Abstract Title

Advancing Environmental Intelligence for Earth Improvement by way of an Interoperable Digital Twin Earth Ecosystem: An Overview and Status of NOAA's Knowledge Mesh Broad Agency Announcement

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Abstract

The National Oceanic and Atmospheric Administration (NOAA) has initiated a transformative effort to enhance environmental intelligence through its Knowledge Mesh (KM) Broad Agency Announcement (BAA)[1]. Released in May 2024, the BAA addresses NOAA's strategic need to improve discovery, access, interoperability, agility, and trust in its environmental processing. This initiative builds on foundations laid by the Earth Observation Digital Twin (EO-DT) program[2] to foster advancements in social environmental equity and enhance resilience to weather and climate challenges.

The KM represents a conceptual keystone for realizing a next-generation, interoperable, and potentially auto-evolutionary information ecosystem that provides open access to creation and use of process-threaded, semantically contextualized facts, captured in real-time during various interactions with the world, via a unified, multi-modal, multi-utility access interface[3]. The KM is intended to accept, resolve, capture, and integrate diverse and highly contextual queries and instructions provided by a diverse range of NOAA users (personas) including scientists, operators, policy makers, and public interests through use of a dynamic multi-world digital replica that integrates a variety of fabric and agent based features and capabilities.

By leveraging cutting-edge technologies such as natural language processing (NLP), graph neural networks (GNNs), and foundation models (FMs), the KM model is intended to enable users (both human and machine) to extract actionable insights and make wisdom-based decisions that are grounded in full multi-resolution context of NOAA's vast authoritative information and the broader trusted ecosystem it connects to. As use of the knowledge mesh grows, the full

provenance digital record of interaction - composed of fully linked requests and responses related to addressing concerns of what now, what if, and what next - is intended to provide the basis for an evolutionary and dynamic digital twin foundation model.[4]

In September 2024, NOAA awarded contracts totaling $5.4 million to Booz Allen Hamilton, Element 84, Noblis, and Orion Space Solutions.[5] These partners are exploring innovative approaches to constructing, grooming, and exploiting the KM. Key goals include ensuring factual grounding, reducing and communicating process-coupled uncertainty through federated methodologies, and enhancing interoperability with other federal data systems, such as those managed by NASA, USGS, and NSF. These exploratory studies emphasize open science principles, prioritizing reproducibility, transparency, and collaboration across the scientific and operational communities.

Addressing the ubiquitous ‘isolated stovepipe’ problem of the current spatial data infrastructure paradigm, the KM will enable seamless integration of multimodal data streams via dynamic and advanced analytics processes, supporting diverse user requests ranging from “What are the flood risks in my area?” to “Can you summarize trends in sea surface temperatures over the past decade?” This functionality is critical for addressing challenges at the intersection of ecological, socio-economic, and physical systems, exemplified by use cases in various coastal, ocean, terrestrial, atmospheric, and space domains.[6]

By adopting advanced AI and machine learning techniques within a federated, open, and process-driven communications architecture, the KM is intended to serve as a reference model for integrating FAIR (findable, accessible, interoperable, reusable) and TRUST (transparency, responsibility, user focus, sustainability, technology) principles into operational practices. Through connections enabled by the NESDIS Common Cloud Framework (NCCF) Open Information Stewardship Service (OISS), results from this study are closely informed with active operational satellite and remote sensing efforts; international digital twins standards development, and foundational interagency/international digital twins and knowledge sharing pilots.[7]

Through this BAA, NOAA aims to establish a scalable, interoperable framework that meets mission objectives and sets a new global benchmark for access to and exploitation of open environmental intelligence. As these studies progress, NOAA’s Knowledge Mesh will demonstrate its capacity to enhance decision-making, foster collaboration, and support sustainable solutions for a resilient “One Earth”.

References

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