Developing, Deploying, and Strategically Evolving the NASA Earth Science Research Knowledge Database, Enterprise Architecture, and Future Solutions Network

GEORESOURCES INSTITUTE
MISSISSIPPI STATE UNIVERSITY

FINAL REPORT
NASA GRANT # NNS06AA67D

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1.0 Introduction

The Mississippi State University GeoResources Institute is pleased to provide the final report deliverable under NASA grant awarded to the Mississippi Research Consortium through NASA award number NNS06AA67D to the University of Southern Mississippi. This work took place from March 2006 through December 2007. The NASA contract monitor was Mr. Troy Frisbie at Stennis Space Center.

Under this project, the NASA Applied Sciences Program has funded the Mississippi Research Consortium (MRC) to develop information technology that will facilitate searches for potential applications of NASA assets to various needs in the earth sciences community. In particular, it will help generate ideas for new ways to use NASA missions, research, and/or models in conjunction with operational decision-making processes (or decision support systems) to achieve a particular benefit to society. The main output of this work is the development of information technology that will facilitate that ability. The resulting system is called the Earth Science Knowledge Base (ESKB).

The ESKB contains an index of relevant NASA research result publications in a database that is compatible with the evolving NASA “Mission to Models” (M2M) database and shares relevant table space with it. In particular, fields from this system identifying relevant NASA missions, models, and data products are used to cross-index the data collected on published results of research projects. Fields characterizing the research results based on the six earth science focus areas and the twelve applications of national priority are included. In the course of developing the ESKB, novel uses of existing online databases and search tools have been developed. In addition, data mining tools have been developed for facilitating the proper characterization of research results.

In addition to research results, the ESKB includes data that characterizes the current network of NASA earth science partners. This includes information on organizations and agencies funded by or partnered with NASA to conduct earth science research, technology, and applications projects. The relationships between NASA programs and project sponsors are also captured in this knowledge base.

In designing the ESKB, the project team first solicited input from potential users of such a system in order to generate a set of relevant requirements. The results of this user needs assessment are presented in chapter 2 of this report. Chapter 3 describes the overall design and architecture of the ESKB, and in chapter 4 is found a reference to the detailed user guide provided separately. Chapter 5 describes using the ESKB to analyze the network of partners and partnerships in the earth science community. In chapter 6 is found recommendations for future directions and enhancements to the system.

Three appendices are included. Appendix A describes the delivery of candidate solutions in the form of SN Formulation Reports that were submitted to SN Council review. Appendix B lists presentations made from the work of this project in various venues. Finally, Appendix C lists significant meetings participated in by the project team.
Delivered along with this report in separate digital files are the source and executable code of the ESKB and all its data tables, and the presentations listed in Appendix B.

The technical personnel working on the project included the following individuals from the listed institutions:

**Mississippi State University, GeoResources Institute:**
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James Aanstoos (Overall Project Manager)
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Sun-Jun Kim

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**Institute for Technology Development:**
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Daniel Anderson
Kent Hilbert

**SSAI:**
Robert Ryan
Mary Pagnutti
Randy Stewart
Laura Pair
Rose Fletcher
2.0 User Needs Assessment

In order to develop a set of requirements for the ESKB, an assessment of the needs of the potential user community was conducted. This assessment proceeded in two parts: first, a “pre-screening” survey was conducted by email to a number of members of the NASA earth science research community. After reviewing the results of this pre-screening survey, an oral interview survey was created which was conducted by telephone conversations with selected NASA program managers, deputy program managers and directors within the applications arena of the Science Mission Directorate.

Section 2.1 below summarizes the results of the first part, and section 2.2 summarizes the oral interviews.

It should be noted that early in this project the software being developed was divided into two separate knowledge bases referred to as the Research Projects Knowledge Base (RPKB) and the Partnership Network Knowledge Base (PNKB). Since then the two were combined into one knowledge base hereafter referred to as the Earth Science Knowledge Base (ESKB). In the following sections of this chapter the user assessment work makes reference to the original names, since those were the working titles when the surveys were conducted.

2.1 Pre-screening Survey Results

The following is a summary of the pre-screening survey. We issued a total of 45 questionnaires and received 13 responses that we were happy with. The distribution of respondents was as follows:

Number of respondents by institution

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The results summary is based on the 13 completed questionnaires. The information was analyzed by accumulating total responses and total number of respondents for each question answer. The graphs below are based on the number of respondents. Keep in mind that the survey had multiple-selection questions, therefore, the percentages given represent percent of people who chose a given item. The percentages are allowed to total over 100 because of the multiple selections.

SECTION: A

**Purpose:** Currently access to information about NASA-funded research and its results is fragmented and often difficult to find. The following set of questions is an assessment tool to help:

- Determine how researchers are currently locating information about NASA–related and/or NASA-funded research information before writing a proposal.
- Determine what tools (web applications, search engines etc.) researchers employ when reviewing NASA Earth-Sun Science research.
- Determine what type of information researchers want and need in their work.

1. How do you begin a literature review for a NASA-related or remote sensing research project?

2. How do you search for previously conducted NASA-funded research and are there NASA databases / Applications that you use in your search?
3. Of these search tools, what qualities are most useful?

Of these search tools, what qualities are least useful?
4. What search criteria do you use to find information about NASA-funded research?

5. What information would you like available to you in the NASA research database?
6. Describe the ideal search tool to help you find NASA-related and/or NASA funded research in your area of interest?

7. Once the NASA database is developed, it must be kept up to date. Would you be willing to submit information to it?

8. What NASA National Application Area does your research activities belong?
9. Would you be willing to contribute further in the development of a Research Knowledge Database by participating in a workshop at a future date?
**Purpose:** To gather information for characterizing and communicating the current state of NASA Earth-Sun Science research network partnerships.

1. In what situations have you needed information about NASA partnerships?

   ![Bar chart showing the percentage of respondents for different situations]

   - Collaboration: 40%
   - Tech Expertise: 30%
   - Data Provider: 20%
   - Proposal Strategy: 10%
   - Other: 0%

2. How do you currently find information on NASA partnerships?

   ![Bar chart showing the percentage of respondents for different methods]

   - WEB: 80%
   - NETWORKING: 15%
   - NSPIRES: 5%
   - M2M: 3%
   - Other: 0%

3. What details would you most like to know about a particular NASA partnership?

   ![Bar chart showing the percentage of respondents for different details]

   - Institution Info: 60%
   - Researcher Info: 50%
   - Funding Info: 40%
   - Partnership Type: 30%
   - Focus Appl Area: 20%
   - Other: 0%

4. Would you be interested in past partnerships or just current partnerships?

   ![Bar chart showing the percentage of respondents for interest in past partnerships]

   - Past Partnerships: 10%
   - Current Partnerships: 90%
   - Other: 0%
5. How could it benefit you to have an accessible database on NASA partnerships?

6. Please provide any additional information, general thoughts or suggestions that can help in the design and implementation of a research knowledge and/or partnership database to suit your needs.

The following is a sample of the answers:

   a. Our company provides high resolution imageries (orthophotos) to various US and international clients, having a partnership and data sharing will mutually be beneficial to our scientists, NASA, and other scientists in our research areas.

   b. NASA should provide a better account of their view on state of the art in a given area and provide a clear statement on what they believe is a required direction for research in this area.

   c. Yet another independent tool may not be practical, but if it were connected to other tools then we all might benefit.

   d. As I noted above, I’ve never had directly collaborative projects with NASA, as I have only recently (past 3 years) considered that my research
fit into their bailiwick. My research has always been lab based and physiological or molecular biological microbial ecology. Recently, I’ve been involved in EPA STAR, USDA CSREES, and DoD agro-terrorism (plant) research, all of which could have benefited from NASA databases. The first did; and we successfully used NASA satellite databases in our work in collaboration with scientists from the research institutions throughout the Gulf of Mexico and in Alabama. The second did not because of lack of funding resources from USDA to extend the project to RS, though USDA indicated a strong interest. The third is ongoing and it has always been in the works to use RS and “pattern recognition” algorithms to identify crop sabotage or agro-terrorism activities.

e. As a researcher, it is my job to know the state of the art in my field. However, as a user of research I do not know the details of what is available. Linking the researcher to user is difficult and is perhaps the purpose of the data bases… ?? I don’t know what users are looking for and am not sure I can help. Getting user requests into a information exchange database would be useful so , as a research I can possibly direct them to research solutions.

2.2 Survey Results from Program Manger Interviews

Eleven program managers (PMs), deputy program managers and directors within the applications arena of the Science Mission Directorate were surveyed about the Research Projects Knowledge Base (RPKB). Most were familiar with the concept of the RPKB some had helped write the solicitation and some had worked on precursory-type projects. The surveys were conducted as informal interviews, generally 20-30 minutes in duration. The results of these discussions are summarized below.

Current Tools
All managers said they mainly use their network of contacts as their primary information source to determine new trends, areas needed for solicitations, and funding focus areas. Conferences such as American Geophysical Union, IEEE International Geoscience and Remote Sensing Symposium, etc. further this network knowledge base. While some managers felt that was sufficient, many managers expand upon that knowledge with NSPIRES and by doing further searches with Google Scholar. Many feel that the information available on NASA websites is incomplete and difficult to search. To quote one manager: “NASA does a miserable job of getting information out. The information is scattered. It’s a mess.”

Need for RPKB
The need for RPKB is debatable among managers. Some managers feel that the majority of the information they need, they already get from network contacts and their own personal ‘sum of knowledge’. Some managers imagined the RPKB would be akin to the components system “coin chart”. They thought the data would not be in a useable form because it would be missing hard science inputs for the Decision Support Tools (DSTs)
and Earth Science Models and as a result become out dated. Other managers sited a Bectel study as evidence of the need for the RPKB. In the study, Bectel researched the literature to determine new trends in research. They used the information collected to develop or incorporate DSTs into NASA, to learn the Primary Investigators (PIs) and to determine NASA spacecraft and sensor missions for the future. Finally, some managers felt that the significant number of proposals and grants each year required such a system to track and utilize the research generated.

**Potential Benefits of RPKB**
Most managers think the RPKB would be an excellent tool with many benefits, especially in the area of generating solicitations. It would help:

- bridge the interface between observations and models
- create a mechanism for data transfer
- with time savings
- finding researchers doing related research (especially new investigators)
- identify potential collaborators
- find areas for solicitation but avoid duplication
- stop double dipping by PIs who find two similar solicitations (rare but very embarrassing to NASA officials)
- make sure things aren’t duplicated
- make sure things aren’t missed
- generating reports
- “find out what the competition is doing”
- who is doing what/where/when
- what their budget is
- the magnitude of the effort
- find tie-ins that aren’t obvious, like between coastal oceanography and air quality
- research e.g. physics about aviation for weather forecasting systems
- avoid lost information and connections associated with turn over in personnel

**Database Sustainability**
The issues with database sustainability are:

- timeliness of the information (requiring input by PIs or other workers)
- accuracy (requiring expert scientific oversight, workers to correct errors, responsibility by some oversight institution)
- responsibility for maintenance

**Timeliness Suggestions**
Timeliness issues could be addressed by user input of data. A survey of the NASA user community (universities, government agencies and industry) showed that 80% of respondents would be willing to contribute to the RPKB. Some program managers were willing to encourage or even mandate that their PIs maintain their information in the database as a requirement for funding. They sited the Department of Defense (DOD) as a model for success. However several program managers would not be willing to force their PIs to enter their information and results as it would place an additional burden upon the PIs and make NASA solicitations less appealing/competitive. They would expect that information would come from NASA Shared Services Center (NSSC).

**Oversight, Accuracy and Responsibility**
The issue of database accuracy is tied to the larger issue of funding. Several program managers indicated that oversight of the database was required, specifically qualified, expert scientific oversight. The database needs to be the responsibility of an institution or program center. Managers indicated repeatedly that there would be very limited tolerance by users for the database if it had significant errors or was not kept up to date. They indicated that, though people would be tolerant of growing pains, issues of accuracy or timeliness could not linger beyond one year. If the database were under institutional
oversight then it would be more likely to be maintained appropriately. It was also suggested that the RPKB be made a “distributed system” with various nodes where it can be loaded and/or updated. Then a PM can identify personnel within their program to be responsible.

**Funding Suggestions**

Most managers stated that it would be difficult and expensive to sustain the RPKB once created. Suggestions from managers on sustaining the RPKB fell into three categories: 1. The Solutions Network assigns it to a center e.g. Goddard, Langley, Marshall, Stennis etc. in the same way that Distributed Active Archive Centers (DAACs) are funded by operational funding from satellite missions 2. NASA should employ “configuration management” where Science Mission Directorate would skim a percentage for the repository (i.e.1/12 of the responsibility would go to each of National Application Areas Program managers) 3. Becomes a requirement of the proposal ○ Funding pending submission of information into the database ○ DOD uses this model successfully for maintaining input once a database system is funded 4. It should be funded on a year-by-year basis under a research & development Strategy

**Expectations for the RPKB**

**Design**
The RPKB should interface with Missions to Models (M2M). This format should allow an assessment and evaluation process of DST (feasibility scale of say good to poor) in M2M and extracting specific supporting research results from RPKB. The output can then be submitted for RPC or processed through Land Information System (LIS). The system should have sufficient “filters” that can allow for sorting info by specific subject, time period (say past 4-5 years), etc in addition to “keyword” searches.

**Content**
The system should be able to allow users to track projects in time and across programs and agencies. In addition, the RPKB should help map network of collaborators over time. The system should take into account the fact that under National Applications (NA) of priority there are specific projects or activities. Therefore make concerted efforts to identify the subprojects so that users can narrow their search to NA projects sublevel. The system should distinguish projects in terms of local, regional, and global perspectives. References to publications are necessary but may not be sufficient without detailed accounts or abstracts of the research results. This is important considering the fact that PMs are more interested in the evaluation and assessment of the research results per se in order to make decisions about the DST, potential gaps, and generation of reasonable hypothesis.

**Evaluation**
During RPKB prototyping process make sure to involve NASA active (practicing) scientists in the evaluation and validation instead of just general users. This will ensure practical feedback from primary users. PMs should be contacted to facilitate the process.

**Provision of Papers**
Some managers felt frustrated that it is difficult to obtain papers about a certain subject. They would like RPKB to go beyond Google scholar and provide the entire article. When questioned about this, opinions were varied widely and included:
- papers generated by NASA funded research belong in the public domain and should be freely accessible
- knowledge base should contain citations to primarily peer-reviewed journal articles
- knowledge base should not become a repository for papers, just abstracts

**Searching across Government Agencies**

Several managers expressed desires concerning the scope of the RPKB. The system should not only focus on NASA related research results and on-going activities but instead should also provide an avenue into activities done by other agencies (government and private institutions such as NOAA, USDA). This would allow users to look beyond NASA collaborations as well as map out who else is doing what, how, when, and where. They felt there would be tremendous advantages, including:
- cost reduction from avoiding duplication with other agencies
- cost reductions from shared field programs
- increased competitiveness

**Information on Future work**

Managers also desired that the database would contain more information about future work, including:
- planned missions
- planned research
- upcoming solicitations
- planned research locations

One manager was concerned that the RPKB should be able to collect or access information not necessarily needed at this time but of potential future use, e.g., congressional districts or number of graduate students educated on the award. Finally, some managers commented on their desire to collect information about the user’s desires for certain data products that may become the foundation of future missions.

**Candidate Solutions**

The majority of PMs expressed reservations as to the use of RPKB to generate ideas, projects or candidate solutions (CSs) “on the fly”. They pointed out the fact that most of them probably already have ideas as to what they would like to do within their programs and that the only limitation is available funds. They also said that usually the process involves multi-faceted approach involving not only evaluation of research results but most importantly networking and contacts with other scientists.

Others expressed the fact that using RPKB for CS applicable to specific programs may prove difficult for operational agencies in the sense that the majority of research results deal with basic research that may be too general. Part of the skepticism was generally to do with the database format of RPKB which according to their experiences does not serve specific purposes very well due to large amounts of information and access pathways (that may not make all the necessary connections). These systems are said to be good for “first” order information and not for detailed analysis. Generation of ideas requires
identification of DSS owners and NASA supporting products; therefore it is important to make sure that the system makes this connection.

**Conclusions**
The overall perception was that this tool could potentially be an excellent resource. All managers applauded the effort and wished it success. The biggest pitfalls they foresaw relate to maintenance. The monies exist to build and populate the database, but without an institutional oversight at an expert scientific level, the database was doomed to become error-riddled, and out of date. Most researchers would have limited tolerance of a year or less for either failing before returning to their previous methods.
3.0 Earth Science Knowledge Base (ESKB) Design

INTRODUCTION

Through the Mississippi Research Consortium, NASA has sponsored a Solutions Network project to develop and deliver knowledge base tools and technologies for compiling NASA Earth Science research results. The primary objectives of the knowledge base tools are to enable 1) compiling the results of NASA Earth Science research, 2) associating the research and results with NASA resources that include observing systems, sensors, data products, models, and decision support tools, and 3) stratifying the research and results by relevance to applications of national significance and science focus areas. This integrated set of tools and technologies has been named the Earth Science Knowledge Base (ESKB).

The ESKB is designed as a user-friendly database application with client-server database functionalities for populating information about NASA research and results. The ESKB provides enhanced exploration capabilities for users to readily identify NASA projects of interest and search for desired research results. The ESKB design has incorporated database tables that contain information about NASA partners and projects, NASA observing systems, sensors, and data products, as well as models and decision support tools. The ESKB will provide an extensible basis for NASA and NASA-funded researchers to provide vital information about the results of past and existing NASA research. This information will deliver enhanced understanding about critical earth science questions as well as insight to potential research directions and NASA assets that may be brought to bear on the research questions of the present and future.

STATEMENT OF NEEDS FOR THE ESKB

NASA scientific data missions are charged with delivering meaningful data and products benefiting science as well as society. Thus, NASA has placed significant programmatic- and enterprise-level emphasis upon research to operations (R2O) as well as missions to models (M2M) in its applied earth science programs. In the emerging era of computational science, NASA faces the tasks of identifying novel uses and new adaptation of NASA data in meaningful ways, building upon successful research of the past to deliver value-added benefits that multiply the beneficial application of NASA data and computational results. This approach is extensible to reducing risks for future missions by evaluating the application of simulated data products from future missions so as to better compile forward knowledge about potential high-value applications of future data streams. In this light, the need for and importance of a knowledge base such as the ESKB to provide understanding of past successful pathways of data to knowledge (D2K) is critical to identifying new applications and directions for the appropriate use of current and future NASA resources in a manner complementary to both R2O and M2M.
EARTH SCIENCE KNOWLEDGE BASE (ESKB)

- The ESKB encapsulates and delivers knowledge and understanding by organizing and depicting research results in light of the abundance of digital data, models, and analysis frameworks utilized in the experimental process.

- ESKB enables new approaches or novel adaptations to be formulated based upon a solid research foundation, thereby identifying pathways that reduce risk and accelerate the translation of knowledge into new applications that stimulate societal benefits.

ITERATIVE DESIGN AND DEVELOPMENT PROCESS

The ESKB was designed to provide structured and guided exploration of NASA awarded research and results to enable harvesting of results that would lead to new research formulation. Arriving at design specifications and requirements, and developing the application required iteration in design and development processes. Through a process of prototyping, testing, feedback, and refinement, final requirements for the ESKB interface, functionality, and contents were developed.

In implementing the requirements of the ESKB, an iterative process was required to develop, test, gather feedback, and refine virtually every aspect of the application. From the ESKB splash screen to every interface, user feedback was required to determine if the application met requirements. Critical user functionalities such as data entry, exploration, and reporting were included in the iterative development process. In addition, the integration of NASA Enterprise Architecture (EA) and M2M data bases, research partner data, and GCMD keyword databases were all conducted and verified via testing, evaluation, and regular coordination meetings among MRC project partners and NASA personnel.
ESKB DATA BASE DESIGN AND TABULAR STRUCTURE

The ESKB was designed to provide a fully functional stand-alone client database for exploring and capturing NASA research results as well as a multi-tier client-server database that presents and extends information about NASA research projects, research results generated, and resources employed to generate the results. Within the ESKB, projects and research results may be associated with vitally important national applications and science questions addressed. To accomplish this, a normalized relational database tabular structure was designed with relational tables developed to capture the main ESKB content, provide key lookup information about research results, provide vital information such as NASA resources found in the M2M database and GCMD keywords, as well as to store information about NASA solicitations, award and results abstracts, and other keyword tables. This section presents information about the NASA table design as well as the tabular entities in the main ESKB tables and lookup tables. Table spaces incorporated from M2M and GCMD are also presented in the context of their use in the ESKB. MS Visio was used as a tool to enable design of the database and relational structure for the ESKB.

![Figure 3.1. Entity relationship diagram (ERD) generated in MS Visio for the ESKB.](image-url)
Table 3.1. ESKB Relational Data Base Tables and Their Descriptions

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<th>Description</th>
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**Solicitation and Keyword Information Tables**

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GENERAL ARCHITECTURE OF THE ESKB

The general architecture of the ESKB is a multi-tier architecture that also allows stand-alone operation. The stand-alone client application was developed using MS Access. Prototyping of the ESKB was conducted in MS Access and Client-Server functionalities were developed using MS SQL Server as the back-end data base and MS Access as the client application. The selection of an MS Access client and SQL Server backend was largely driven by the general availability of the MS Access application for client use, the ease of prototyping a database application in Access, and the need for the application to easily integrate with the NASA M2M and NASA Enterprise Architecture (EA) data bases which were developed in SQL Server.

ESKB CLIENT FUNCTIONALITY

The ESKB client developed in MS Access includes integration of the NASA Missions to Models (M2M) and Global Change Master Directory (GCMD) database information. The primary ESKB functionalities include:

ESKB Guided Data Exploration Tools
- Explore the web for information about NASA research projects and identify results of research for inclusion in ESKB or for consideration in new research formulation
- Explore NASA research projects at the award level and conduct keyword searches against proposals to determine linkages with new research ideas and opportunities
- Explore summary information about projects and results.

ESKB Data Entry and Review
- Compile solicitations and awards, principal investigator details and linkages to observation systems / sensors, models, data products, and other resources used.

ESKB Summary of Research Results
- Identify summary research results via linkages, resources, and communities of practice.

ESKB CLIENT-SERVER FUNCTIONALITY

The client-server functionalities of the ESKB were designed and developed to enable the core application to be extensible, to enable content to be accumulated via distributed client use, and to enable clients to incrementally update the server or pull information from the server to the client to ensure the availability of the most up-to-date information. Another key aspect of client-server functionalities is the ability for the user to be granted rights to add and/or modify content for specific projects.
**Client Initialization** – The ESKB client, when operating in a connected client-server mode, connects to the server, makes a pull of needed updates, enables user registration, establishes edit and user rights for the user, and handles connections, updates, and synchronization.

**Data Exploration** – The ESKB client enables guided data exploration of NASA research projects and research results. Initially populated data provide a subset of research projects and results, but for the capabilities of ESKB to be fully realized distributed client-server use and content addition will provide additional content for exploration and sharing results among NASA user communities of practice.
ESKB Data Entry – Using the ESKB to add content for research results requires connectivity to the server to provide control over edit rights and to resolve any content conflicts. The client synchronizes upon initialization and pushes updates to the server after the editing session is complete.

General Client-Server Synchronization Scenarios – Extending the content of the ESKB requires two-way synchronization between the server and distributed clients. Synchronization from the server to clients is necessary to provide full, up-to-date information on the client side needed for a content rich exploration and discovery environment. Synchronization from the server to the client may occur upon initialization or through a user-directed pull of server data. Synchronization from the client to the server is necessary to extend the content of the ESKB and to provide data to NASA user communities of practice, researchers and program managers.
DESIGNING THE ESKB INTERFACE

The functionalities of the ESKB are accomplished through the design of the ESKB database and the implementation of interfaces that deliver the functionalities to the user. The ESKB provides interfaces for guided exploration of NASA research results, entry and review of NASA research results, and identification of summary research results along with resources and linkages central to conducting research and developing results. A description of all interfaces and how they are used may be found in the user’s guide section of this report.

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**Earth Science Knowledge Base (ESKB)**

**Client Release Version 1.0**

The ESKB Client Release Version 1.0 links data about awarded NASA research projects and their research results, relevant national applications and science focus areas. The ESKB enables research results exploration and links NASA research results with resources such as data products, models, and decision support tools used to develop results. The addition of research content will occur over time as Principal Investigators (PI) and others add vital results to the ESKB. The developers of this tool are not responsible for the content submitted by others. User feedback is essential to enhancing application capabilities and addressing maintenance needs. Your input is valued and encouraged so please use the feedback mechanism to help us improve and enhance the ESKB.

---

**Guided Data Exploration Tools**

- Search By National Application/Keywords
- Search By Principal Investigator
- Data Entry and Review
- Research Results Summary
- Feedback
- Close

---

**Figure 3.2.** Main interface to the ESKB for providing access to full client ESKB functionalities including guided exploration tools, data entry and review capabilities, research review summarizing capabilities, and a feedback mechanism.
DESIGNING, PROTOTYPING, AND DEMONSTRATING FUNCTIONALITY
BY ESKB FUNCTIONAL AND CONTENT DEVELOPMENT

The ESKB was developed through a collaborative and iterative process to provide exploration, content management, and research results discovery services and capabilities. In developing the ESKB, the following activities were accomplished:

• Initial Population of Awards: ESKB includes information for over 4800 awards.
• Project Abstracts: Where available project award abstracts have been uploaded.
• PI and Project Information: The ESKB captures information about the principal investigator (PI), project title, institutional involvement, and NASA grant number where available.
• Research Results: The ESKB captures key information that include article names, publication type, journal, co-authors, keywords, and relevance to national applications, science focus areas, and GCMD keywords. It also provides solicitation, award, and article abstracts and important research result findings.
• NASA Resources: The ESKB captures information about NASA resources employed to deliver the research results. These resources include observing systems, sensors, data products, models, decision support tools and other resources.
• ESKB Content: To provide a functioning ESKB that extended the design beyond prototype and proof of concept, a set of NASA awarded projects were identified that included published research results, many of which were identified as being relevant to a set of priority sensor systems, models, and decision support tools.
• Content Emphasis: Research results for projects with Coastal Management focus was deemed appropriate for initial content emphasis, however, results for other application areas are present.

DESIGNING AND DEMONSTRATING CAPABILITIES TO ASSIST IN DEVELOPING CANDIDATE SOLUTIONS THROUGHT THE ESKB

The ESKB structured and guided approach to developing new NASA research candidate solutions may deliver accelerated capabilities to devise experiments designed to rapidly evaluate new applications of NASA resources and assess the value of a given research formulation. In the new NASA Rapid Prototyping approach to scientific experimentation, novel adaptations of models and decision support tools are proposed as candidate solutions which incorporate new forms of data and information for experimental evaluation. Novel combinations of data [proposed as improvements to model processes] introduce requirements for resources needed to handle new data which can stretch research budgets and may introduce risk to the successful outcome of the experiment. In
the context of ESKB, past successful results may be identified and employed to identify high-likelihood research candidates for which risks have been reduced via this new approach that delivers research results mining and enables “computational” thinking.

By providing relevant baseline science results, the ESKB is a valuable tool that may be used by subject matter experts as well as new investigators to identify NASA research results that meet criteria for a given research idea framework. This capability enables research formulation by delivering understanding about past NASA-selected research projects similar to the concept being considered. The ESKB facilitates rapid identification and access to publications about research that support a candidate solution, and provides critical linkages necessary for understanding data needs and applicability for use in priority models and decision support tools.

DESIGN OF THE ESKB TO IDENTIFY CANDIDATE SOLUTION PATHWAYS

To identify research results, any pathway can be selected that considers NASA resources or other linking factors as an organizing concept. The ESKB provides an interface that enables the user to rapidly identify research results in summary form that shows for each result or publication, what NASA resources, models, or DSTs were employed to deliver the results. The diagram above indicates that the pathways to an identified solution are not necessarily linear and not limited to a prescribed set of directions. The ESKB was
designed to provide an extensible and flexible set of tools and technologies for exploring, compiling, and building upon NASA research results.
4.0 ESKB User Guide

A detailed user guide has been developed for the ESKB and is distributed along with the appropriate version of the system. The user guide for version 1.0 is delivered as a separate PDF file along with the source code and executable module for the ESKB.
5.0 Network Analysis Report: Analyzing Agency, Institutional and Science Communities of Practice for the NASA Applied Science Solutions Network

Purpose and Scope

The Earth Science Knowledge Base has been designed to communicate information on the set of connections within the Earth Science community of practice. ESKB enables users to analyze interactions within the Earth Science community so that characterizations of the network can be made as to its health, dynamism, effectiveness, strength, intensity, and diversity. Existing and previous NASA applications and web resources have been leveraged to make these network depictions possible. Some of these tools include the Missions to Models database (M2M), NASA Procurement Management System (NPMS), NASA’s Research Opportunity Archive (Office of Earth Science), NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES), NASA Shared Services Grant Status review web portal, the Earth-Sun System Architecture Tool (ESAT), and the Earth Science Enterprise Network Diagram. Additional NASA and non-NASA maintained resources have been reviewed and leveraged to generate supplementary depth to the illustrations of network activity. These resources include The Federation of Earth Science Information Providers (ESIP) and the Committee on Earth Observation Satellites (CEOS), NASA’s Scientific Data Buy Program, as well as special assistance from Program Planning Specialists at NASA Headquarters. Query of data tables enables analysis as described later in this chapter; however, equally important is the review of research results summaries through interfaces built into ESKB. These results have been stratified along areas of science interest and provide useful breakdown of the research, the resources utilized, and pertinent data about the program which funded it.

Data Content and Approach

A set of relational database table space has been compiled through various means to deliver the requisite network characterizations. Solicitation information from 1997-2007 has been collected via the Research Opportunity Archive (Office of Earth Science). This data provides a look at the types of programs that NASA considers valuable to Earth Science research and enables users to examine their ability to contribute to operational programs in the future.

Information regarding awarded contracts and grants has also been collected and, when possible, been linked to the solicitations facilitating their award. This information has been captured from NPMS through a web-page ‘scraping’ routine. The results were then thresholded based on their relevance to Earth Science. This was accomplished by identification of keywords and assessment of the description of work to be performed. Both solicitation and award information contained links to the awarded institutions and,
in the case of solicitations, to the Principal Investigator leading the research project. These connections enable an examination of the interconnectedness of the network of partners engaged in NASA Earth Science research. Also attached to these interactions are relevant dates (solicitation award, project initialization and completion) enabling temporal analysis of activities. When feasible, the awarded contracts and grants have also been connected, through table linkages, to the research results and published articles they funded. NPMS also contains award value in dollars so that measurements of the fiscal health of network sectors can be made, however, that data has not been included in ESKB.

Through assistance from NASA Headquarters, a set of Memoranda-of-Understanding (MOU), Memoranda-of Agreement (MOA), Space Act Agreements, Letters of Cooperation, and Interagency Agreements. Information about these high-level agreements provides additional perspective about the overall goals of connected agencies which, in turn, drive research projects and grants.

Through the research results harvesting technologies built into ESKB and the linkages between research results and awarded contracts and grants, evidence of further collaborations and connectivity can be derived from authorship and co-authorship of published research articles.

Finally, data was collected about each of the partnering institutions. Partners were stratified by what sector they represent (business, non-profit, academia, etc) and where they are located (physical office, work performance location) so that analysis along these veins can be conducted. Each recorded published article accessed through the Research Results Summary Interface in ESKB is stratified along Science Focus Area and National Application enabling the communities of practice to monitor themselves.

**Metrics**

The following statistics and tables offer details about the NASA’s Earth Science community-of-practice. Pairing this data with the Applied Science Directorate’s goals and objectives can potentially provide program managers with a tool to measure success or compliance against those goals and objectives. Research scientists and PIs could use this statistical data to identify collaborators and discover like-minded institutions and programs. Both groups can use the data to recognize gaps or overlaps in funded research.

Data collected has yielded information about 1,546 partnering institutions including 40 governmental agencies which have entered into high-level agreements, like MOUs, with NASA. ESKB also contains data related to 9411 unique contracts and grants that have been awarded. These awards constitute 27,953 contract-years indicating an average contract length of nearly 3 years.

The following figures, charts, and graphs are meant to demonstrate capability of ESKB and provide a glimpse of the diversity and strength of the network. A cursory analysis of
these statistics is provided in a later section of this document, however, the implications and course of action derived from such statistics can only be made by decision makers within NASA’s Applied Sciences Directorate or NASA management at-large or by individual researchers and PIs representing their respective institutions.

**Analysis and Conclusions**

The information compiled about specified published articles and subsequently accessed via the Research Results Summary Interface (figures 5.1 and 5.2) within ESKB acknowledges the scientific networks and demonstrates the capabilities and capacity of the community of practice. Additionally, the data gleaned from query of ESKB table space through either automated means or through customized query building using ESKB table space (as seen in Figures 5.4 – 5.6) can be enabling to members of the community, especially those attempting to make a contribution or examine the network for efficiencies (or inefficiencies). Figures 5.3 – 5.6 provide examples of the types of data that users may find useful. For instance, a user reviewing the data in Figure 5.3 may get a glimpse of which types of institutions the community is made up of. A user may also notice the increase in awarded programs involving glacier and glacial process research noted in Figure 5.4 and surmise that NASA is attempting to meet the demand for increased understanding of climate change. Whatever the users’ interest, ESKB will enable discovery of the state of the Earth Science network or more specific communities of practice with the ability to harness research results and transfer them into operations activities.
ESKB - Research Results Summary Interface

**Summarize Research Results**

**Linkages**
- National Application: (N/A)
- Science Focus Area: (N/A)
- Science Question: (N/A)
- Societal Benefit: 

**Resources**
- Observation System: Topographic Experiment/Poseidon
  - Sensor: NASA Radar Altimeter
- Data Product: 
- Model: (N/A)
- DST: (N/A)

**Community**
- Principal Investigator: (N/A)
- Partner/Institute: GODDARD SPACE FLIGHT CENTER

**By Award**
- Award Number: (N/A)

**View Summary Search Criteria**

NASA Component;Partner Institute

[Clear/Reset]
## ESKB Research Results Summary Interface

### 1) Navigate to select projects of interest

<table>
<thead>
<tr>
<th>(First)</th>
<th>(Prev)</th>
<th>(Next)</th>
<th>(Last)</th>
</tr>
</thead>
</table>

### 2) Research Result Summary (Record 5 of 11)

<table>
<thead>
<tr>
<th>National Application:</th>
<th>Disaster Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Award Number:</td>
<td>NA05-0604</td>
</tr>
<tr>
<td>Award Start Date:</td>
<td>6/24/1999</td>
</tr>
<tr>
<td>Award End Date:</td>
<td>6/30/2002</td>
</tr>
<tr>
<td>Principal Investigator:</td>
<td>Birkett, Charon, M.</td>
</tr>
<tr>
<td>Award Title:</td>
<td>Altimetric Remote Sensing of the Amazon: Contribution to Surface Water Dynamics</td>
</tr>
<tr>
<td>Article Title:</td>
<td>Surface water dynamics in the Amazon Basin: Application of satellite radar altimetry</td>
</tr>
<tr>
<td>Journal Name:</td>
<td>JOURNAL OF GEOPHYSICAL RESEARCH</td>
</tr>
<tr>
<td>Year Published:</td>
<td>2002</td>
</tr>
</tbody>
</table>

### Linkages

- **National Application(s):** 2
  - Disaster Management
  - Water Management
- **Science Focus Area(s):** 3
  - Water and Energy Cycle
  - Earth Surface and Interior
- **Societal Benefit(s):** 1
  - Improve ability to monitor and predict flood events
- **Science Question(s):** 0

### Resources

- **Observation System(s):** 1
  - Topographic Experiment/Poseidon
- **Sensor(s):** 1
  - NASA Radar Altimeter
- **Model(s):** 1
  - EGM96
- **Data Product(s):** 0

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**Figure 5.2**
Figure 5.3
Figure 5.4

Number of "Glacier" related projects

*Incomplete Data available for 2007
Figure 5.5

Number of Awards by Science Focus Area 1997-2007*

*Incomplete Data available for 2007

- Atmospheric Composition
- Carbon Cycle and Ecosystems
- Climate Variability and Change
- Earth Surface and Interior
- Water and Energy Cycle
- Weather
- No Data

Figure 5.5
Number of Partners Engaged in NASA Earth Science Research 1997-2006

Figure 5.6
6.0 Recommendations for Future Enhancements

ESKB CONTENT DEVELOPMENT, DEPLOYMENT, AND USE

The development of the ESKB occurred through close partnering and collaboration with NASA Stennis Space Center. Through the development process it became apparent that some degree of focused content development, application deployment, and use model was needed that could be extended to other locations, groups, or centers throughout NASA and among NASA researcher communities. Through discussion about desired direction with NASA Stennis Space Center, a focus on Coastal Management for content was identified as an ideal opportunity to develop an application with relevance to research partners and NASA Stennis Space Center.

Research projects were screened and a subset was identified. A primary goal was to select a set of coastal management research projects upon which to focus as well as projects that fell into other application or science focus areas. For these identified projects, research papers were acquired by using ESKB exploration tools and ESKB content was compiled on data entry templates that included author information, publication title, journal, web link, publication abstract, and other data about the publication. To identify and associate research resource information, each publication was screened for mention of NASA observing system, sensor, and data products as well as models and DSTs. All of these content areas were compiled for the selected project’s publications and entered into the ESKB.

As a deliverable requirement of the MRC project, candidate solutions were identified that focused largely on coastal management as well as coastal hydrology applications. In doing so, the ESKB was employed in an integral role to identify research results that related to the national application and for which NASA data, models, and/or decision support tools provided science resources.

RELEASING AND EVOLVING THE ESKB

With the release of the ESKB, NASA has a new tool which offers enabling capabilities for cumulating knowledge about the use of NASA resources to advance science and benefit society. The appropriate use and evolution of the ESKB will require the resources to stand up and support the release of the ESKB client as well as to establish and maintain the ESKB client-server environment.

ESKB support will be required to ensure that initial client use is adequately supported for content providers as well as application users, that any problems with client use are appropriately handled, and so that any problems that occur with the client – server environment may be addressed.
In addition to developing initial support for the release of the ESKB client-server application, maintenance and enhancements are needed for the ESKB to make it a more fully-functional, extended tool that handles the diverse science needs of NASA. ESKB areas of evolution are generally described as follows:

Evolving the Use of ESKB: It is anticipated that the initial use of the ESKB will be limited to groups with insight as to its application as well as belief in its overall utility to deliver benefit and value. A critical initial step will be designating a NASA or partner research center to provide critical support to standing up the ESKB for use. As a logical extension to this it would seem appropriate to select for this role a group involved in the development of the tool with a commitment to adding content as well as capabilities to the application.

Content Evolution: As ESKB content grows, statistical information will be available to quantify resources identified in research results as being most critical or commonly used. Similarly, as ESKB content grows along with statistical insight concerning use of resources, better understanding will be available about underutilized resources as well as potential areas of application for those resources. Potential areas of content evolution include the following areas:

- Contributing Agency Research Results: Incorporating Earth Science research results funded by various contributory agencies such as NOAA, USGS, and EPA. This additional content could extend the utility of the application by incorporating a significantly larger body of knowledge and delivering it to a wider audience.

- Extending Research Network Partner Resolution: Extending the utility of ESKB to deliver relevant information about network relationships and activities, additional finer resolution connections could be added to the data content relating subcontract arrangements and alternate partnering schemes.

Science Mission and Data Product Support: ESKB content will provide supporting structure and past findings to strengthen future plans for science missions, experimental directions for application of new or future data products in well-studied applications, and will provide a method of supporting findings that will enable risk reduction in developing plans for basic and applied research. Building new applications on the successes of the past is an ideal utilization of the ESKB.

Community of Practice Deployment: To ensure initial success of the application, it makes sense to designate an initial focal community of practice to develop content and provide feedback about needs for architectural evolution of the application. Since initial efforts were focused upon coastal management and hydrology, it would seem logical to select this as the appropriate area of focus for the deployment of the ESKB to a collaborative research network focused on coastal management.

Evolving the Application: To extend the user base of ESKB as well as its functional capabilities, it is necessary to evolve the application beyond the current client-server model. A web-browser client to the content as well as for data entry is a next logical step as well as
advanced tools for “self-population” and “self-organization” of data content. Another likely evolution of the application is a slimmed-down set of application interfaces that are specific to individual user types such as investigators, managers, or researchers. Additional enhanced interfaces for illustrating network connectivity and exchanges could be folded into this slimmed-down set as well. These steps will be evolutionary in nature that will build upon an initial “extensible” design that was developed to ensure ease of evolution, future development, and successful deployment of the ESKB.

RECOMMENDATIONS FOR FUTURE USE AND EVOLUTION OF THE ESKB

The recommendations for the future use and evolution of the ESKB are largely stated in the previous sections and are summarized as follows:

- Identify and fund an ESKB support group. The support group should be highly familiar with the design and implementation of the ESKB. The support group should be charged with supporting the ESKB, its release to a designated user community in a pilot project effort, and for conducted specific functionality evolution tasks.
- Fully support an initial client release and provide information about the ESKB to NASA Centers, researchers, and program managers.
- Identify a user community to function as a pilot user group for initial release and community-based use of the application.
- Identify near-term maintenance and evolution tasks for the ESKB that might include
  - Developing a web-based client
  - Extend content capabilities to include contributing agency research results
  - Extend content capabilities to include finer resolution of partner roles as well as research subcontractor information so that all collaborators delivering results may be identified
  - Evolve the application interfaces for enhanced abilities to illustrate aspects of the NASA research partnership network
  - Evolve the application and interface so that the application has enhanced capabilities to self-populate with research results information as well as to self-organize the presentation of information in ways that may be controlled and dictated by user preference.
- Integrate data base enabled content analysis tools for PDF, word, and other document types for easy extraction, quantification, and indexing of NASA relevance from published research results.
- Continue to mine and update the contents for NASA grants website for the remainder of FY07 and beyond.
- Identify, establish, and support long-term goals and directions for deployment, use, maintenance, and evolution of the ESKB.
The project team was required to deliver a total of nine (9) candidate solution Formulation Reports. In November 2007, the team completed a total of ten (10) such reports and uploaded them to the NASA Solutions Network hub for review by the SN Council. (Council reviews were completed in early December.) A summary of these 10 reports is provided as an attachment to this document in a separate file.
Appendix B: Project Presentations

The project team participated in numerous opportunities to make presentations in various venues, updating NASA and the earth science community on the progress of this work. The following list summarizes the presentations made, and the actual presentations are provided as separate files delivered along with this final report.

July 2006 SN “Mini-workshop” at NASA Stennis, presentations by Chuck O’Hara and Daniel Anderson

December 2006 American Geophysical Union Fall Meeting:

J Aanstoos, D Shaw, C O'Hara, T Frisbie, “Information Technology Infrastructure for the NASA Earth Science Enterprise Solutions Network”


D Anderson, D Lewis, C O'Hara, S Katragadda, "Developing and Deploying a Partnership Network Knowledge Base for Analysis of the Partners and Components within NASA’s Earth Science Community"


December 2007 American Geophysical Union Fall Meeting:

D Anderson, E Johnson, D Mita, L Dabbiru, S Katragadda, D Lewis, C O'Hara, "Investigating Pathways from the Earth Science Knowledge Base to Candidate Solutions"


J Aanstoos, D Shaw, C O'Hara, T Frisbie, "Information Technology for Harvesting NASA Earth Science Research Results"
Appendix C: Project Meetings

In addition to frequent intra-team project meetings and teleconferences and the academic conferences listed in Appendix B, the team provided significant participation in the following meetings:

July 2006 SN “Mini-workshop” at NASA Stennis. Most of the MRC SN team attended; see presentations in Appendix B.

April 12-13, 2007, SN Workshop at the University of Maryland. Many of the SN team attended; see presentation in Appendix B.

January 30, 2007, Waternet Solutions Seminar at CREW. Jim Aanstoos shared SN insights and participated in discussions with NASA HQ staff and the Waternet Solutions project team.

In addition, at least one member of the project team participated in the public portion of all the NASA Solutions Network Council meetings by teleconference.