Summary and Analysis of the UND Independent Architecture Study

The UND team's focus for the ECS Independent Architecture Studies was on the infrastructure, both programmatic and architectural, needed to support their estimate of millions of potential ECS users in the general public. The primary component of their architecture was the Public Access Resource Center or PARC, which is a value-added service that can be layered onto the ECS architecture but is currently not within the scope of the ECS program. The UND team recommended that EOSDIS plan to support millions of users based upon current levels of data utilization at existing climate and agricultural research centers and the rapid growth of Internet Mosaic users during the past few years. The primary guiding principle for their architecture was to allow user demand to drive system evolution in a manner similar to natural selection, that is where the PARCs that are successful will survive and others will die out. They recommended that COTS be used wherever possible to support the broadest community of users at the lowest cost, and that direct broadcast of data be a long term commitment of ECS and NASA in order to ensure timely access to data at the lowest cost. They presented a prototype PARC for agriculture called an AgPARC, that was based on a system currently in use at the Regional Weather Information Center (RWIC) at UND and several scenarios primarily in the agricultural user community which would benefit from EOS data. They recommended further that EOSDIS begin an educational effort aimed at informing the general public of the potential benefits of EOS data and of the EOSDIS program and provided a sample Mosaic home page to accomplish this for agriculture users. Finally, they provided data on network performance in real testbeds indicating that there are several variables that must be addressed to determine end-to-end application performance, and they used the BONeS network simulation tool to compare various topologies for interconnecting the DAACs including the Version 0, hypercube, mesh, and fully connected topologies.

Note: In the following discussion, we attempt to tie recommendations to potential implementation of the concept of PARCs as a primary interface to the ECS for non-science users and as an intermediary component of the overall EOSDIS architecture situated between ECS and the general public. The basic premise and approach of PARCs as funded entities within EOSDIS is a significant programmatic issue that we do not address further.

Bullet Descriptions

Information Management

• **Layer on top of current ECS architecture:** The UND team study focusses on the development of PARCs that will be layered on top of the current ECS architecture that supports archiving at the DAACs. This layering is viewed as both a short and long term evolution and depends on the applications domain needs of the non-science users.

Categorization: EVO (S/L)

This concept is consistent with the ECS architecture concept of "Value added providers" (VAPs). This concept supports VAPs with both a subscription-based and a query-based interface into ECS holdings, and allows VAPs to generate derivative products and distribute them freely to the community. Initially, many of the NASA-funded Science Computing Facilities (SCFs) are expected to function as VAPs. As time goes forth, a number of additional discipline-oriented secondary providers are likely to arise, and the ECS architecture needs to demonstrate scalability of the secondary distribution mechanism that will support this growth.

• **PARCs use client server model:** The obvious choice for development of a PARC in both the near and long term is client-server (p.36)

Categorization: EVO (S/L)

The secondary provider interfaces need to be developed to support client / server interaction between the secondary providers and the core system.

• **PARC interoperability** : Has implications for compatibility with ECS.
SQL-2, OSI: Recommended for development of a PARC today (p. 36)
DCE: Recommended for use today (p. 36)
SQL-3, COTS (Sybase Enterprise Manager) : Recommended for development of a PARC within 2-5 years. (p.36)
Object-oriented products (CORBA, objectbase systems): Recommended for development in the five year time frame (p. 37)

Categorization: ECS, PDR, EVO (S/L), R&D

In an overall sense, none of these items directly address ECS, as they are guidelines for technology implementations of PARCs, which currently fall outside of the scope of ECS. Hence, PARCs will be free to choose whatever implementation strategy they desire. This is consistent with the heterogeneous provider foundation of ECS. In order for PARCs to interoperate with one another effectively, they may desire to select implementation technologies that are well aligned with ECS implementation plans. These recommendations of the UND team are consistent with ECS technology implementation plans.

• **PARC data access**
Standard indexed and access methods: Those available from COTS vendors for use today in the short term (p. 37)

Categorization: ECS, PDR, EVO (S)

These recommendations for PARC architectures are a bit more conservative than current ECS plans. Early releases of ECS will most likely employ type-extended database systems, in addition to currently available relational products. As these products mature and become more widely adopted, we would expect PARC implementations

Specialized utilities such as residual bit vector indexes: For longer term implementation for purposes of query acceleration; developed in conjunction with COTS products (see section 3.4.2).

Categorization: EVO (L), R&D

The team recommends looking at new indexing techniques to speed query execution. Residual bit vectors are just one area ECS should explore. Others include spatial indexing techniques, feature-based indexing techniques, etc.

• **PARC-IMS search and access use Mosaic-like interfaces**: Hypertext point and click interfaces such as Mosaic are adequate for most users for the forseeable future. Universal, compatible interfaces between different user communities (e.g. agriculture and education) are not needed - depend on COTS instead(p. 48)

Categorization: ECS, EVO (S/L)

The UND team advocates the use of COTS Web client technology for accessing ECS data. ECS currently plans on using WWW-based browsers like Mosaic, extended with service-specific interfaces to support, e.g. more complex search criteria, and a more dynamic interaction (stateful sessions). This is necessary to support some of the "higher end" ECS user requirements.

• **PARC data management software**

Sybase and Arc/Info: For implementation of a PARC today use the most capable COTS technologies available (p. 43).

Arc/Info and Object/Relational Product: In the short term use upgrades of Arc/Info and plan to move toward use of an object/relational product, but suspend choice until O/R products mature (p. 43).

Integrated GIS, DBMS, Objectbase mngt, visualization: For long term use develop integrated systems based on openness, capability, viability, compatibility with COTS (p. 44).

Categorization: EVO (S/L)

PARC data management software will most likely be based on current implementations of Arc/Info and Sybase. These products will improve over time, and will evolve to support extended data types and a more unified geospatial data model. ECS technology evolution is consistent with this recommendation, albeit at a more agressive pace. In particular, the ECS data model will look to merge GIS and relational models through a geospatial data model. ECS is tracking efforts such as OGIS (Open Geodata Interoperability Specification) to plan for evolution to standards-based products.

• **PARC DASMA catalogue should use COTS data management products such as DCE for distributed catalogue management**: Catalogue managers accompanying COTS data management products will be adequate for PARC implementation in short term. DCE recommended.

Categorization: ECS, EVO (S)

The UND team recommends COTS-based catalogue management approaches. This is consistent with initial Advertising service implementations within ECS, which will employ Web-based browser access to relational implementations of advertisements through an HTTP gateway. The underlying mechanism by which distributed advertisements are accessed and searched will be described at PDR.

• **Proto AgPARC example design of PARC for EOSDIS**: An existing system is in use that implements some of the functionality needed for a PARC and can be useful as a model and prototype for further development, especially for agriculture.

Categorization: PRG

The ECS team should explore the prototype AgPARC as a driver for it's value added provider (VAP) interface.

Network Management

• **PARC-DAAC connectivity**

T-1, T-3, internet: Recommended use of T1 and T3 for short term connection between PARCs and DAACs (p. 91).
ATM, B-ISDN: Rapid evolution of networks to use of ATM and B-ISDN in the next 2-3 years.
Based on NII: Long term recommendation is to support connectivity between PARCs and DAACs using the available National Information Infrastructure.

Categorization: EVO (S/L)

Current plans are to equip Science Computing Facilities with responsibilities for product quality assurance with network service to DAACs in proportion to their respective network needs. Other SCFs will rely on the Internet for connectivity with some upgrades supported by the ESDIS project. The ECS team's assumption is that newer networking technologies such as ATM will be used where possible and where cost effective in providing this bandwidth to SCFs. Additional PARCs will need to rely on NII upgrades to existing Internet technology under the current program structure.

• **PARC-PARC connectivity**

T-1, T-3: Same as PARC to DAAC above.
ATM, B-ISDN: Same as PARC to DAAC above.

Categorization: EVO (S/L)

Current network plans do not explicitly interconnect SCFs. These facilities, as well as other candidate PARCs, would communicate via Internet and the evolving National Information Infrastructure.

• **USER-PARC connectivity**

dial-up phone lines (to 38800 bps): Implementation of user-PARC connectivity should be accomplished with existing phone lines today.

ATM, B-ISDN: Short term recommendation includes availability of ATM and B-ISDN for non-science users.

ISDN, B-ISDN: Reductions in cost and improvements in technology will make ISDN and B-ISDN a long term candidate (p. 92).

Categorization: EVO (S/L)

The UND team makes the point that many users of EOSDIS, and of value added provider services, will connect via "personal connection" networking technologies such as dialup lines and ISDN. Hence access to VAPs/PARCs will occur across a wide range of bandwidths, from dialup lines through ATM. It is recommended that the ECS team track the development of "personal connection" technologies to understand the capabilities of its user base over time.

• **ECS developers involved in ATM field trials**: To gain experience with actual network throughput, ECS should be involved in field trials.

Categorization: ECS, PDR

This is being done in conjunction with the ESDIS program office, and with a number of ATM networking testbeds that are in existence.

• **NFS outperforms custom RPC (should be used when available)**: This recommendation was made in the context of supporting connectivity between an existing proto-AgPARC (at RWIC) and users. NFS outperforms in the following ways: portability across UNIX-based systems as well as MS-DOS based microcomputers; fails gracefully; controlled access to files.

Categorization: PDR

While NFS provides a more portable "interface" to network-shared data than does RPC, there are a number of problems with it in a WAN environment. Performance of NFS in a "slow network" environment, such as is often realized in cross-country Internet links, is poor. And although the file transactions may be handled gracefully in a volatile network environment, there are some issues with supoort for multi-user locking. Finally, access is controlled through the Unix rwx/ugo permissions, which may not be appropriate for large, complex data objects, where granularity of access may need to be managed at a "subfile" level. ACL-based services implemented through the RPC mechanism can avoid a number of these problems, albeit at the cost of developing a more complex interface. Such issues should be presented at PDR, along with a suitable discussion of AFS/DFS features aimed at eliminating some of the WAN-based NFS difficulties.

• **Flexible layered protocol using TCP/IP and SLIP**: TCP/IP useful for direct connection of microcomputers to network. SLIP useful for serial connections and MODEMs. Both fit as part of a layered communications protocol (p. 67).

Categorization: PDR, EVO (S/L)

This is really a non-issue, as there are a number of solutions (including COTS) available which provide complete solutions for Ethernet or serial line-based connections. Microsoft, for example, now ships TCP/IP and both Ethernet and SLIP/PPP drivers as part of its standard operating system. Trends towards "Internet-ready" Unix workstations are expected to cause Unix vendors to follow suit.

• **Inter-DAAC connectivity evolve to ATM and bandwidth on demand**: In the context of a small number of DAACs with dedicated communications links, expectation is that upgrades will be made as technology evolves from current T-1 or fractional T-1 to support ATM and bandwidth on demand (p. 86). This is recommended as the short and long term approach.

Categorization: ECS, PDR, EVO (S/L)

These items are concerns for ESDIS in planning the network connections among the DAACs, and between the DAACs and the SCFs. The ECS architecture needs to be able to support bandwidth "reservations" for appropriate applications and/or users, and to leverage the relevant networking capabilities when they mature.

• **Telecomm. choices for non-science users diverse and heterogeneous**
CATV Coax (Analog and Digital): High penetration of CATV among non-science users makes it a logical choice for near term (p. 89).
Unshielded Twisted Pair (ADSL), Passive Optical Network: Long term possible comm technology with higher bandwidth. Assumes fiber to the home.
Hybrid Fiber and Wireless: High bandwidth, probably as part of the NII.

Categorization: EVO (S/L)

Again, these are issues for ESDIS in determining the optimal technologies to implement the bandwidth requirements levied by current distribution requirements. As these technologies mature and become "interwoven" into the fabric of the NII, the system should support their use in a transparent manner through common transport level protocols.

• **Network performance of ATM indicates 16% utilization (real testbeds)**: End-to-end application performance of networks is dependent on many variables including the host configuration and software. The UND team recommendations are that ECS be involved in the actual use of these network systems in order to better predict performance. Several example network technologies are discussed in the context of speciic configurations that may or may not be useful to ECS. In most cases, the effective utilization is far below the anticipated maximum throughput, which has important implications for overall architecture design (p. 99).

Categorization: ECS, PDR, R&D

ESDIS and the ECS team are aware of such studies, and are actively involved in a number of ATM testbedding efforts to better understand the issues and implications. They also need to track (and perhaps promote) advances in protocols for ATM.

• **BONeS simulation of inter-DAAC topology indicates hypercube, mesh fully interconnected outperform Version 0 topology**: A BONeS simulation compared the cell throughput and cell delay for three alternatives (hypercube, mesh, fully connected) to the Version 0 topology of the DAACs. In the case of throughput, as the traffic load was increased, the BONeS simulation correctly modeled the Version 0 topology and indicated that in the three alternatives, with additional links the bandwidth demand on a given link is lower since traffic is more efficiently routed through the other links, resulting in overall improved network efficiency and throughput. Fully connected provides the best throughput with mesh and hypercube slightly less efficient although significantly more efficient than Version 0. Cell delay was roughly constant for each of the four topologies as the traffic intensity increased. However, cell delay with respect to Version 0 was 25% better for hypercube, 33% better for mesh, and 38% better for fully connected (p. 128).

Categorization: PDR

These studies may provide useful tools to the network design team in determining the optimal layout for the inter-DAAC topology over time. The analyses in the UND studies need to be revised to take into account version 1 technology, bandwidth, and topology plans.

• **Optically switched WDM Networks provide virtual topology suited to application needs**: In the long term, a virtual topology of any kind (hypercube, mesh, fully) can be embedded over an irregular physical topology consisting of optical fiber links employing WDM (p. 131).

Categorization: EVO (L), R&D

Such techniques should be tracked as part of the long term networking plan.

• **Premature to recommend complex object management approaches such as CORBA**: A decision to base ECS architecture on CORBA network services is premature and could be an impediment to use in the short term(especially by PARCs). Treat CORBA as a long term option for future ECS development (p. 47).

Categorization: PDR, EVO (S/L)

In the long term CORBA will provide the network services required by the open, distributed and extensible architecture of ECS. However, CORBA implementation in the early releases of ECS is not advisable due to the relative immaturity of object oriented COTS products for network services. Early versions of ECS will preserve the option to implement CORBA in the long term without making the system dependent upon the availability of CORBA COTS products in the short term. Assessment of the maturity of CORBA technologies will be an ongoing activity within the ECS development project.

Other Architectural Issues

• **Direct broadcast of data should be supported**: Direct broadcast of data is critical to providing widespread availability of data, especially for application needs with short turn around time (i.e. less than 48 hours).

Categorization: PRG

Programmatic issue that needs to be considered by ESDIS and NASA HQ.

• **Advisory panel should include non-science users**.

Categorization: PRG

Programmatic issue that needs to be considered by ESDIS and NASA HQ.

• **Over-arching data policy is free data at near real-time**: Free data at least at the level 0 and 1, possibly higher levels. Recommendation based on the view that taxpayers have already paid for the data at some low level (not as value is added).

Categorization: PRG

Current EOS policy is to distribute data at the marginal cost of fulfilling a user request. Changes to this policy fall within the purview of NASA HQ.

• **Defer selection of data products as long as possible**: This maximizes the options and potentially lowers the cost.

Categorization: PRG

Specification of the products that will be produced and archived within ECS is the responsibility of ESDIS and NASA HQ.

• **EOSDIS provide educational outreach to engage millions**: Recommend better outreach to ensure EOSDIS success with the public in both short and long term. UND team has made a good start at providing this through several means including Mosaic home pages.

Public awareness and positive perception
Tutorials and courses
New multimedia tools, MTPE and PARC Mosaic pages, webcrawlers/worms, AgPARC Mosaic page example

Categorization: EVO (S/L), PRG

These are excellent suggestions which are implemented at the programmatic level within NASA via the use of Cooperative Agreement Notice programs and other outreach efforts.

• **Technology Assessment**: Consider assessments of both networks and computing trends.

Categorization: ECS, PDR

This is being done through a number of channels, including an ECS Technology Assessment team, ECS and ESDIS prototyping efforts, NRAs, and CANs.

• **Scenario Assessment**: Several moderately detailed scenarios should be further assessed for relevance to ECS (even as it is currently focused).

Categorization: ECS, PDR

The UND work includes some interesting additional use scenarios that should be considered in the ECS user modeling effort.

• **Data from DAACs is replicated to PARCs that need it**: Raw EOSDIS data and some higher products replicated from DAAC to PARC as needed by particular application area served by PARC. Place standing orders for data copies from DAACs (p. 42).

Categorization: EVO (S/L), PRG

This is currently supported within the current ECS architecture, commensurate with adequate resource availability for generation and distribution.

• **Store data encoded, decode on demand only** : Recommendation in the context of exsiting RWIC system to avoid spending time decoding observations - decode on demand only (p. 70).

Categorization: EVO (S/L)

This relates to the "precomputed products" vs. "compute-on-demand" tradeoffs to be made within the production subsystem of the current architecture.

• **DAACs archive and provide access for earth science users, and have large storage capability**: UND team view is that DAACs will be busy with archiving and serving SCFs and earth scientists and will not be able to support millions of non-science users. Therefore, they should concentrate on archive and science user support.

Categorization: ECS, PDR

This is precisely the rationale behind the value added provider (VAP) concept in the current architecture. The VAP network will serve as a "secondary provider" layer to a variety of "vertical" data markets, including additional earth scientists, policy makers, and the educational community.