Spaceflight Operations Services Grid Prototype

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1. Introduction: NASA organizationally supports many types of space based operations using many types of applications from five different locations. They are Johnson Space Center (JSC) for Shuttle and International Space Station (ISS) vehicle operations, Kennedy Space Center (KSC) for launch operations and Marshall Space Flight Center (MSFC) ISS payload operations all in support of manned flight, Jet Propulsion Laboratory (JPL) for deep space projects and Goddard Space Flight Center (GSFC) for free flying satellites. These delineations evolved early in NASA's creation and still exist today. Because of early technologies and operational concepts most services in support of NASA missions were developed in a stovepipe fashion specifically for an individual mission. Networks were non existent. Communications were provided by point to point circuits at very low speeds. PCs were non existent. Computing was expensive and primitive. Data storage was cumbersome and also expensive. Since NASA's support of space flight mission operations, computing technology and concepts, communications in the form of networking and data storage and archiving have evolved to the point where application of advanced concepts to space flight operations and other non flight operations activities is necessary. NASA has implemented information technologies e.g. client/server, Web and higher bandwidth circuitry but at the same time has become a follower in technology use and implementation. NASA's networks are still virtually point to point circuits of moderate speeds. NASA has not been the leader of technology provisioning that it used to be. Instead NASA seems to shy away from advanced technologies.
2. Statement of Problem: NASA over the years has developed many types of technologies and conducted various types of science resulting in numerous variations of operations, data and applications. For example, operations range from deep space projects managed by JPL, Saturn and Shuttle operations managed from JSC and KSC, ISS science operations managed from MSFC and numerous low earth orbit satellites managed from GSFC that are varied and intrinsically different but require many of the same types of services to fulfill their missions. Also, large data sets (databases) of Shuttle flight data, solar system projects and earth observing data exist which because of their varied and sometimes outdated technologies are not and have not been fully examined for additional information and knowledge. Many of the applications/systems supporting operational services e.g. voice, video, telemetry and commanding, are outdated and obsolete. The vast amounts of data are located in various formats, at various locations and range over many years. The ability to conduct unified space operations, access disparate data sets and to develop systems and services that can provide operational services does not currently exist in any useful form. In addition, adding new

services to existing operations is generally expensive and with the current budget constraints not feasible on any broad level of implementation.

To understand these services a discussion of each one follows. The Spaceflight User-based Services are those services required to conduct space flight operations. Grid Services are those Grid services that will be used to overcome, through middleware software, some or all the problems that currently exists. In addition, Network Services will be discussed briefly. Network Services are crucial to any type of remedy and are evolving adequately to support any technology currently in development.

a. Spaceflight User-based Services: These services are those that enable Space and Ground operations to occur. The existing services are voice, video, telemetry management and command management. The importance of each of these with the exception of commanding and telemetry depends on the mission being supported. Manned flight is much more dependent on voice communications than is free flying satellite operations. These four base services are currently provided by many disparate systems and applications. For NASA to support the new Mars Initiative new services must be integrated into the mix of services. New services include Web-based measurement delivery and video distribution, high performance processing (i.e. access to supercomputing services), data mining, visualization, collaborative tools for development, operations and subsequent science and discipline specific application sharing. These services do not interact well if at all. Replacement of services is not now considered feasible on a wide basis that is making services i.e. command management, available to some current and all future projects and programs from a single source.
b. Network Services: Networks have evolved over the last decade to the point that effective throughput has enabled Grid technologies to emerge and evolve. Once network technology evolved beyond the T1 (1.544 mbps) then Grid type technologies albeit initially limited where possible. Now with the emergence of Dense Wave Division Multiplexing (DWDM) data transfer rates are very adequate to support Space-flight operations. Figure 1 depicts the network connectivity to be used.

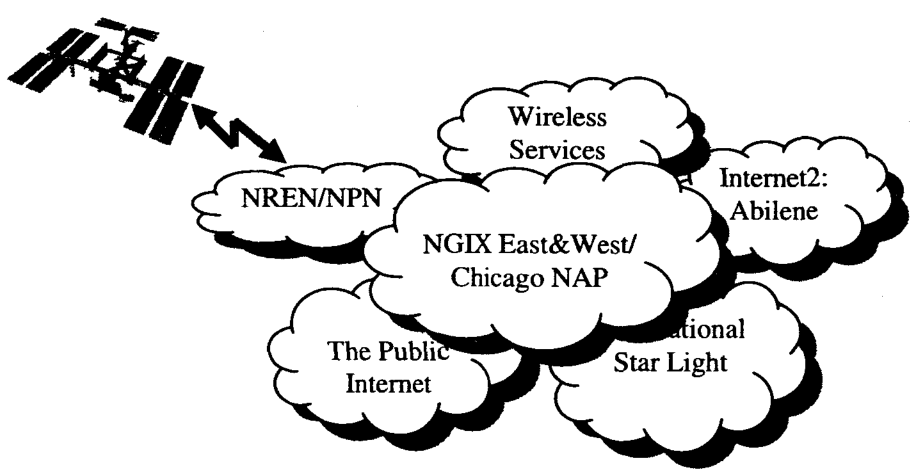

Figure 1, Existing Network Connectivity in Support of the SOSG

c. Grid Services: Grid services will provide the middleware services required to deliver current and new services to the user. In this case the user can be a flight controller at JSC, an ISS payload Principal Investigator or a flight/payload vehicle engineer. Grid technologies embody the services that bring together disparate applications, services, data and operations. Some core grid services include resource location, security both machine to machine and user, high speed file transfer, Brokering Service, Naturalization Service, Execution Service, Event Monitoring Service and Information Service.

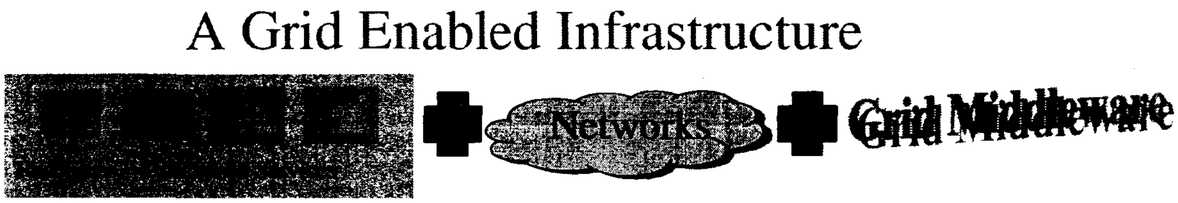

Figure 2, The Grid Model

In the Grid Model depicted in Figure 2 the three components are comprised of: the Resources that are services listed in Table 1 below, the Network as depicted in Figure 1 and the development of the Grid middleware required to enable Grid services along with ancillary services like portal and portlet development. Several Grid services specific to the implementation of the SOSG are required. They are systems performance and measurement, profile database and virtual organization manager, network services, streaming management service stream binding service and a SOSG application launcher.

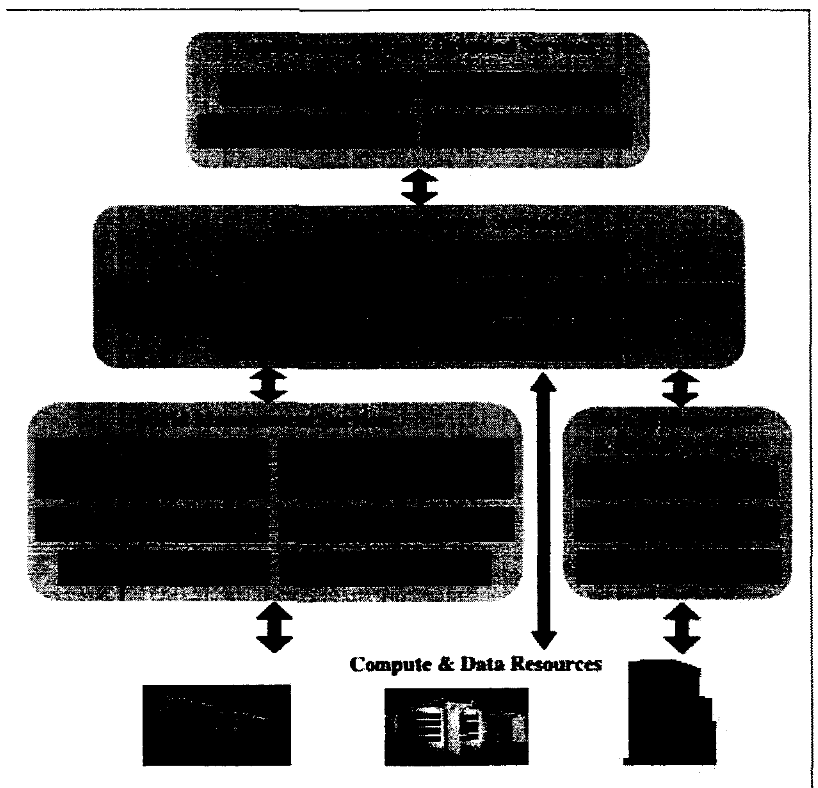

Figure 3, The Grid in Greater Detail

3. Hypothesis: Given the evolution in network technology and current state of Grid technologies a Grid implementation of the services described in paragraph 2 above embodied in a Spaceflight Operations Services Grid Prototype will demonstrate the feasibility of applying Grid technology to space flight operations. Further, that Grid technologies will 1) enable collaboration between scientists, engineering, operations that will enhance their respective disciplines in ways not visualized today, 2) provide new services to many projects/programs/disciplines that are not feasible when applied to an individual requirement, and 3) generate new information and knowledge from the disparate data located throughout the Agency.

   It is anticipated that by applying Grid technologies to NASA systems, applications and data, Grid technologies will make current systems/applications supporting spaceflight activities more efficient, reduce development costs for future spaceflight system replacements and upgrades, enable inter-discipline science collaboration creating new information and knowledge with significant cost savings. In addition, collaboration (more effective communications) between various NASA organizations, programs and projects will occur.

4. Solution: To begin the solution, create a Grid prototype for demonstration purposes. This Prototype will consist of all the end-user services listed in Table 1, Grid enable them where feasible based on Grid technologies and where Grid technologies are not feasible, base the end-user services implementation on Web-based technologies. This will be accomplished through a collaborative effort between several NASA centers, academia and industry.

User Based Service:	**Base System/Status**	**Definition:**
Data/Telemetry Mgt	Telescience Resource Kit (TReK)/Operational	Provide TReK telemetry management services
Experiment/System CMD Mgt	TReK/Operational	Provide TReK command management services
ISS DL Video Distribution	GViDS/In development	Provide varying bandwidth rates to all VOs, sense native network and adjust rate
Web Measure Delivery	TReK/EZStream/Operational	Provide individual measurements over the Web and to wireless devices
High Performance Processing	ARC/IPG/Operational	Access massively parallel and other processing cycles in real and near real-time
Data Mining	UAH Data Mining/Operational	Analyze and combine new and archived data to find new information and knowledge
High Volume Network Storage	UAH NW Storage/Operational	Use massive storage capabilities thru the Web securely
Mission Voice	IVoDS/Operational	Access the mission voice loops provided by IVoDS
Collaborative Internet Voice	CVoDS/In development	Upgrade to IVoDS to provide application sharing,

		IM, video telecon and mission voice
Video Auditorium	Video Auditorium/In testing	A new approach to video teleconferencing still in development
Application Sharing (Example)	Caution and Warning/ Currently being Web enabled	Ability for a user to "plug in" discipline specific applications under the Grid services umbrella
System Performance and Measurement	TBD	For the prototype and beyond measure network and application performance
Networks Connectivity	NREN/Abilene/Operational	All network connectivity from the prototype to the users
Network Service	TBD	

Table 1, Services List, Base System with Status and Description

The premise associated with a prototype is that the services supporting ISS payload operations are operational at the Payload Operations Integration Center (POIC) located at Marshall Space Flight Center (MSFC), Huntsville, Alabama. These services will be either replicated or provide streams from the operational systems (video and telemetry) for the prototype in a "quasi operational mode". However, there are no operational services supporting any mission related activities with this prototype. New services that are currently not provided by the POIC are being generated by other systems currently under development. These systems are depicted by other than Operational status. Table 1 depicts the service, followed by the service/application system provider/status and a brief description of the service. As shown, most services are ready for Grid enabling.

5 Use Case Description: What follows is a visionary description of a remote principal investigator using the SOSG to conduct science from his/her experiments running on the International Space Station. A PI has an experiment that has been accepted for flight on the Space Station. The first thing this PI does is to register him/her using the SOSG registration portlet. At this point the PI is created an account within the SOSG environment. After registration, the PIs portal environment will be set such that he/she now has access to the following services: Registration Service Portlet, New Service Request Portlet, Certificate Request Service Portlet, and Information Service Portlet. Each of these will be presented in individual portlets from within the overall SOSG portal.

After initial registration set up, the PI will need to request a SOSG user certificate via the request cert portlet. This certificate will be an X.509 certificate and will be issued by the NASA IPG's Certificate authority. This cert will allow the PI to have single-sign on access to all the resource and applications he has access to while using the SOSG services. After the PI has received his/her cert, he/she will now be able to construct the portal interface to provide access to the applications needed to conduct his/her science.

Let's assume this PI has been authorized to use a telemetry processing service (TReK) and has an allocation on the High Performance Computers (HPC) at the NASA Advanced Supercomputer Center. The PI will use the portal customization screen to organize his applications. From a pull down menu the PI selects TReK and HPC. By doing this, several additional portlets are added in addition to the two selected. This is due to dependencies that are pre-arranged. By selecting HPC, a portlet for access to the IPG resource broker is available, as well as a portlet for the IPG execution manager. In addition, data mining tools are provided. By selecting TReK, additional portlets will be available. The PI can then place the portlets in a configuration that is acceptable to the PI, then saves the state so that he can now log out and log back in and his environment will be reestablished, this is called the PI's "Grid Context" [1]:

To begin using these applications, the PI would use TReK as he would normally except he would be using the interfaces provided by the portal. Let's assume that he is monitoring a few parameters for off-nominal conditions, and that this condition is met. The PI can then take these parameters and drag them from the TReK portlet into the job creation window where a grid job is created based on some pre-configured data the PI added, such as the code set to be run, the input parameters, etc. After dragging the data to the job creation window, the PI can now launch a data-mining job to locate any previous results that shared similar conditions. He can also fire off a simulation that uses these off nom parameters to predict possible evolutions of the experiment if the ISS environment is not corrected, etc. It is desirable that the previous actions be scriptable so that the PI does not need to be monitoring the portal. In addition to the core applications that the PI uses, he also has the ability to display various environmental data in graphical form within his portal. For example, he can have a portlet that represents the power production of the ISS solar panels, the current job load of the NAS computation grid, live video of his experiment on the ISS, and a list of other associates that are currently working on experiment data.

Let's assume that after the data mining and simulation are completed, some interesting results are produced. The PI is now able to use chatting and video services to collaborate with his associates within his Virtual Organization (VO) on the results. A VO is a group of like minded predetermined participants e.g. specific science discipline.

Finally, after all the collaboration and excitement is competed, the PI is preparing to exit the portal when he is prompted to enter some metadata about the data and results that were just collected and analyzed. Upon completion, all the data products that were created, the recipe for creating them, and the metadata the PI entered is stored into the SOSG data archives so that others within the VO can search it and in the future, this data will be available for other science and public use.

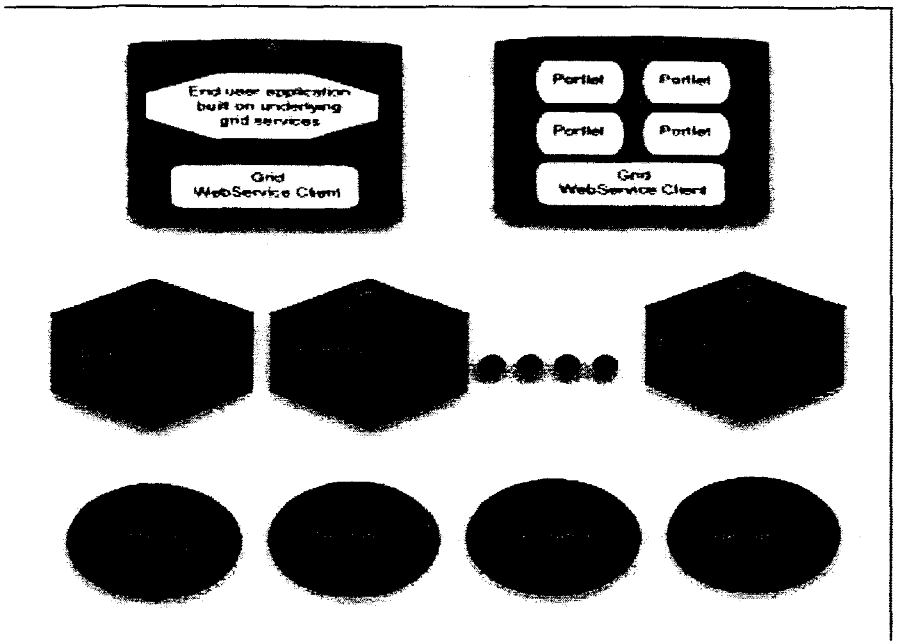

Figure 4: The SOSG Services Based Architecture Concept Diagram

5 Figure 4, The SOSG Architecture: Figure 4 shows a conceptual diagram that represents the services based model that will be used to support the SOSG Prototype. Through various mechanisms, (e.g., Portals, User written applications, command line programs, etc.), a user will have access to various capabilities instantiated as grid web services. Through these services, users will have a consistent access to various resources and well as capabilities that can easily be reused or stitched together to form larger complex applications that bring to bear multiple capabilities for a particular purpose.

The overall architecture for the SOSG consists of two elements:

(a) A portal architecture for presentation, administration and access to SOSG services

(b) A services architecture for creation of and access to SOSG services

These are described in more detail below:

(a) The SOSG Portal: The vision for the SOSG portal is for it to be the single interface that brings together all the SOSG applications for the benefit of the users of the four VOs that SOSG will be supporting. It is the vision that this portal be a captured portal where users are able to access all tools and services needed for him/her to conduct science research setup based on the user's profile. The portal in a secure controlled fashion provides this access. For this to be true, all applications and/or services must be grid enabled web services.

The SOSG portal effort we will be adopting is the Global Grid Forum (GGF) recommended portal architecture, which is based on the idea that the portal server is the container for "user facing" Grid service clients which are designed according to the portlet model specified in the JAVA standards document: JSR168 Portlet Specification. http://jcp.org/aboutJava/communityprocess/review/jsr168/. A portlet is "a server component that controls a small, user-configured window in a "pane" on the user's web browser" [1].

(b) <u>SOSG Services Architecture</u>: One the goals of the SOSG is to eventually provide a consistent interface to several applications that are part of the NASA Marshall Spaceflight Center Payload Operations Integration Center. A consistent and standard interface will allow for general re-use of common software, easier access to multiple services and the ability to easily link several services together to create a new more intelligent or capable service.

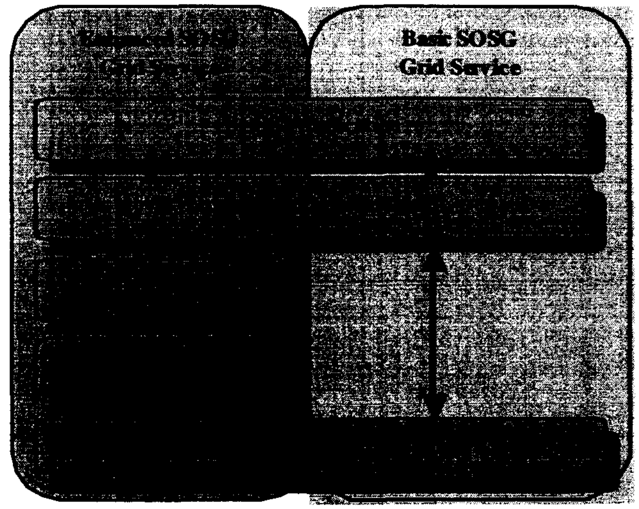

Figure 5: SOSG Layered Approach To Grid Services

To accomplish this, the SOSG team has decided to adopt the standards from the W3C and GGF as the guiding standards for the construction of SOSG services. For the SOSG, there will be 2 types of services; (1) Basic SOSG Grid Service (BGS) and (2) Enhanced SOSG grid service (EGS). In short, the BGS will primarily be a web service based on the W3C standards, but will incorporate a GSI-Enables WS_SECURITY library that support grid authentication and authorization. An EGC will be a fully compliant OGSA grid service. The reason to have the basic option is to provide an alternative for those applications that do not require the OGSA extensions such as statefullness, stateful interactions, transient instances, lifetime management, etc. [2]. Figure 5 represents a layered architecture for both the SOSG BGS and EGS.

This architecture relies on the following enabling technologies to accomplish the objectives, these include:

a) Grid Infrastructure Toolkits

The Globus Toolkit® is a set of fundamental technologies needed to build computational and data grids - persistent environments that enable software applications to integrate instruments, displays, computational and information resources that are managed by diverse organizations in widespread locations. The toolkit consists of a set of core services that can be used either independently or together to develop useful grid applications and programming tools. These include services for job management, data movement, resource information and security.[3]

b) Web Services

The advent of *XML* makes it easier for systems in different environments to exchange information. The universality of XML makes it a very attractive way to communicate information between programs. Programmers can use different operating systems, programming languages, etc., and have their software communicate with each other in an interoperable manner. Moreover, XML, XML namespaces and XML schemas provide useful mechanisms to deal with structured extensibility in a distributed environment.

Similar programmatic interfaces to the ones available since the early days of the World Wide Web via HTML forms, programs are now accessible by exchanging XML data through an interface, e.g. by using

SOAP Version 1.2 , the XML-based messaging framework produced by the XML Protocol Working Group.

The power of Web services, in addition to their great interoperability and extensibility thanks to the use of XML [4, 5], is that they can then be combined in a loosely coupled way in order to achieve complex operations. Programs providing simple services can interact with each other in order to deliver sophisticated added-value services. [http://www.w3.org/2002/ws/Activity]

c) OGSA

The Open Grid Services Architecture (OGSA) integrates key Grid technologies (including the Globus Toolkit®) with Web services mechanisms to create a distributed system framework based on the Open Grid Services Infrastructure (OGSI) [6]. A Grid service instance is a (potentially transient) service that conforms to a set of conventions, expressed as Web Service Definition Language (WSDL) interfaces, extensions, and behaviors, for such purposes as lifetime management, discovery of characteristics, and notification. Grid services provide for the controlled management of the distributed and often long-lived state that is commonly required in sophisticated distributed applications. OGSI also introduces standard factory and registration interfaces for creating and discovering Grid services. It should be noted that OGSI and Web services standards are being combined into a new set of standards the WS-Notification and the WS-Resource Framework that was announced in January 2004.

d) Security

Security for these services through Grid technology has and is being designed into the technology. This is unlike the Internet/Web technologies that were developed without security in mind. Grid security is maintained on several levels. First Grid enabling services provides for local security policy management (without affecting local security), and provides strong encryption and authentication for access and networking. Grid security is a significant focus of the Grid standards development effort of the Global Grid Forum.[7]

6 SOSG User Base: Once the Prototype User-based services are created and Grid/Web enabled four virtual organizations will be initiated with the objective that users identified with each VO will use and assess the services. The four VOs are: 1) Payload Control Center Operations (PCCO), 2) Payload Science Operations (PSO), 3) Flight Control Center Operations (FCCO) and 4) Educational Outreach (EO). For each VO a user base will be selected from: 1) the POIC for PCCO, 2) for the PSO several university based Principal Investigators who either are flying or have flown experiments on ISS, 3) for the FCCO the JSC Mission Control Center, and 4) for the EO a select set of schools already organized under one of several NASA sponsored educational programs will be recruited.

For each VO, specific services as indicated in Table 2 will be assigned. These services are required for each VO to function. Although collaboration is not a VO, the User-based services to be provided by the SOSG will enable significant collaboration between disparate NASA user communities.

Service:	1. PCCO	2. PCO	3. FCCO	4. EO
1. Data/Telemetry Mgt	X	X	X	
2. Experiment/System CMD Mgt	X			
3. ISS DL Video Distribution	X	X	X	X
4. Web Measure Delivery	X	X	X	X
5. High Performance Processing	X	X	X	
6. Data Mining	X	X	X	
7. High Volume Network Storage	X	X	X	X
8. Mission Voice	X	X	X	
9. Collaborative Internet Voice		X		
10. Video Auditorium	X	X	X	X
11. Application Sharing		X		X
12 System Performance & Measurement	X		X	
13 Networks Connectivity	X	X	X	X

Table 2, Virtual Organization Predominate Service Summary

Once the User-based services are Grid enabled, the Grid services identified in paragraph 2.a. are functional and the VOs are organized, parallel use by the four VOs. A written questionnaire with a follow up interview process will be initiated to determine usefulness, technical and cost feasibility and other applicability factors for each User-based service. With this user generated data, the insight of our hands on implementation of the SOSG Prototype and an appropriate peer review, a set of recommendations will be made concerning the efficacy of the application of Grid technologies to space operations and possibly NASA ground activities.

References

[1] D. Gannon, "Grid Portals: A Scientist's Access Point for Grid Services (DRAFT)," M. P. G. Fox, B. Plale,G. von Laszewski,C. Severance, J. Hardin,J. Alameda,M. Thomas, J. Boisseau, Ed.: Global Grid Forum Standards Document, 2003.

[2] S. Parastatidis, "Web and Grid Services: Architectures and Technologies." http://savas.parastatidis.name.

[3] "The Globus Project."

[4] D. Fallside, "XML Schema Part 0: Primer," 2001.

[5] A. Hoheisel and U. Der, "An XML-based Framework for Loosely Coupled Applications on Grid Environments," *Lecture Notes on Computer Science*, vol. in preparation, 2003.

[6] S. Tuecke, K. Czajkowski, I. Foster, J. Frey, S. Graham, C. Kesselman, T. Maquire, T. Sandholm, D. Snelling, and P. Vanderbilt, "Open Grid Services Infrastructure Version 1.0," The Global Grid Forum June 27 2003.

[7] I. Foster, C. Kesselman, G. Tsudik, and S. Tuecke, "A Security Architecture for Computational Grids," presented at 5th ACM Conference on Computer and Communications Security, 1998.