

NASA Earth Science Technology for Earth System Digital Twins (ESDT)



NASA Earth Science Technology Office (ESTO) Advanced Information Systems Technology (AIST) program



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AIST Thrusts



Optimize measurement acquisition using many diverse observing capabilities, collaborating across multiple dimensions and creating a unified architecture

Assimilate Observations

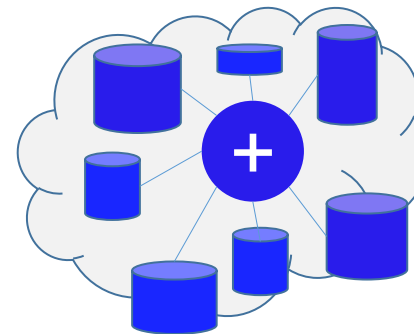
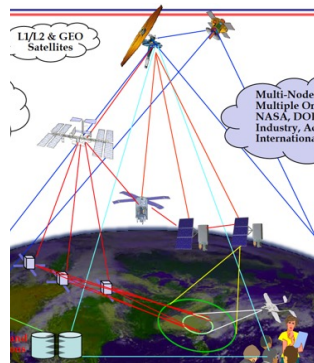
Enhance and enable focused Science investigations by facilitating access, integration and understanding of disparate datasets using pioneering visualization and analytics tools as well as relevant computing environments

New Observing Strategies (NOS)

Analytic Collaborative Frameworks (ACF)

Acquire coordinated observations

Track dynamic and spatially distributed phenomena



Assimilate many various data into models and analytic workflows.

What additional observations are needed?

Example: NOS testbed for fire hazard detection
https://esto.nasa.gov/forums/estf2021/Presentations/June10/Grogan_NOST_ESTF2021.pdf

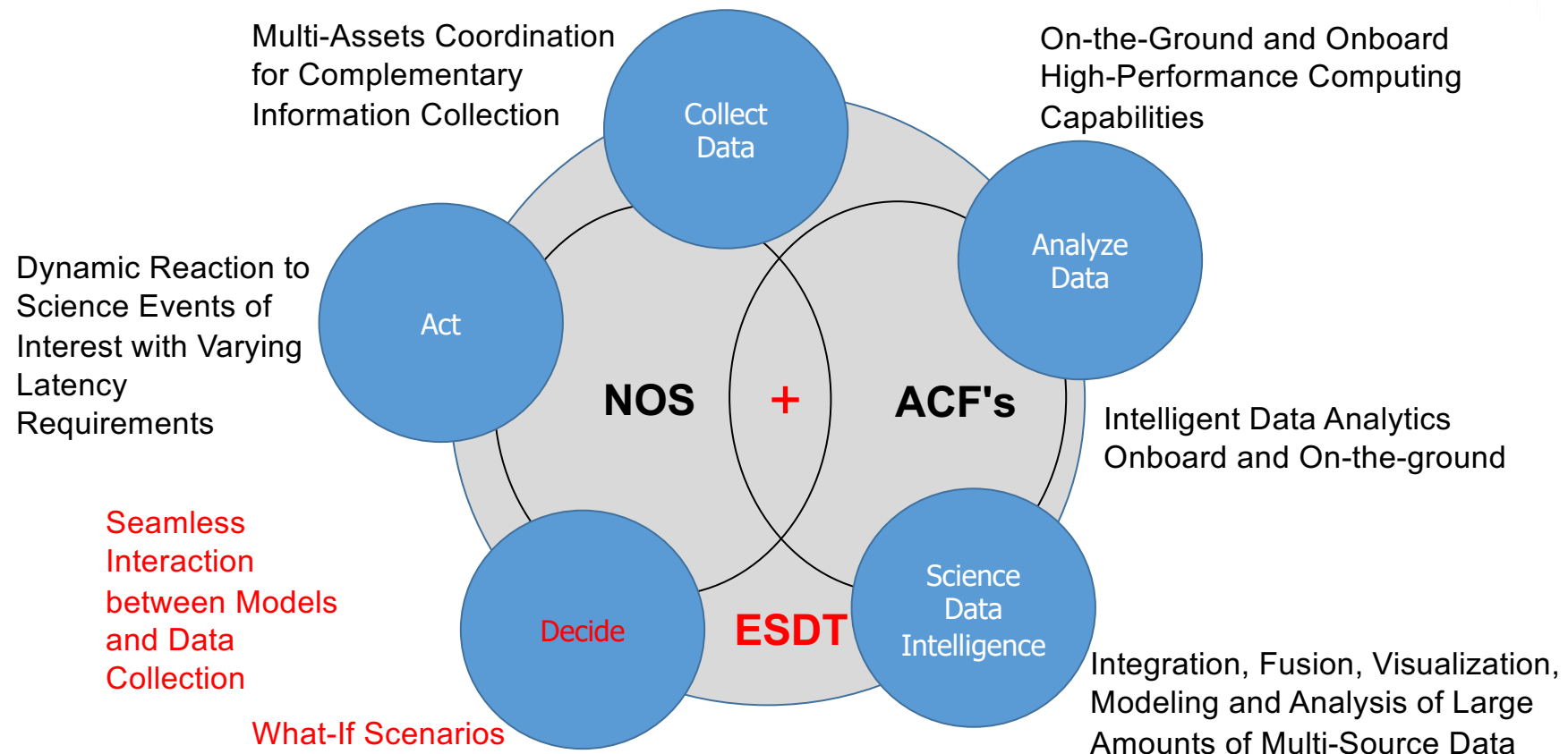
Observation Requests

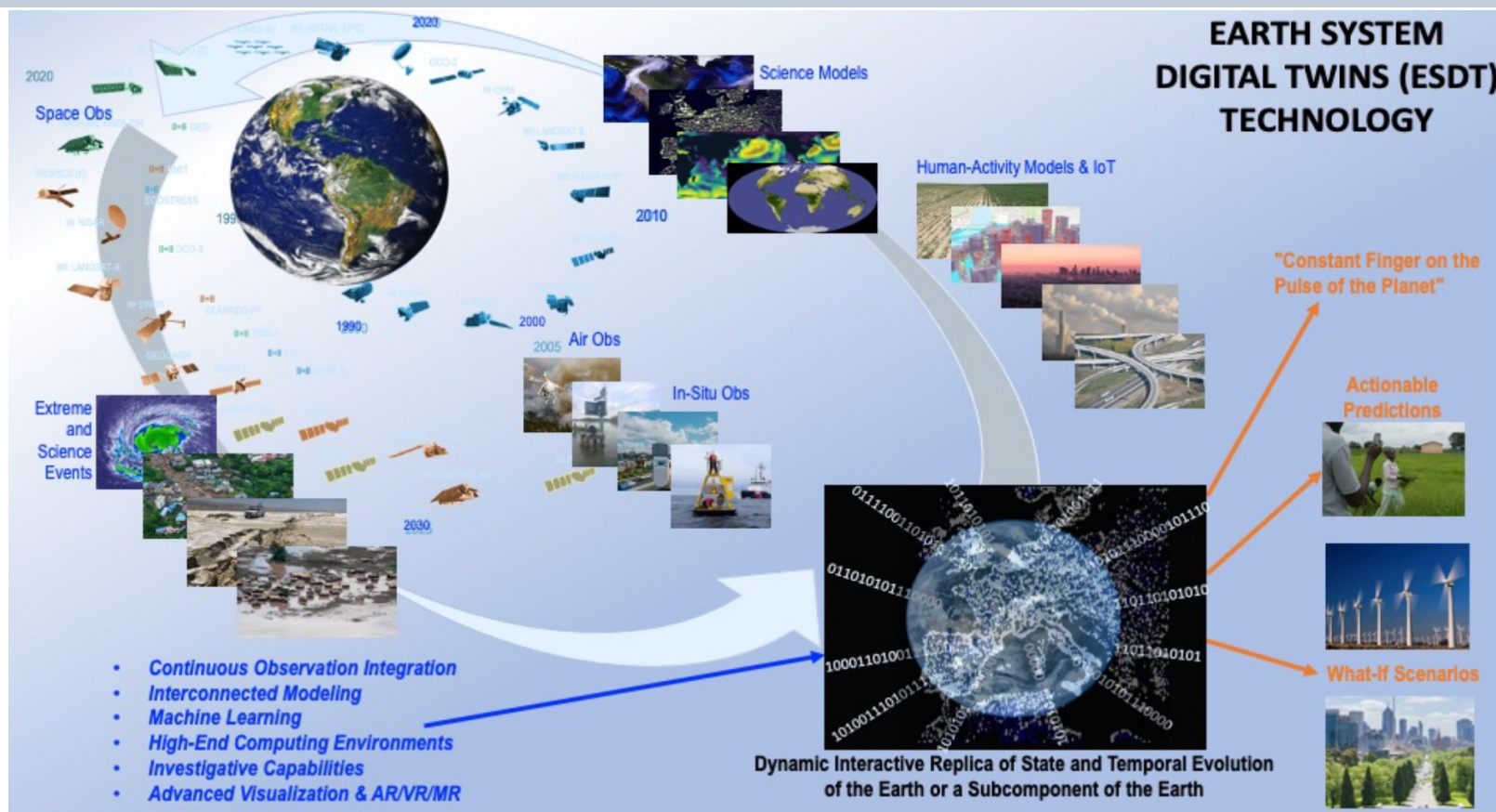
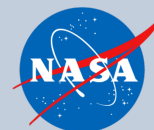
Example: OceanWorks, ACF for Ocean Science
<https://oceanworks.jpl.nasa.gov>

NOS+ACF acquires and integrates complementary and coincident data to build a more complete and in-depth picture of science phenomena

ESDT = New AIST-21 Thrust

Continuous Integration of NOS and ACF Technologies





Earth System Digital Twin (ESDT)



- Interactive, integrated, multidomain, multiscale, digital replica of the state and temporal evolution of Earth systems. Dynamically integrates
 - Relevant Earth system models and simulations
 - Other relevant models (e.g., related to human activities)
 - Continuous and timely observations (e.g., space, airborne, ground, over/underwater, socioeconomic, IoT)
 - Long-time data
 - Analytics, Artificial Intelligence (AI) tools
- Allow running hypothetical (“what-if”) scenarios to improve the understanding, prediction of, and mitigation/response to Earth system processes, natural phenomena, and human activities and their interactions.

ESDT Key Technologies



- Agile interaction and interoperability between measurement acquisition (NOS) and science investigations (ACF)
- AI to enable quickly requesting, integrating, fusing diverse and timely Earth observations into ESDTs
- Frameworks for data ingest from multiple, integrated models, and/or moving to multi-discipline, inter-related systems
- Leveraging Model-Based System Engineering (MBSE)
- Digital Thread developments
 - Link digital twin capabilities
 - Enable design requirements, records, provenance to be easily reviewed and address issues within digital twin
- Technologies for federated ESDTs

ESDT Key Technologies (2)



- Enable “what-if” investigations
 - Multi-scale simulations, statistics, uncertainty quantification, causality
 - Computational hardware and software to enable faster runs
 - Statistical models, machine learning models, surrogate modeling
 - User interfaces, visualization, augmented reality (AR), mixed reality (MR) for complex systems of systems

Related Information



- References on Digital Twins and related: https://esto.nasa.gov/files/0_2021-07-22_ESDT_References.pdf
- AGU'2021 Invited Session, SY14 - "Towards Earth System Digital Twins (ESDT)"
 - SY14A: "Toward Earth-System Digital Twins I – Oral", Chairs: J. Le Moigne and M. Cole, <https://agu.confex.com/agu/fm21/meetingapp.cgi/Session/127107>
 - SY14B: "Toward Earth-System Digital Twins II – eLightning", Chairs: M. Seablom and L. Friedl, <https://agu.confex.com/agu/fm21/prelim.cgi/Session/127120>
- Special Issue of Journal “Frontiers in Water” on “Understand and Improve Infrastructure Resilience to Hydrological Extremes Using Artificial Intelligence and Digital Twins”
 - Full papers due April 30, 2022
 - <https://www.frontiersin.org/research-topics/25358/understanding-and-improving-infrastructure-resilience-to-hydrological-extremes-using-artificial-intelligence-and-digital-twins>