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Adaptive Cross-Reality Information Mediation (AXRIM) (Summary Technical Report, Oct 2024–Sep 2025)

by Mark Dennison and Jade Freeman

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Adaptive Cross-Reality Information Mediation (AXRIM) (Summary Technical Report, Oct 2024– Sep 2025)

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14. ABSTRACT The Adaptive Cross-Reality Information Mediation (AXRIM) program researches and develops tactical cross- or extended-reality (XR) capabilities that enhance dismounted squad situational awareness, survivability, and lethality in contested and complex battlefield environments. Efforts focused on the following key areas: development of a serverless multiuser common operating picture framework, non-emissive spatial localization and mapping among head-mounted displays (HMDs) and robotic and autonomous systems (RAS), 3D One World Terrain integration with Unity's commercial game engine, HMD-based RAS control interfaces, and integration of all of these capabilities with the XR Tactical Assault Kit application from the Program Executive Office Soldier under the Soldier-Borne Mission Command program of record. This report presents the Summary Technical Report for the AXRIM program.					
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Executive Summary

This Adaptive Cross-Reality Information Mediation (AXRIM) program researches and develops tactical cross- or extended-reality (XR) capabilities that enhance dismounted squad situational awareness, survivability, and lethality in contested and complex battlefield environments.

FY25 efforts focused on the following key areas: development of a serverless multiuser common operating picture framework, non-emissive spatial localization and mapping among head-mounted displays (HMDs) and robotic and autonomous systems (RAS), 3D One World Terrain integration with the Unity commercial game engine, HMD-based RAS control interfaces, and integration of all of these capabilities with the XR Tactical Assault Kit application from the Program Executive Office Soldier. This Summary Technical Report presents the closeout technical report for the AXRIM program.

1. Introduction and Mission Description

The Adaptive Cross-Reality Information Mediation (AXRIM) effort investigates and develops techniques that intelligently integrate local and external data sources across different interaction modalities to enable enhanced situational awareness, shared understanding between echelons, augmented information representations, and accelerated decision-making. It provides techniques that support at-the-edge situational awareness and accelerate decision-making among distributed humans and agents. Specifically, the research focuses on improving decentralized yet collaborative decision-making agents through intelligent mediation and delivery of tactical information to dynamic immersive, augmented, and conventional displays that are adaptive to the user and context.

2. Research Goals

The research goals for this program are as follows:

- Enhance distributed decision-making and situational awareness through mediation and delivery of integrated data sources to an extended-reality common operating picture (XR COP) with multiple views that enable exploitation of opportunities with speed and precision (Figure 1), and
- Enable dismounted human-machine integrated formations (HMIFs) with spatially aware XR interfaces to execute intuitive command and control (C2) over robotic autonomous systems (RAS).



Figure 1. U.S. Army use-cases relevant to AXRIM research.

3. Program Objectives

The program's objectives include delivering knowledge products and software for information synchronization, non-emissive spatial localization, and C2 over air and ground robotic systems through Soldier-Borne Mission Command (SBMC) hardware.

Transitioning software into the XR Tactical Assault Kit (XRTAK) application from Program Executive Office (PEO) Soldier enables rapid integration and testing with Soldiers on the SBMC program of record.

4. Current State of the Art

Heads-down, hands-full interfaces limit the portrayal of tactical information, reduce survivability, and cannot enable HMIF to efficiently execute robotic autonomous C2. Current commercial head-mounted displays (HMDs) leverage emissive sensors for spatial referencing, which make them unusable for tactical operations in contested environments.

Portrayal of robust 3D battlefield information is limited by device processing, access to data on tactical networks, and availability of recent usable photogrammetric data for lower-echelon operations.

5. Major Partners

Key external partners in this effort include the Johns Hopkins Applied Physics Laboratory, who are experts in robotic platforms; the U.S. Army Combat Capabilities Development Command (DEVCOM) Soldier Center, who provide TAK expertise; the University of Southern California Institute for Creative Technologies, who provide expertise in 3D geospatial terrain integration; and the MITRE Corporation, who provide expertise in XR application development. The team also collaborated with Soldiers from the 11th Armored Cavalry Regiment¹ and at the Command and General Staff College.

6. Research Efforts

Through these research efforts, an XR COP capability was developed to assess the effects of shared spatial presence on user understanding of mission environments. Integrated multi-resolution 3D terrain data were collected from drone and satellite photogrammetry to assess the impact on user understanding of complex battlefield environments.

Methods were studied for achieving spatial localization with 6 degrees of freedom between HMDs and other systems using only non-emissive sensors. Methods were also explored for generating near real-time 3D geometry of the operating environment from low size, weight, and power, and non-emissive Soldier and robot-borne sensor payloads.

We also explored ways of commanding and controlling RAS through HMDs using both digital pass- and see-through methods for visualization.²

7. Findings

As a result of this AXRIM program, we accomplished the following:

- Deployed multiuser COP capabilities on PEO-Soldier-provided HMDs (IVAS 1.2), resulting in an invitation to transition new capabilities into PEO Soldier's XRTAK program within the TAK Product Center.
- Successfully demonstrated non-emissive RAS-HMD spatial localization and HMD-based first-person view control of a quadruped robot navigating outdoor and urban environments.
- Integrated Government off-the-shelf software enabling XRTAK to support One World Terrain (OWT) data from the Maxar/Product Manager for OWT.

8. Payoff/U.S. Army Impact

The payoff and impact for the U.S. Army is providing Soldiers with non-emissive, spatially localized XR systems for intuitive control of RAS and easier understanding of information distilled from complex data sources.

9. References

1. Dennison M et al. Cross reality (XR) for shared mission planning and analysis. DEVCOM Army Research Laboratory (US); 2024 Dec. Report No.: ARL-TR-10039.
2. Petlowany C, Pryor M, Hahn N. Gaze-based augmented reality interfaces to support scalable human–robot teaming. In: 2024 33rd IEEE International Conference on Robot and Human Interactive Communication (ROMAN); 2024 Aug 26–30; Pasadena, CA. IEEE; c2024. p. 1899–1906. <https://doi.org/10.1109/RO-MAN60168.2024.10731399>

List of Symbols, Abbreviations, and Acronyms

3-D	Three-dimensional
ARL	Army Research Laboratory
AXRIM	Adaptive Cross-Reality Information Mediation
C2	Command and Control
COP	Common Operating Picture
DEVCOM	U.S. Army Combat Capabilities Development Command
FY	Fiscal Year
HMD	Head-Mounted Display
HMIF	Human–Machine Integrated Formation
OWT	One World Terrain
PEO	Program Executive Office
RAS	Robotic and Autonomous Systems
XR	Cross- or Extended-Reality
XRTAK	XR Tactical Assault Kit

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