Earth System Digital Twins (ESDT) Workshop

Lightning Talk

A Framework for Global Storm Resolving OSSEs

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Project Objectives

ESDT 2022
OCTOBER 26–28, 2022

Science and Technology Objectives

- Enable global storm resolving Observing System Simulation Experiments (OSSEs)
- Enable simulation of past, present and future observing systems from global storm resolving Nature Runs.
- Address computational challenges that prevent existing technologies from scaling to spatial resolutions that will be needed by end of the decade.

Application Objectives

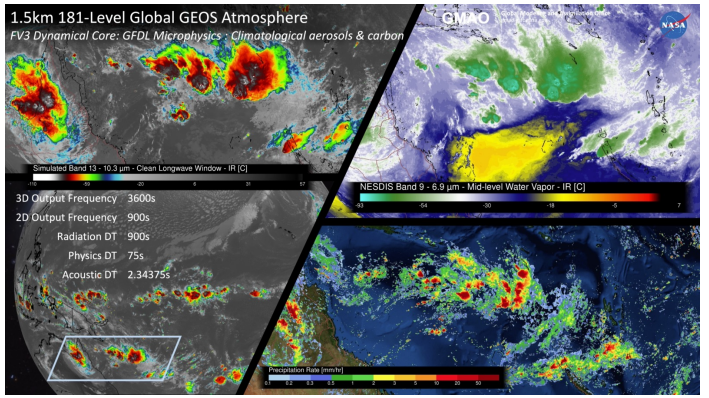
- Leverage and engage the *Joint Effort for Data Assimilation Integration* (JEDI) community by providing simulation of NWP observing system including all-sky radiances, accounting for the effect of aerosols
- Enable simulation of PBL related observables, engaging the *Decadal Survey Incubator* (DSI) PBL community
- Engage the Earth System Observatory (DSO) missions in development (AOS, SBG) by providing atmospheric Nature Runs for realistic observing system simulations enabling algorithm development, science and application demonstrations well before launch.

Benefits to Earth Science

- Bridges the gap between advanced earth system modeling and realistic simulation of future observing systems
- Early development of new concepts in model-data fusion enabling science investigations aimed at elucidating physical processes and their representation in models.

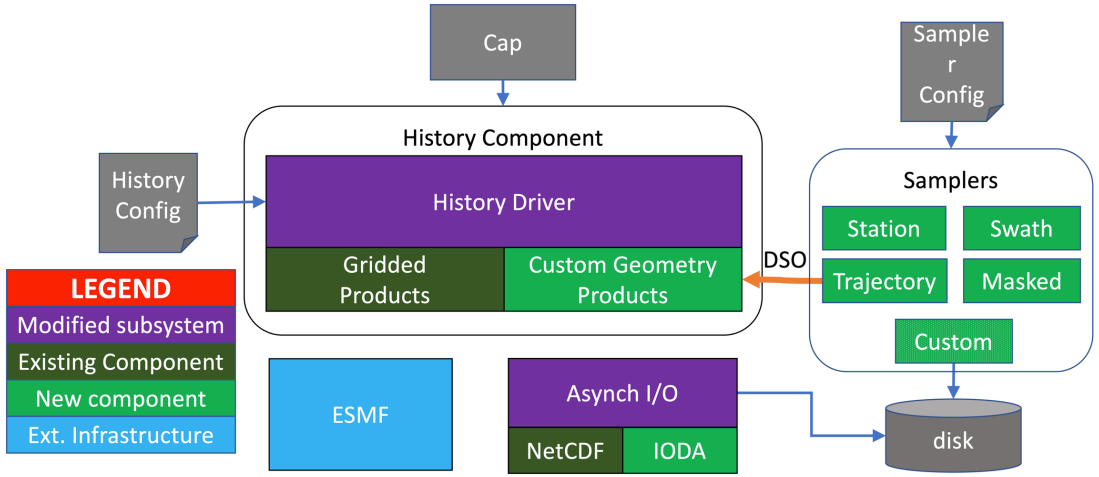
Relationship to ES Digital Twins

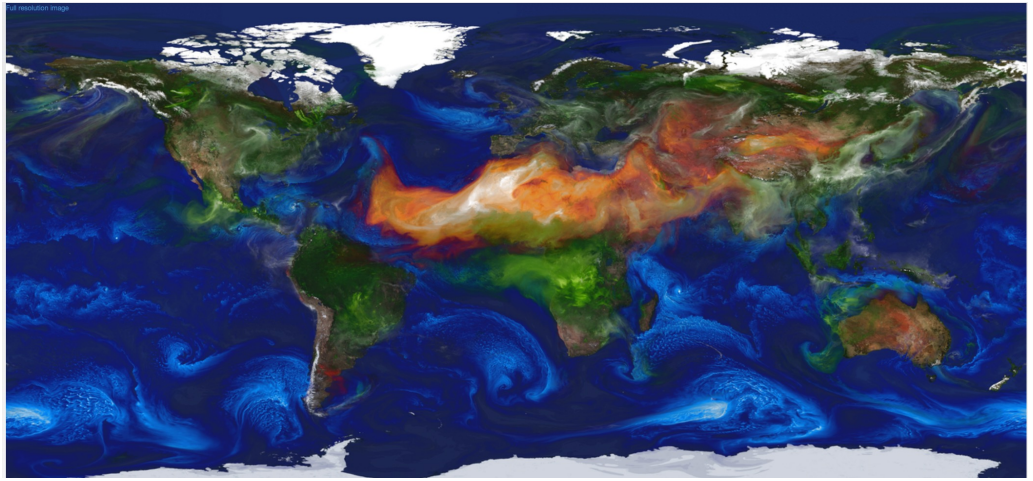
- Develops a framework for producing advanced global storm Nature Runs that are **Digital Replicas** of the Earth System
- Provide a framework for observing system simulations and tools to conduct *what-if* investigations and trade studies for the benefit of NASA missions in development.



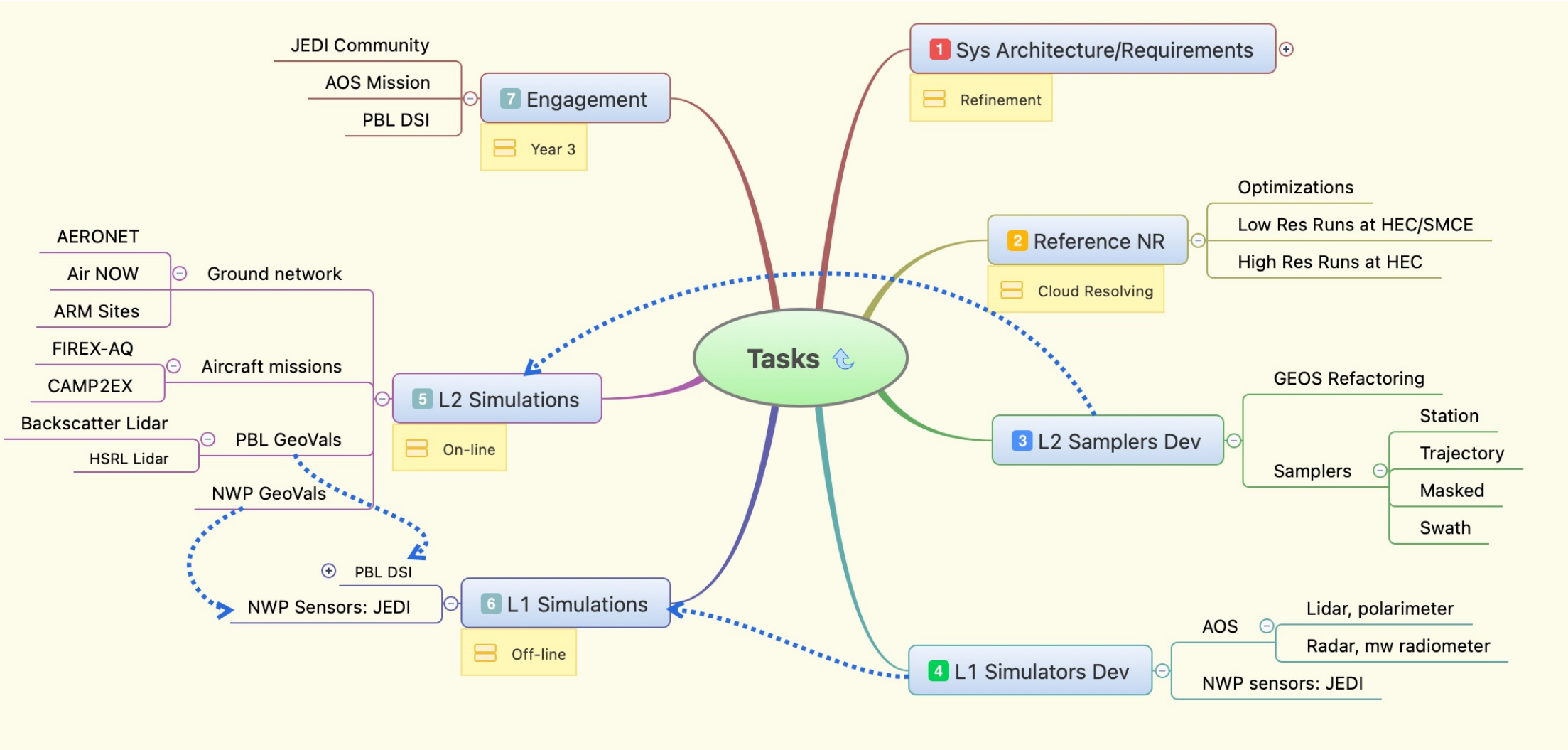
Technology Approach

- Extend parallel I/O capabilities of the GEOS model by including on-line sampling of *Geophysical Variables* at observation locations
  - ground stations, aircraft trajectories, satellite swaths
- Two-phase workflow for generating Nature Runs
  1) Model is spun up in a run with limit output except for frequent checkpoints and browse products
  2) Model is run from spun up checkpoints with output sampled at user specified observation locations
- Definition of a flexible API for custom geo-location samplers, allowing maximum flexibility





Technology Approach



Earth System Digital Twins (ESDT) Mapping

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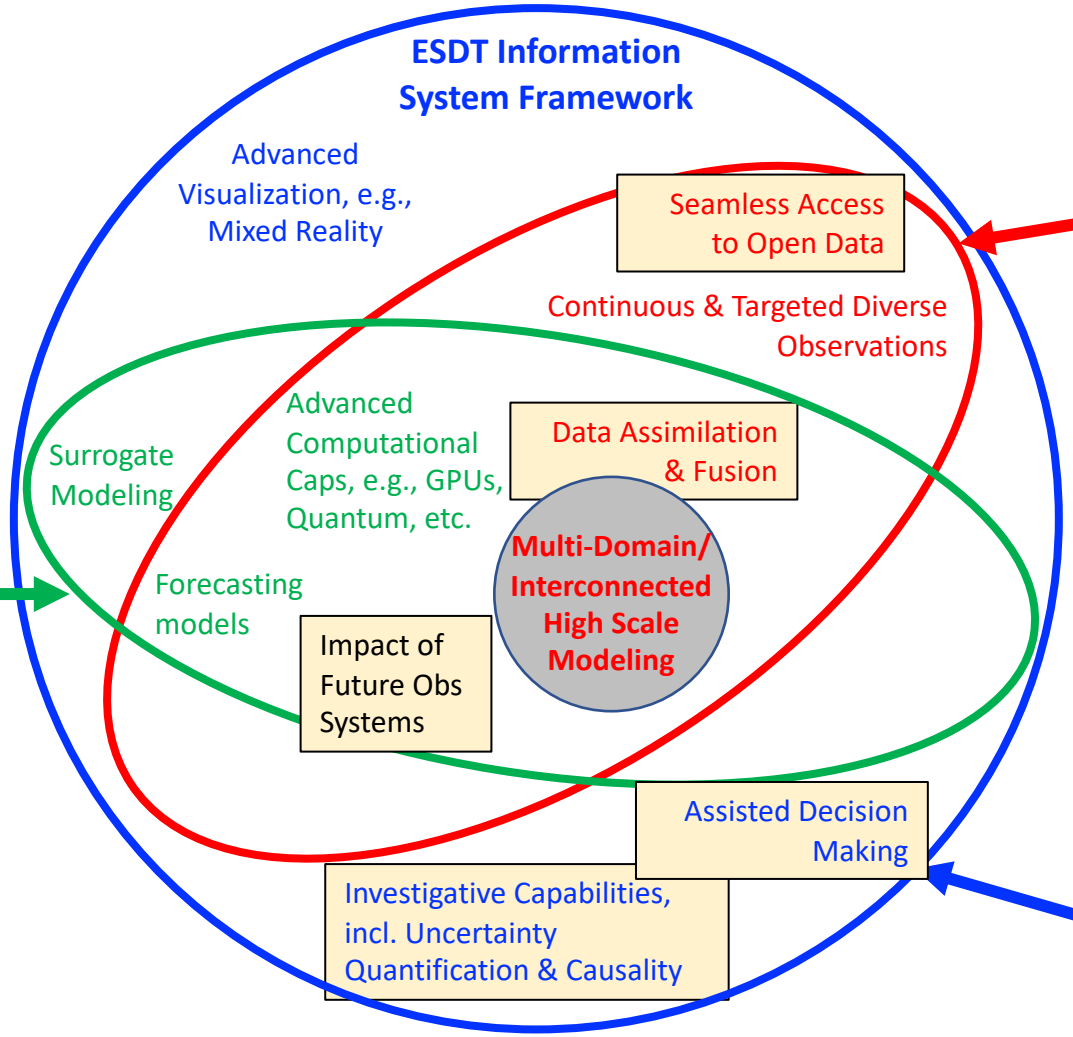

(1) Up-to-Date *Digital Replica* of Past and Current States of Earth System
(Global Storm Resolving Scales)

(2) Real-Time (RT) or Near-RT *Forecasting* of Future States of Earth System

(3) Impact Assessment by running What-If Scenarios for Hypothetical Future States of Earth System
(Explores Future Observing Systems)


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Appendix: AIST ESDT Description

Towards understanding the evolution and interactions of Earth's most complicated systems

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AIST leads NASA's Earth System Digital Twins (ESDT) efforts, developing novel technologies for integrating diverse Earth and human activity models, continuous observations and information system capabilities to provide unified, comprehensive representations and predictions that can be utilized for monitoring as well as for developing actionable information and supporting decision making. Using insights generated from its Novel Observing Strategies (NOS) and Analytic Collaborative Frameworks (ACF) efforts, AIST pioneers ESDTs that could be used to help researchers better understand the fundamental Earth systems that impact everything from wildfires to climate change.

Organized around interconnected, multi-domain, high-scale modeling capabilities, the three major components of an ESDT are a continuously updated **Digital Replica** of the Earth System of interest, dynamic **Forecasting** models and **Impact Assessment** capabilities.

The ***Digital Replica*** is fed by continuous and targeted diverse observations, powered by Data Assimilation and Fusion, and provides an accurate representation of the *current state of the system*.

Forecasting is facilitated by advanced computational capabilities, Machine Learning (ML) and Surrogate Modeling, and provides real-time or near-real-time prediction of *future states of the system*.

Finally, ***Impact Assessment*** uses the Digital Replica and forecasting capabilities with ML, causality, uncertainty quantification and advanced computation and visualization capabilities for running large amounts of simulated predictions quickly and at various spatial and temporal scales, opening the door to investigating "what-if" scenarios. These will allow to understand better the impact of one system on another one, and better predict Earth Science events, e.g., severe weather events. This third component provides *hypothetical future states of the system*.

The latest AIST project solicitation requested technologies dedicated to furthering AIST's three strategic ESDT goals, which are:

1. To develop information system frameworks that provide continuous and accurate representations of systems as they change over time.
2. To mirror various Earth Science systems and utilize the combination of Data Analytics, Artificial Intelligence, Digital Thread and state-of-the-art models to help predict the Earth's response to various phenomena.
3. To provide the tools to conduct "what-if" investigations that can result in actionable predictions.

These goals will allow future Earth System Digital Twins to better represent, predict, and investigate complex Earth system phenomena. In total, AIST selected thirteen projects to further develop its ESDT efforts according to these strategic principles. These projects will explore technologies for better ESDT infrastructure, ML-surrogate modeling for ESDT applications, ACF for ESDT applications, and fully-functioning ESDT prototypes.

A complete list of selected AIST-21 projects can be found here.