Data	Asset optimisation, adaptive streaming, intelligent content delivery

OpenAI
Sora
& Roblox

Text to
Video & 3D
Worlds

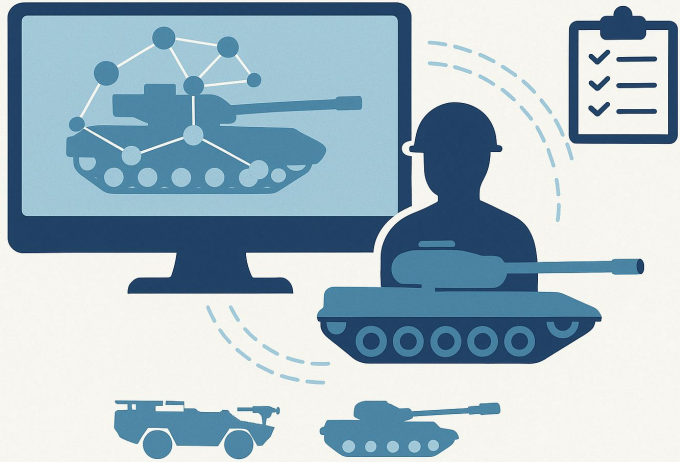


The Metaverse Signifies the Trend from 2D Digital Worlds to 3D Digital Worlds



The Real World is 3 Dimensional (!)

Seizing the 3D (Data) Future



The Mirror Domain



The Learning Arena



**The Cognitive
Terrain**

Shared Worlds

Innovation

...

Rift Drone (2014)

AR.Drone 2.0
Oculus Rift
Unity

Xbox 360 Controller
Open-Source Software

<https://github.com/daraosn/oculus-drone>



https://youtu.be/3WmQ1_8ytaM?si=nsmukHRH8IEMII33



THINKE

Questions?

XR Data

A Strategic Asset

Andy Fawkes | Reality Reimagined Expo 2025
Battlelab, Dorset | 26 June 2025
andy.fawkes@thinke.co.uk