NATIONAL
TEST & EVALUATION
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The Application of Synthetic Natural Environments for M&S Support of Testing Net-centric Federations

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Purpose

- To examine the considerations to be addressed by the tester in the development of a synthetic natural environment (SNE) for use with M&S federations that are supporting a test event.
- Objectives
  - State the significance of SNE to M&S and T&E
  - Describe how a SNE is developed
  - Describe how SNE data are exchanged
  - List examples of SNE applications in LVC for T&E
  - State how SNE implementations may be assessed for T&E adequacy

The tester must be convinced that the synthetic natural environment is a valid representation of the real world in which the system under test must operate.

Outline

- Introduction
- Environmental Data Considerations
  - time, position, lines of sight, propagation and weather
- Environmental Effects
  - EDCSS
- Integration of live, virtual and constructive elements.
- Exchange of SNE Data
  - SEDRIS
- Synthetic Natural Environments & Testing

Introduction

- For the T&E Community, Net-centric includes M&S Federations:
  - Testing Net-centric Applications
    - Battle Management
    - Command & Control
    - Tactical Communications and Processors
  - Using Net-centric Capabilities to Facilitate the Conduct of Tests
    - Networks
    - Data Repositories
    - Data Discovery
    - Data Mediation

Introduction (Continued)

- DOT&E Initiatives, Nov 24, 2009
  - **Plan realism in early testing**
  - Only approve TEMPs with reliability growth curve
  - Specify producer's risk in test plans
  - Monitor demonstrated/predicted/potential reliability

Early Testing Requires M&S and
M&S Requires Synthetic Natural Environments

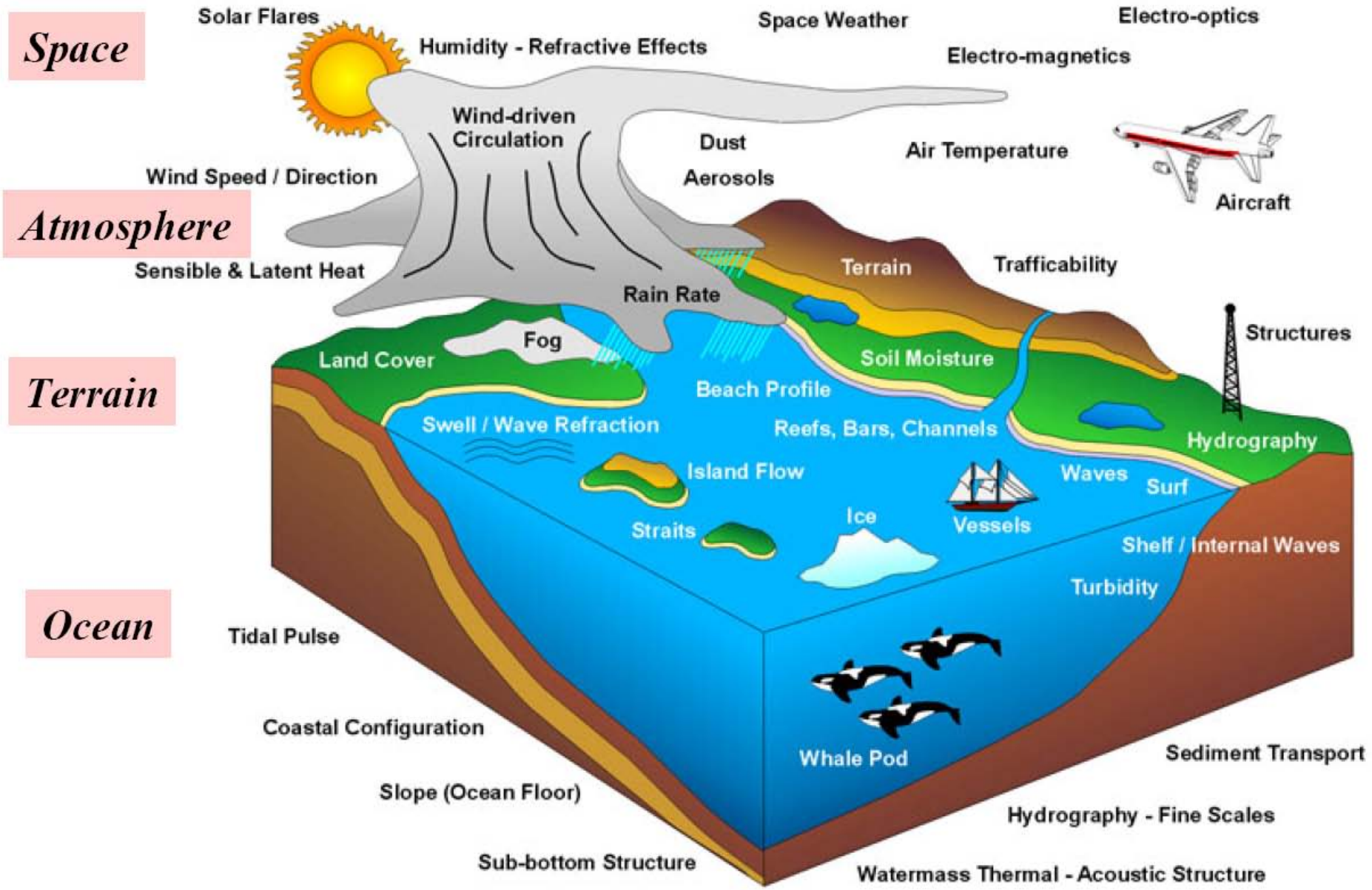
Introduction

- Historic Reluctance of Test Community to Use M&S to Support T&E
  - Skeptical of Results
  - Questionable Algorithms
  - Poor Representation of Environment . . .
- Looking Forward—M&S is an Essential Element of T&E
  - High-power Computers & Algorithms
  - Systems too Big to Test in Field
  - No Way to Field Coalition and Opposing Forces

Introduction

- Models and Simulations Exist in a “Virtual World”
  - The Synthetic Natural Environment (SNE) is their “Virtual World” or “Reality”
  - For T&E the SNE must be an Accurate Representation of the Real World
- Must Also Represent Interactions Among Elements of SNE—***not*** just Static Data

Elements of the Natural Environment



Definitions

- Synthetic Natural Environment (SNE)
  - Representation of Physical World in which Models and Simulations of Systems Exist and Interact.
- Environment
  - The texture or detail of the natural domain—Terrain, Weather, Day, Night, Cultural Features, and Processes that Influence their Effects on a system

Synthetic Natural Environments

- May be Real or Imaginary
  - **Real** ☞ **Observed** Physical Conditions
  - **Imaginary** ☞ **Extremes** of Design Envelope
  - **Imaginary** ☞ **Game** or **Exercise** Environment
- For Live-Virtual-Constructive (LVC) Events SNE Must Represent Actual Field Environment
  - Safety
  - Realism
  - Assessment

Environmental Data Considerations

- Accuracy and Precision
- Consistency
- Scalability
- Data Sources
- Data Conversion
- Continental Drift
- Time

Accuracy and Precision

- Accuracy is how close a measured value is to the **actual (true) value**.
- Precision is how close the measured values are **to each other**.
- Examples of Precision and Accuracy:

Low Accuracy
High Precision

High Accuracy
Low Precision

High Accuracy
High Precision

Accuracy and Precision

- What is being measured?
  - Driven by Metrics of Interest
- What level of accuracy is required?
  - Determines the Required Precision and Accuracy of Individual Elements of Algorithm
- What level of precision is available?
  - Historical Data Limitations
  - Notional or “Standard” Data

Consistency

- Are Environmental Effects Consistent Across all Domains? . . .
  - Wind Effect on Waves
  - Precipitation Effect upon Terrain
  - Weather Effects on Electromagnetic Propagation and Visibility
- For T&E cannot Ignore Interactions
  - Use of “Steady State” or Manual Manipulation of the Data Set Introduces Errors

Scalability

- Ability of Environmental Data Set to Support Simulation Federates using Different
  - Formats
  - Units
  - Levels of Precision or Resolution
- Driven by Tactical Data Processors being Simulated
- Deals with Interpolation/Extrapolation of Source Data

Data Sources

- Use Authoritative Sources
  - National Geospatial-Intelligence Agency (NGA)
  - National Oceanographic and Atmospheric Administration (NOAA)
  - USAF Combat Climatology Center (14th WS)
  - U.S. Geological Survey (USGS)
  - Allied & Coalition Agencies
- Use Care when Synthesizing Data
  - Traceable to Common Reference/Metric
  - Correlated to Tactical Data Processor Inputs

Data Conversion

- Conversion of Units
  - National Institute of Standards and Technology (NIST)
  - Base Conversions on Standards at Time Data Collected
    - Time
    - Distance
    - Mass

1959 Change in Definitions:
1” = 25.4000508… mm ➔ 1” ≡ 25.4 mm
1 # = 0.453 592 37… kg ➔ 1# = 0.453 592.4277 kg

- Conversion of Coordinate Systems
  - Legacy Systems versus WGS-84 Geoid
  - GEOTRANS
    - NGA
    - Absolute Error (WGS-84) ≤ 23m Horizontal & 18m Vertical
    - Earth Only
  - Spatial Reference Model
    - SEDRIS (ISO/IEC-18026)
    - Fire-control Accuracy
    - Geodetic and Celestiodetic

Continental Drift

- Due to Plate Tectonics, the Land is Moving with Respect to the WGS 84 Reference Datum
  - For Geodetic Accuracy, Specify Date of Observation/Calculation when Referencing Coordinates
  - Also must Correct GPS Positions

Continental Drift Impacts

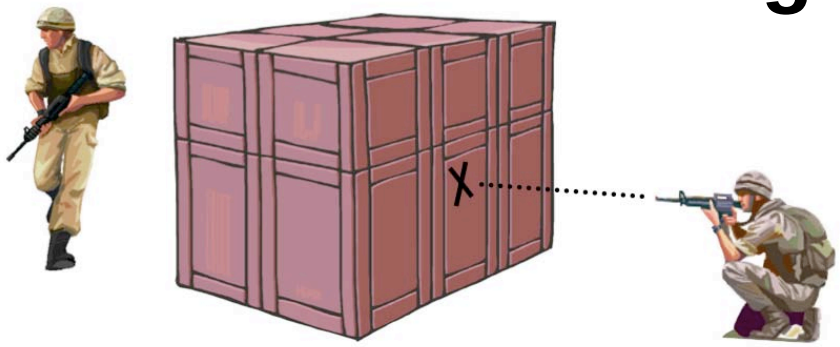
After Action Report Impact for Live Events

- 1m tracking error + 1.9m terrain error = up to 2.9m total error
  - (root sum square ~2.1m)
- 2.9 meters could be the other side of a building

Source: Susanne Riehemann, SRI International - SISO 2009 Fall SIW – RED Workshop

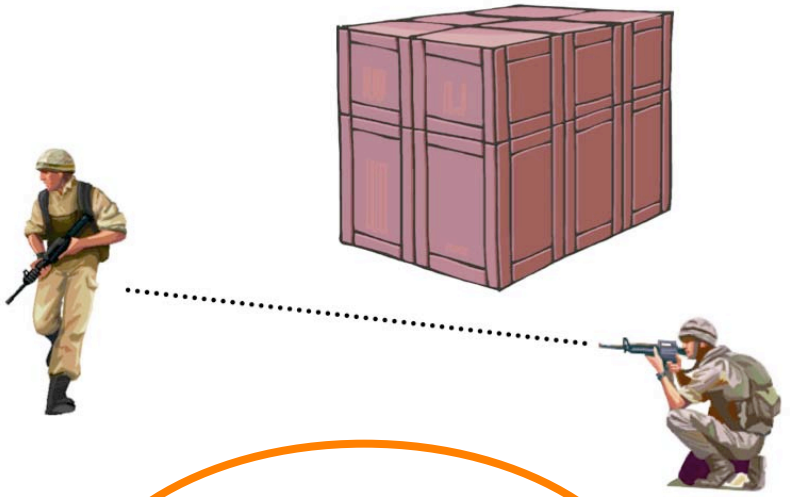
Continental Drift Impact

Interoperability Impact: Line of Sight Fair Fight Issues



Live OPFOR hiding behind real terrain feature

can't be seen by Live Blue combatant



Virtual Blue combatant has no problem seeing avatar for Live OPFOR

Source: Susanne Riehemann, SRI International - SISO 2009 Fall SIW – RED Workshop

Time

- Local Time (LCT)
- Coordinated Universal Time (UTC) or (GMT)
- Global Positioning System Time (GPS)
- Long Range Navigation Time (Loran-C)
- Temps Atomique International (TAI)

An example of time conversions for October 8, 2009

System	**Time** (y-m-d h:m:s)	**Day**	**Date**	**Location/Epoch**
Local	2009-10-08 **12:23:11**	Thursday	Day 281	Time-zone UTC-4 (EST)
UTC	2009-10-08 **16:23:11**	Thursday	Day 281	MJD 55112,6826
GPS	2009-10-08 **12:23:26**	Week 1552	40406 S	Cycle 1 week 0528 Day 4
Loran	2009-10-08 **12:23:35**	GRI 9940	353 s Until	Next TOC 16:29:04 UTC
TAI	2009-10-08 **12:23:45**	Thursday	Day 281	34 Leap Seconds

Time Step/Refresh Rate

- Data Supplied in Discrete Intervals
  - Interpolation Required for Use
  - Ensure Intervals Small Enough for Required Precision
  - Ensure Data Supports Required Simulation Accuracy
  - Check Boundary Conditions
- Data Provided as a Function
  - Validate Algorithm across Range being Utilized
  - Check Precision
  - Check Processing Time to Return Values

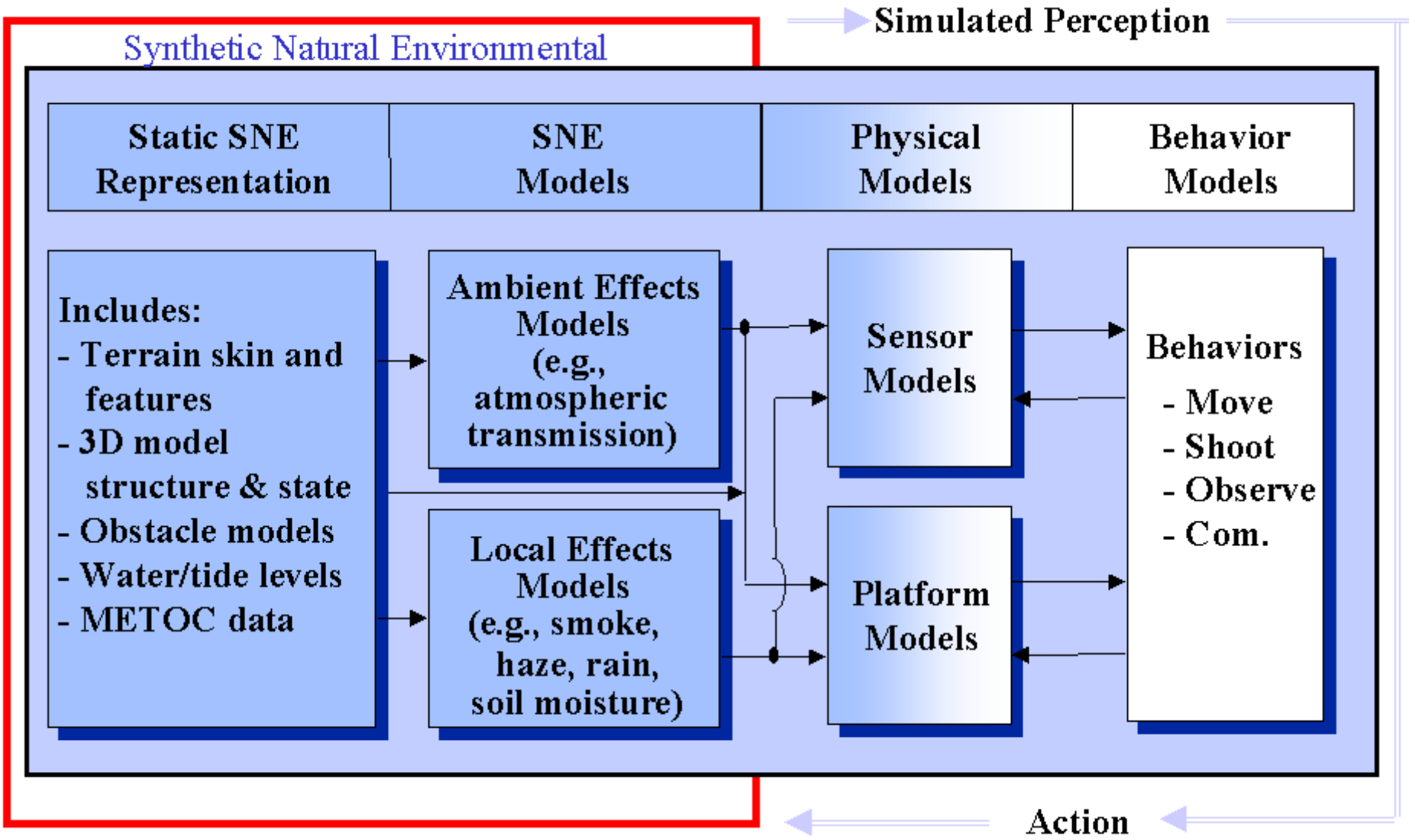
Time in LVC Events

- Synchronous versus Asynchronous
  - Most Tactical Data Processors Operate Asynchronously in Operational Situations
    - Limited by OpArea Extent & Tactical Comms
    - Link-16 & CEC have Limited Range
  - Distributed, LVC Events Can Span Continents
    - Synchronicity Prevents Errors from “Run-ahead”
    - Messages Remain in Sequence for Valid Event
    - Event Protocol Maintains Synchronicity by Controlling Execution (e.g.: HLA)
  - Synchronicity Affected by Transport Medium
    - Line of Sight, Fiber/Copper, SATCOM
    - Travel/propagation Time

Correlation of Phenomena

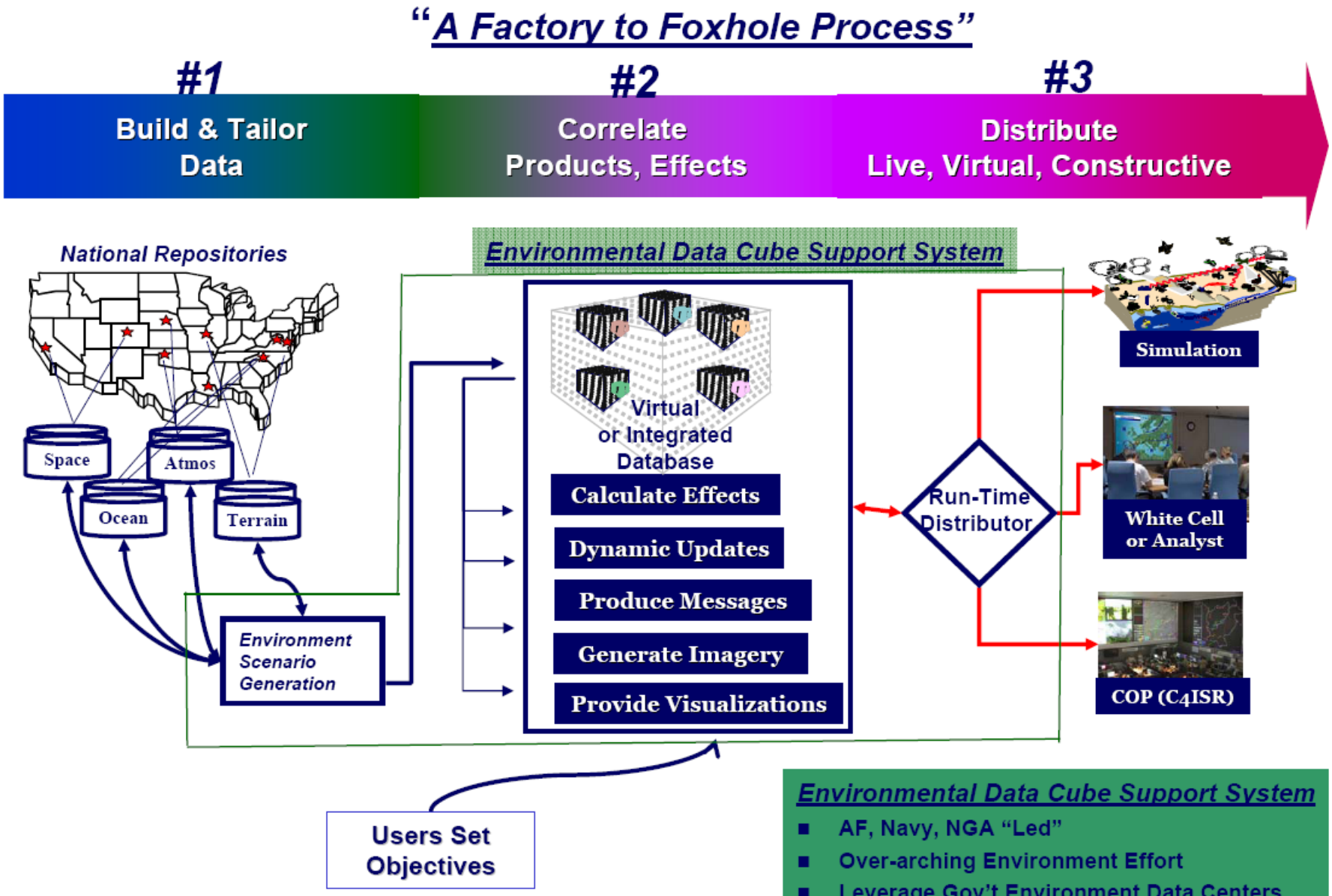
- The SNE is Dynamic NOT Static
- Phenomena Interact with Each Other
- SNE Responds to Simulation
  - Weapon Effects
  - Infrastructure Changes
  - Jamming
- Validate SNE Phenomena Interactions
  - In Terms of Performance Metrics for Test
  - For Correct Representations to Federates

The Synthetic Natural Environment



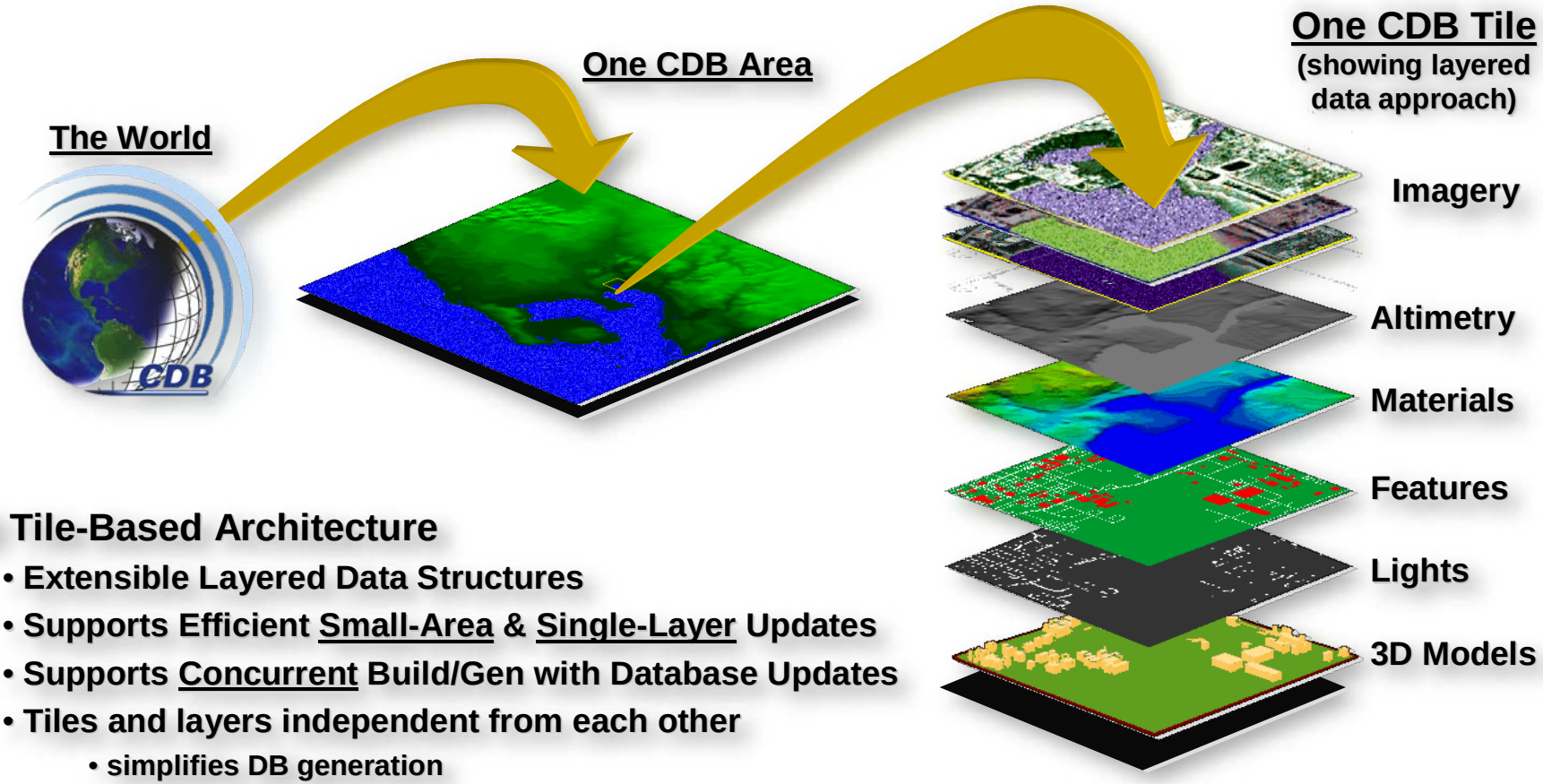
Source: Web-based Technical Reference on Simulation Interoperability, Michael D. Proctor (Editor).

Environmental Data Cube Support System



Source: USAF ASNE Brief to the Defense M&S Conference, March 2008

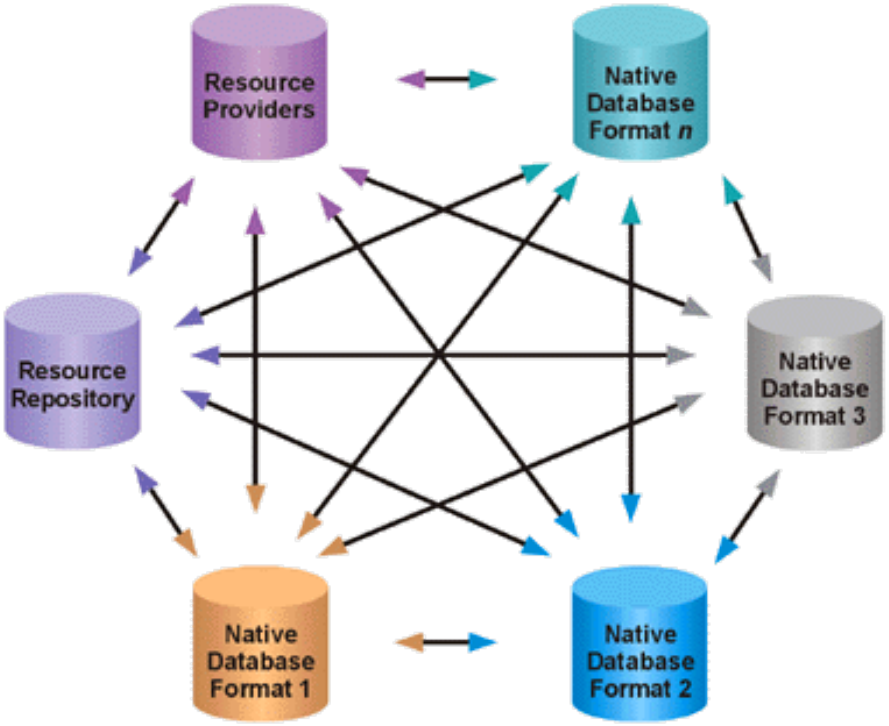
SOCOM Common Database

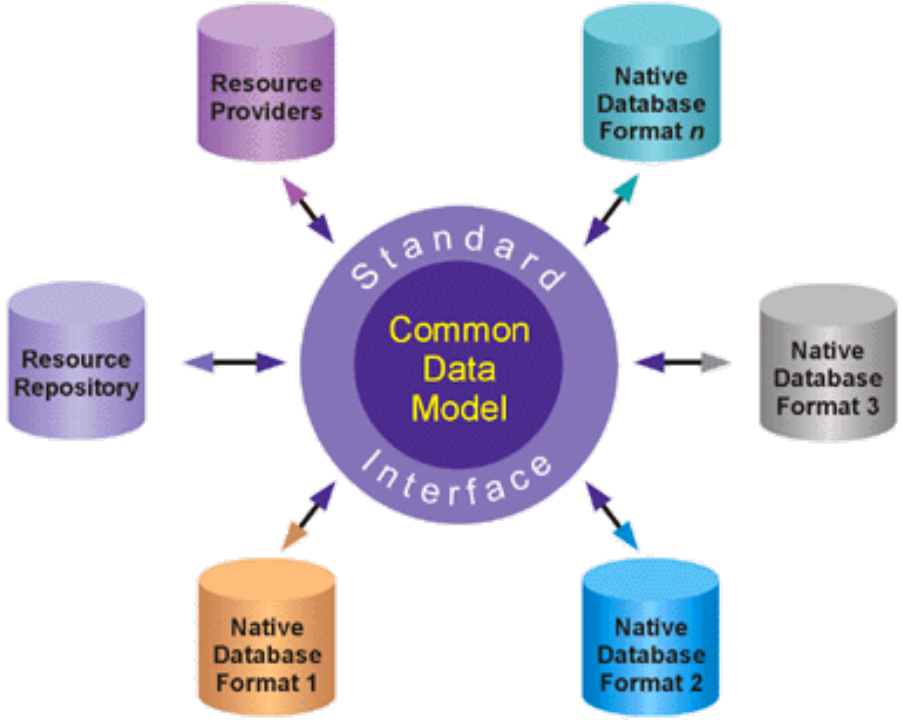


CDB Tile-Based Architecture

- Extensible Layered Data Structures
- Supports Efficient Small-Area & Single-Layer Updates
- Supports Concurrent Build/Gen with Database Updates
- Tiles and layers independent from each other
  - simplifies DB generation

Point-to-Point Distribution and Data Mediation





- Expensive and time consuming
- Often unreliable and non-interoperable
- Unique conversion needed for each source
- Increase in sources geometrically increases number of conversions

- Significant reduction in conversion cost
- Higher reliability, interoperability, integration, and reduction of correlation error
- Common and open standards, tools, and software reuse

Producer Formats

- Three General Types
  - Geographic
  - Imagery
  - 3-D Models
- For Synthetic Environments
  - User Must Consolidate into Single Structure
  - Features & Phenomena Layered in Database

SEDRIS Standard Applications

SEDRIS Data Representation Model (DRM)

Gives the constructs to express and "shape" environmental data

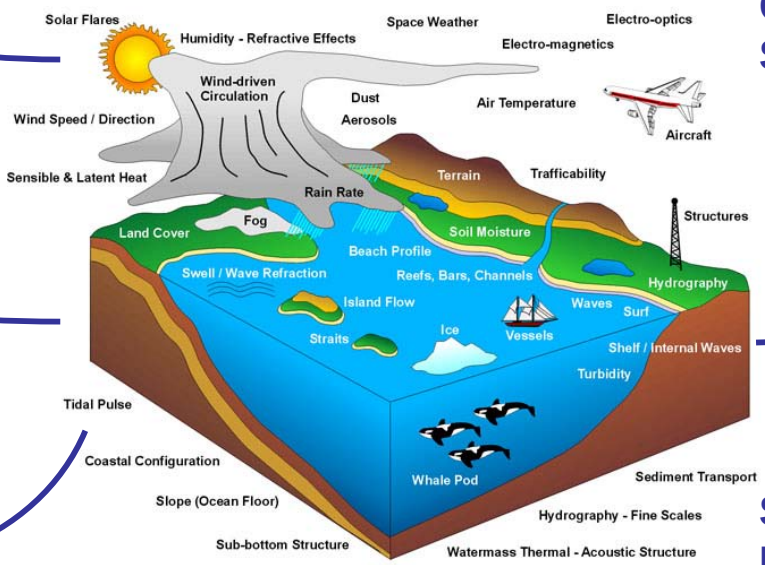
DRM, EDCS, and SRM are used together to describe the environment

Environmental Data Coding Specification (EDCS)

Names and identifies types of objects in an environmental description

SEDRIS Spatial Reference Model (SRM)

Makes the environmental description readable in other coordinates



SEDRIS Application Program Interface (API)

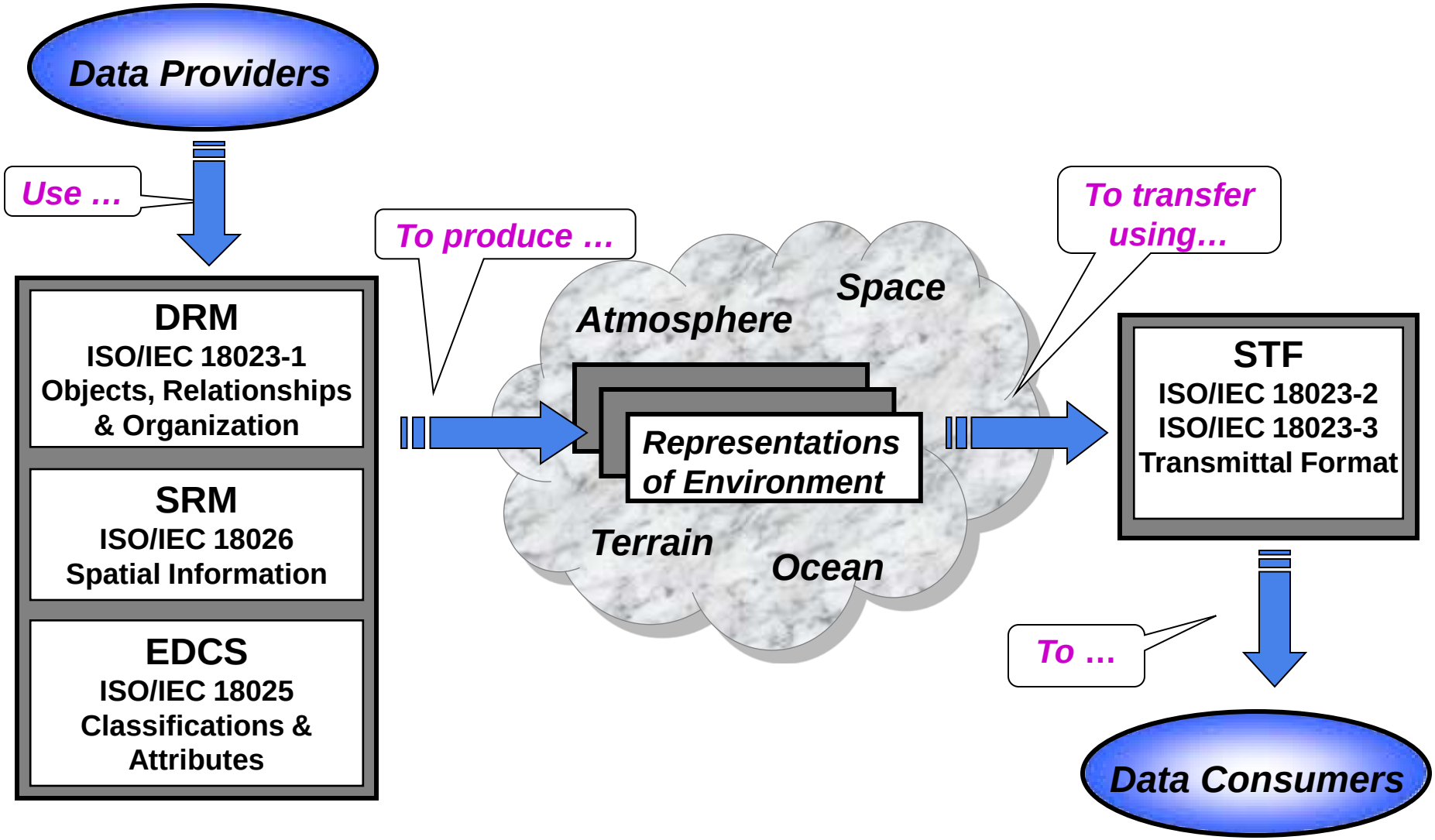
Provides software access to individual elements of environmental data

API and STF are used to exchange the description of the environment

SEDRIS Transmittal Format (STF)

Transfers complete "chunks" of environmental data

How SEDRIS is Used -



Data Verification, Validation and Certification

- Definitions
- Scale/resolution
- Accuracy of Conversions of Units
- Time step/refresh rate
- Correlation of Phenomena
- Type of Synthetic Data
  - Representation of the Live Environment
  - Representation of a Notional Environment
  - Representation of an Imagined Environment

Data Certification

- Certification of a data set is the statement by its developer that it meets specified accuracy and precision criteria and has been validated against accepted standards.
- On the user's side of the equation, the data are certified for use with a specific M&S application. (Part of the accreditation process)

Synthetic Natural Environments and T&E

- Requirements for SNE are Driven by the M&S Requirements for T&E Support
- SNE Incorporates Relevant
  - Environmental Factors
  - Interactions
- SNE Accuracy and Precision
  - To Support T&E Objectives
- Realistic Test Environment
  - Test Boundaries of Operating Environment
  - Stress System—Areas not Possible in Field Test

Testing the Net-centric System

- Information Operations Network Analysis Model (IO/NA)
  - To optimize the planning and execution of operational tests, and extrapolate beyond available test conditions to support operational evaluations
  - The IO Range and other communities use it for training, experimentation
  - Provides three major capabilities:
    - **N*etwork Visualization***
    - ***Network Scenario Development***
    - ***Network Analyzer***
- Synthetic Natural Environment—Incorporates:
  - Environment at all Nodes
  - Inter-node Propagation Effects
  - Physical Vulnerabilities to Attack
  - Conditions at Alternate/Back-up Sites

Testing Systems in a Net-centric Environment

- Test by Relevant Use Case
  - The Internet & GIG Considered a “Given”
    (System Operating in Net-Centric Environment)
  - Scenario Must Stress/Test Key Performances
- Preload Scenario Environment at All Nodes
  - All Relevant Factors Included
  - Ensure all Interactions Verified & Validated
- Test Capability of Net to Support System
  - Correctly Report/Propagate Changes (Weather …)
  - Measure Data Flows and Latencies
  - Ability of Nodes to Remain Synchronized with Event
  - L-V-C Units have Common Operating Picture

Summary

- Models and Simulations are Essential for the T&E of Net-centric Systems
  - Systems are too big to test in lab
  - Can’t take operational system down for test
- A Valid Synthetic Natural Environment is Required for Valid M&S Results
  - Replicates Field Operating Conditions
  - Able to Stress System to Design Limits
- Tools are Available to Support SNE Development