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Open Software Standards for Next-Generation Community Satellite Software Packages

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Outline

- The Challenge: Developing Next-Generation Systems
- The Solution: Open Standards for Community Processing
- Building an Open Standard
  - Componentized Architecture
  - Metadata Model
  - Data Fusion
  - Choosing Appropriate Interfaces
- Prototype Implementation: AER Algorithm Workbench
- The Path Forward

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The Challenges

- New satellites and instruments offer new capabilities but with increasing complexity, data volumes and data rates
- Speed introduction of new and improved algorithms
- More complex algorithms including data fusion from multiple instruments and other data sources
- Tighten the Research-to-Operations-to-Research loop
- Broaden the algorithm developer community
- Add increasing capability for collaboration
- Flexibly employ new computing technologies such as cloud computing

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Solution: Open Standards for Community Processing

- **Overall Objective**
  - Open frameworks that allow easy integration and test of complex, high-performance algorithms from multiple contributors
- **Support R2O2R Cycle**
  - Simplify transition of software from development to operational environments, as well as permitting new and updated software to be tested in development environments and returned to operations
- **Flexible Integration of Complex Algorithms**
  - Powerful tools for integration of algorithms across multiple missions and infrastructures, including modification of spectral characteristics and cadences
- **Reduce Manual Configuration**
  - Complex and evolving systems require minimized manual intervention to prevent error and reduce overhead

Open interfaces facilitate robust interoperable systems

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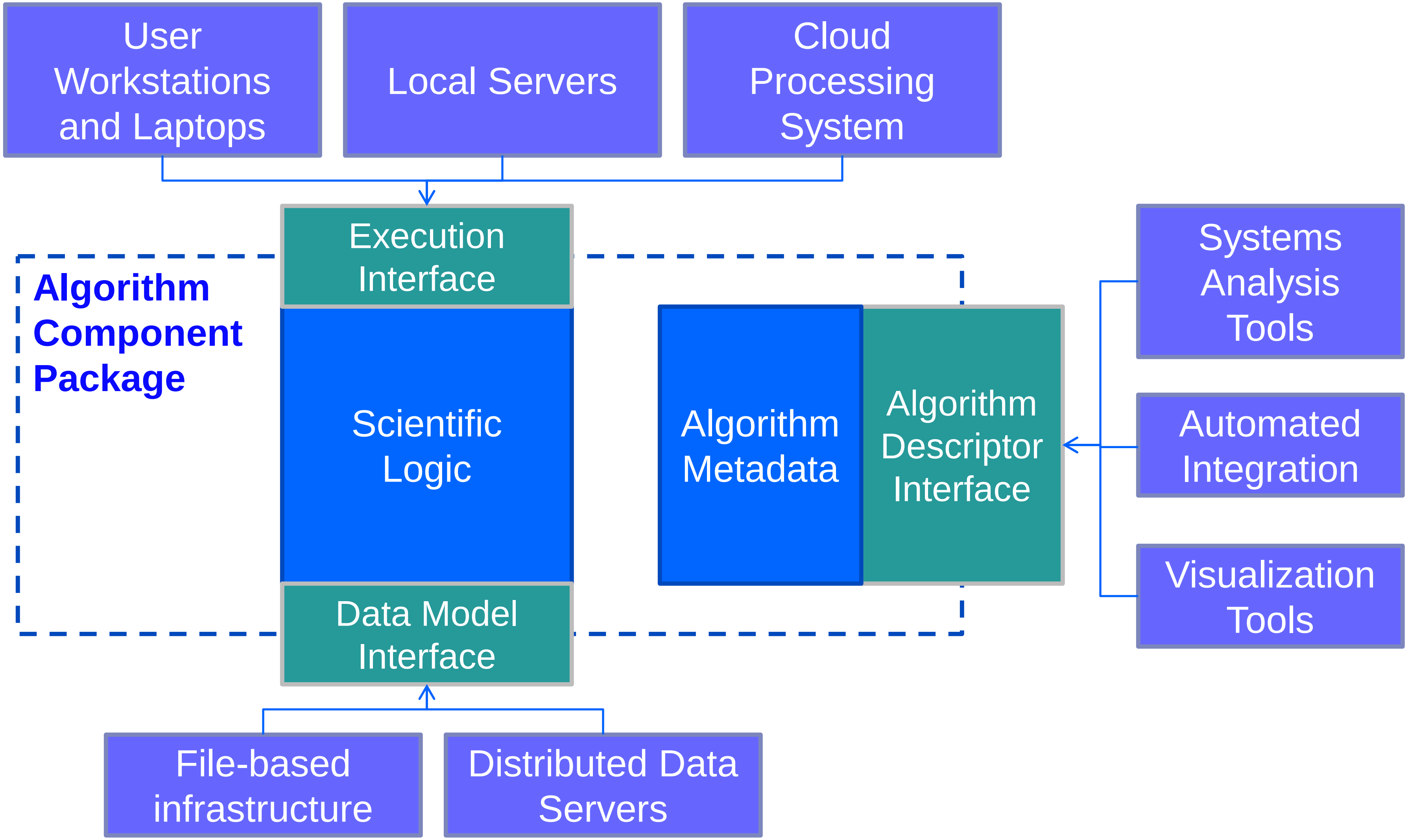
Key Solution Elements

- Algorithm component architecture
  - Algorithms must be transferable to different environments
  - Well-defined interfaces for compatibility with a broad range of infrastructure and support software
- Metadata model
  - Describes key component characteristics in machine-readable form
  - Complete system configuration is expressed as data-driven model
  - Layered design facilitates adaptation to different environments
- Data Fusion controller
  - Coordinates algorithm and system configurations to schedule execution
  - Has generic interfaces for monitoring multiple asynchronous data streams in varied environments

Algorithm Component Architecture



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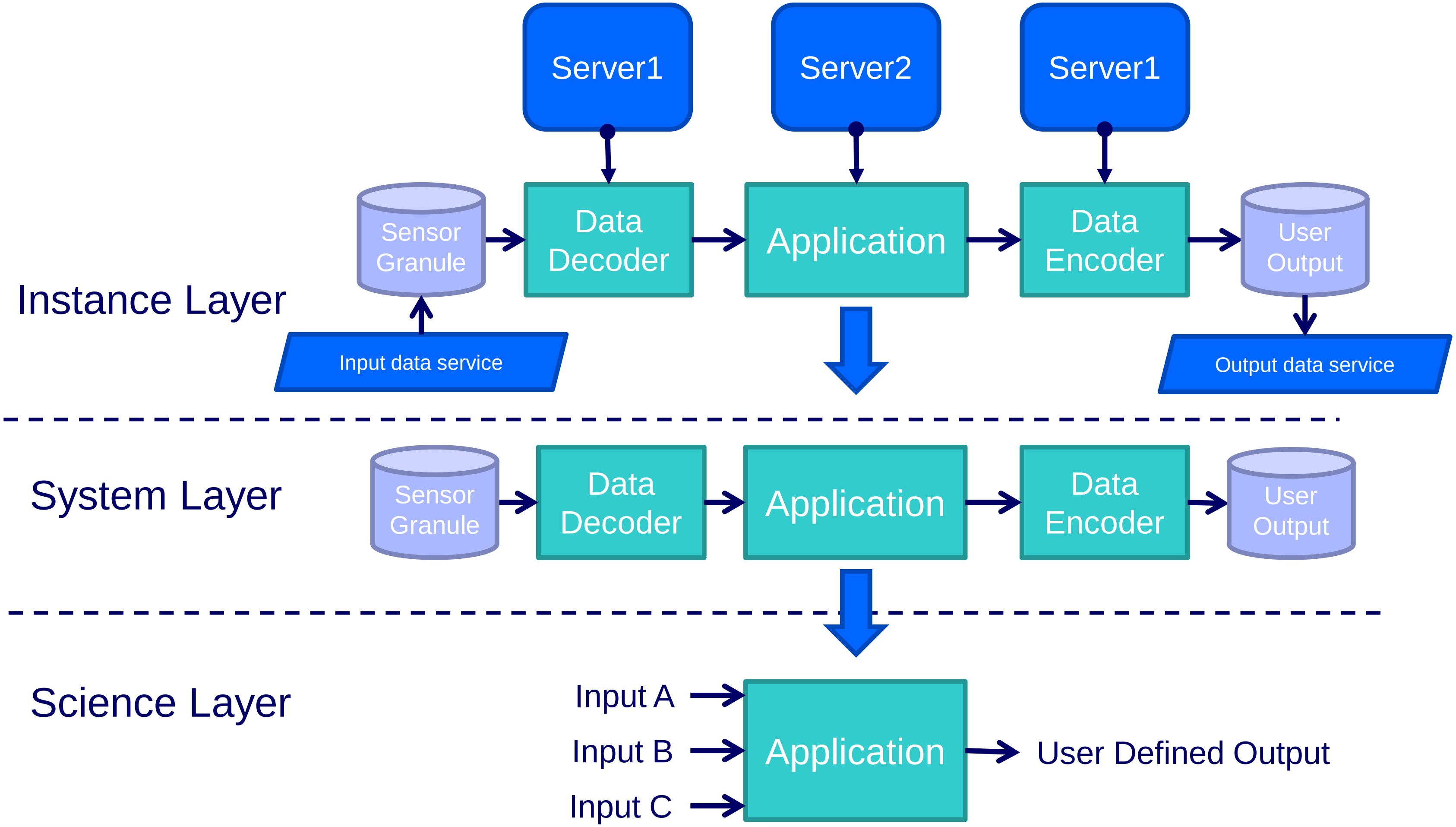
Component-Based Design

- All data processing elements of the system are encapsulated as components
  - Data processing algorithms, importers, and exporters are wrapped in common interfaces
  - Standard approach allows portability
- Components provide complete package for integration
  - All software, accessed using standard interfaces
  - Metadata describing functionality
- Components are reusable
  - Multiple processing infrastructures, workstation vs. server vs. cloud
  - Adapt to new platforms and sensors
  - Use common tools for visualization and analysis

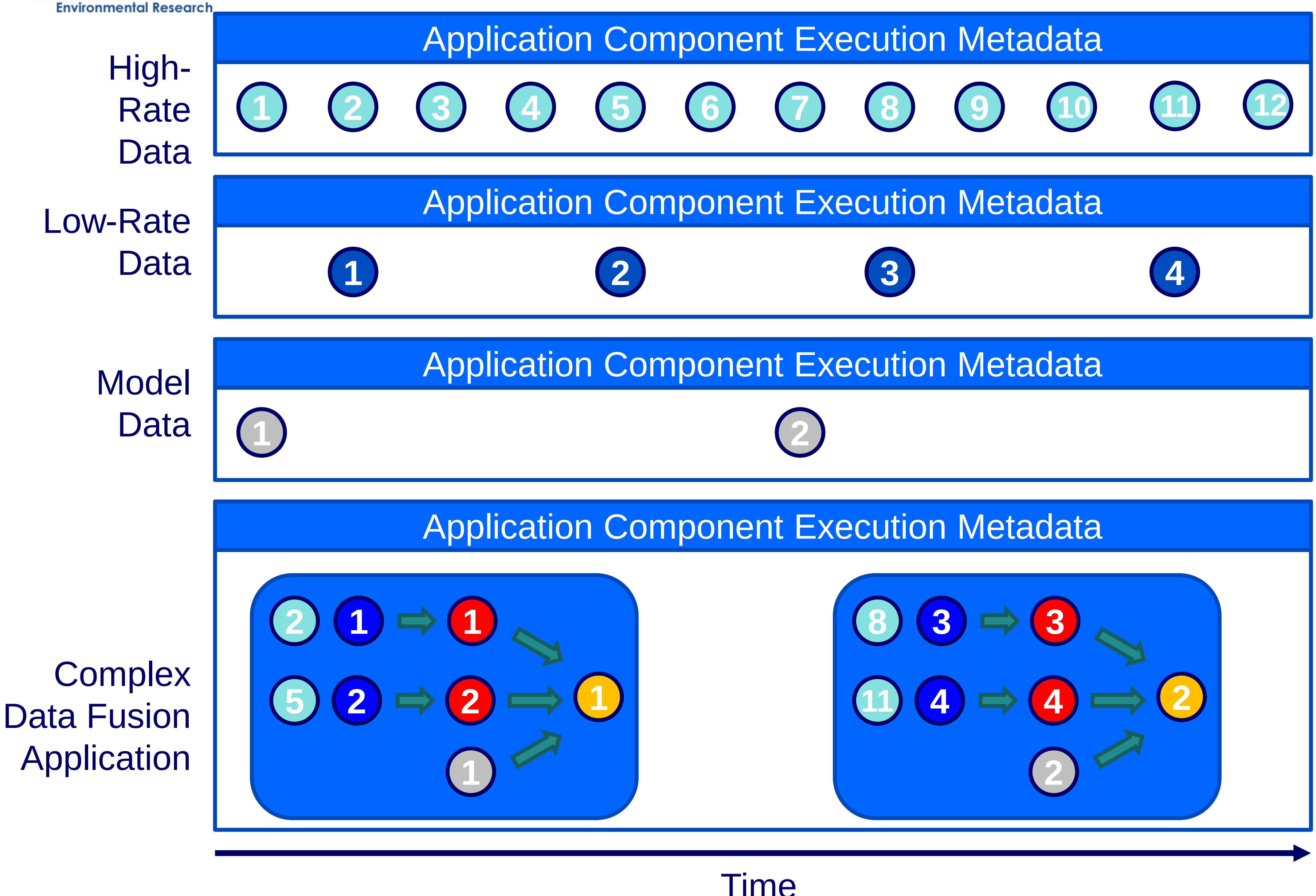
Algorithm Metadata Model



Algorithm Metadata Model

- Describes software using programmatically-accessible interfaces
  - Enables automation and flexible tools that can be reused in multiple contexts
  - Move toward shared algorithm baselines that do not require re-engineering for each new system, leverage previous development
- Layered approach allows reuse in different contexts
  - Science layer describes inherent capabilities of software components, is used wherever that software is run
  - System layer describes abstract interconnections between processing components, allows processing systems to be ported between multiple environments
  - Instance layer describes precise mapping of system to concrete computing resources, allows configuration to be effectively CM'd and audited, rather than relying on brittle startup scripts
- Engineering to provide enough commonality to be useful
  - Avoid overgeneralization that offloads work to configuration rather than system

Data Fusion Controller



Data Fusion Controller

- Controller monitors multiple data streams and coordinates the execution of data processing components to meet user requirements
  – Ingests system metadata model
  – Listens for signals from processing infrastructure indicating data availability
  – Generates signals indicating that a particular component should be run when its predecessors are available
- Flexible design allows extension and infrastructure upgrade
  – Easily change data cadence
  – Generic signals interface allows interoperability with both simple and high-performance infrastructures

Interface Design Challenges

- Interfaces between infrastructure and computational software must be chosen carefully, balancing between generic and specific capabilities
- Overhead and risk are incurred with both too-generic and too-specific solutions

Overly-Generic Interface

Infrastructure Software	User Software

- Small number of built-in functions
- Integration between user software relies on convention
- Requires large amounts of glue code and application-specific configuration
- Pushes burden of implementation on users

Overly-Specific Interface

Infrastructure Software	User Software

- Infrastructure has large number of application-specific methods and interfaces
- Evolving system needs may require large changes to infrastructure and user software
- Certain types of software may not match conceptually, and be completely unable to fit

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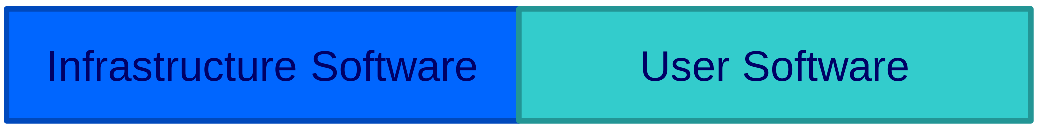
Choosing Effective Interfaces

- AER has hard-won experience in developing ground system interfaces
- Lessons learned inform careful selection of interface capabilities to minimize overall cost and risk

Balanced Interface



- Infrastructure has carefully-chosen methods to support broad categories of user needs
- Easy to add new user software, infrastructure has data-driven capabilities to adapt
- Smaller overall software footprint, less configuration required for working system

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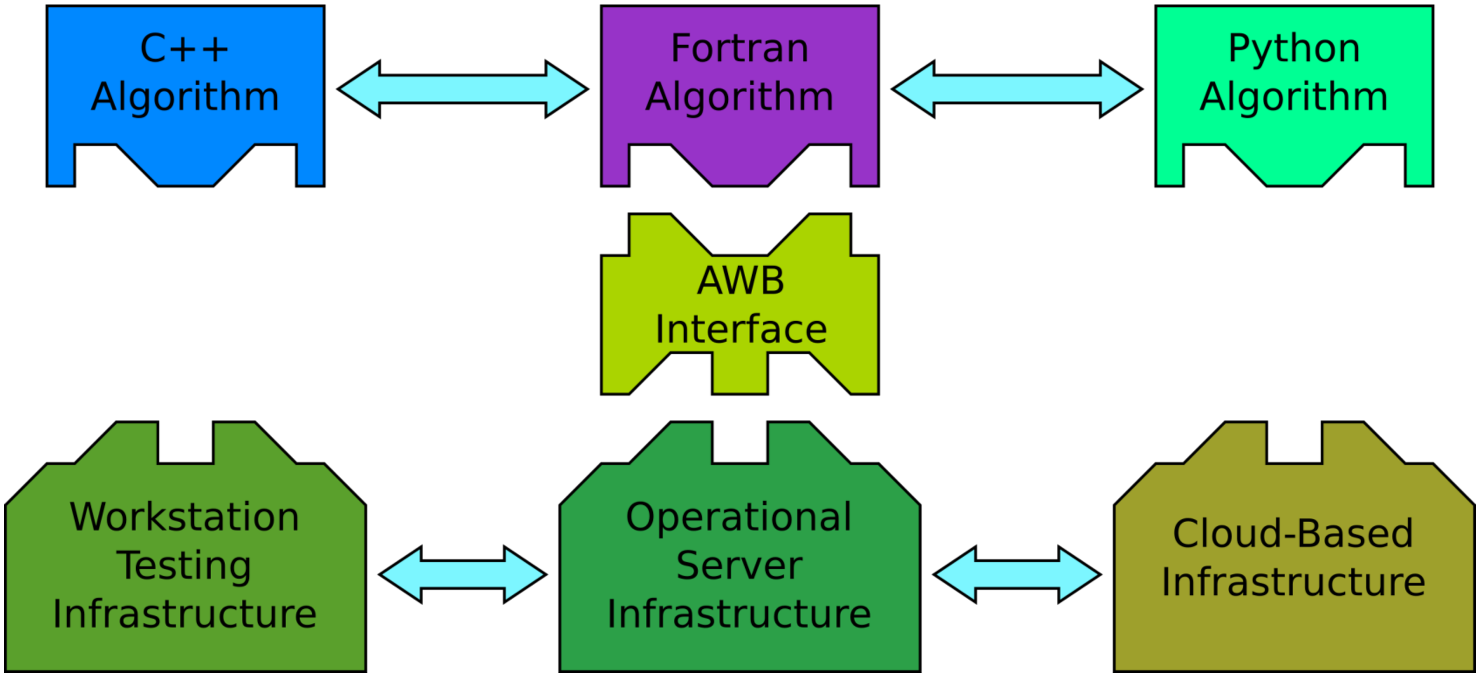
Heritage and GOES-R

- AER has been developing cutting-edge operational technologies for decades
  - Data Model approach
    - AER has championed the use of common data model interfaces (DMI)s on numerous civilian and DOD LEO/GEO atmospheric/ environmental remote sensing programs
  - GOES-R Demonstrated Large-scale operational capability
  - Single common Data Model Interface allowed shared development between distributed AER and Harris teams
  - Updates to algorithm science are easily tested by science developers, and the software is directly integrated into operations
- AER Continues to develop Ground System technology based on lessons learned
  - Reduce overhead and system configuration time
  - Advanced capabilities for multi-nodal and cloud-based computation

AER Algorithm WorkBench: Flexible, Multi-Platform Science



- Standardized interface for algorithms and infrastructure allows both to be swapped without code changes
- Algorithms in different languages run in the same environment
- Users can change/add algorithms, reformat data types and sectors using standard interfaces

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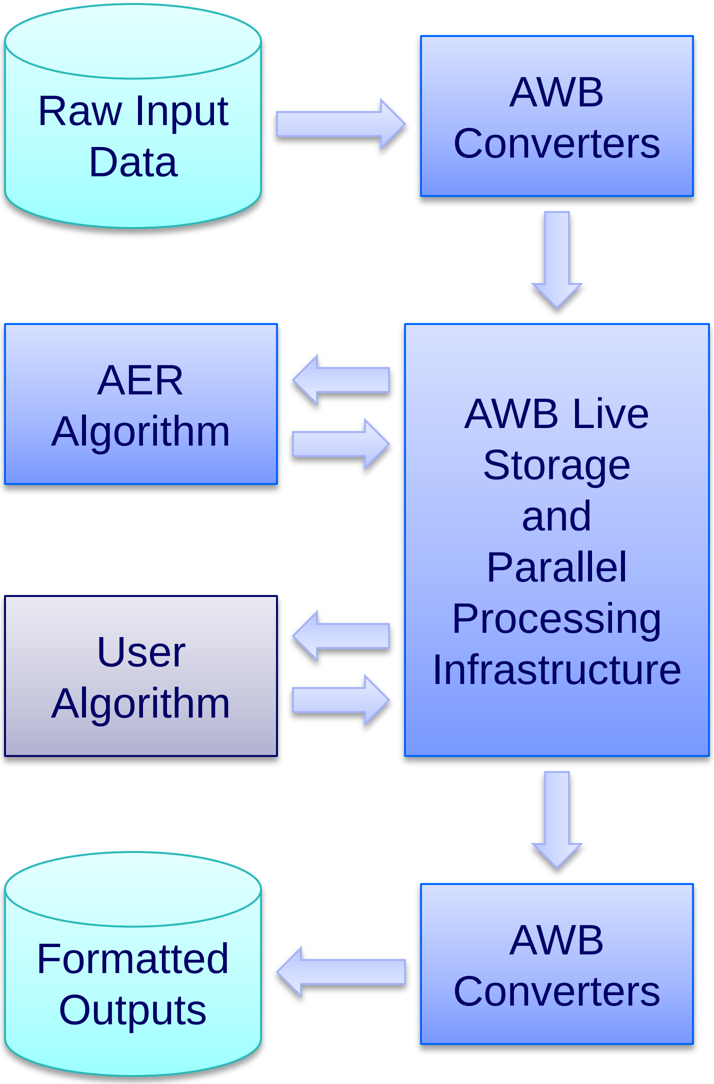
AWB Scalable Processing Infrastructure

- The AWB provides all software necessary for processing data
  - Ingests unprocessed inputs
  - Automatically partitions data
  - Provides data to each algorithm
  - Collates and processes outputs into user-specified sectors and formats
- Scales to meet user needs
  - Automatically uses available cores
  - User-selectable processing areas
  - Tunable to maximize throughput vs. latency
  - Runs on laptops, workstations, cloud servers
  - Suitable for one-off and continuous processing systems



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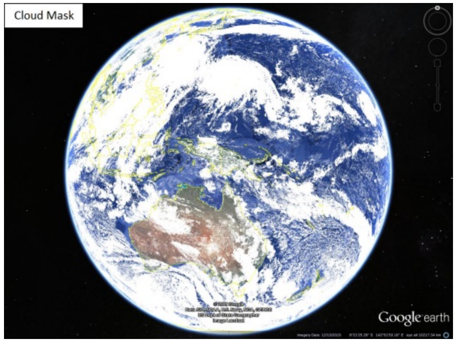
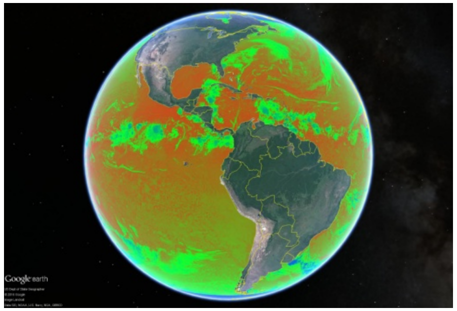
AWB Multi-Mission Platform

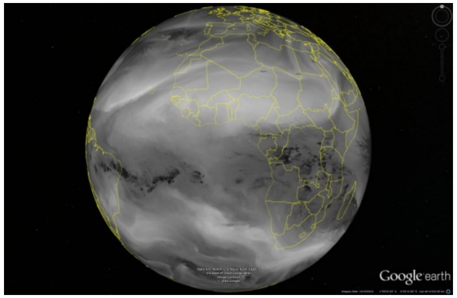
- Algorithm Components adapt easily to diverse missions
  - Simple data reformatters can adapt algorithms to new sources
  - Entire algorithm processing chain can be reused
- Reusing algorithm code across missions fosters collaboration
  - International communities can use the same science and provide more consistent data for users
  - New missions benefit from invested cost in algorithm development



Cloud Mask
Source: Himawari 8 AHI



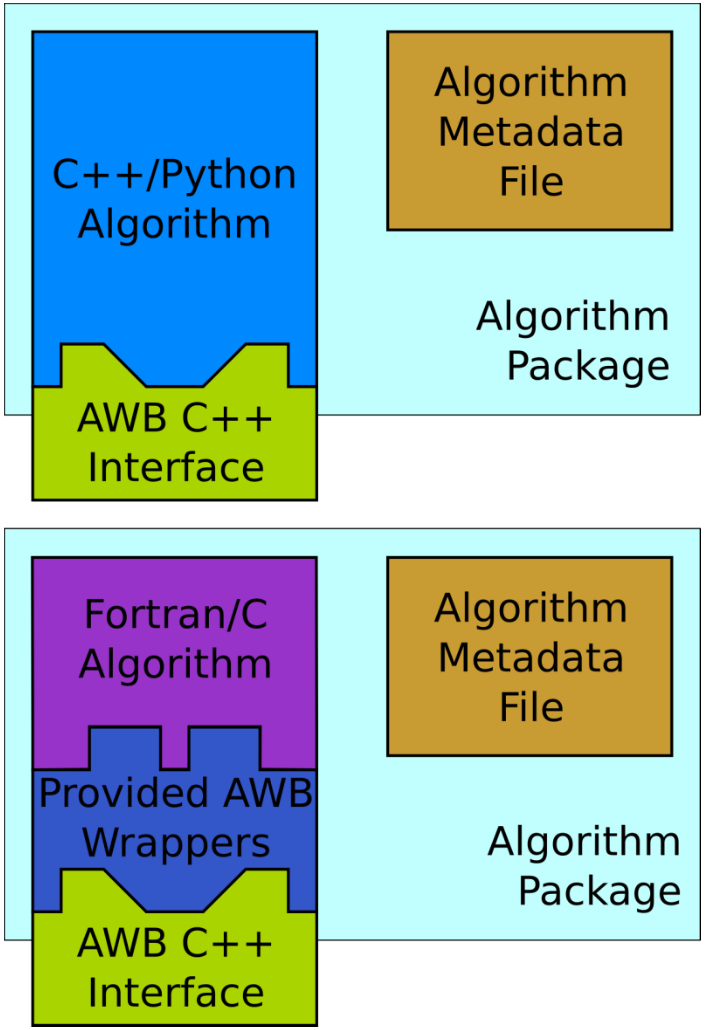
SST Composite
Source: Simulated ABI



6.4 µm Radiance
Source: Simulated FCI FDHSI

AWB Tools for developing new and migrating existing algorithms

- **Complete algorithm package has several elements**
  - **Science code**
  - **Data interface**
  - **Algorithm metadata file**
- **Assemble algorithm packages**
  - **C++ and Python code can natively interface**
  - **Other languages can use provided wrappers to easily cross the language barrier**
  - **Packages require metadata file describing inputs and outputs**
- **Algorithm packages can be immediately used in AWB cloud processing system**



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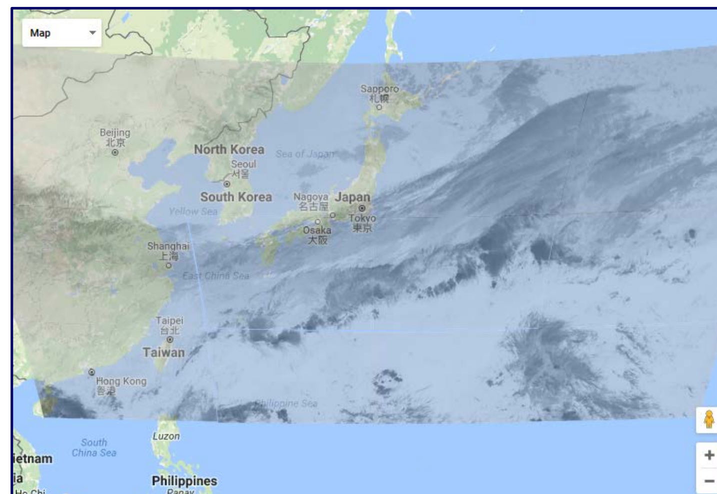
AWB in the Cloud

- Tools for system management
  - Web console can manage all features
  - Upload new execution scripts to continuously process data
  - Instantiate new servers
- Tools for analysis, visualization and data distribution
  - Use built-in google maps visualization to observe data live during generation
  - Data can be distributed to diverse tools using THREDDS

Process	Status	State	Count
anc-ip-10-0-0-240	inactive		0
mock-ip-10-0-0-240	inactive		0
abi_tarp-ip-10-0-0-240	inactive		0
imagery-ip-10-0-0-240	inactive		0
clouds-ip-10-0-0-240	inactive		0
anc-ip-10-0-0-106	active		1
mock-ip-10-0-0-106	active		1



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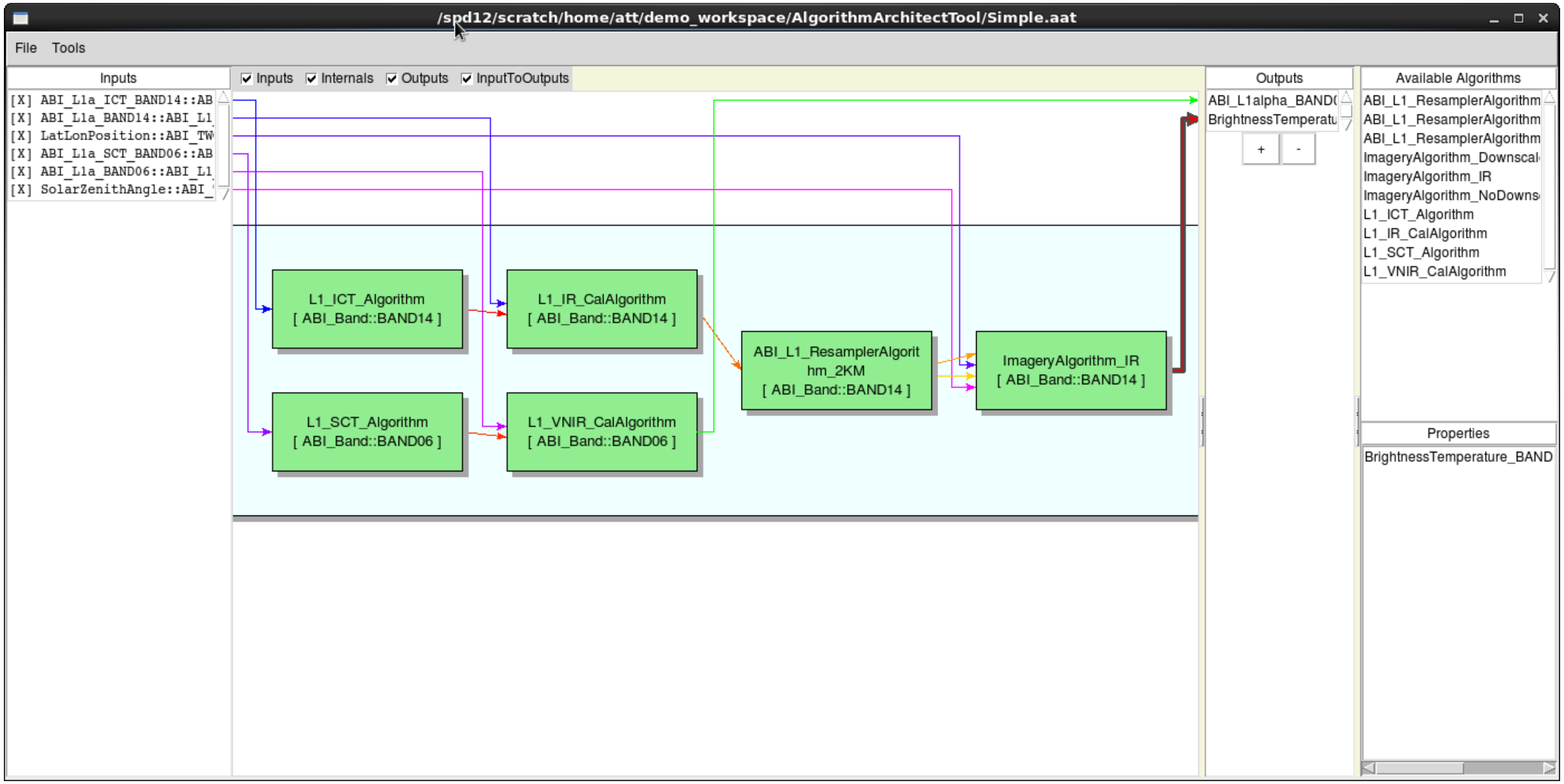
AER Algorithm Architect Tool

- Visualization of science algorithms and data flows
- Dynamically-generated, built from component metadata
- Allows users to inspect and analyze systems
- Demonstrates viability of data-driven execution



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The Path Forward

- Key action areas
  - Community awareness of open software principles
  - Avoid proliferation of multiple standards
  - Prevent vendor lock-in
  - Begin assembling user requirements from various stakeholders
- Lessons learned
  - OTS Software is essential for building systems, but does not solve the problems alone
  - Robust software requires accommodating diverse workflows
  - Configuration can become more burdensome than the software that uses it

Remote Sensing Open Processing Workshop

- We are looking to put together a workshop for interested parties
  - Algorithm Developers
  - System Integrators
  - Government and Organizational Representatives
- Potential Venue
  - 2018 AMS Annual Meeting (Austin, TX)
- Points of Contact:
  - David Hogan (Business) dhogan@aer.com, 781-761-2270
  - Alexander Werbos (Software) awerbos@aer.com, 781-761-2322