COMPUTING, INFORMATION AND COMMUNICATION TECHNOLOGIES (CICT)

Science Goal Monitor: Tools for Science Goal Capturing and Onboard Goal Monitoring

Mission Infusion Task Report

COVER SHEET (FOR ALL STEP 2 PROPOSALS ONLY)

SOLICITED NASA PROPOSAL APPLICATION IN RESPONSE TO ANNOUNCEMENT NRA2-38169	**LEAVE BLANK** **NUMBER** **REVIEW GROUP**
PLEASE FOLLOW INSTRUCTIONS CAREFULLY	**DATE RECEIVED**

IA. COMPLETE TITLE OF PROJECT:
Science Goal Monitor: Tools for Science Goal Capturing and Onboard Goal Monitoring

1b. PROPOSAL TOPIC: Automated Reasoning

2. PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR (First, middle, and last name; degrees; position)
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5. TAXPAYER IDENTIFICATION NO. (TIN)

6. NAIS CODE

CAGE CODE

7. HAS THIS PROPOSAL (OR SIMILAR REQUEST) BEEN SUBMITTED TO ANY OTHER AGENCY?
■ No ☐ Yes IF YES, SPECIFY AGENCY AND YEAR SUBMITTED:

8. WILL HUMAN SUBJECTS BE USED IN THE PROPOSED RESEARCH: ■ No ☐ Yes

9. CO-INVESTIGATORS (First, middle, and last name; degrees)	10. CO-INVESTIGATOR'S ORGANIZATION
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11. OTHER PARTICIPATING ORGANIZATIONS (e.g., NASA Field Centers or Other Institutions):
SMARTS collaboration at Yale University

12. DATES OF ENTIRE PROPOSED PROJECT PERIOD	13. FY2004 BUDGET	14. FY2005 BUDGET	15. FY2006 BUDGET	16. TOTAL BUDGET
From: 10/1/2003	Total Cost: $238K	Total Cost: 0	Total Cost: 0	Total Cost: 0
Through: 9/30/2004	NASA Contribution: 0	NASA Contribution: 0	NASA Contribution: 0	NASA Contribution: 0

17. APPLICANT ORGANIZATION (Organization Name)
NASA Goddard Space Flight Center

18. TYPE OF ORGANIZATION (U.S. ONLY)

☐ For Profit (General) ☐ For Profit (Small Business) ☐ For Profit (Woman-owned Business) ☐ For Profit (Minority-owned Business) ☐ Non Profit

☐ College or University (General) ☐ College or University (Historically Black or other Minority) Public, Specify: ■ Federal ☐ State ☐ Local

19. ORGANIZATION OFFICIAL TO BE NOTIFIED IF AN AWARD IS MADE (Name, title, address, and telephone number) Julie Loftis, Branch Head, Code 588, NASA GSFC, Greenbelt, MD 20771 301-286-5049	20. OFFICIAL SIGNING FOR APPLICANT ORGANIZATION (Name, title, and telephone number) Julie Loftis, Branch Head, 301-286-5049
21. PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR ASSURANCE: I agree to accept responsibility for the technical conduct of the project and to provide the required progress reports if a grant is awarded as a result of this application. Willful provision of false information is a criminal offense (U.S. Code, Title 18, Section 1001).	SIGNATURE OF PERSON NAMED IN BLOCK 2 (In ink; "Per" signature not acceptable.) Date:
22. CERTIFICATION AND ACCEPTANCE: By submitting the proposal identified in this Cover Sheet/Proposal Summary in response to NRA2-38169, the Authorizing Official of the proposing institution (or the individual proposer if there is no proposing institution): 1) certifies that the statements made in this proposal are true and complete to the best of his/her knowledge; 2) agrees to accept the obligations to comply with the sponsoring agency award terms and conditions if an award is made as a result of this proposal; and 3) if the applicant organization is an entity of the United States of America, confirms compliance with all provisions, rules, and stipulations set forth in the three Certifications contained in this NRA (namely, i) Certification Regarding Debarment, Suspension, and Other Responsibility Matters -- Primary Covered Transactions, ii) Certification Regarding Lobbying, and iii) Certification of Compliance with the National Aeronautics and Space Administration Regulations Pursuant to Nondiscrimination in federally Assisted Programs). Willful provision of false information in this proposal and/or its supporting documents, or in reports required under an ensuing award, is a criminal offense (U.S. Code, Title 18, Section 1001).	SIGNATURE OF PERSON NAMED IN BLOCK 20 (or person named in 2, if there is no proposing institution) (In ink; "Per" signature not acceptable.) Date:

BUDGET SUMMARY

From 10/1/2003 To 9/30/2004

	RECIPIENT'S COSTS	NASA USE ONLY	
	A	B	C
1. Direct Labor (salaries, wages, and fringe benefits)	$238K		
2. Other Direct Costs:			
a. Subcontracts			
b. Consultants			
c. Equipment			
d. Supplies			
e. Travel			
f. Other			
3. Indirect Costs			
4. Other Applicable Costs			
5. SUBTOTAL -- Estimated Costs			
6. Less Proposed Cost Sharing (if any)			
7. Carryover Funds (if any)			
a. Anticipated amount			
b. Amount used to reduce budget			
8. TOTAL ESTIMATED COST	$238K		
APPROVED BUDGET			

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1. ABSTRACT

Upcoming Space Science and Earth Science missions face many of the same information technology hurdles: the need to dramatically increase onboard automation in order to both effectively handle an exponentially increasing volume of scientific data and to successfully meet dynamic, opportunistic scientific goals and objectives.

Two long-standing paradigms must be changed in order to achieve this: (1) that the observing schedule and scientific processing can only be managed on the ground with significant human interaction, and (2) that all scientific data is downloaded and archived regardless of its scientific value. So far, these paradigms have been necessary because onboard computing has not been capable of permitting significant onboard science analysis and download capacities and/or cost thresholds have not been able to meet the rate at which scientific data is collected. In order for these paradigms to change, we must be able to: capture and interpret the science goals of observing programs, translate those goals in machine interpretable language; and develop onboard capabilities that allow spacecrafts to autonomously react to science opportunities that may be lost if the spacecraft must wait for ground-based manual intervention. In addition, both scientists and engineers must understand what capabilities are needed onboard for success. Further, metrics must be developed to realistically understand the potential increase in science returns and the risks involved in onboard analysis, and the costs to develop a production-ready system (both software and hardware).

We are designing and developing the Science Goal Monitor (SGM) system with the objectives of a) prototyping user interfaces to capture science goals in a fashion that the scientist can use and understand, b) evaluating existing and emerging software to dynamically evaluate science data on board the spacecraft, and c) providing a simulation framework that missions can use in their early conceptual design phases to understand and predict the effectiveness of SGM on their missions.

During the project so far, we have done much of the research and evaluations we set out to do in our original proposal. We have been working with the astronomers of Yale University's SMARTS (Small and Medium Aperture TelescopeS) project to lay out the specific science goals that we will use to test our prototype SGM system and to define the metrics that we feel will help us evaluate SGM's effectiveness. We are in the process of implementing interfaces between SGM and the systems that the SMARTS team currently uses for their scheduling and data processing.

We have also added a significant second collaborative partner, the Earth Observing-1 (EO-1) mission, for a prototype demonstration to support evolving sensor web concepts. With the EO-1 demonstration, SGM is being used to input scientific goals related to interpreting AQUA and TERRA's MODIS Rapid Fire data, and then coordinate an automated high-priority image request of a specific area-of-interest through to the EO-1 spacecraft. While the specific science scenarios we have implemented for this demonstration are intentionally simplistic, this demonstration highlights an additional new domain of potential contributions of SGM to the Earth Science domain: that of automated multi-mission coordination of science processing and reactive processing.

In the first year of SGM, we have laid a feasible but ambitious set of astronomical goals within the SMARTS collaboration, and extended the promise of SGM into the realm of Earth Science with our EO-1 collaboration. While the first year has focused much on research and core fundamentals, the second year of the SGM project has the primary phases of implementation and execution that will allow us to realize and measure the full potential of SGM.

2. NASA RELEVANCE

Infusion of automation technologies into NASA's future missions, which include constellations, formations, federations, sensor webs etc., will be essential to achieving a substantial increase is scientific returns. Hence, a major objective of the CICT IS program is to investigate strategies that increase spacecraft autonomy. A critical component of increasing spacecraft autonomy is to provide an as-yet-unrealized ability for spacecraft to perform opportunistic science and in-situ management of scientific activities. An important reason this has not yet been achieved is that missions and scientists are culturally and politically averse to risk when it comes to automation of scientific activities. Unless we develop strategies that will help reduce the perceived risk associated with increased use of automation, we will not be able to contain costs.

New space-based scientific platforms which include instruments such as hyperspectral imagers, are able to acquire more data than can be downloaded. For such platforms, just automating the spacecraft's technical operations will not intelligently handle the increasing volume of scientific data. In order to optimize science data selection and download, we must begin automating both scientific data analysis and reactions to that analysis in a timely and still scientifically valid manner. In other words, we must teach our platforms to dynamically understand, recognize, and react to the scientists' goals. The Science Goal Monitor (SGM) will help progress towards building intelligent spacecraft.

The SGM project applies the emerging efforts to perform goal oriented onboard scheduling. It is a proof-of-concept prototype to determine if we can effectively and efficiently obtain reliable and relevant data from scientists to make science driven scheduling changes and to measure that effectiveness. In SGM, there will be new, rapid, flexible, and autonomous approaches to analyzing the quickly growing stream of data. *The tools being developed in the SGM will help to improve our ability to monitor and react to the changing scientific status of observations. Such tools will be enablers for spacecraft autonomy.*

2.1. RELEVANCE TO THE SPACE SCIENCE ENTERPRISE

The Space Science Enterprise 2003 Strategy [1] states in part: "Information technology that will allow ready access to and an analysis of an unprecedented volume of data from multiple spacecraft in diverse locations and improved spacecraft autonomy to reduce spacecraft operations costs." SGM contributes to this strategy by:

? **Improving returns on the investment by reducing the response time to science events.** The top-level priority of SGM is to build a framework for the express purpose of increasing scientific returns for any mission that wants the flexibility to respond to scientifically defined events. This will be achieved by providing scientists and observatories with tools that reduce response time to scientific events, thereby reducing science data loss and failed observations, plus increasing the ability to do opportunistic science.

? **Improving spacecraft autonomy using user specific onboard data analysis.** As data volumes increase, communication and data downloading will become more difficult and expensive. The SGM tools that are used to capture science goals *per science program* can also be used to provide strategies to perform basic onboard analysis of images to assign download priorities and select compression techniques, allowing an observatory to reduce data download costs.

? **Multi-tiered data analysis at varied locations and data pipeline delivery stages.** The increasing power of computing allows us to apply multi-tiered analysis to near-real-time data transmissions that were not possible a few years ago. SGM exploits these by mixing on-board analysis with ground-based analyses. We are building our components to be distributable. The purpose being that different steps of the goal monitor could be performed on different sub-systems and at different stages of the data pipeline delivery. One such objective is to enable part of the analysis processing to occur on board as an in-flight system so that valuable data transmission times could be made more efficient.

2.2. RELEVANCE TO THE EARTH SCIENCE ENTERPRISE

The Earth Science Technology Office [2] identifies sensor webs and automation as important information technology activities. Many of the bullets in the section above on relevance to Space Science are also applicable for Earth Science as they are relevant to increasing spacecraft autonomy and increasing the science returns from spacecraft. In our discussions throughout we have used the words "science" to mean both Earth science and applications programs. The following highlight some features of SGM in the context of sensor webs for the Earth Science Enterprise.

? **Developing science campaign management strategies for sensor webs.** For an effective sensor web, not only do the higher-level goals of a science campaign need to be well understood, but various space-based and ground-based resources need to be coordinated to achieve the science goals. In short, there needs to be an effective strategy to manage the science campaign. SGM's EO-1 demonstration (see section 3.2) is this first step towards developing effective sensor webs, and enables a new strategy for Earth observation measurements.

? **Obtaining high-level goals to get a user-friendly interface into sensor webs.** SGM will provide several new tactics and capabilities for obtaining and analyzing data. Its design is intended to span missions and provide a platform on which new suites of tools to perform goal analysis can be easily built and refined. A unique feature of this proposal is the scientific focus of the analysis. Rather than specifying goals in computer-oriented terms and algorithms, we will be endeavoring to provide an interface that lets the scientist focus and articulate their science goals in scientific terms. This will allow scientists to define goals per science project rather than a "one shoe fits all" strategy per mission/instrument.

? **Improved communication between spacecraft for coordinated reactions to science events.** As our EO-1 demonstration shows, SGM's "campaign" management capabilities will significantly improve the ability to coordinate actions of multiple spacecraft in response to science events from either ground-based systems or from other spacecraft. This ability to coordinate inter-spacecraft communications for upcoming sensor web applications will in general improve the science returns on otherwise independent earth science missions.

3. TECHNICAL PLAN

3.1. BACKGROUND: WHAT IS THE SCIENCE GOAL MONITOR?

The Science Goal Monitor (SGM) is a prototype software tool being developed by NASA's Advanced Architectures and Automation Group (Code 588) to determine the best strategies for implementing science goal driven automation in missions. It is a set of tools that will capture the underlying science goals of an observation, translate them into a machine interpretable format, and then autonomously recognize and react in a timely fashion when goals are met. SGM will provide users with visual tools to capture their scientific goals in terms of measurable objectives and be able to autonomously monitor the science data stream in near-real time to see if these goals are being met. Our prototype is designed for use in a distributed environment where some analysis can be performed onboard a spacecraft, while other analyses can be performed on the ground.

Figure 1 and Figure 2 show a high-level diagram of SGM in the context of both of our collaborations. First, with the astronomers involved in Yale University's SMARTS (Small and Medium Aperture TelecopeS) project, we model and test ways in which SGM can be used to improve scientific returns on observing programs involving variable astronomical targets. Second, in a new collaboration with the EO-1 mission, we coordinate analysis of data received from the MODIS instruments flying on the AQUA and TERRA satellites with a dynamic autonomous request for higher-resolution images from the EO-1 satellite based on a set of scientific criteria.

Our objective for SGM is to focus on capturing, recognizing and reacting to scientific events. It is not our intention to focus on developing the scientific algorithms, nor on developing advancements in scheduling systems. Rather, SGM affects operational strategies by providing a flexible system for reacting to science goals. It is designed to enable easy "plug-in" of pre-existing algorithms and interfaces to multiple data sources – which might be instruments, ground-systems, internet-based data sources, or scheduling systems. Further details on the concepts behind SGM can be found in [3] and [4].

3.2. OBJECTIVES AND OVERVIEW OF ACCOMPLISHMENTS

In our initial proposal, we established the following objectives for the Science Goal Monitor:

? Using a set of astronomically oriented scenarios, develop a working prototype science goal monitor to perform in-flight science-oriented processing, and dynamically and autonomously adjust science tasks accordingly; determine realistic requirements for in-flight hardware and software, metrics for measuring the monitor's scientific effectiveness, and a costs and risks analysis for developing a production flight-ready version; and

? Develop and document an initial protocol and standard for describing astronomical observing goals.

During the past 10 months we have made significant progress towards these original objectives. We have evolved our objectives on the basis of our efforts to date and opportunities we've encountered. The SGM project is currently focusing its prototype functionality towards two collaborations – the SMARTS collaboration and the EO-1 collaboration.

Throughout this document we use the time line used in our original 2002 technical plan (see [5]). In working with the SMARTS team, we have:

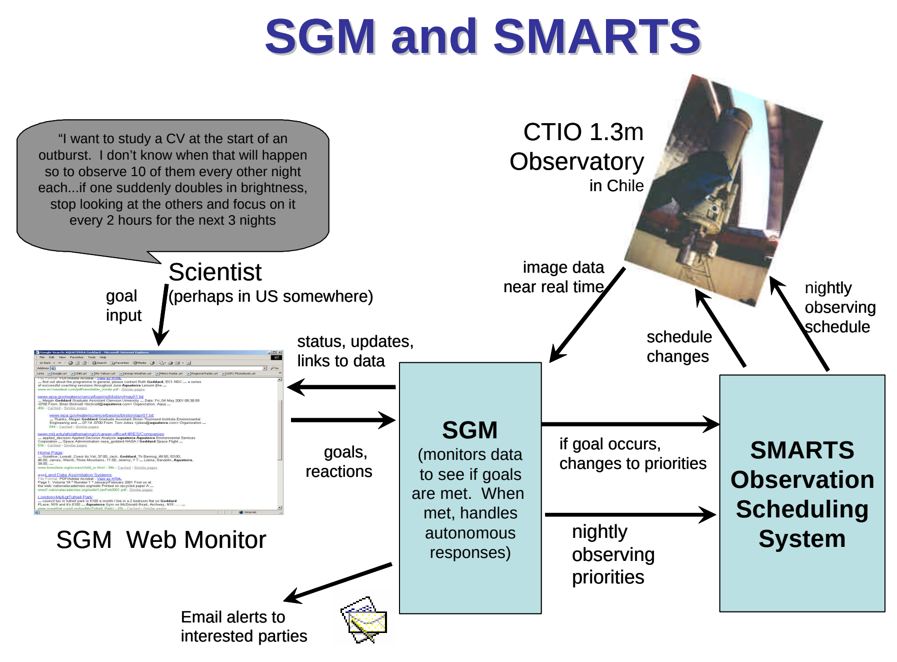

Figure 1, SGM and SMARTS Context Diagram

1. Evaluated the current state of the planning and processing tools currently used by the SMARTS, and begun work to upgrade those tools so that SGM can eventually interface with them for automatic analysis and determination of the status of the science goals;

2. Evaluated and established a baseline suite of software tools for providing the processing capabilities that SGM and SMARTS will need;

3. Worked with several of the science investigators on SMARTS observing campaigns to thoroughly evaluate what their science goals are and how their observing strategies change as they evaluate the observations taken to date;

4. Identified three SMARTS campaigns that provide the best scenarios to test SGM and have begun modeling the observing strategies and science goals (see [7]);

5. Defined a variety of metrics (see [13]) that we can use to establish and evaluate SGM's effectiveness. Baseline measurement of these metrics is scheduled to begin with the fall 2003 semester[1] of SMARTS observing.

The SMARTS program was in its first observing cycle during the spring of 2003 This has been an advantage for SGM in that the SMARTS team has not had a well-established suite of operational processes that are difficult to change. The disadvantage has been that the SMARTS team members have not had a baseline set of science programs and pre-existing statistics with which SGM can be compared. Also, since the paradigm of defining an observing program as a set of science goals and reactions is unusual from the scientist's perspective, we have opted to focus on a subset of the current SMARTS programs that rely primarily on temporally variable targets. These are the programs where the paradigm is most applicable and its impact most easily measurable.

[1] The observing cycles for the SMARTS team closely parallel academic semesters as the majority of the users are affiliated with partner universities and typically are reference with similar nomenclature as academic semesters, e.g. Fall 2003.

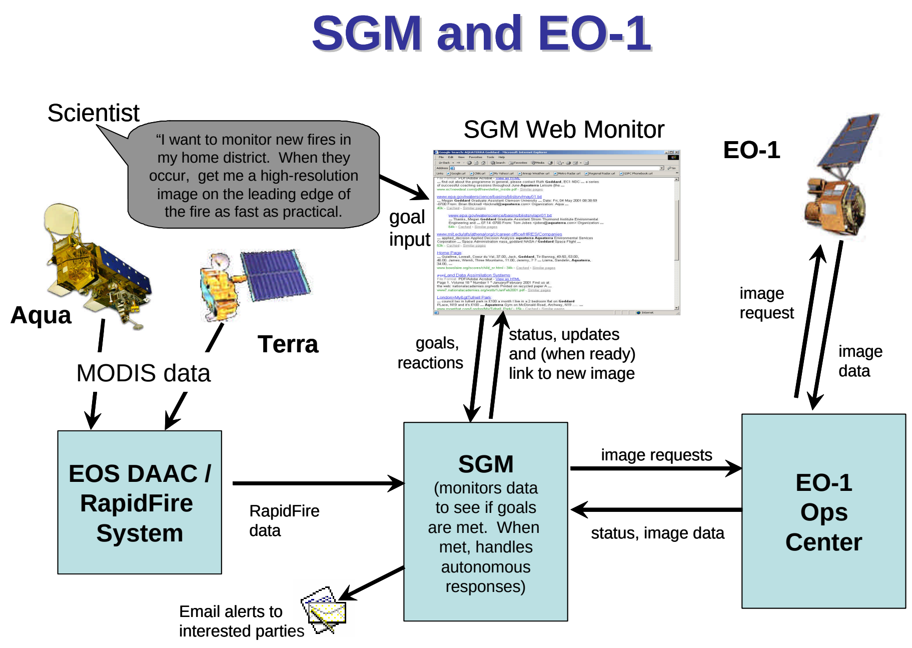

Figure 2, SGM and EO-1 Context Diagram

New Opportunity to Extend SGM to the Earth Science Domain

We have also had a new opportunity to collaborate with the Earth Observing–1 (EO-1) mission team on a prototype that expands the relevance base for SGM. In the EO-1 prototype demonstration, SGM serves both as a science analyzer and a multi-mission coordinator in a sensor web related application. In the EO-1 prototype, SGM monitors science data processed from the MODIS instruments flying on AQUA and TERRA satellites looking for specific events. In a recent prototype demonstration, SGM monitored the daily list of active priority fires from the Remote Sensing Applications Center (RSAC) [5] and when a fire was identified in a scientist's specified region of interest, SGM analyzed the recent history of the fire from the MODIS Rapid Fire data in that area to isolate the latest center of activity, and then coordinated with the EO-1 planning systems to request and monitor a high-priority high-resolution image from EO-1. SGM's web-based monitor also provided the user with a live monitor of the status of his/her image request and automatically linked to the new EO-1 image when it became available. This specific science demonstration of monitoring a known active fire is relatively simple, but it shows the promise of coordinating data from different sources, analyzing the data for a scientifically relevant event, autonomously updating and rapidly obtaining a follow-on image. Such quick analysis and coordination can in the future be used to support tactical fire fighting.

While we initially proposed SGM as an analyzer/monitor for remote astronomical instruments, this new collaboration with EO-1 positions SGM for infusion into a significantly wider range of current and upcoming NASA missions and science domains. It has also provided a practical focus for developing and refining the internal software capabilities within SGM. Further, it has helped expand our design focus so that SGM will more easily adapt to a wider range of missions than our initial expectations. Finally, EO-1 is also in the process of testing and evaluating JPL's ASPEN and CASPER planning and scheduling systems. CASPER and ASPEN have been lead candidates in our initial planning to provide interfaces with SGM, where SGM needs adaptive scheduling. By collaborating with EO-1, the SGM team not only widens its infusion domain but simultaneously gains experience in using and interacting with ASPEN and CASPER, which will make the implementation phases of SGM in the SMARTS environment faster and more productive.

In adapting our schedule to accommodate the EO-1 collaboration, we have put slightly more emphasis in the first 10 months on core prototype development in SGM than we had originally planned, and we have moved back slightly the development of models for our SMARTS science scenarios. We have successfully demonstrated the EO-1 prototype with two scientific scenarios: the active fire monitor described above and simpler pre-cursor where SGM monitor just the MODIS data for fires in a specified region. Our initial science scenario was used to monitor an area of Angola, Africa and autonomously coordinate and submit a high-priority image of the EO-1 satellite. In our just completed, US-based demonstration, SGM has handled a more complex scientific scenario involving coordinated data from two distinct data sources. This demonstration was performed as this Mission Infusion Task Report was being finalized. *Our SGM EO-1 collaboration not only demonstrates a future NASA need, but for the near future provides an effective "operational prototype" for Earth science applications.*

3.3. PHASE IA – REFINE GUIDELINES, SCENARIOS FOR TESTING ON GROUND-BASED OBSERVING

3.3.1. Knowledge Acquisition and Goal Development with SMARTS Operations Team

The primary goal of Phase IA has remained largely unchanged since our initial proposal, and the phase is largely complete at this time. The goal of this phase has been to integrate and adapt SGM's goals and abilities to the SMARTS operations paradigms. To achieve this we have conducted a number of discussions and had two on-site meetings with the SMARTS operations team. During these meetings we were able to draw on their current observations, develop a solid data base of actual observing archives, logs and other documentation about their current scheduling processes, and review the existing operations tools that are used by the SMARTS team. These discussions have helped us identify immediate "high impact" project goals. These short-term goals will provide some basic tools that will change the currently manual process into a more automated process which is essential for SGM.

The high impact goals that we have identified for implementation during Phases II and III are:

? **Develop an automated interface which will enable SGM to interact dynamically with an active nightly observing schedule.** In order for SGM to eventually be able to implement scheduling recommendations, it is essential that there be an automated scheduling tool that SGM can interface with. Since the bulk of the SMARTS scheduling is currently performed manually, we have developed a simple scheduling assistant tool for SMARTS that automates the maintaining of lists of observations desired, scheduled, and completed. This tool is being tested by the operations staff. It will be in use with the start of the fall 2003 observing cycle. This tool automates much of the labor-intensive "cut and paste" processes that the SMARTS team has used to develop their night schedule. The tool has been quick and inexpensive to develop, but provides us with the automated interface that will be essential for SGM and provides the SMARTS team with a significant and immediate labor-saving efficiency boost.

? **Provide an initial simple "Goal Analyzer" for use at the observatory on the mountain**. The initial Science Goal Analyzer (SGA) will calculate the magnitude of the target and standard stars in the field and then determine if there have been any magnitude changes from the previous observation of the same field. This is generally the first step in data processing and analysis of many of the SMARTS science monitoring projects and is currently being manually performed by the operators on requested targets each night. Thus, this goal analyzer when implemented will have an immediate impact, especially on projects that are monitoring for outbursts and flares in targets where fast response to science events is essential. We are in the process of finalizing the specifications for this tool. This simple SGA will include proactive communication with scientists and also save operator manual labor.

? **Integrate a "seeing"[2] measurement to generate a dynamic nightly schedule.** At present the SMARTS team generates only one schedule for the night. But science returns should increase significantly if the schedule can adapt to changes in night conditions, such as atmospheric seeing. Being able to regenerate the observing schedule at least once during the night when the seeing conditions change will be a big step towards adaptive scheduling which is an essential part of SGM. It will also provide us with experience to handle targets of opportunity[3] that are very disruptive to the schedule. We are in the process of determining the necessary specifications for this operation.

3.3.2. Knowledge Capture with SMARTS astronomers

The capture and articulation of science goals is an essential part of the SGM system. To design and develop this we needed to generate effective science use cases. This implies that we need to understand how scientists specify their objectives such that SGM can process them. In our initial meeting with the SMARTS team we obtained all of the 18 science proposals that were approved for the first observing season. The SMARTS proposals are fairly simple and contain just the information on target location and observing strategy (larger observatories usually require observers to include scientific justification sections in their proposals). The proposals were reviewed and the high-level science objectives/goals for each proposal were determined. Of these 18 proposals, 8 proposals were long term monitoring programs and 10 were just pointed observations. We then interviewed the principal investigators of the 8 monitoring programs. In these interviews we focused on determining: the high level science goals for the program; the nature of the targets; source(s) for the target coordinates; how the astronomers currently plan their observing runs; the criteria for establishing priorities and resolving conflicting priorities for programs with multiple targets; and finally, what science data analyses could be automated and used for science event detection, etc. After the interviews, we determined how SGM would be useful for each of the projects and what action SGM was expected to take. The actions that SGM could take were then written up in detail and reviewed by the scientists. Of the 8 possible observing proposals we have focused on three and documented them as our science "use cases". Each use case is a scientific scenario that is distinct in its science goals; is representative of the larger pool of SMARTS programs; is programmatically challenging; and will effectively test the various aspects of SGM. The three cases are summarized here, and discussed in detail in [7].

1. The X-ray binary scenario is ideal for SGM because it needs to monitor an unpredictable event (change in the target's brightness) and capture it as effectively and efficiently as possible. Further, the observing strategy may change when the event is detected.

2. The Supernova scenario has observations that are constrained by night conditions and has very strict demands on the observing strategy and associated data processing.

3. The Gamma-ray scenario will test how SGM and the scheduler interact with each other. In this program SGM's task will be more as a task manager for not only the observing night, but the entire observing season.

3.3.3. Establishing Metrics for SGM

Another important task for Phase IA was to work with the SMARTS astronomers to review and establish metrics by which we can judge the effectiveness of SGM. Observatories have defined metrics

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[2] *Atmospheric conditions such as turbulence and clouds affect the quality of the image. This image quality is said to be seeing. Seeing imposes the greatest limitation on ground based telescopes.*

[3] *Targets with unpredictable events that are scientifically interesting. For example, supernovae, gamma-ray bursts, solar flares, etc.*

in many different ways to track their various processes and contributions to the scientific community ([8] through [12]). For operational metrics, observatories often rely on statistics such as percentage of time spent exposing a detector. On the science side, traditional metrics frequently include long-term measures such as the number of citations in refereed scientific journals. However, to effectively measure the effectiveness of SGM as a dynamic science tool we needed to identify metrics that help measure science return in a dynamic fashion. We have therefore established a baseline set of new metrics (described in [13]) that we hope will help quantify and demonstrate where and how SGM is most effective in improving quality and efficiency in scientific terms.

In conversations with the SMARTS astronomers, we have established a set of metrics to see if the following goals of SGM are being achieved:

? Reduce the time taken to change/implement observing strategies in response to scientific events
? Reduce time spent on maintaining science programs, thus increasing the time spent on scientific analysis

Baseline measurement of these metrics is scheduled to begin with the fall 2003 semester of SMARTS observing prior to introducing SGM into the process. We will continue to track these metrics as we introduce and tune SGM within the SMARTS environment.

There are two types of metrics that we will use. The first are operational metrics that will quantitatively measure the amount of time spent on various tasks by SMARTS operations staff and astronomers. If SGM is successful, the total hours spent in rote work, which deals with the planning and maintenance of a science program, should go down. The second metric is scientific success. This is a more subjective measure, yet it will be effective in measuring SGM's successes as perceived by a scientist. This metric is important because scientists, especially astronomers, are averse to automation. They remain leery of expert/automation systems and are not yet convinced that their unique goals can be effectively and accurately captured and executed.

3.4. PHASE IB - INITIAL PROTOTYPE DEVELOPMENT AND STANDALONE TEST

Phase IB has been running concurrently with phase IA as was our original intent. Phase IB has consisted of evaluations of existing tools and the initial prototype development of the core components of SGM. Our progress on prototype SGM development has, thus far, been primarily focused on the components needed for the EO-1 prototype demonstrations and has included implementation of components to monitor several types of data streams, interact via asynchronous messages with external missions, and perform goal monitor on the initial goals necessary for the EO-1 demonstrations. Our evaluation of existing tools had led to several conclusions which are described next.

3.4.1. Evaluate existing tools and integration options

3.4.1.1 Planning and Scheduling systems

SGM was designed with the assumption that the mission in which it is deployed has an existing planning and scheduling system that is responsible for maintaining the observation schedule. SGM interacts with this system, to instruct it to modify the schedule when a goal has been triggered. *We specifically wanted to avoid any scheduling implementation within SGM, given that several planning and scheduling systems already exist.* SMARTS, however, does not have a planning and scheduling system. Currently, the SMARTS schedule is maintained in text files and handled manually. Therefore, we knew that part of the SGM task for SMARTS would be to choose a planning and scheduling system, develop SMARTS models for it, and integrate it into the SMARTS operations, at least enough for our prototype. The obvious candidates which are well-known in the community are ASPEN and SPIKE.

SPIKE [14] is a planning and scheduling system written by the Space Telescope Science Institute (STScI) for the Hubble Space Telescope (HST). SPIKE has existed for many years and is now used by many astronomical observatories including FUSE[4] and VLT[5]. SPIKE's primary flaw is its complexity and from SGM's perspective the inability to migrate it for onboard use. Given that it was designed for HST, it is quite robust, but also very complex. In talking with existing SPIKE users, we discovered that it can be difficult to use and typically requires STScI experts to assist new missions in customizing it to their needs. SPIKE is written in Lisp and requires Lisp knowledge in order to configure it. Since the scheduling requirements for SMARTS are substantially less complex than those for a large observatory like HST, we felt that SPIKE would be overkill for our needs, and would introduce unnecessary learning curve and complexity not only into the SMARTS project, but for any onboard use.

ASPEN [15] is a planning and scheduling system written by JPL for ground-based scheduling. ASPEN is designed for modularity and easy adoption by different missions of varying complexity [16]. We have spent some time with ASPEN and found it to be relatively straightforward and easy to use. Its plan language is reasonably simple and should allow us to construct a SMARTS model with relative ease. Our collaboration with EO-1 gave us additional momentum for choosing ASPEN. EO-1 is using CASPER for its autonomy prototype efforts. CASPER [17] is the onboard version of ASPEN. Both tools share the same plan language and are very similar internally, other than CASPER being designed for onboard use and ASPEN for ground use. Further, EO-1 plans to replace MOPSS, their ground-based scheduler, with ASPEN, as MOPSS has proven unable to fulfill the needs of the autonomy prototype. Therefore SGM has a strong incentive to also adopt ASPEN, as it will allow us to share the same planning and scheduling interface for both SMARTS and EO-1. We will also be able to leverage the onsite expertise of the EO-1 team, which should make development of the SMARTS module easier.

3.4.1.2 Data Analysis and Pipelining systems

SGM performs near real-time analysis of science data in order to trigger science events based on the scientist's goals. The actual analysis that is performed is specific to each type of observation, and the set of possible analyses that may be required is infinite. SGM handles this with an architecture that allows arbitrary analyses to be installed within SGM, some of which may execute within SGM, while others may link to existing analysis packages. It would make little sense to rewrite an analysis algorithm that already exists in some other data analysis package. Hence, we have looked at existing data analysis packages to determine which might be useful for our analysis needs.

Instrument Remote Control (IRC) [18] was developed by the Advanced Architectures and Automation branch of GSFC to provide a collaborative, adaptive framework for the distributed control and monitoring of remote instruments. IRC's main attraction is that it includes a number of data analysis algorithms built into the system. IRC is, however, intended for direct real-time use of an instrument or telescope, and is not designed for automated analysis. But while IRC as a whole may not be suitable for SGM, some of the algorithms embedded within it may be. Since IRC was developed onsite, we have ready access to its source code and will consider it as one more possible source for analysis algorithms and design patterns as they are needed.

The Image Reduction and Analysis Facility (IRAF) [19] is a general purpose software system for the reduction and analysis of astronomical data, IRAF has a long history in the astronomical community and is quite popular with many astronomers. Not only does IRAF contain numerous analysis algorithms, but

[4] *Far Ultraviolet Spectroscopic Explorer*

[5] *Very Large Telescope*

astronomers often write their own analyses as IRAF scripts built on the existing IRAF analyses. Therefore interfacing with IRAF as a provider of analysis algorithms within SGM will be important for SMARTS. Fortunately IRAF has a flexible interface which allows external programs to run IRAF scripts in batch. This will allow SGM to interface to IRAF relatively easily. Also, Starlink [21] is a new data analysis tool which is heavily used by European astronomers and is very similar in function to IRAF. Because it is written as a collection of Java libraries, Starlink would enable much tighter integration with SGM than IRAF. So we are considering both tools.

OPUS [21] is a distributed data processing pipeline system developed at the Space Telescope Science Institute. It is used by several astronomical observatories to handle their data processing pipeline. We looked at OPUS as a way to coordinate pipelines of data analyses where each analysis is a separate process that takes data as input and produces some data as a result. Our experience with OPUS is that it is fairly easy to configure and use. We expect OPUS to be useful in the future once we begin to support more complex scenarios that require multiple linked analyses.

3.4.1.3 Infrastructure Tools

Phase IB also included an evaluation of tools necessary for the underlying infrastructure of SGM. These tools had to be suitable for both SMARTS and EO-1, and should be scalable to future missions as well. We also wanted to use other tools instead of developing our own wherever possible. Finally, given that our customers' budgets were known to be quite limited, we were interested in pursuing open source tools as much as possible.

SGM requires a relational database management system to store data for the set of campaigns and goals. We considered MySQL [22], a popular open source database that is widely used in the commercial world. Ultimately, though, we chose another open source database called HSQLDB [23]. While both are fine solutions, we favored HSQLDB because of its small size and its simplicity of operation, while still retaining a robust feature set and scalability. Regardless, we are strictly adhering to the JDBC standard which allows us to plug-in a different database without changes to the code which uses that database. We are also using an object to relational mapping technology called the ObJectRelationalBridge (OJB) [24]. OJB implements a standard called Java Data Objects (JDO) which allows us to decouple the database design from the rest of the system, so that the application code is independent and decoupled from the underlying physical database structure and implementation.

Finally, because we are developing the SGM front-end as a web application, we needed a web server and servlet container in which to deploy our front-end application. While several possibilities exist, the Apache web server and Apache Tomcat servlet engine have become almost de facto standards in the open source web community, so their selection was quite easy.

3.4.2. Develop core software for EO-1 demonstration

Phase IB saw the development of software intended for the EO-1 sensor web demonstrations. This consisted of further enhancements to the core SGM engine, plus EO-1 specific modules that plug into the SGM architecture. This has helped the overall SGM effort by providing a focused need for SGM core enhancements which will be generally useful for SMARTS and other missions as well. The individual components of the SGM architecture are shown in the Figure 3 below, and the custom EO-1 components are highlighted. Note that each EO-1 component can be replaced by a SMARTS component without changing the core SGM code, as is shown in the Figure 4.

Phase IB accomplishments for EO-1 have included:

? Enhancements to the underlying structure of SGM's model of goal definitions to support the EO-1 scenarios.
? Support for processing data "channels" from several different sources (such as FTP, HTTP, and e-mail alerts)
? Ingesting and analysis of data sources such as MODIS' Rapid Fire data and the RSAC's Active Fire database
? Database-driven persistence mechanism for goal data
? EO-1 campaign class which implements the EO-1 sensor web science scenario

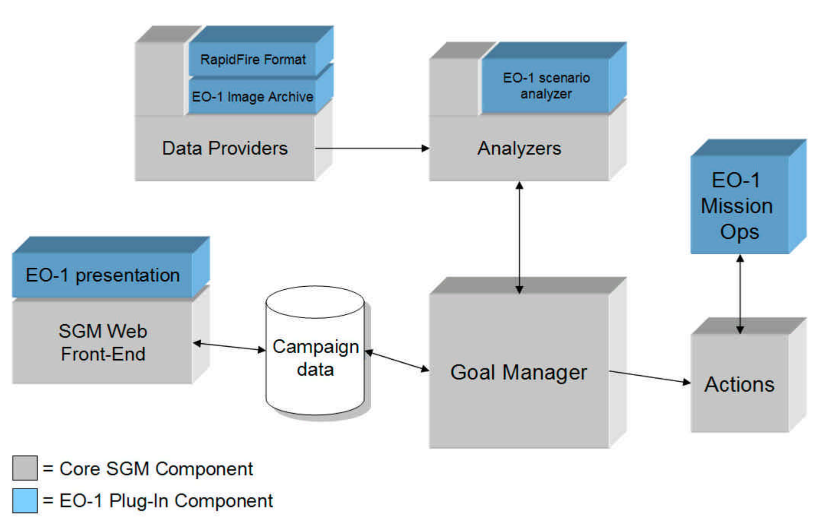

Figure 3, SGM architecture with EO-1 plug-in components

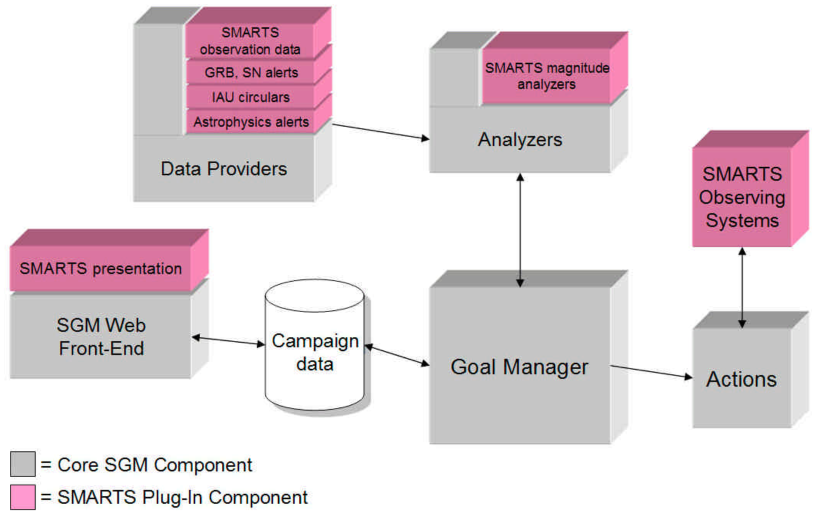

Figure 4, SGM architecture with SMARTS plug-in components

? Implementation of a web-based SGM end-user front-end
? EO-1 custom pages for web-based front-end

3.4.3. Develop initial automation capability for SMARTS

In conjunction with the science case formulation phase being conducted for SMARTS, we began to develop some basic automation capability that was needed. SGM requires that some fundamental telescope operations tasks be available via software, and since SMARTS operations are currently done manually, new software is needed. These tasks include planning and scheduling, the determination of schedulability, and the acquisition and storage of observation data. As was mentioned before, we hope to use third-party tools to accomplish much of this. Nevertheless, we did develop a simple scheduling assistant that allows the SMARTS team to manipulate the nightly observation schedules which was previously done by manually editing text files. Our hope is that once the SMARTS team transitions to using this assistant, we will later change its internals to use a full-fledged scheduling system (most likely ASPEN) without changing their interface to the system, thus making that transition easier. This is the beginning of what will eventually be the full automation of SMARTS operations with SGM as the core system.

3.4.4. Refine detailed plan for Phases II and III Products

Our final task for phase IB was to create a more detailed plan for what we will accomplish in phases II and III. Since we are still in phase IB at the time of this writing, this task is ongoing. However our current results are described in the following sections.

3.5. PHASE II – TEST, EVALUATE AND TUNE PROTOTYPE PERFORMANCE AGAINST BASELINE DATA

Phase II of the project remains fundamentally unchanged by our collaboration with EO-1. We will start with Phase II about a month later than we originally intended, however, the core capabilities of the prototype will have been further developed through the collaboration with EO-1 so that we anticipate no significant schedule loss completing Phase II. The objectives of Phase II remain to test and tune SGM using a controlled environment and a mix of simulated and actual data from previous semesters of SMARTS observing. By using a "controlled" environment we will be able to provide repeatability in testing so that we can effectively tune and improve SGM's reactive abilities, and also understand and improve the quality of the metrics we use to understand SGM's scientific effectiveness.

The detailed tasks for Phase II are scheduled to be revised and reviewed after this report is submitted. The higher level objectives for Phase II are as follows:

? Track and develop database of "pre-SGM" metrics as per Phase IA described above. This will include, where possible, not just tracking statistics for the Fall 2003 observing semester, but also looking back at the Spring 2003 observing semester to calculate additional data for our baseline metrics.

? Complete implementing test environment for parallel testing of SGM. This will include installation of tools for the SMARTS team to automate and speed the transfer of data from the observatory to the SGM test environment.

? Complete implementation of our SGM's campaign and observing models. This will enable us to begin executing SGM on our targeted campaigns defined in Phase IA.

? Run SGM repeatedly using both simulated data and real data in a structured environment. Compare SGM's reactions against the reactions and analyses of observing scientists. Refine and re-factor SGM as necessary to improve its reactions

? Refine SGM user interfaces to allow scientists to enter and edit their campaign goals. Perform usability testing with the scientists to improve the interface's responsiveness and usability.

? Phase II will conclude with a review of its success, lessons learned, and metrics accumulated during the phase. During this review, the final tasks and priorities for Phase III will be updated and revised.

3.6. PHASE III – TEST PROTOTYPE IN "LIVE" OBSERVING ENVIRONMENT

The final phase of our project will involve adapting SGM to work in a live observing environment using one or more of the SMARTS observatories. This will involve the following steps:

? Adapt SGM's interfaces to integrate with "live" observing data from the observatory's detectors.

? Run SGM through several observation cycles with SGM interpreting the data received and making "recommendations" only. The actual decision making on the observing priorities will continue to be made by the SMARTS operations staff.

? Once both the SGM and the SMARTS teams are comfortable with the effectiveness of SGM, we plan to perform several additional observing cycles, where the decisions on observing priorities are made only by SGM itself.

? Measure the effectiveness of SGM throughout the phase using our established metrics and compare the results with our baseline expectations.

? Write up our final project report that will include: our successes, lessons learned, risks and rewards for using SGM, analysis of issues involved in infusing SGM into a production, flight-ready environment.

3.7. EXPECTED IMPACT AND INFUSION

3.7.1. SGM's Value for Scientists: The ability to specify and perform dynamic, opportunistic science

Science campaigns in the future will often involve data acquired from multiple spacecraft or instruments/telescopes. For example answering such questions as "What changes are occurring in global land cover and land use, and what are their causes?" will require data from multiple satellites and instruments. Similarly, understanding the characteristics of accretion disks around black holes will not only require multi-wavelength data but also the ability to capture flares and other temporal phenomenon. Current mission operations in both Space and Earth science enterprises have very little to no coordination across missions and often do not have the ability to respond rapidly to science events.

To get the best data for any given project, it is important for the scientist to have influence in how the observation is actually executed. Currently, for space-science observatories, after the observer submits his/her proposal, changes to an observing program are done only if something dramatic has happened to the detector or spacecraft and often no changes are made for scientific reasons as they disrupt the schedule too much. *Since the observer has little voice in how the observatory responds to science driven anomalies, the resulting observational data may be less than optimal, or even useless.*

Today, in the Earth science domain we have a number of satellites orbiting the Earth but there are no coordinated observations, because the missions are separately managed and there is also no communications between missions. Yet, Earth science campaigns would greatly benefit from coordinated observations as many of the phenomenon need multi-spacecraft data.

SGM would capture the user's plan for the observation execution, including instructions for what to do in case certain conditions/events occur. These "contingency plans" would be triggered when the SGM analyzer detects science events that match the observer's criteria, or can be used in the scheduling of observations. SGM is unique because it seeks to capture the original intentions of the scientist (goals) and to use those goals in the short-term processing/planning of the mission.

3.7.2. SGM's Value for Observatories: Reduced response times to science events, increased science return

SGM will be ideal for any mission that desires shorter response times to science events. With this proposed effort, science features or events can be discovered in the data in "real-time" rather than weeks or months later by manual analysis. This problem will be exacerbated by the increasing data volumes that are expected from upcoming missions. Further, capturing the scientist's original goals and contingency plans, then allowing that information to affect the actual execution of the observation, increases the ability of an observatory to do opportunistic science.

Currently, in the space science domain, depending on the availability of observatory staff, when data quality checks are performed, they include such things as automated checking for proper execution and basic pipeline data calibration. There is no check to determine if data are useful to achieve the original science goals. In a resource-constrained environment with minimal staff, SGM can also be used to automatically determine the status and quality of the data by comparing the observations with the desired scientific goals of the program. This is especially useful when data volumes are large and manual checks are not possible. SGM benefits any mission that has experienced scientifically failed observations, because such failures can be discovered faster. By automating some of these manual tasks, SGM can help contain science operations costs.

3.7.3. Applicability of SGM to other domains

While our initial focus has been astronomical observing campaign targets and coordination of Earth Observing satellites, SGM is applicable to a large pool of potential domains where there is a desire to dynamically change what to do next, based on some recognized feature of a current action. For earth science imaging satellites: the ability to recognize that the upcoming suites of targets are cloud-covered and therefore not worthwhile; for solar observatories: the ability to recognize the start of a flare and stay on that target instead of continuing to the next target; for constrained download environments: the ability to perform initial quality analysis on an image and if certain objectives are not met, then download only a highly compressed lower-resolution copy of the image and archive aboard the full image for retrieval only if specifically requested (or for discard after some period of time). Or, vice versa, if a satellite is not scheduled to perform a major data download for some period of time, then an onboard evaluation might trigger a high priority (and high cost) download and/or trigger priority messages to the operations center. Similarly, an initial onboard detection algorithm might trigger a priority request for search of archival data on the ground, helping scientists recognize high-value data quicker than their routine data analysis techniques might achieve. *If we have the ability to determine the status/quality of an observation before transmission to earth, we can use our limited data communications resources efficiently.*

While this project will not fully implement all of the above possibilities, SGM will significantly advance the understanding and state-of-the-art for several of the technological drivers that will allow these types of science to be an integral part of mission operations in the future. Through SGM, the risks and benefits to automated, dynamic scientific decision-making will be analyzed and better understood. Capturing science *goals* rather than the *mechanics* of an observation, performing near real-time analysis of data to determine if goals are met, and reacting quickly to new scientific opportunities, can lead to more than just a step forward in automation. It represents a wholesale change in the current paradigm of onboard science operations. *Both of our collaborations, EO-1 and SMARTS, give this project a unique ability to mix prototyping and software development using iterative, agile software development techniques. Further, software testing is performed in actual production environments where we can use metrics from our tests to measure and then compare SGM's performance to current operations.* SGM will answer many unknowns about the risks and costs of developing and flying increasingly automated spacecraft capable of opportunistic science.

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5. MANAGEMENT PLAN

5.1. CODE 588 / MAIN PROJECT TEAM

Mr. Jeremy Jones, the Principal Investigator, will perform the direct management of this grant. Mr. Jones is also the project lead representing Goddard's Code 588 and provides overall technical direction. Along with Mr. Jones, Ms. Sandy Grosvenor will be responsible for the software development effort. All team members will be working closely with daily contact on this project. They bring extensive, proven records of accomplishment in the management and development of the Scientist's Expert Assistant (SEA) (which received Honorable Mention in the 2001 NASA Software of the Year award), and other software tools for other NASA missions to this project. Dr. Koratkar will provide the science perspective and will regularly interface with SMARTS and EO-1 scientists to solicit feedback on the software as it progresses. This team also has been successful in infusing the developed software into missions. For example, SEA has been infused at Space Telescope Science Institute as HST's proposal development tool the Astronomer's Proposal Tools (APT). Some modules of SEA have also been used by the Virtual Telescopes in Education (VTIE) project. VOLT another project developed by this team has been infused into the RXTE mission and some modules of VOLT are also being used by APT.

5.2. CONTRIBUTIONS OF THE TEAM MEMBERS

Goddard's Code 588 is a group that specializes in exploring and developing new technologies for improving scientific return and reducing mission operations costs. The project team has a long history of successful application development. Most of the members on this team were primary developers for the development of the SEA. Our team also includes a number of members who have been instrumental in the development of proposal preparation systems (RPS2), and data visualization and access tools (JSky tools).

Specifically, Dr. Koratkar will provide the leading scientific direction for the project. Dr. Koratkar's background as both an active research astronomer and as a past key member of STScI's user support staff gives her a unique perspective and blend of experiences. She was also the lead scientist on the SEA team. Dr. Koratkar is currently employed by the University of Maryland Baltimore County (UMBC) and will be partly funded by this proposal and her other science research funds.

Ms. Grosvenor was the lead author of the Exposure Time Calculator component of the SEA. She has a strong background both in object-oriented programming, end-user applications development and Java-based rule-based applications. Her educational background in mathematics will also be helpful.

Mr. Jones has been the Goddard team leader for the SGM and SEA projects and was the lead author of the SEA's Visual Target Tuner module. He will continue to provide his expertise in software development as well as serving as the overall team leader on this project.

Groups within EO-1 such as the software development teams and research scientists, and members of the SMARTS science team, will be consulted frequently for feedback. They have already via numerous discussions helped us generate the SGM use cases. They will provide the user feedback on the software as it is developed, and will continue to refine the science cases that drive development.

5.3. EO-1 COLLABORATION

Over the past year we have developed a close relationship with the EO-1 team. Our work thus far has directly contributed to EO-1's goals for more autonomous operations, and the EO-1 team members have been quite eager to provide information and assist us in this effort. Members of the operations staff develop EO-1 specific software that is required by SGM as needed. EO-1's management, including Dan Mandl, the mission operations manager, have expressed strong support for continuing this collaboration so that these efforts at improving EO-1 operations and generating new measurement strategies for Earth science may continue. Thus we expect a continued strong relationship with the EO-1 team. We will continue to meet weekly with the operations staff. Further, through the EO-1 team, we have developed relationships with several geophysicists who are EO-1 users and who cover different earth science domains. These relationships have provided the necessary science background for our development thus far, and we will continue to utilize these people as we develop more complex and scientifically interesting use cases.

5.4. YALE/SMARTS COLLABORATION

Our contact with the SMARTS group was initially through Dr. Charles Bailyn, the principal scientist for SMARTS. Dr. Bailyn put us in contact with several of his colleagues and graduate students who have assisted us in defining science cases and evaluating software prototypes. This included two trips to Yale where we met them and exchanged ideas. We have also had a number of telephone discussions. Dr. Bailyn continues to support this effort because it is very much in line with the goals of the SMARTS program and will contribute to automating their existing telescopes at the Cerro Tololo Interamerican Observatory (CTIO) in Chile. So far the primary product from this collaboration has been a set of astronomical science cases derived from previous SMARTS programs that are most suitable for demonstrating the usefulness of automated science analysis. In the coming year, these will become the foundation for our SMARTS development. We will continue to interact with the Yale/SMARTS staff/scientists to solicit feedback on our prototype as it is developed, and to refine the science cases as needed.

6. FINANCIALS

6.1. COST INFORMATION

The following table shows that the requested funds would be spent entirely on direct labor in support of this effort. This is broken down into a single full-time software engineer who will implement the proposed system, and a small fraction of time from an astronomer who will gather science cases and generally function as a lead user. Note that this labor is in addition to 0.5 FTE of civil servant software engineer support being provided by the Advanced Architectures and Automation branch of GSFC.

6.1.1. Detailed Cost Plan for FY04:

Category	**Cost**
Salaries and wages	$238K
Benefits	$0K
Supplies	$0K
Services	$0K
Equipment purchases	$0K
Data purchases	$0K
Computer services	$0K
Publication costs	$0K
Communications	$0K
Travel	$0K
Overhead	$0K
Other	$0K
TOTAL	*$238K*

6.1.2. Breakdown of Direct Labor (salaries, wages, and fringe benefits):

Number	**Title**	**Time**	**Pay Rate**
1	Software Engineer	1.0 FTE	$178K
1	Astronomer	0.5 FTE	$60K

6.2. CONTRIBUTIONS FROM OTHER RESEARCH

This project benefits from the contributions of the Yale/SMARTS and EO-1 teams who have generously volunteered some of their time to assist us in this effort. These contributions primarily consist of scientist input into defining our requirements and providing feedback on our prototypes as they are developed.

6.3. CURRENT FUNDING FROM OTHER SOURCES

This project does not receive funding from other sources, except for the 0.5 FTE of civil servant labor provided by GSFC.

7. RESUMES

Resumes are included below for Principal Investigator Jeremy Jones, and Co-Investigators Anuradha Koratkar and Sandy Grosvenor. Following these resumes is a list of relevant publications co-authored by the members of the team.

7.1. JEREMY JONES

8535 Hayshed Lane
Columbia, MD 21045
Tel: 410-995-1777
Email: Jeremy.E.Jones@nasa.gov

Qualifications and Experience:

Jeremy Jones is the project lead for the Science Goal Monitor (SGM) project at NASA's Goddard Space Flight Center. Mr. Jones earned his bachelor's degree in computer science with honors from the University of Georgia in 1994 and a master's degree in computer science from Johns Hopkins University in 2002. He has over nine years of experience in applied research and development supporting NASA missions and scientists. His past projects include the Scientist's Expert Assistant (SEA) which was awarded Honorable Mention in the 2001 NASA Software of the Year competition. Mr. Jones works as a computer engineer in the Advanced Architectures and Automation Branch of NASA's Goddard Space Flight Center.

Education:

Master of Science (Computer Science) 2002, Johns Hopkins University, Baltimore, MD
Bachelor of Science with Honors (Computer Science) 1994, University of Georgia, Athens, GA

Professional Experience:

NASA Goddard Space Flight Center, Greenbelt, MD, 1994 - Present

Software architect, developer, and project leader for the Advanced Architectures and Automation Branch:

? Managed the Scientist's Expert Assistant (SEA) and Visual Observation Layout Tool (VOLT) projects.

? Designed and developed significant portions of multiple software projects including the above SEA project.

? Wrote the Visual Target Tuner tool which is used by the Hubble Space Telescope's Astronomer's Proposal Tools observing tool system.

? Designed and developed software for several other NASA systems including mission operations, data processing, and instrument control systems.

? Author or co-author of over a dozen papers on SEA, VOLT, SGM, other software projects for improving the productivity of NASA missions.

Fellowships, Academic Honors, and Awards:

- ? NASA Software of the Year Award, Honorable Mention 2001, for the Scientist's Expert Assistant software prototype that provides interactive tools for proposal development.
- ? Center of Excellence Award, February 2000.
- ? Outstanding Performance Awards, 2002, 2000, 1997, 1996, 1994.

7.2. DR. ANURADHA P. KORATKAR

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University of Maryland, Baltimore County
1000 Hilltop Circle
Baltimore MD 21250
Tel: (410) 455-8899; Fax: (410) 455-8806
Email: koratkar@umbc.edu

Qualifications and Experience:

More than 12 years of research in the field of Active Galactic Nuclei (AGN) physics using multi-wavelength spectroscopic data. Anuradha is actively involved also in the technical aspects of observational astronomy. She has more than 10 years of experience with observatory operations and more than five years of experience being a scientific lead in projects that will optimize observatory operations and maximize scientific returns. Her IT research projects leverage on the use of the Internet and the latest developments in software technologies. Such leveraging of technological changes is critical for improving spacecraft operations in an era of limited resources and unlimited user needs. She championed the development of the innovative software – the Scientist's Expert Assistant that was awarded Honorable Mention in the 2001 NASA Software of the Year competition.

Education:

Doctor of Philosophy (Astronomy) 1990, University of Michigan Ann Arbor, MI,
Master of Science (Astronomy) 1989, State University of New York Stony Brook, NY,
Master of Science (Mathematics) 1983, University of Hyderabad Hyderabad, India,

Professional Experience:

Goddard Earth Science and Technology Center (GEST), University of Maryland, Baltimore County, March 2003 - present

Dr. Koratkar has published 50 refereed journal publications and 20 contributed papers in the field of Active Galactic Nuclei (AGN) physics. For her research work, she has used both space-based and ground-based observatories to obtain multi-wavelength spectroscopic observations in the UV, optical and X-ray. She has also made presentations at dozens of reviews and colloquia, edited three conference proceedings, and supervised six undergraduate students and three post-docs. Her science community activities involve serving on several peer review committees, working groups and organizing scientific and technical meetings both within STScI and the larger astronomical community

Space Telescope Science Institute (STScI), Baltimore, MD 1990 – March 2003

New Innovation Projects Scientist 2000 – present.
As a scientist in the Developments, Technology, and New Innovations Team, Dr. Koratkar is tasked with developing and being lead scientist for projects that will maximize scientific returns from the HST. These projects leverage off the many advancements in information technology.

Group Lead, Project Scientist Group 1996 – 2000
Dr Koratkar initiated, developed and implemented strategies/policies to optimize efficiency in proposal preparation, execution and analysis process. She has also developed the guidelines for user support at STScI, streamlining operations with a view to eventually achieving "cheap operations." Dr. Koratkar has also acted as the lead scientist championing the development of the innovative prototyping software - the Scientist's Expert Assistant for Hubble Space Telescopes's successor the James Webb Space Telescope.

Faint Object Spectrograph (FOS) Instrument Scientist 1992 – 1996
An Instrument Scientist at HST, Dr Koratkar enabled and advocated the scientific use of the instrument and provided Guest Observer support, interacting with observatory staff and the scientific community at large.

Fellowships, Academic Honors, and Awards:

? NASA Software of the Year Award, Honorable Mention 2001, for the Scientist's Expert Assistant software prototype that provides interactive tools for proposal development.
? Space Telescope Science Institute Group Achievement Award 1997, for Amazing Space Project.
? Space Telescope Science Institute Group Achievement Award 1996, for Data Quality Project.
? Space Telescope Science Institute Individual Achievement Award 1994, for Calibration of Faint Object Spectrograph.
? Goddard Space Flight Center, NASA Group Achievement Award 1994, for the successful completion of the calibration/maintenance program of the First Servicing Mission of the Hubble Space Telescope.

7.3. SANDY GROSVENOR

Science Systems and Applications, Inc
NASA/Goddard Space Flight Center
Building 23, Room W409
Greenbelt, MD 20771
Tel: (301) 286 6676; Fax: (301) 286-1768
Email: sandy.grosvenor@gsfc.nasa.gov

Qualifications and Experience:

Sandy Grosvenor is a Senior Staff Computer Scientist for Science Systems and Applications, Inc (SSAI). She has been responsible for the design and development for much of the internal architecture in the Science Goal Monitor (SGM) and Scientist's Expert Assistant (SEA). Ms. Grosvenor has over 24 years experience in software development with an emphasis on end-user applications. For the last seven years, she has been working full time with Goddard Space Flight Center's Advanced Architectures and Automations group developing and evaluating applications of new software technologies for NASA missions. She is the co-author of over 10 papers on either SEA or uses of graphical end-user software for helping manage NASA missions.

Education:

Master of Science (Computer Systems Management) 2000, University of Maryland, College Park, MD
Bachelor of Arts (Economics and High Honors in Mathematics) 1979, Smith College, Northampton, MA

Professional Experience:

Science Systems and Applications, Inc, Greenbelt, MD, 2003 - Present
Booz | Allen | Hamilton, Seabrook, MD, 2000 – 2003
Federal Data Systems, Greenbelt, MD 1996 – 1999
Located on-site at NASA's Goddard Space Flight Center, providing technical support, software design and development for Code 588, Advanced Architectures and Automation Group. Major projects include:

? Scientist’s Expert Assistant (SEA), design and development effort to explore user support alternatives for the astronomical proposal development for the upcoming James Webb Space Telescope. SEA was developed entirely in Java to provide visual tools to replace extensive text base and labor intensive proposal process.

? Requirements Generation System (RGS): a multi-platform (Macintosh and Windows) client-server system to support definition and tracking of mission requirements.

Government Systems, Inc (GSI), Chantilly, VA (now CACI), 1986 – 1996
Project manager and software developer working primarily in proposal, benchmarks, and system conversions

Data Resources, Inc, Washington, DC, Lexington, MA, and New York, NY, 1979-1986
Consultant and project manager supporting and developing a variety of DRI's econometric and business analytical products.

Fellowships, Academic Honors, and Awards:

? NASA Software of the Year Award, Honorable Mention 2001, for the Scientist’s Expert Assistant software prototype that provides interactive tools for proposal development.
? Eagle of Excellence Award, GSI, 1988, 1990, 1992

7.4. PUBLICATIONS

The following papers highlight contributions of the principal investigator and/or co-investigators relevant to the present research effort:

Science Goal Driven Observing, **Koratkar, A., Grosvenor, S., Jones, J.** E., and Wolf, K. R., 2002, ADASS XII, ASP Conference Proceedings, Vol. 295. p.152

Science Goal Driven Observing: A Step towards Maximizing Science Returns and Spacecraft Autonomy, **Koratkar, A., Grosvenor, S., Jones, J. E.**, Memarsadeghi, A., and Wolf, K. R., 2002, SPIE 4844, 250.

Automation of Coordinated Planning Between Observatories: The Visual Observation Layout Tool (VOLT), Maks, L., **Koratkar, A.,** Kerbel, U., and Pell, V., 2002,SPIE 4844, 273.

Kronos Observatory Operations Challenges in a Lean Environment, **Koratkar, A.,** Peterson, B.M., and Polidan, R.S., 2002, SPIE 4854, 286

Designing the Next Generation of User Support Tools: Methodology, **Koratkar, A.**, Douglas, R. E., Gerb, A., **Jones, J. E.**, Peterson, K. A., & Van Der Marel, R. P., 2000, Observatory Operations to Optimize Scientific Return II, Peter J. Quinn; Ed., Proc. SPIE Vol. 4010, p. 90.

NGST's Scientist's Expert Assistant: Evaluation Results, **Koratkar, A.,** Burkhardt, C., Fishman, M., **Grosvenor, S., Jones, J.** E., Ruley, L., & Wolf, K. R., 2000, SPIE Vol. 4010, p. 225.

A New Paradigm for User Support and Software Tools, Miller, G., **Koratkar, A.,** & Golombek, D., 2000, ADASS IX, ASP Conference Proceedings, Vol. 216, p.12

Linking science analysis with observation planning: a full circle data lifecycle, **Grosvenor, S., Jones, J.** E., **Koratkar, A**. Li, C., Mackey, J., Neher, K., & Wolf, K. R., 2001, SPIE, 4477, 200.

Code sharing and collaboration: experiences from the Scientist's Expert Assistant project and their relevance to the virtual observatory, **Koratkar, A., Grosvenor, S., Jones, J. E.,** Li, C., Mackey, J., Neher, K., & Wolf, K. R., 2001, SPIE, 4477, 208.

8. OTHER ENCLOSURES

8.1 Letter of Support: Charles Bailyn

8.2 Letter of Support: Dan Mandl

8.3 JPL Press Release: NASA Satellites Eye Forest Fires

8.1. LETTER OF SUPPORT: CHARLES BAILYN

Subject: letter of support
From: Charles Bailyn <bailyn@astro.yale.edu>
Date: Thu, 14 Aug 2003 15:27:40 -0400 (EDT)
To: jeremy.e.jones@nasa.gov
CC: korathkar@stsci.edu

Dear Dr. Jones and Dr. Koratkar,

I am writing to express my enthusiasm, and that of the SMARTS team, for continuing our collaboration with you and your colleagues on testing your Science Goal Monitor and associated software on SMARTS operations.
As you know, SMARTS is a consortium of seven institutions that has operated three telescopes at Cerro Tololo Interamerican Observatory since Feb 2003; we expect to add three new partners and expand to include a fourth telescope in Feb 2004.

The preliminary scheduling tool that you have devised has already proved useful, and we look forward to further iterations of that software.
Our operations team looks forward to continuing our conversations on how to improve scheduling in general, and perhaps collaborating on creating and testing software. We will continue to share observing logs and other records of our work with you, and to report the results of experiments in scheduling.

We look forward to continuing our work together!

Yours Sincerely,

Charles Bailyn
SMARTS Principal Scientist
Yale University

8.2. LETTER OF SUPPORT: DAN MANDL

Subject: Letter of Support for SGM
From: dmandl@pop500.gsfc.nasa.gov
Date: Fri, 15 Aug 2003 13:51:27 +0000
To: jeremy.e.jones@nasa.gov
CC: daniel.j.mandl@nasa.gov

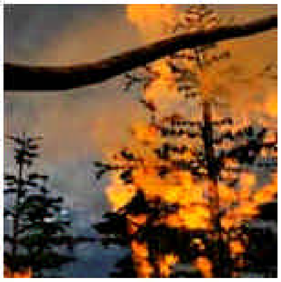
I would like to express my strong support for the collaboration being conducted between the Science Goal Monitor effort and the EO-1 mission. At present, we are working towards streamlining the EO-1 operations as much as possible and providing a customer interface that would allow automatic tasking of the EO-1 satellite in response to customer selections. We are currently developing a proof-of-concept prototype that will automatically task EO-1 using forest fire data from MODIS. The SGM effort has served as the controller in this system, interfacing to MODIS data, handling customer requests, and issuing observation tasks to the EO-1 ground system. This prototype demonstrates a rudimentary Sensor Web system, a subject which is of key interest to Code Y.

Dan Mandl
EO-1 Mission Director

8.3. JPL PRESS RELEASE: NASA SATELLITES EYE FOREST FIRES

2003 News Releases

NASA Satellites Eye Forest Fires
August 20, 2003



Related Links:
+ View related video (Requires RealPlayer)

If a forest catches fire and no one is around to see it, can it call for help? The forest cannot call, but thanks to new technology developed by NASA, firefighters may get the word faster through new, high-tech eyes in the sky.

New software developed by NASA's Jet Propulsion Laboratory, Pasadena, Calif., helps link NASA's Earth science satellites together to form a virtual web of sensors with the ability to monitor the globe far better than individual satellites. An imaging instrument flying on one satellite can detect a fire or other hazard, and automatically instruct a different satellite that has the ability to take more detailed pictures to take a closer look. If the images show that a potential hazard does exist, the responding satellite provides data to ground controllers, who then report the fire to forest officials and to an interested science team.

Artist's concept of sensor "seeing" forest fire.

"Essentially, we are adding the response mechanism to the detection process," said Dr. Steve Chien, JPL principal scientist in artificial intelligence. "This is a first step to enabling users of satellite remote sensing data to specify the kind of data they want, such as forest fires or floods, rather than the traditional request to, say, look at northern Montana."

One of the core components in this collaborative effort is the Science Goal Monitor system being developed at NASA's Goddard Space Flight Center, Greenbelt, Md. The system enables scientists to specify what to look for and how to react in descriptive rather than technical terms. Then the system monitors science streams of data to identify occurrences of the key events previously specified by the scientist.

"When an event occurs, the system autonomously coordinates the execution of the scientist's desired reactions between different observatories or satellites," said Jeremy Jones, Goddard's task leader for the monitor system. "This is designed to be adaptable to many different types of phenomena and supports a wide variety of sensor web configurations."

Using the sensor web method, investigators no longer have to rely on after-the-fact data analysis to determine what happened. The information can be used to rapidly respond to hazardous events such as forest fires.

For example, moderate-resolution imaging instruments that fly on both NASA's Terra and Aqua spacecraft observe the entire globe every day. The instruments' data is automatically processed on the ground within hours of acquisition by the Rapidfire Center at the University of Maryland, College Park. If this processing detects a hot spot, scientific criteria can be used to automatically redirect the Earth Observing 1 satellite to provide high-resolution images. When that information comes back to a scientist for interpretation, it is made available to forest officials to determine the appropriate response. All this can happen in 24 to 48 hours, compared to a typical lead time of 14 days for preplanned observations.

The satellite sensor web demonstration is a collaborative effort between JPL and the Goddard Space Flight Center. The Rapidfire Center is led by Dr. Chris Justice.

JPL is managed for NASA by the California Institute of Technology in Pasadena. More information on JPL is available at http://www.jpl.nasa.gov.

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JPL