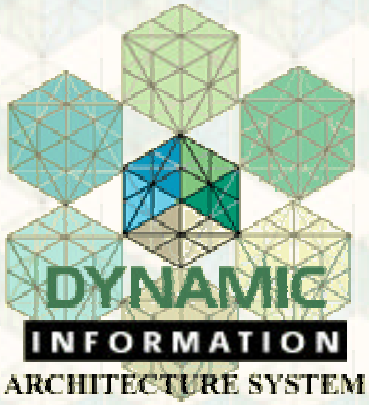
Dynamic Information Architecture System (DIAS):
A Flexible Object-Based Software Framework for Modeling Complex Environmental Systems



Prepared for:
National Centers for Coastal Ocean Science
NOAA
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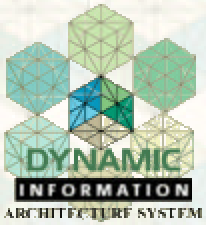
Argonne National Laboratory



ANL's Decision and Information Sciences Division

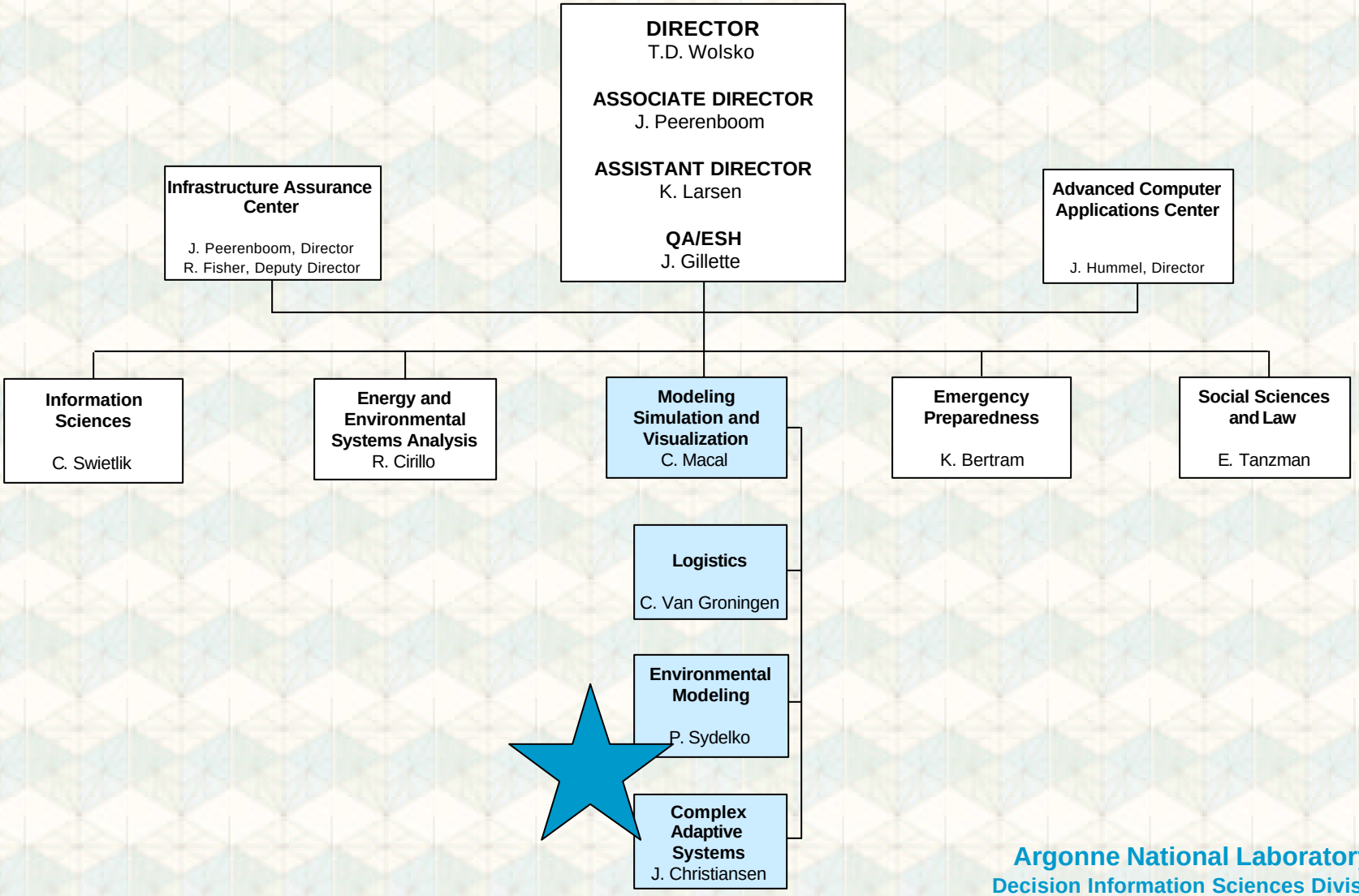
- Multi-disciplinary staff of around 250
- Engineering (energy systems)
- Computer and information sciences
- Mathematics, operations research, and decision analysis
- Social sciences (economics, sociology, political science, and law)
- Physical sciences

Web Site: http://www.dis.anl.gov

DIS Develops Models, Information Systems and Decision Tools

- **Energy/Environmental/Economic Systems Analysis:** integrated analysis of issues from a systems perspective (30 years of developing, applying, and transferring analytical tools)
- **Infrastructure Assurance:** development and application of methods for protecting infrastructures, mitigating the effects of disruptions, and responding and recovering from incidents (applied our energy systems expertise to IA since 1996)
- **Modeling, Simulation and Visualization:** development and application of models, simulation, and visualization tools
- **Information Sciences:** development of information architectures and networks, digital libraries, intelligent query systems, and visual interfaces
- **Emergency Preparedness and Consequence Management:** simulation tool development, preparedness evaluation and training (20+ years of experience for FEMA, Army, DOE, …)

Modeling, Simulation and Visualization Group



Dynamic Information Architecture System (DIAS)

- **DIAS, an object-based software *framework* for modeling and simulation:**
  - **A software framework for building process-based discrete event simulations and decision support applications**
  - **Completely object-based and distributed**
  - **Domain-neutral (not tied to a specific discipline or subject area)**
  - **Under development at ANL/DIS since 1993**
  - **Implementation in Java**

Web Site: http://www.dis.anl.gov/DIAS

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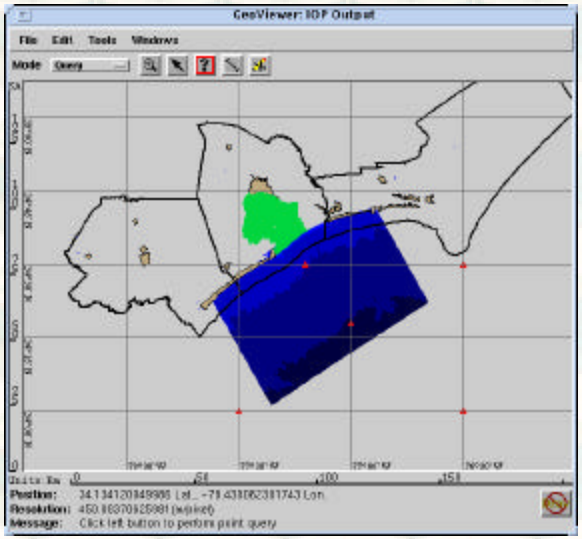
DIAS Evolution and Sponsor Applications



DIAS

DEEM

Kaiser Permanente

USA Logistics Integration Agency

Joint Warfare System

USA Forces Command

South Florida Water Management District & USAE Corps of Engineers

Defense Modeling Simulation Office

USAF Air Weather Service

The Joint Staff/J-8 & DOE

Fundamental Components of a DIAS Simulation

Software objects that represent the real-world entities that comprise the domain

Simulation models that express the dynamic behaviors of the domain entities

DIAS EXAMPLES

Natural Entities
- The atmosphere
- A waterbody
- A fish

Societal Entities
- A local developer
- A rural community

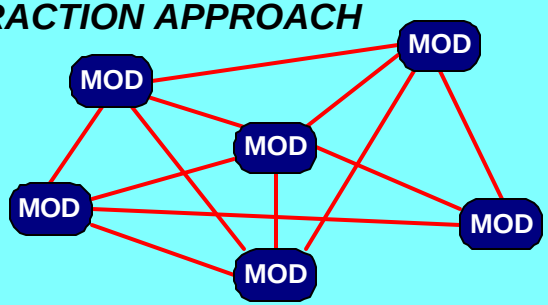
Infrastructure/Artifact Entities
- A regional water management system
- A city block

Processes
- Atmosphere: evolve state
- Waterbody: implement contaminant fate and transport
- Fish: accumulate toxins
- Developer: build tract of houses
- Regional water management system: perform stormwater runoff

DIAS Framework is Flexible and Extensible

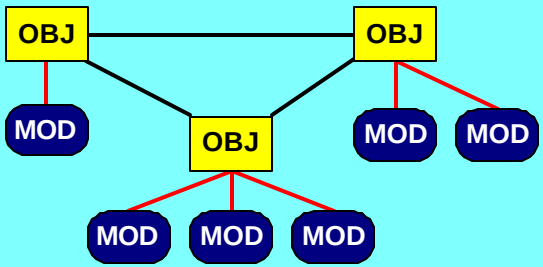
- *The domain objects, not the models, are "in charge" of the simulation.*
- *Models communicate only with domain objects, never directly with each other.*
- *Models are linked to objects on the fly, at run-time, based on simulation context.*
- *Domain object definitions are flexible, context-sensitive.*

TRADITIONAL MODEL-TO-MODEL INTERACTION APPROACH



(Many inter-model links to be maintained -- brittle and fragile)

DIAS OBJECT-MODEL INTERACTIONS



(Fewer, simpler links to be maintained -- flexible and robust)

DIAS design promotes *flexibility, scalability, ease of upgrade*

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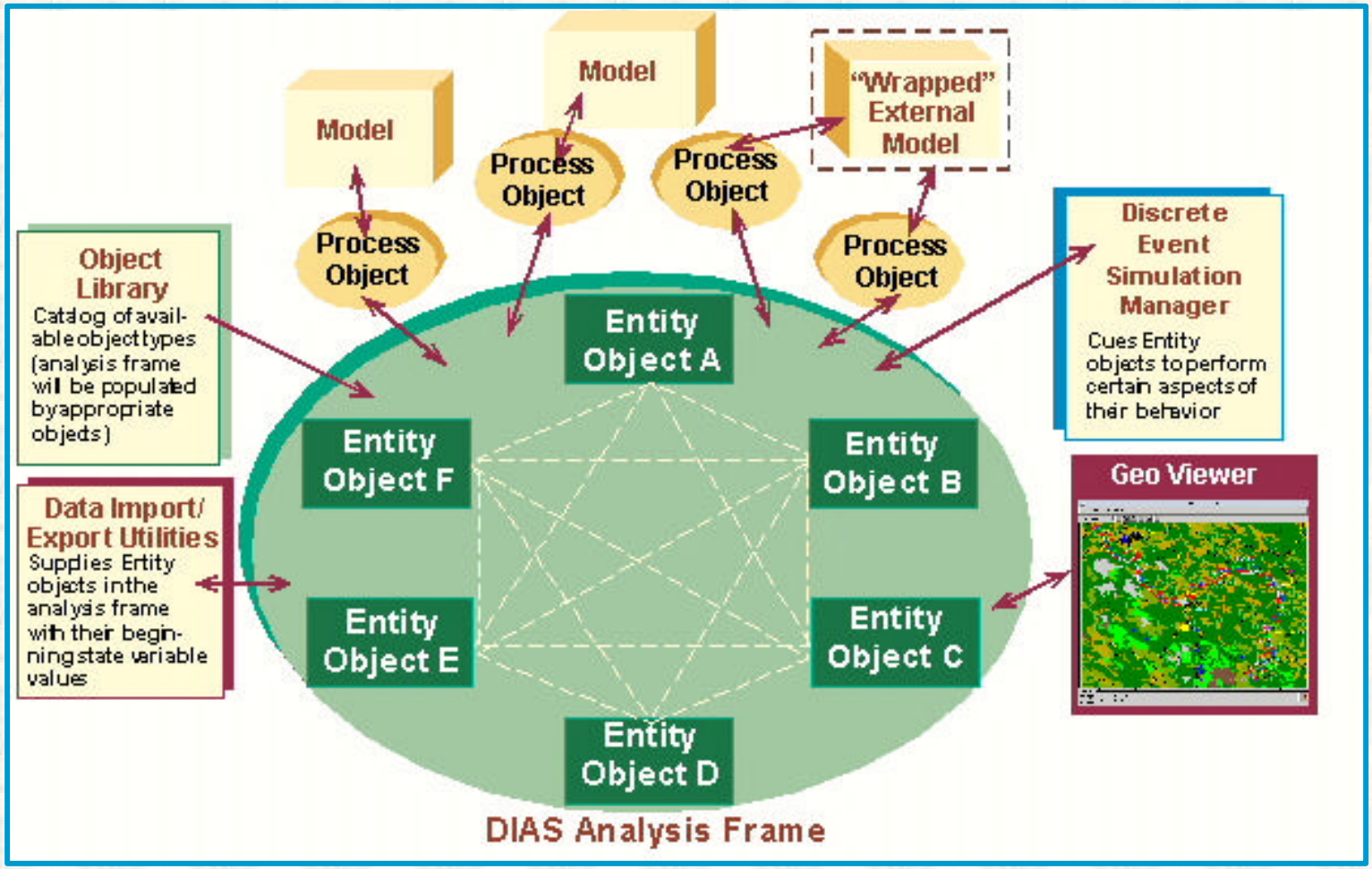
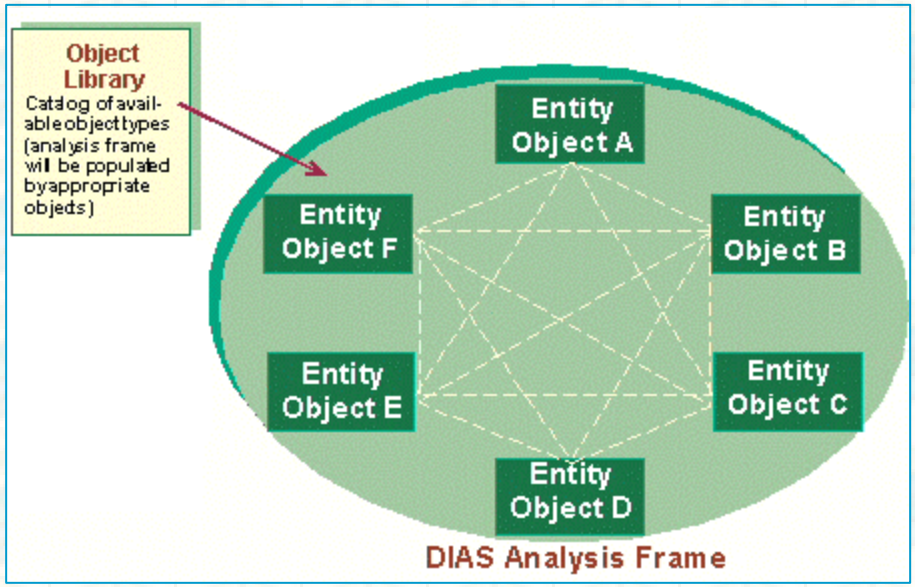
Conceptual Diagram of DIAS Architecture



DIAS Entity Objects

- Object library of real world entities
- Object classes support a diverse array of multi-disciplinary applications
- Object design is fundamental and generic
- Objects are extensible, allowing for support of new models and applications



DIAS Entity Objects (Cont.')

- **An object receives and sends messages and contains programming code called a method (describing how the object should behave) and data (information that describes the object).**
- **DIAS Entity objects carry both:**
  - ***Parameters (State)*** - properties of an object and the current value of these properties
  - ***Aspects (Behavior)*** - how an object acts and reacts in terms of its state changes and through methods (functions) associated with the object

Conceptual Vegetation Domain Object Design

Parameters (State)	Aspects (Behavior)
Leaf Area Index	Local
Patch Size	Seed Dispersal
Root Length Density	Water Use
Roughness Indices	Regional
Stomatal Resistance	Fragmentation
Canopy and Ground Cover	Evapotranspiration
Successional Stage	Global
Total Biomass	Carbon Cycle
	Total Biomass Production

Spatial Data Sets

- **The Spatial Data Set (SDS) concept was devised to allow DIAS Parameters to express the spatial dependencies needed for environment objects**

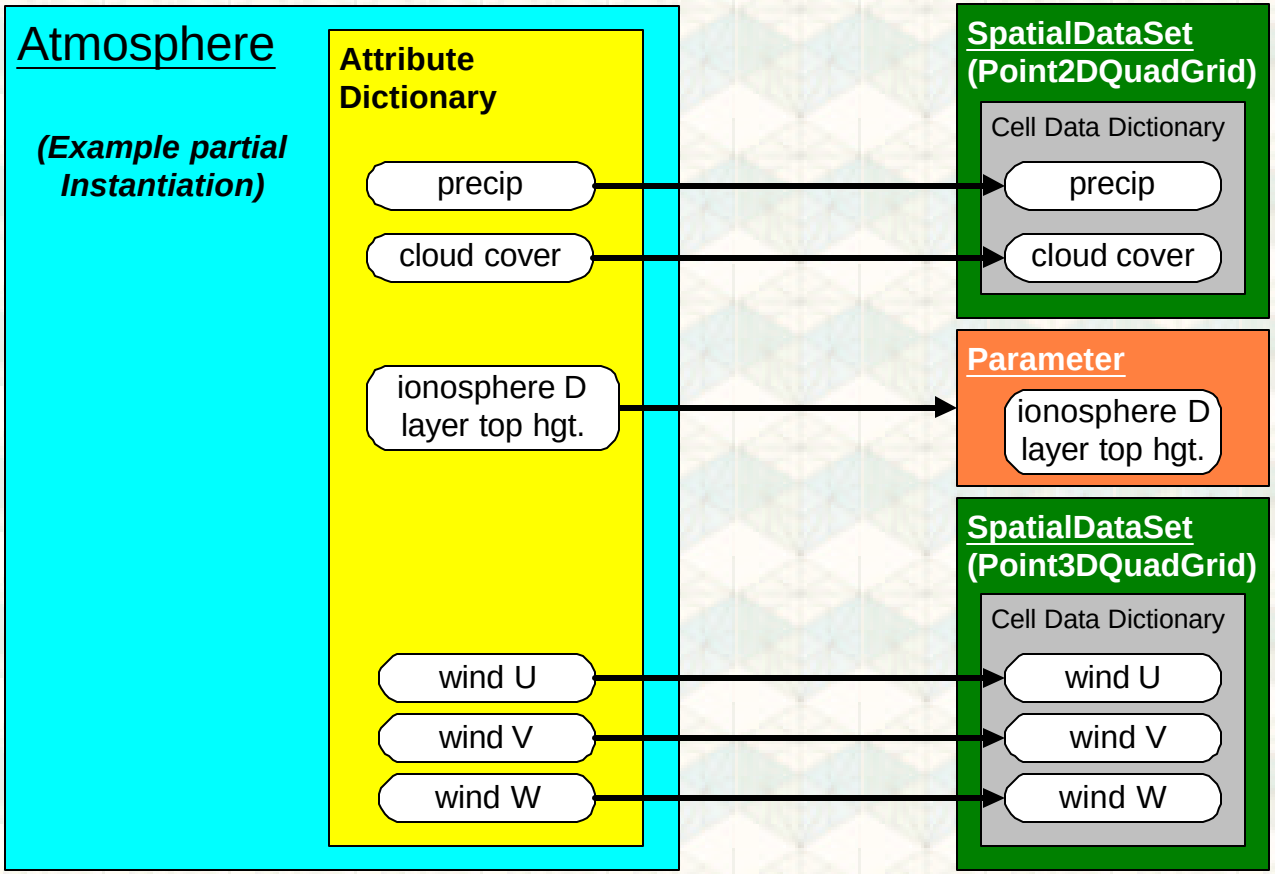
- **SDS can extend object attribute specifications to include spatial dependencies**

  Parameters that are object attributes can actually reside physically in an SDS. These attributes can still be accessed by the object in much the same way as its normal scalar attributes.

- **SDS can aid in the compression of spatial data**

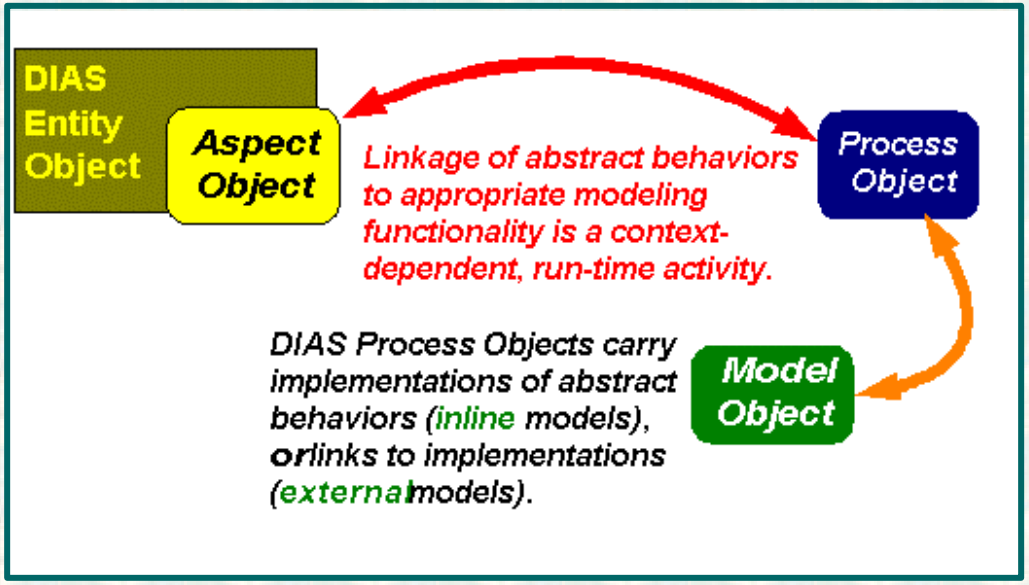
  Space is saved by requiring only one specification of a spatial partitioning scheme (SDS) to serve many parameters that have the same spatial layout, even if these parameters are aspects of different objects.

SDS Application Example: DIAS Atmosphere Object



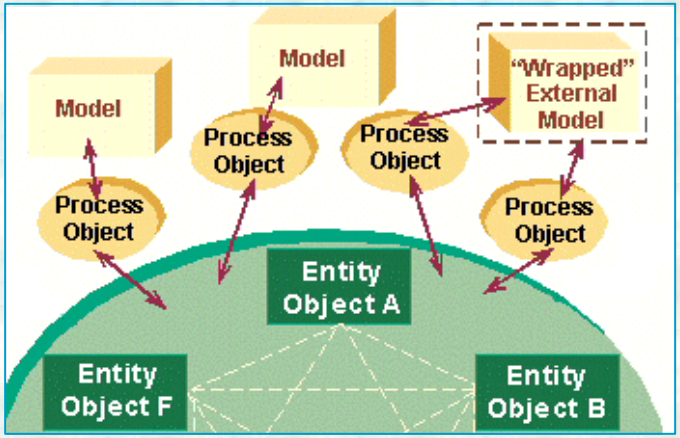
DIAS Abstracts Entity Object Behaviors

- **DIAS is extensible:**
  - **Object class definitions contain an abstract description of the various aspects of the object's behavior via their Aspect (of Behavior) objects (the "what"), but no implementation details (the "how")**



DIAS Process Object

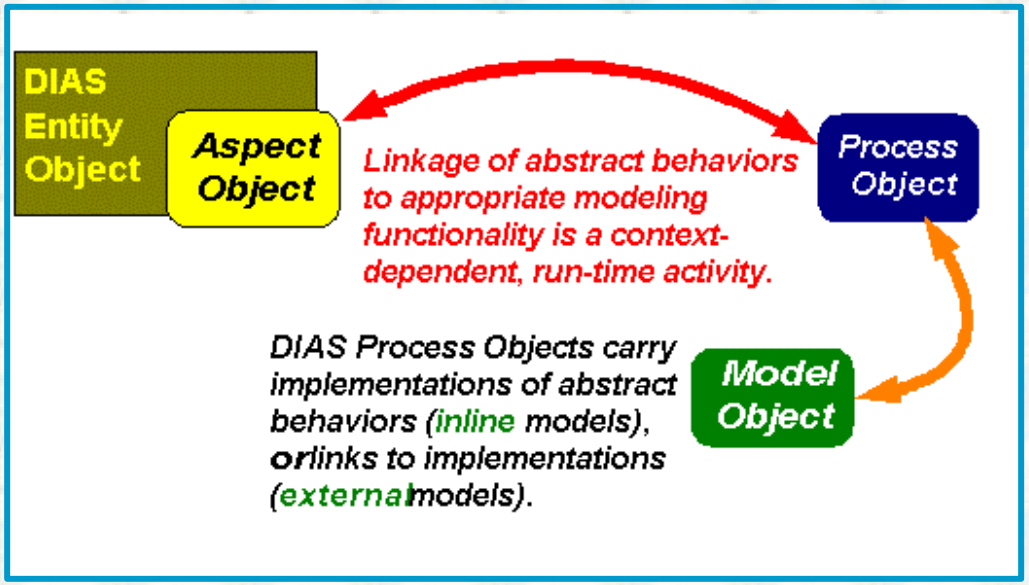
- The DIAS Process object provides context-specific behavior for an Entity object.



- There is one DIAS Process object for each Aspect in a simulation.
  - Entity declares behavior abstractly through Aspect objects
- In the case of external (e.g. legacy) model integration, a Process object would be associated with a specific subroutine in the external model source code.
- For internally coded DIAS models, the Process object is connected to a specific Model object method that contains the calculation and thus provides the Entity behavior.

DIAS Process Object (Cont.')

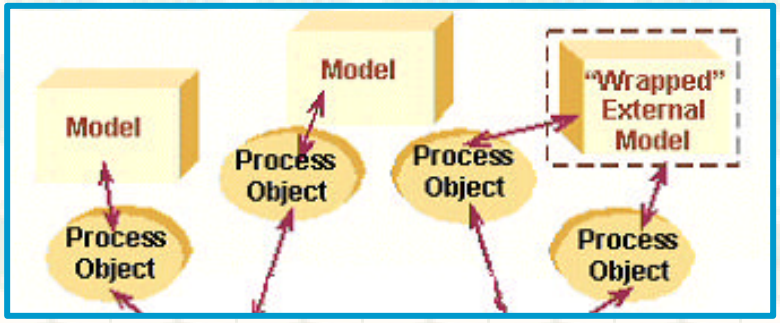
- **Process object is the only object with knowledge of both the Entity "world view" and the Model (or external) "world view".**



- **Responsible for all data translation, unit conversions**
- **Data aggregation/disaggregation issues**
- **Controls the packaging of Entity data needed as input to models, as well as the unpackaging of model output data and its distribution to the Entities**

DIAS Model Object

- The DIAS Model object
  - Contains one method per Process object it serves
  - Responsible for calculations for each Process



Internal DIAS models:
DIAS Model object methods contain the actual model code (written in Java) that performs the calculation.

External model:
Model methods call out to the Model Controller to execute an external model subroutine.

GeoViewer: An Object Oriented GIS Toolkit

- Dynamically coupled to underlying intelligent objects, their functionality and data
- GIS toolkit for object-oriented systems
- Runs as a stand-alone product, extended with additional analysis functionality, or embedded into another framework
- GIS functionality: Navigate, create, query, view, and manipulate objects
- Data translator architecture: Provides a common framework for ingesting any data
- Embedded in other architectures:
  - DIAS (Dynamic Information Architecture System)
  - JWARS (Joint Warfare System)
  - DOOGIS (Dynamic Object-Oriented Geographic Information System)

GeoViewer Extended to the World Wide Web

Dynamic Object-Oriented Geographic Information System (DOOGIS)

- Java client runs in web browser or as an application
- GeoViewer spatial database engine is used as server
- Spatial and domain objects are sent to the client via CORBA (Common Object Request Broker Architecture)
- It allows analysis to be performed on client or server

Uses

- Advanced Driver and Vehicle Advisory Navigation Concept (ADVANCE)
  - Produced for the Intelligent Transportation System, the ADVANCE project determined if the real-time information given to motorists would help them avoid congestion and improve the quality of their trip
- NABIR Data And Information Management System (NADIMS)
  - This Web-based spatial information management system supports cost-effective sharing of data among DOE's Natural and Accelerated Bioremediation Research (NABIR) Program investigators

DIAS Areas of Application

DIAS has been under development and applied to applications for a series of governmental and private sector sponsors with very diverse needs

Examples of DIAS-based simulation systems completed or in progress:

Integrated land management and land use planning at military training bases

Health care: integrated physiological, clinical, and logistical simulations

Integrated oceanic systems simulation

Avian population dynamics for an endangered species

Agricultural and social sustainability of ancient urban centers

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Integrated Ocean Architecture (IOA)

a virtual marine environment
within which diverse ocean domain processes can interact,
to provide support
for analysis and operations

- **Funded by the Department of Defense Modeling and Simulation Ocean Executive Agent:**
- **Argonne's IOA partners**
  - **US Naval Research Laboratory, Stennis Space Center**
  - **US Army Corps of Engineers Waterways Experiment Station**

Argonne POC: John Christiansen
Phone: (630) 252-3291
Email: jhc@anl.gov

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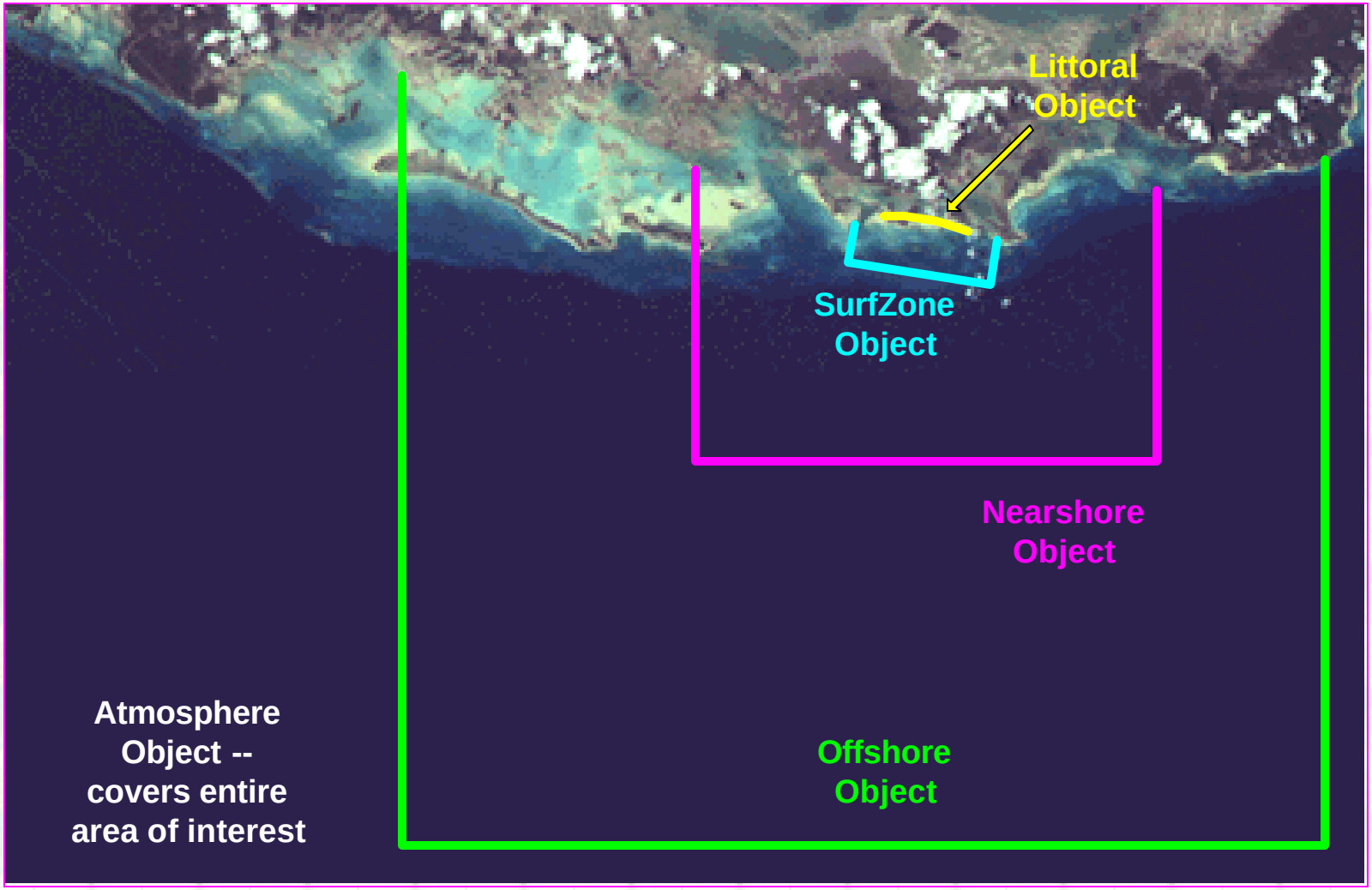
Notional Spatial Layout of IOA Domain Objects



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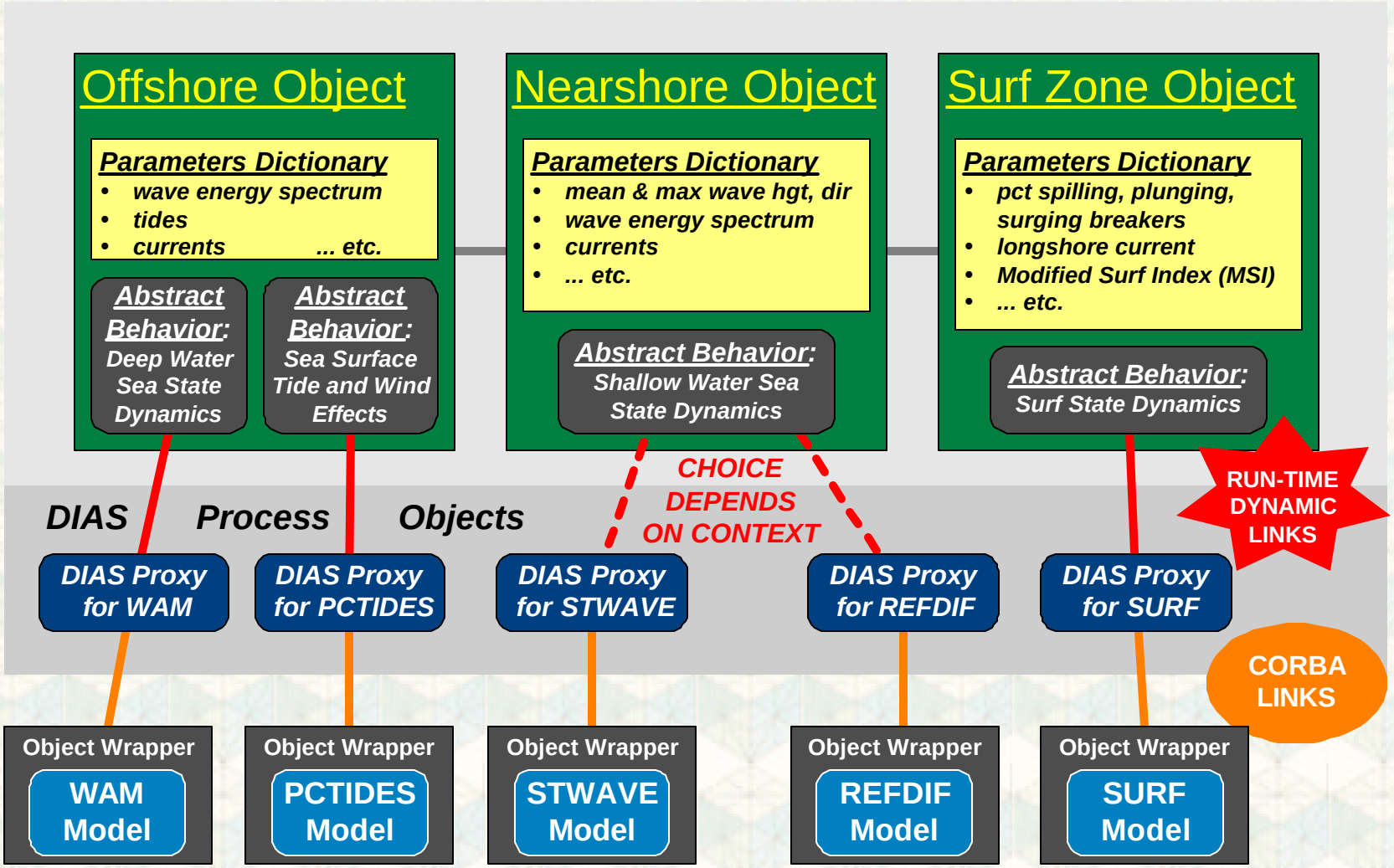
IOA Object-Model Connections in DIAS



Computational Archaeology: Virtual Ancient Mesopotamia

ANL/DIS is collaborating with the University of Chicago's Oriental Institute to build and exercise a dynamic object model of ancient Mesopotamian urban/agrarian life.

The model

Addresses the complex dynamics of ancient Mesopotamian urban centers; in particular their sustainability, growth, or decline in the face of increasing environmental stress

Represents natural processes (e.g., weather, crop growth, hydrology) and societal processes (e.g., farming practices, kinship-driven behaviors) interweaving on a daily basis across 200-year scenarios

Argonne POC: John Christiansen
Phone: (630) 252-3291
Email: jhc@anl.gov

Work continuing under new NSF Biocomplexity grant

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Integrated Installation Natural Resource Management

Object Oriented – Integrated Dynamic Landscape and Analysis System (OO-IDLAMS)

- **Vegetation Dynamics Model**
  - Represents natural physical succession AND forest spread processes
- **Henslow's Sparrow Habitat Model**
  - Reimplemented as an Environmental Systems Research Institute (ESRI®) application
- **Military Training and Land Management Models**
  - Represents Fort Riley land use and land management plans: Training, Burning and Planting

Funded by Strategic Environmental Research and Development Program (SERDP)

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Avian Population Dynamics Model for the Red-cockaded Woodpecker

- **Sponsor: USACE, Engineer Research & Development Center (ERDC) – Construction Engineering Research Laboratory (CERL) and Fort Benning, GA**

National Wildlife Federation: http://www.nwf.org

- Implement an agent-based, spatially explicit population model for the RCW based on published model by Letcher et al. (1998)
- Implement the RCW model generically within an object-oriented framework (Dynamic Information Architecture System [DIAS]), which can provide:
  - Reuse
  - Modularity
  - Expandability
  - Integration with other models

Benefits of an OO Approach to Model Integration

- **Dynamics:**
  - Allows the simulation to reflect the dynamics of living ecosystems, land uses, and land management activities
- **Reusability:**
  - Allows for the integration of existing legacy-type models without a lot of reworking
  - Encourages the development of object libraries that contain a large number of reusable objects to represent a wide variety of natural and artificial elements of the environment
  - Reduces the long-term cost of re-developing objects and technologies
- **Flexibility:**
  - Easily evolves, incorporating new data, concepts, and technologies
  - Supports software applications that can operate at multiple spatial and temporal scales

DIAS and Interagency Collaboration

- **ANL has been member of MOU Framework Technology Working group to help to facilitate cross-agency collaborative efforts**
  - DIAS team has been facilitating the Model Execution subgroup
  - Working group includes various agencies working in the area of model integration with representation from EPA, DoD, USGS, ARS, PNNL, and NOAA