

170-WP-009-001

Issues to Consider in a Federated Environment

**White paper - Not intended for formal review
or Government approval.**

June 1996

Prepared Under Contract NAS5-60000

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Abstract

The Earth Observing System Data and Information System (EOSDIS) will evolve toward an increasingly distributed federation of information providers and users, enabling wide participation among the earth science community. This paper discusses the users' and providers' perspective on the issues that arise when providing data and services in this federated environment, with the intent of provoking further discussion. Federation users' issues include information discovery, searching for specific data, correlating data across distributed providers, analyzing fused data, and accessing related information. Providers' issues include identifying interested users, dealing with multiple data formats, automatically disseminating information, security and system management, and long term archival. All of these issues are considered within a cost-constrained environment.

Keywords: Federation, Earth Science Information Partner, ESIP, information discovery, data providers, security, user services.

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1. Introduction

1.1 Purpose

In July 1995, the Board on Sustainable Development Committee on Global Change Research conducted a review of NASA's Mission to Planet Earth program which includes the Earth Observing System Data and Information System (EOSDIS). While the EOSDIS review findings were in general favorable, the Committee recommended that NASA *reconfigure EOSDIS to transfer responsibility for product generation, publication, and user services to a competitively selected federation of partners in government, academia, and the private sector*. It was suggested that such a reconfiguration might accelerate system evolvability and help stimulate a wider range of participation from outside the EOS community.

This paper examines some of the issues that must be considered in providing data and services in a federated environment. It is intended to motivate discussion on what capabilities should be provided by competitively selected Earth Science Information Partners (ESIPs) and to what extent the ESIPs must cooperate together to meet the needs of federation users.

Contributors to this white paper include Steve Fox, Richard Meyer, Nick Singer, and Paul Fingerman of ECS and Gail McConaughy and Ken McDonald of EOSDIS.

1.2 Organization

This paper is organized as follows:

- Section 2 examines issues surrounding *using* data and services in a federated context: information discovery, searching for specific data, correlating data across distributed providers, analyzing fused data, and accessing related information.
- Section 3 examines issues surrounding *providing* data and services in a federated context: identifying interested users, dealing with multiple data formats, automatically disseminating information, security and system management, and long term archival.

1.3 Review and Approval

This White Paper is an informal document approved at the Office Manager level. It does not require formal Government review or approval; however, it is submitted with the intent that review and comments will be forthcoming.

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2. Using Federated Information and Services

2.1 Background

Historically, data systems which support earth science and particularly earth observation have been reasonably successful at capturing data and storing it for subsequent analysis. They have tended to be less successful at supporting the science research community in locating, accessing, and analyzing data effectively. While these issues have been resolved more recently within closely integrated research fellowships, the federation is likely to be characterized by far greater geographical dispersion, heterogeneity, and autonomy. The increased diversity and quantity of information that will be available to the research communities in the federation can enable greater utility if the system supports the users' needs. Key issues are:

- discovering relevant information
- searching for specific data within a data set
- correlating data across multiple data sets and providers
- fusing and analyzing data
- directly accessing related data to support applying user specific analysis methods to the data

Each of these issues is examined in greater detail below.

2.2 Information Discovery

The first issue a federation user encounters is how to locate appropriate information. An experienced user, particularly a researcher with highly focused expertise, knows from experience where to look for data. S/he knows which provider has the best data selection, highest quality of information, knowledgeable user support, and price to service ratio best suited to the user's needs. If this experienced user needs to search for related information, such as research papers or an environmental model, s/he can turn to known scientific peers from within the research community to begin searching for information.

For new users, or experienced users commencing work with a new data type, though, information discovery can be a somewhat more challenging process. That user may be familiar with a different terminology than that used by the provider, or have different definitions for the same term. For instance, does the criteria "temperature <=5" mean temperature of the Earth's surface, a bulk temperature for the top 30 cm of the ocean, or a point in an atmospheric profile, and does "5" refer to degrees Celsius, Fahrenheit, or some temperature class? User groups usually have different vocabularies based on the disciplines they are interested in, and even within disciplines there can be important differences.

Vocabulary differences can be addressed in a variety of ways, including mandating a common set of terms to be used within the earth science community, developing a comprehensive thesaurus (an integrated guide-type document or central library of such documents), tailoring search tools to the terms and search styles of their user communities, or applying new search techniques such as “concept search” or “query by example”. Some of these solutions require closely integrated information providers and others presume relative autonomy.

With language differences resolved, the next issue facing the new user searching for information is completeness and accuracy. How will s/he know that the search returned all viable information sources? Without inspecting each provider’s data, can this user determine whether it provides the best coverage s/he needs? In the closely integrated provider (see Definitions) world, these questions are readily answered: the Federation maintains a directory of all data providers and their products, along with information in the metadata about coverage, processing applied, etc.

In a more autonomous world, there would not necessarily be a reliable and current directory or common metadata. Currently, users can locate registered providers through advertising services, implemented in several earth science systems as well as more general World Wide Web applications, which direct the user to the provider for more information. These services are currently jointly maintained but could be distributed as needed (perhaps subdivided into ‘data marts’ by user community, event, etc.).

The issue of locating appropriate information and services is not constrained to earth science information. With the continued rapid growth of information available on the World Wide Web, researchers in the public and commercial domains are seeking ways to provide these services. The automated searching and indexing tools, a growing technology on the Internet, will provide some or all of the needed services. The developers and users of these general tools are performing the same comparisons of architecture and utility that a distributed system must: whether to have centrally managed indexes, how to appropriately distribute information, whether to maintain information hierarchically, whether to use active / intelligent /distributed search agents, etc.

Information discovery issues:

- How are differences in terminology resolved?
- How can users be assured they have discovered all appropriate information?
- How do users assess the quality of information they find?

2.3 Searching for Specific Data

Once the earth science user has located the provider[s] of relevant data set[s], s/he must determine which parts of the data are actually useful. In the case where all data providers support the same core set of product information or metadata, and where that core information describes qualifications on which the user wishes to select data, the user can readily restrict the search. For instance, if a user is interested in data from a single sensor over a given time and

area and processed with a specific scientific algorithm, s/he can locate it in today's closely integrated systems.

However, there are many providers who do not support searches of data to these qualifications. For instance, some data providers may be stewards of historical archives, valuable data which is impractical or costly to migrate to a closely integrated environment. Likewise, other Federations, with other standards, will be the source of valuable data in which the search criteria will not be uniformly supported. These data may still be searched on some basic attributes, depending on how the Federation is implemented. For those attributes which overlap with the core set, the less-aligned data sets can be mapped and accessed through a gateway, possibly a reusable function of the interface layer, or perhaps the responsibility of the data provider or a third party service. As users search data less closely aligned with their own earth science model, the search criteria will be more difficult to implement. One possible solution is to define a minimum standard for searching across sites. Another is to dynamically relax the search criteria, with the user's concurrence, if federation users accept such a reduction of precision as the cost of having access to a wider range of data (and performing post-analysis on a larger set of less well-quantified data). Other alternatives include incremental searches, fuzzy searches, and predefined rules for handling incomplete metadata, etc.

Data searching issues:

- What are the minimum search attributes the federation requires support for? How are they maintained?
- Who should translate among different data models?
- How much diversity in earth science models will users accept?
- Is all data available to all users, or do some data require user authorization?

2.4 Correlating Information Discovery Across Distributed Providers

Searching for data within one data set is important, but many earth science research problems can only be achieved using coincident searches, where the results from one search are used to constrain a query on another database: coincident searching or database 'joins' in relational terminology. For instance, one August morning a meteorologist might seek the most recently acquired wind, temperature, and current information over an ocean area which historically tends toward hurricanes during August. Such a query would first visit the historical archives to narrow the search to those areas within the region of interest which have seen more than one hurricane in the last decade. In the second phase of the search, the query would visit the recent current, wind, and temperature databases, providing pointers to all of those data sets over the areas resulting from the first search.

Within loosely integrated provider systems, coincident searches are currently achieved by a user extracting the data or indexes from several data sets which map to time/space and other attributes of interest and performing the "join" using local tools. In some cases this is a practical

proposition; in many others it is not. A significant breakthrough could be made by making coincident data queries a function that one can expect from the federated system.

Aside from the computer resources required to make a distributed database join, there are many other problems to be faced in implementing coincident searching in a distributed environment. The two most important are optimization of the query (i.e. what order and where should the separate parts of the query be performed), and the differences/complexities of vocabulary used in the query and database schemata (e.g. an oceanographer may have a different meaning for temperature than an atmospheric scientist). The federation should make it as easy as possible for data providers to support coincident searching even if it is limited to a subset of attributes. The federation might not mandate providers to support coincident searching at their local site; if coincident searching is valuable on a specific data set but a provider doesn't have the resources to support it, a separate service provider may be able to provide the required functionality.

Distributed data correlation issues:

- Should distributed correlations be automated among loosely integrated provider systems, or should scientists be responsible for the correlations?
- Where should intermediate data be joined?
- Should queries be optimized across autonomous providers?

2.5 Analyzing Fused Data

Having located data, the user will want to apply a tool to do something to it. This might be a tool to visualize the data or extract some parameters. In the current, loosely integrated environment, this has been achieved by ordering the data set(s) from the data center(s), which is then delivered to the user, who would then apply local tools to the data using their own local resources. This operations concept will still be valid for many users, but increasingly researchers may seek fusion to be part of the service delivered by federated providers.

In many cases the tool and data will be collocated, e.g., a provider will offer a visualization tool which works with the data they advertise to the network. As tools become more sophisticated and the data become increasingly distributed, it is possible to foresee the need to direct data to a tool located somewhere else on the network. For example, a provider might offer a value-added high throughput compute service onto which a user may load a computer intensive analysis algorithm; the user then directs the data from the data provider to the service provider and views the results at his/her workstation.

The ability to direct data at a tool implies the issue of metadata and data format compatibility, not an issue in a closely integrated federation but more problematic to one integrated loosely. The tool and data obviously must be compatible, or a bridge will be required in order for this approach to work. The user also needs to know when they are initiating a potentially costly process.

Conversely, researchers may wish to move their own tools directly to the data provider. The model of ordering data to be delivered to the researcher's facility often severely limits the

volumes of data that can be utilized effectively, constraining the analysis by resources available at the user site. An ideal data system could support users in submitting personal methods to be used at a provider's site.

Data analysis issues:

- What, if any, standards should exist to ensure compatibility between analysis tools and data formats?
- What standards are required for data documentation to facilitate analysis?

2.6 Accessing Related Data

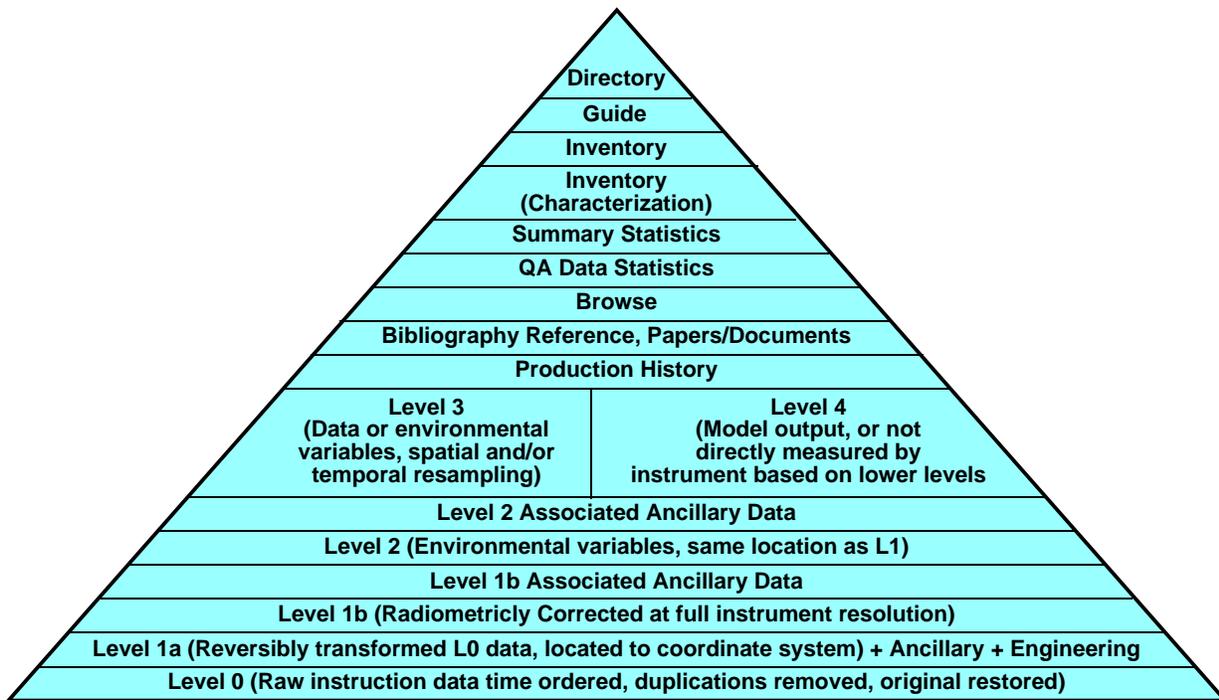
Having identified a suitable data set to support a research activity, the research user often becomes very knowledgeable about the data set. Having achieved this level of experience the user will often change the nature of their interaction with the system, requiring more direct access to the data itself for customization and analysis. The user will, however, still need support in finding and utilizing related data to help interpret the primary data sets, and, perhaps, for specialized services (subsetting, statistical products like averages or smoothed series) on later editions of the well-known data.

For data from earth observation satellites the types of data that might be related in a “collection” can be characterized as a data pyramid (see Figure 2-1). Many types of non-earth observation data could be characterized in a similar way. In an ideal data system, users would be able to navigate between the various layers in the data pyramid using contextual links. For example, if a researcher were studying some higher order binned data and noticed an unusual value in a small area, they should be able to access the lower levels of the data pyramid to look at the data that was used to create the higher order product without having to reenter search criteria for a new data set. An ideal federation would offer mechanisms which data providers can use to offer such linking to their customers.

Further, users extracting data from the system for specialized analysis often require supporting documentation and software utilities. The same mechanisms which support drilling down to lower data levels should support user access to documentation.

Related data access issues:

- Should there be a standard mechanism for accessing different levels of analysis of the same data?
- In the event that different levels of data are offered by different providers, what interface standards are needed to ensure appropriate access?



*Source: ESDIS Project/NASA/GSFC

94E008-003 (V1)

Figure 2-1. EOSDIS Data Model

3. Providing Federated Information and Services

3.1 Background

Federated information and service providers will represent many communities, from large-scale data archives to niche research. Some of the most important data providers for the earth science community will be users themselves. Users provide data because they want to make them available for collaborative purposes within a known research group, a consortium project team or the entire earth science community. A similar type of “community” data provider is a value-added service provider who is targeting a specific community with a specialized service (e.g., education and commercial service providers).

At one end of the information spectrum will be the *closely integrated* providers who guarantee data quality, availability, and service levels. These providers are often geographically dispersed and support different scientific disciplines, but they share a common vision of how they provide data and interact with their user community. They provide environmental information at a pace agreed to with a larger user community, archive it for long term use, and support a data model and architecture which enables their users to readily fuse and analyze distributed, disparate data.

At the other end of the information spectrum are *loosely integrated*, or autonomous providers who produce and share information on their own schedule, to their own quality standards, and in their own format and architecture. Loosely integrated providers could range from individual scientists who wish to make their research results widely available for collaborative projects, to stewards of historical data, to providers who are philosophically and architecturally aligned with another federation’s vision.

In each case the providers want to support their user community effectively while retaining autonomy over the information and services provided. Yet while autonomy is essential, providers need to minimize the resource and schedule costs of providing new services and new data sets. Key provider issues in the federation are:

- identifying interested users
- dealing with multiple data formats
- automatically disseminating data to subscribers
- providing service guarantees
- managing security, the information system and the site
- managing user accounts
- archiving long term data

Each of these issues is examined in greater detail below.

3.2 Identifying Interested Users

As with any other endeavor, environmental information providers, and particularly value-added providers, will need to reach their user “market”. In a self-sustaining federation, providers will also want to assess the size of the market and forecast returns on investment. Traditionally, this market is initially reached through “advertising” ranging from conference announcements to paying for visibility through another service. Within information media such as the World Wide Web and current earth science information systems (CEO, ECS), providers typically announce their services through other providers. On the World Wide Web, a provider can choose from numerous, and continually increasing, sites at which to make their announcements. In current earth science information systems, there are fewer advertising sites with a higher consistency in the information they provide end users. Advertisements in the federation will probably be achieved through some mix in these levels of consistency / autonomy and centralization / distribution; those methods which dominate will provide the tools to enable users to discover relevant information. Providers of “authoritative” data (e.g., the full archive of a given sensor’s measurements and analyses) and services will likely want to aid potential users searching for that information by distinguishing their offerings from similar but non-authoritative sources. This may be achieved through a peer-reviewed advertising service or “federation approved” and managed advertising service.

User identification issues:

- How much consistency is desirable in implementing a federated advertising service?
- How are “authoritative” providers identified to users in a federated environment?
- What is the size and value of the “market” for information and services?

3.3 Dealing with Multiple Data Formats

The traditional earth observation model of providing data in the form of standard 'products' with a defined format is not ideal for many research uses. Inevitably, such products are a compromise among the various scientific investigations that may need forms of the data varying in such characteristics as granularity, gridding and even production or pre-processing algorithms.

For example, a provider might wish to store an altimeter data set with each granule related to an orbit revolution in a time ordered fashion for simple archiving from a continuous processing scheme. This data structure is clearly not efficient for studies of local geographic areas such as areas of extreme wind events, and ice shelf elevation. In such a case, the research user might need to reprocess potentially large amounts of data to customize the standard products into an 'information' product targeted at their research area (arranged by map location rather than orbital time in the preceding example). The federation could enable providers to offer their data sets in several different formats and views, allowing research scientists to select among these representations the one they want, or indicate a list of preferences in their retrieval requests.

The development of standards is moving in a promising direction with self-describing formats and linked software tools for input, output, and visualization, but it is clear that a single solution

is unlikely to be successful for all types of data, particularly when legacy data is included. The federation can encourage the use of data interchange standards by providing common tools for generating and accessing standard format data items. Or the federation can allow *de facto* standards to emerge, along with appropriate tools, enabling more rapid evolution but possibly rendering some legacy data obsolete and/or driving costs up through proliferation of conversions between formats. A likely middle ground would be to encourage standards and provide conversion utilities linking those standards with other popular formats as needed, or as economically justified.

Data format issues:

- What role should the federation take in developing data format standards?
- Should the federation provide standard format conversion tools?
- What influence should legacy data have over the evolution of standards?

3.4 Subscribing to Data

The volume of earth science data is rapidly increasing and can be a daunting task for researchers to keep up with even in today's environment. In a federated environment, the challenges can be even greater. One solution to this challenge is the use of subscription services in which a researcher would 'subscribe' to data, papers, algorithms/models, and information on new services that are relevant to their research interest. In the current environment, subscription services for on-line journals are increasingly available, enabling readers to register their areas of interest and be informed whenever relevant topics are covered. Extension of this service to data and methods could be a powerful tool.

For example, data subscriptions are useful in situations requiring near real-time data. When conducting a surface measurement campaign, alerts on events may be required to maximize the measurement opportunity. Near real time data may also be needed for discrete events such as a volcanic eruption, hurricane, or oil spill, where the event may trigger other analysis activities. Or data acquisition could be triggered by a filter supplied by the researcher (e.g. a user algorithm for indicating the possible presence of blooms of toxic phytoplankton in ocean color data).

Subscriptions could be value-added services, provided by a third party. They could be bundled into a data provider's service, presuming some level of standardization among subscription servers. Or emerging technology could make these services readily available directly to users.

Subscription issues:

- Are standard subscription methods necessary?
- What interfaces would user-defined or value-added subscription services require of providers?
- What events should be subscribable?
- What actions should subscriptions trigger?

3.5 Service Guarantees

The range of requests that users will submit to the federated system will result in processes at the providers which will take a highly variable amount of resources. Providers, particularly those who are loosely aligned to the federation, will make a variable amount of capacity available to meet those requests. The user needs to be able to forecast the time a request will take, and the total cost.

The federation will be geographically dispersed and linked through the Global Information Infrastructure. Closely integrated information providers will likely have certain bandwidth performance requirements to meet, but more autonomous providers will have greater latitude in network performance. Likewise, closely integrated providers will meet certain criteria for guaranteed availability, while loosely integrated providers will not.

Some requests that users submit to the system only make sense if a certain service time can be guaranteed. For example, if a user wishes to visualize 100 images to select the most appropriate data, the delivery of the images needs to be efficient enough that the task can be completed in a reasonable time, and this performance can be guaranteed at the start of the task. Service level guarantees are particularly important to value-added service providers.

In implementing a federation of loosely integrated providers, one function of the interface layer might be to support service level negotiations, both from the data provider and the infrastructure.

Service guarantee issues:

- Should the federation require “minimum” service levels or other service level agreements from all but the most loosely integrated providers?
- Should there be a standard means of assessing resource requirements vs. provider capabilities?

3.6 Security and System/Site Management

As with all aspects of the federation, requirements for security will vary with the information being provided, its uses, and its user community. Issues to consider in a security risk analysis include an estimate of the *value* of the environmental information in terms of cost to reconstruct

if contaminated or lost, and in terms of liability if compromised. Then, potential security *threats* are characterized. Typical threat categories include:

- natural and physical (e.g., fires or floods)
- unintentional (e.g., untrained or careless users)
- intentional (e.g., interception of user information or malicious destruction of archive data)

For information providers, *vulnerabilities* to these threats can be identified and quantified, along with the damage that would result if the threat were successful. This establishes a baseline against which to measure the cost-effectiveness of proposed countermeasures. Using this analysis, the federation, or each provider independently, can determine whether the cost of the proposed countermeasure would be offset by a reduction in the probability of a threat succeeding or a reduction in the damage if the threat did succeed. Again, closely- to moderately integrated providers can be expected to conform to security requirements more stringently than can autonomous providers.

In addition, sites may have a policy for allocation of resources and monitoring costs associated with supporting data sets. Researchers may want to get feedback on their use of the network, or the use of their computing facilities by other users. Some sites may want to collect information to monitor the quality of the services which they are offering or obtain statistics on how usage is distributed (e.g., what kinds of data are requested most frequently). Aside from reporting to funding agencies, the information may also be used to assist in the optimization of node and network functions.

Security and system management issues:

- What would be the cost to its sponsors (an earth science community, a nation, or a group of nations) if a given information set were lost or compromised?
- What would be the cost to interdependent systems and their sponsors if a given information set were lost or compromised?
- Are there a core set of system management functions required of all providers?

3.7 Account Management

While many earth science information products can be readily offered at no cost to the end user, a large and valuable class of information and services require payment. Clearly, large data orders and value-added services and information have some end user financial charges associated with them. In a federation, how should such financial transactions be managed? At one end of the spectrum, each provider could implement his/ her own system for charging user fees, including designing information requests and securing user information from interception. At the other end of the spectrum, a user might interact with a single distributed account management system, maintaining a debit / credit account that is valid with all information providers and ordering data and services through a standard interface. Considerations on how standard or

autonomous these services are will need to balance convenience to both providers and users, as well as cost to implement and maintain.

Account management issues:

- Should financial transactions between information providers and users be managed centrally or be autonomous?
- Should there be standards for protecting customer information in account management?

3.8 Long Term Data Archival

Data set providers will generally support a data set for the life of a research program. At the end of the program, data may be retired, archived locally, or transferred to another institution for long-term maintenance. This is a likely scenario for the moderately integrated data providers, who provide standard/special products to the earth science community for a period during verification and validation before transfer for long-term management and service provision at an archive.

Loosely integrated providers, particularly researchers sharing information as a courtesy, may have neither the infrastructure to archive nor the staff to transfer their data upon conclusion of the research program. The transfer of operational support for a data set from one provider to another should be considered as part of the federated system.

Archival issues:

- How should transfer to long term storage be implemented?
- How should the data be moved so that users can continue to transparently access it?
- Who is responsible for ensuring the success and quality of the transfer?

4. Cost Effective Federation

The preceding sections describe global change researchers' and information providers' perspectives on the issues arising from implementing a federation. This section examines the needs of the other stakeholder in this venture, the sponsors and investors. In an era of flat or shrinking budgets, funding organizations are increasingly concerned with both containing costs and maximizing the value derived from their investments. Thus, resolution of the preceding *functional* issues is clearly balanced by *financial* considerations to ensure a cost-effective, and ultimately successful, federation.

One popular means of balancing these issues is to develop performance indicators reflecting both investments and benefits. Performance against these measures can be estimated *a priori* to aid stakeholders in developing the model for implementation, then tracked throughout to continue to guide improvements. In some cases, measures may suggest that cost savings can be achieved through competition among autonomous participants, and in other cases they may suggest that savings will be achieved through cooperation among participants to leverage investments.

Some performance indicators to consider might be:

- What is the investment required to federate, measured across all participants?
- What is the level of investment required to sustain the system?
- What are the barriers to entry for new information providers?
- How effective are researchers (in terms of time expended and appropriate data assimilated) in using the system?
- How does the system enable learning and innovation, in terms of research results?
- How capable is the system to evolve, and who is responsible for driving the evolution?

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Abbreviations & Acronyms

CEO	Centre for Earth Observation
CEOS	Committee on Earth Observation Satellites
ECS	Earth Observing System Data and Information System (EOSDIS) Core System
EOSDIS	Earth Observing System Data and Information System
ESIP	Earth Science Information Partner
MTPE	Mission to Planet Earth

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