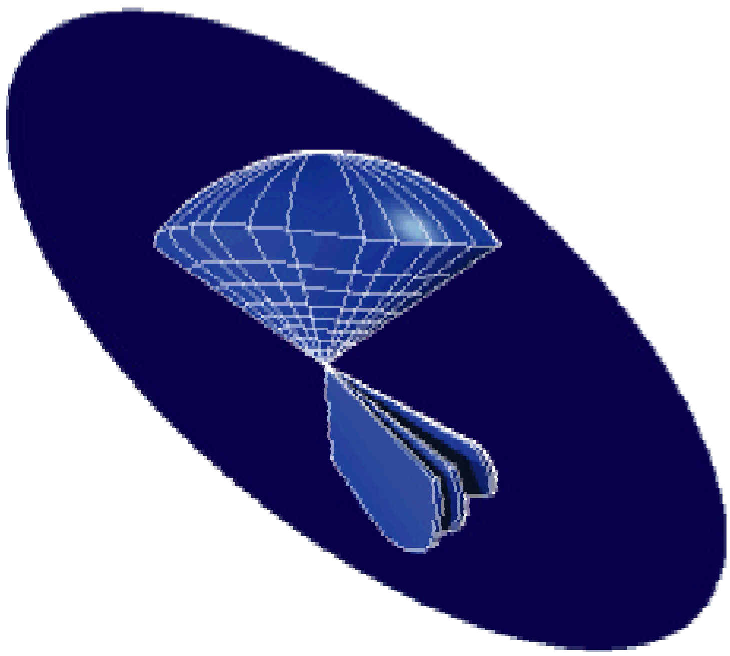
Sloan Digital Sky Survey

Management Plan



Version 1_2

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Sloan Digital Sky Survey
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Revision Log

Version	Date	Revision
1_1	08/24/01	- Updated organization charts to show new Spokesperson and interim chair of the Advisory Council (Figures 1.1, 1.2, and 1.3). - Updated remaining organization charts to show current staffing arrangement. - Revised section 1.2 to reflect interim chair of the Advisory Council. - Revised section 1.3.3 to reflect new Spokesperson. - Revised section 1.3.5 to reflect change in Lead Public Information Officer. - Updated performance graphs in section 2.5.1 to reflect performance through July 2001.
1_2	11/10/01	- Updated Table 2.1. SDSS Cost Control Structure to add JPG and new Spokesperson budget (SSP65) - Updated Table 2.2 Estimated Cost of Survey Operations - Updated organization charts to show personnel changes.

Section 1. Management and Oversight of the Sloan Digital Sky Survey

This section describes the management of the Sloan Digital Sky Survey under the auspices of the Astrophysical Research Consortium. It describes the roles and responsibilities of the Astrophysical Research Consortium, the Board of Governors, the Advisory Council, the Director, the Project Scientist, the Scientific Spokesperson, and the Project Manager. Additional information on the policies of the Sloan Digital Sky Survey may be found on the SDSS website at: http://www.sdss.org/policies/sdss_poo.html

1.1. The Astrophysical Research Consortium

The Astrophysical Research Consortium (ARC) was created to provide the faculty, staff, and students from its member institutions with access to modern astronomical equipment for their research and education programs. ARC owns and operates the Apache Point Observatory (APO) near Sunspot, New Mexico. The ARC-managed facilities at APO consist of a 3.5-m general-purpose telescope and its instruments, and the telescopes, instruments, and ancillary support systems of the Sloan Digital Sky Survey (SDSS). ARC managed the construction and commissioning of these two facilities and today it manages their operation. These two telescope facilities are distinct and each is responsible for its own independent funding. The resources for constructing and operating these facilities have been provided by the participating institutions, private, federal and international sources. The Secretary/Treasurer, Donald Baldwin, and the Business Manager, Michael Evans, administer the funds received by ARC for these projects. ARC disburses some of these funds to the participating institutions through formal agreements and the remainder through contracts managed directly by ARC. The faculty and technical staffs of the participating institutions have provided and continue to provide the technical expertise to maintain and improve these facilities. New Mexico State University, an ARC member, manages the operations at APO for ARC. The ARC Business Manager directly administers large contracts with vendors when it is advantageous to ARC.

Oversight of ARC operations is the responsibility of the Board of Governors, hereafter the Board. The institutions that constitute the Board are the University of Chicago, the Institute for Advanced Study, Johns Hopkins University, New Mexico State University, Princeton University, the University of Washington, and Washington State University. Two members represent each institution on the Board and the members are drawn from active scientists and senior university administrators. The Chair of the Board is Professor Rene Walterbos of New Mexico State University. The Board directly oversees the 3.5-m telescope program but created the Advisory Council to oversee the SDSS, in view of the large scale of the SDSS program and the very large number of institutions participating in that program.

1.2. The Advisory Council

The Board has delegated the oversight and management of the SDSS to the Advisory Council. The Advisory Council actions are governed by the Principles of Operation (PoO), which were prepared by the Advisory Council and approved by the Board. Institutional membership on the Advisory Council has been granted to those institutions that made significant cash or in-kind contributions toward the construction, commissioning, and operation of the SDSS. These are the Participating Institutions. Five ARC institutions that fully participate in the SDSS are the University of Chicago, the Institute for Advanced Study, Johns Hopkins University, Princeton University, and the University of Washington. Fermilab, the Japan Participation Group (JPG) and the US Naval Observatory (USNO) are full participants in the SDSS through Memoranda of Understanding (MOU) with ARC. Each of these fully Participating Institutions may appoint two voting members to the Advisory Council. In addition, the Max Planck Institute for Astronomy in Heidelberg (MPIA), the Max Planck Institute for Astrophysics in Garching and New Mexico State University are Affiliate Members of the Advisory Council through MOU's with ARC. Each Affiliate Member may appoint one non-voting member to the Advisory Council. The Interim Chair of the Advisory Council is Professor Rene Walterbos of New Mexico State University.

1.3. The Director and the Directorate

The Board has delegated to the Director the executive authority for construction and operation of the Survey. To those ends, the Director is responsible for organizing and directing all aspects of the Survey, including the appointment of key personnel. The Director is also responsible for obtaining funds for the construction and operations phases of the Survey on behalf of ARC. The Board, taking into consideration the recommendation of the Advisory Council, appoints the Director for a fixed term. The Board appointed John Peoples, Director Emeritus of Fermilab, as the Director for a second two-year term beginning January 1, 2001. He serves in a full-time capacity through a formal agreement between ARC and Fermilab.

The Director is responsible for preparing an organization plan and submitting it to the Advisory Council for approval. He leads the preparation of proposals for funds for the construction and operations of the Survey. ARC submits these proposals to federal agencies and philanthropic institutions and the Director serves as the Principal Investigator for these proposals. He is responsible for drafting, for concurrence by the Advisory Council and approval by the Board, the Memorandum of Understanding with any new Participating Institution.

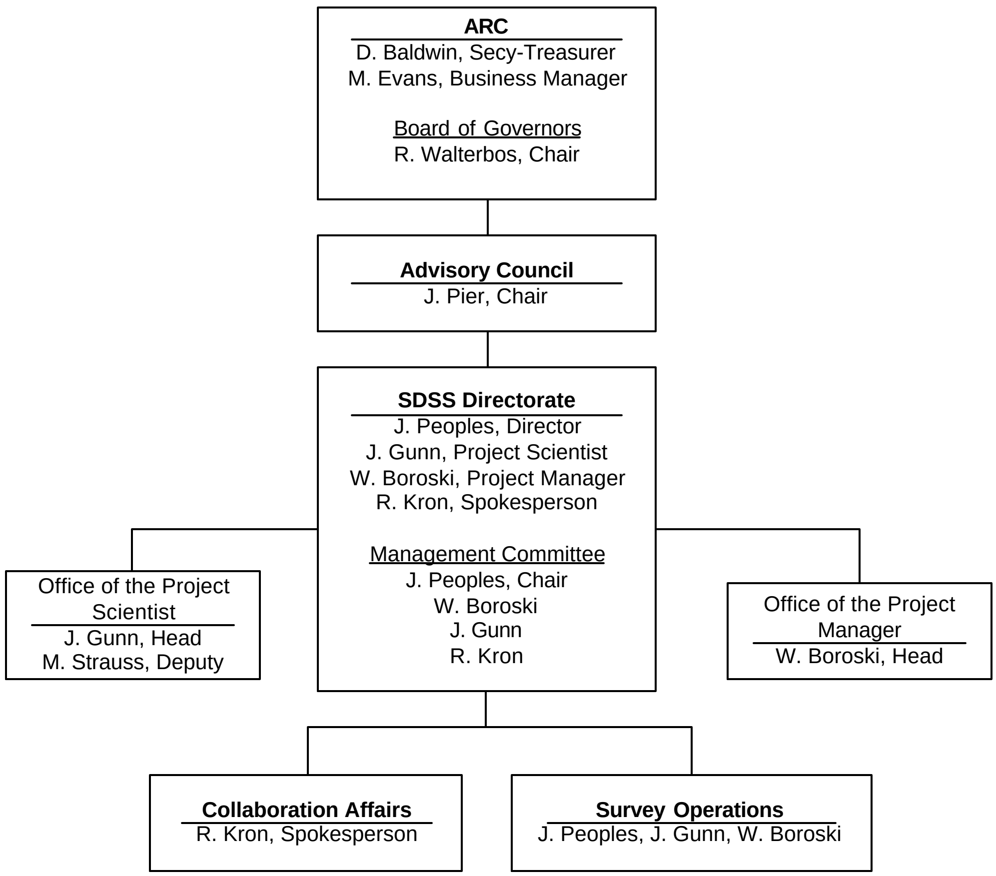
The ARC corporate office, under the general supervision of the ARC Treasurer, assists the Director with the preparation of the annual budgets and monthly financial summaries. The Director submits both an annual budget and a total budget for the completion of the Survey to the Advisory Council. These budgets include all funds and in-kind services needed for construction, maintenance, and operation of the Survey and for acquisition, processing, archiving, and distribution of the data to the collaboration and the astronomical community. The Advisory Council transmits the Director's budgets along with its recommendations to the Board for approval. Monthly financial summaries are provided to the Advisory Council to show expenditures and obligations compared to the annual budget.

The Director is responsible for achieving the Survey Science Goals described in the PoO and to that end he appointed James Gunn, Professor of Astrophysics at Princeton

University, as the Project Scientist and delegated to him the responsibility for assuring that the SDSS will achieve the Science Goals.

The flow of accountability from the Board through the Advisory Council to the Director, and then to the Project Scientist, the Project Manager, and the Spokesperson is shown in Figure 1.1.

Figure 1.1. Organization Chart for ARC SDSS Management



1.3.1. Project Scientist

The Director has delegated to the Project Scientist the responsibility for providing the overall quality assurance for the project and ensuring its scientific integrity. The Project Scientist monitors the performance of all systems and evaluates the scientific impact of proposed changes to the hardware, software, and plans for commissioning and operating the Survey. He is responsible for assuring the Director that the performance of these systems will meet the Science Requirements and that the Science Goals can be met. He is responsible for the preparation and maintenance of the Science Requirements Document that flows from the Science Goals.

The Office of the Project Scientist was formed to assist the Project Scientist. The Deputy Project Scientist, Professor Michael Strauss of Princeton University, assists the Project Scientist in the implementation of his responsibilities. Professor Strauss developed the Science Requirements Document and he is responsible for maintaining this document. He is also responsible for reviewing and auditing other requirement documents that flow directly from the Science Requirements. The Office of the Project Scientist is responsible for developing and coordinating tests that will evaluate the ability of the equipment as constructed and the software as written to meet the Scientific Requirements. The Deputy reports the results of these tests to the Project Scientist and the Director. The Project Scientist reviews the test results and recommends remedial action to the Director when the performance of the equipment or the software could compromise the Science Goals.

1.3.2. Project Manager

The Director has appointed Bill Boroski of Fermilab as Project Manager and created an Office of Project Management. The Project Manager assists the Director in the performance of his responsibilities. The Project Manager, with the support of the Project Office, is responsible for developing and maintaining the project schedule and determining the schedule performance of Survey Operations. He is responsible for preparing the annual Survey budget and the cost to complete the Survey for consideration by the Director and the Project Scientist prior to their submission by the Director to the Advisory Council. He is responsible for tracking project expenditures and reporting them, together with any deviations from the approved budgets, to the Director on a timely basis. He is responsible for preparing the quarterly reports that are distributed to the Advisory Council, and for tracking expenditures against the approved budget.

The Project Manager coordinates the monthly work plan for the engineering effort at APO with the efforts of the engineering groups at the Participating Institutions and the requirements of the observing program. He identifies resources at the Participating Institutions when additional resources are needed to meet the schedule. With the Head of Survey Coordination, he is responsible for informing the Director and the Project Scientist of the state of compliance of Survey Operations with the Science Requirements. He is also responsible for keeping the Director and the Project Scientist informed on the cost and schedule performance of Survey Operations.

1.3.3. Scientific Spokesperson

The Director has delegated the management of the affairs of the Collaboration to the Scientific Spokesperson, hereafter Spokesperson. He has also delegated to the Spokesperson the primary responsibilities for representing the Survey to the scientific community and for raising the visibility of the Survey within the astronomy and physics communities. The current Spokesperson is Professor Richard Kron of the University of Chicago. The SDSS Collaboration elected him to this position effective July 1, 2001. The Advisory Council sets the duration of the term of the Spokesperson, which is currently set at two years.

The Collaboration Council (CoCo) was created to assist with Spokesperson with the discharge of his responsibilities. CoCo advises and supports the Spokesperson. It provides a formal channel for presenting Collaboration issues that require action by the Management Committee or the Advisory Council to the Director and the Advisory Council through the Spokesperson. Since the Collaboration Council has successfully carried out its responsibilities, its role was formally incorporated into the November 21, 2000 revision of the PoO. Each Participating Institution selects one person to represent their institution on CoCo.

1.3.4. Management Committee

The Director created the Management Committee as a forum for the discussion and framing of issues that require action by the Director and/or the Advisory Council. The Director, the Project Scientist, the Project Manager and the Spokesperson constitute the Management Committee and the Director is the Chair. It examines and acts on all issues that have a broad impact on the Survey, including MOUs and other agreements that define the conditions of participation by institutions in the SDSS. When the resolution of an issue requires the approval of the Advisory Council or the Board, it reviews the matter and formulates a recommendation for action by the Advisory Council.

1.3.5. Public Affairs

The Director has established a public affairs office to handle press releases and communication with the news media. The Lead Public Information Officer for the Survey manages communications with the media. The Spokesperson is currently serving as the interim Lead Public Information Officer. The Lead Public Information Officer is responsible for coordinating and organizing the work of the Public Information Officers at the other Participating Institutions in order to assure that the interests of all of the sponsors of the SDSS are properly served. The Director appoints the Public Affairs Coordinator, who is responsible for providing the lead Public Information Officer with the scientific and technical information that will be distributed in press releases and other communications with the media. The current Public Affairs Coordinator for the collaboration is Richard Kron, Professor of Astronomy at the University of Chicago.

1.3.6. External Advisory Committees

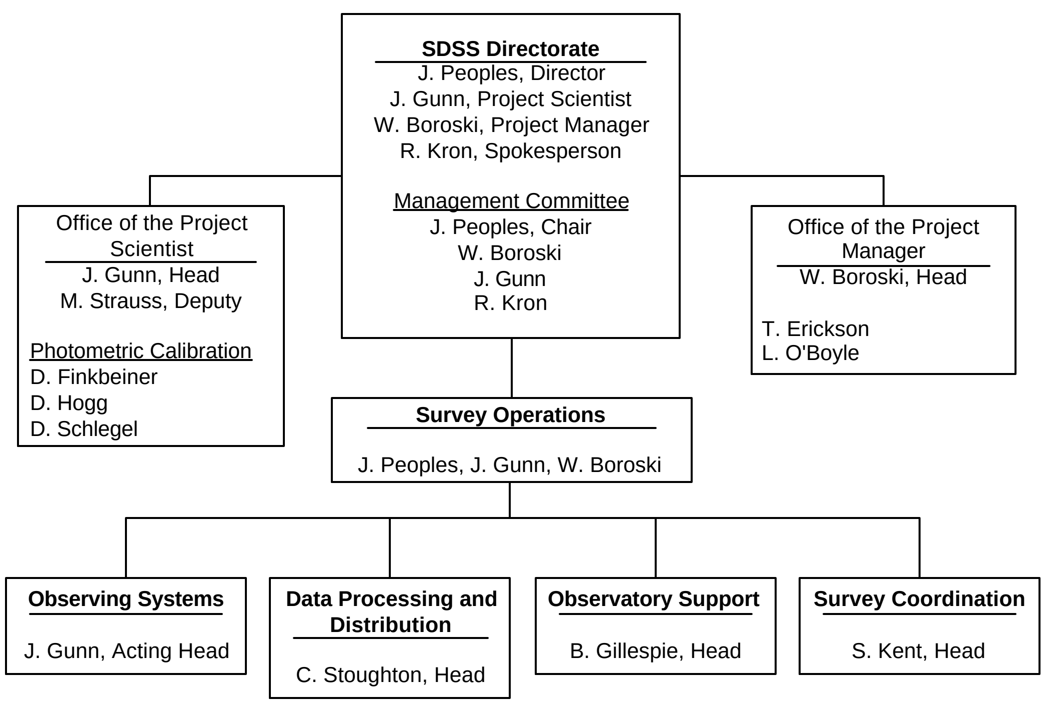
The Director may form ad hoc external Advisory Committees to provide him with advice on the readiness of the Survey to acquire and process data and to distribute the archived data products to the Collaboration and the astronomical community throughout the survey. These committees will review the effectiveness of observing operations, data processing, and the distribution of data to the collaboration and the astronomical community and make recommendations for improvement if survey operations do not meet the expectations of the sponsors. The members of these committees will consist of scientists (primarily astronomers), engineers, and computer professionals with large project experience who are not engaged in the Survey.

1.4. Survey Operations

The Director has formed Survey Operations to provide an organization to manage the construction and operation phases of the Survey. The organization chart for Survey Operations is shown in Figure 1.2. Survey Operations consists of three technical groups – Observing Systems, Data Processing and Distribution, and Survey Coordination – and the support provided by APO through the Site Operations Manager. The personnel for the three technical groups are provided by the Participating Institutions through agreements with ARC. Their responsibilities are briefly described in this section and in much more detail in the Operations Model.

The Director appointed the Head of Observing Systems, the Head of Data Processing and Distribution, and the Head of Survey Coordination. ARC appointed the Site Operations Manager, Bruce Gillespie, whose assigned duties are broader than just the SDSS. The Project Scientist is responsible for setting the goals of the three technical groups and for reviewing the level of observatory support to assure that it is sufficient for the proper execution of the Survey. He sets priorities when the goals of the groups are in conflict. It is noted that Professor Gunn holds the positions of Project Scientist and Head of Observing Systems. Professor Gunn has served as Project Scientist since the inception of the SDSS.

Figure 1.2. Organization Chart for Survey Operations



1.4.1. Observing Systems

The Observing Systems group is responsible for maintaining the Observing Systems in an operational state throughout the observing phase of operations. The Observing Systems consist of the 2.5-m telescope, the CCD imaging camera, the dual spectrographs, the 2.5-m instrument change system, the equipment for plugging spectroscopic plates, the Photometric Telescope (PT) and its instruments, and the data acquisition system for both telescopes. The group is also responsible for maintaining and improving the Observers' Programs and the data acquisition equipment at APO that was provided by Fermilab. In addition, it is responsible for implementing incremental improvements that can increase the efficiency of these subsystems. Finally, it is responsible for assuring that the aforementioned subsystems can meet the Science Requirements. The Head of Observing Systems is Jim Gunn.

1.4.2. Data Processing and Distribution

The Data Processing and Distribution (DP&D) group is responsible for all software and computer systems that are used to process and distribute the SDSS data. The Head of the DP&D group is Chris Stoughton of Fermilab.

The Fermilab members of the DP&D group, with the support of facilities and people from the Fermilab Computing Division, are responsible for processing the data at Fermilab. The maintenance and improvement of the pipelines and related software are carried out by staff from the Participating Institutions under the direction of the Head of the DP&D group. The Head of DP&D is responsible for the coordination of the software development and maintenance among the institutions in order to minimize duplication and to assure that all essential software is capable of processing data at Fermilab. Each institution engaged in the data processing and distribution effort has designated a pipeline coordinator who is responsible for managing the software effort at their institution. The pipeline coordinators and the Head of the DP&D meet on a regular basis to review the state of the software and processing and distribution and set priorities in order to meet survey requirements and schedule. The DP&D group is responsible for the processing the data recorded on tape at APO and placing it in the Operations Database. It is responsible for archiving the data and distributing it to the Collaboration. It is responsible for assuring that the quality of the data in the Operational Database and the Science Archive meets the Science Requirements.

The DP&D group is also responsible for delivering the Data Products to the Space Telescope Science Institute (STScI), in accord with the Data Distribution and Release Plan. The STScI has agreed to distribute the Data Products to the astronomical community during the operations phase of the survey and will serve as the long-term steward of the SDSS Science Archive after the final data release by the SDSS Collaboration.

1.4.3. Observatory Support

Observatory Support is carried out under the direction of the APO Site Operations Manager, Bruce Gillespie, who also has responsibility for managing the 3.5-m telescope operations and the site at large. APO provides all of the basic services and facilities to the three SDSS technical groups that are needed to carry out their work at the site. APO provides and trains the observing staff that carries out the observations for the SDSS. The Survey Coordinator and the Project Scientist provide the monthly observing plan to the observers through the Lead Observer, Scot Kleinman. The Site Operations Manager is responsible for providing the observer team with office and laboratory space, onsite and offsite computer networks, and desktop computing. The Site Operations Manager is responsible to ARC for the safe conduct of all activities at the Observatory. The APO Safety Officer, Mark Klaene, provides the safety oversight of all activities at APO, establishes the qualifications for all people to engage in various tasks while working at the Observatory, and maintains their training records. In order to fulfill this responsibility, APO provides the safety training for the entire SDSS staff engaged in activities at the Observatory.

1.4.4. Survey Coordination

The Survey Coordination Group provides the strategic and tactical direction of the observing program, tracks survey progress, and generates monthly observing plans. Steve Kent is the Head of Survey Coordination; he is also the Head of the Fermilab Experimental Astrophysics Group. Scot Kleinman is the Deputy Head of Survey Coordination; he is also the Lead Observer. The survey operations work plan is coordinated through a weekly teleconference organized by the Project Manager. The participants in the weekly conference include the heads of the three technical groups, the Site Operations Manager, the Lead Observer, key staff at the APO site, and the Project Scientist. When necessary, the Director also participates. The coordination of the efforts of the three technical groups as they relate to the observing program is the responsibility of the Head of Survey Coordination. He and the Lead Observer prepare the weekly and monthly observing plans for consideration by the Project Scientist. The Head of Survey Coordination provides direction for the off-mountain efforts related to the fabrication of plug plates for spectroscopy.

1.4.5. Change Control Board

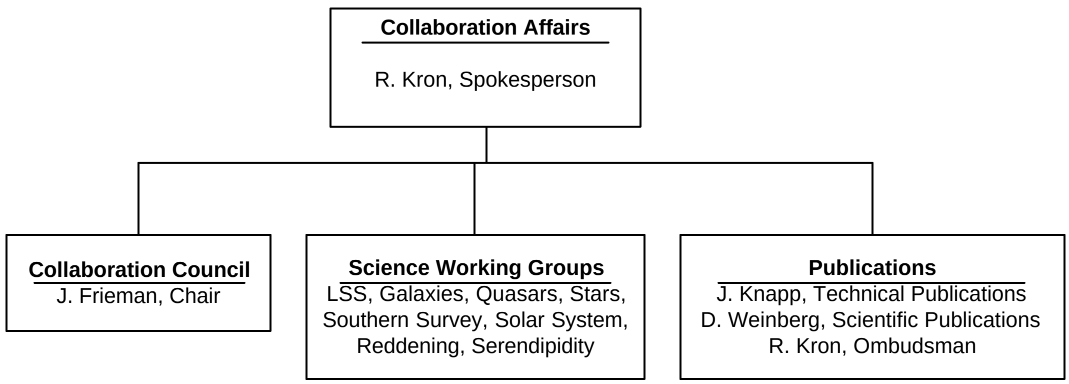
The Director has established a Change Control Board to formally receive and act on proposed significant deviations from the approved budget, schedule, and Science Requirements. The Project Scientist chairs the Change Control Board. The Project Manager prepares the agenda for the Change Control Board meetings and chairs meetings in the absence of the Project Scientist. He is responsible for distributing the decisions of the Change Control Board to the Director for approval and to the heads of the Systems Groups for action.

1.5. Collaboration Affairs

The Collaboration consists of about 150 scientists from the Participating Institutions. Its membership also includes scientists from non-participating institutions who have earned data access through their contributions to the SDSS infrastructure. In addition, its membership includes external collaborators who provide expertise on specific projects.

The size of the Collaboration is about 200 Ph.D. scientists. The Collaboration provides opportunities for its members to exchange information and ideas freely, thereby assisting the pursuit of their individual research goals. Collaboration Affairs was formed to accomplish these goals. The Collaboration Affairs organization consists of the Collaboration Council (CoCo), the Working Groups, and the Publications Office. The organization Chart for Collaboration Affairs is shown in Figure 1.3.

Figure 1.3. Organization Chart for Collaboration Affairs



The Spokesperson is responsible for organizing Collaboration Affairs and selecting the key personnel. A major responsibility of the Spokesperson is to create a healthy collegial environment in which the pursuit of the scientific goals of the SDSS can flourish. Special attention is paid to the mentoring of postdocs and graduate students, and to rules governing graduate student theses involving SDSS data. The principles guiding the work of the Collaboration are spelled out in the PoO. More specific policies, e.g., on publications, have been proposed by the Spokesperson for approval by the Management Committee and the Advisory Council.

The Spokesperson arranges for the organization of presentations at the meetings of professional societies in the course of discharging his responsibilities for representing the Survey to the scientific community and for raising the visibility of the Survey within the astronomy and physics communities. He consults CoCo on these matters and brings them to the attention of the Management Committee. The Spokesperson has created a Publications Office for the Survey in order to provide the Collaboration with a means to oversee the preparation of technical and scientific publications.

The Spokesperson, with the help of CoCo, solicits offers from Participating Institutions to hold Collaboration meetings at roughly six-month intervals. The organization and agenda for each meeting is the responsibility of the local organizing committee. The agenda and special events are reviewed and approved by the Spokesperson in consultation with the CoCo.

1.5.1. Collaboration Council

The Collaboration Council (CoCo) assists the Spokesperson in the management of Collaboration Affairs. It provides advice to the Spokesperson on all Collaboration matters including recommendations for policies on publications, scientific representation, and science projects. The membership consists of one person from each Participating Institution who is appointed by the scientist member of the Advisory Council from that institution. In addition, one of the External Participants is elected by the External Participants to serve on CoCo. The Chair of the CoCo is appointed by the Spokesperson from its members. The current chair is Josh Frieman.

The Chair of CoCo is responsible for ensuring that CoCo meets regularly to discuss matters pertaining to the health of the Collaboration and to advise the Spokesperson. He also forwards requests for External Participant status to the Management Committee along with the recommendation of CoCo.

CoCo is responsible for reviewing proposals for science projects that include external collaborators. External collaborators bring special expertise to a particular project and the capacity to enable the project so that its results can be published in a timely way. In exchange for their assistance, external collaborators are given access to the data appropriate for the specific project and become eligible for authorship on research published by the project team.

CoCo is responsible for organizing and conducting the election of the Spokesperson. The election is conducted three months before the expiration of the term of the current Spokesperson. The Director will appoint an acting Spokesperson in the event the Spokesperson resigns or becomes unable to serve and will request that CoCo conduct an election for a new Spokesperson.

1.5.2. Working Groups

The Working Groups (WG) facilitate the work on Key Projects and the science goals of the survey. The Collaboration and the Working Groups are organized to allow individual scientists a great deal of freedom in pursuing their scientific projects. For example, any participant may join in any project. Working Groups (WG) were formed to address specific topics, including large scale structure, clusters, galaxies, quasars, stars, serendipity, southern survey, reddening, and solar system. The Director, on the recommendation of the Project Scientist and the Spokesperson, may create a new WG or dissolve an existing WG. The WG are responsible for defining Key Projects, which collectively define the Core Program of the SDSS. The WGs are to consider the complete flow of data relevant to each WG from the CCD's through calibration to final publication. A WG may propose improvements to the Project Scientist for calibration processes, analysis software, data processing software, and data distribution processes to the Collaboration. These requests will be reviewed by the Project Scientist and the Project Manager in the course of formulating recommendations to the Director for changes to Science Requirements or to the scope of work specified in the Work Breakdown Structure, when such changes are necessary.

The Project Scientist and the Spokesperson will prepare a charge for each WG. The Spokesperson is responsible for providing the charge to the WGs and to review their activities from time to time. The Director will appoint the chairs of the Working Groups for a fixed term. When a chair of a WG is not filled, the Spokesperson will propose names to the Director for the chair of a WG, and when appropriate co-chairs for a WG. The Spokesperson and the Working Group Chair will appoint members and leaders of the science team for each Key Project.

1.5.3. Core Program and Key Projects

The Working Groups are responsible for defining the Key Projects and their scope. The Project Scientist will review the scope of each Key Project. Key Projects are presumed to constitute the Core Program of the Survey. The WG chairs will propose specific criteria and procedures to select Key Projects to the Project Scientist for his consideration.

The WG chairs will propose team members and leaders for each Key Project for consideration by the Spokesperson. While the selection should be based on achieving the scientific goals of the Key Project, recognition should be given to those who have made major contributions to the SDSS. The Spokesperson will assure that an appropriate balance is struck between the number of junior and senior members on each Key Project team. Membership on a Key Project is open to all Participants who wish to participate in a given Key Project. The Spokesperson will collect and organize the Key Projects, ensure that the guidelines described above have been followed, and adjudicate disputes. If he/she judges that a WG has not developed an adequate set of Key Projects, he/she may recommend that the Director augment the list of Key Projects and solicit interest from Participants in the formation of additional teams. The Spokesperson will bring any institutional issues, such as adequate representation of ARC and MOU Participating Institutions on the Key Projects and Working Groups, to the Management Committee for resolution.

1.5.4. Publication Office

The Spokesperson created the Publications Office to provide a means to disseminate scientific results in draft form to the collaboration. This enables review of the scientific content of draft papers. The Spokesperson appointed David Weinberg as the publication coordinator for scientific publications and Jill Knapp as the publication coordinator for technical publications. The Spokesperson maintains a web page on www.sdss.org listing all published papers and papers approved for publication in refereed journals. These papers include papers posted on astro-ph and conference proceedings. A separate, internal web page, accessible only to the Collaboration, is maintained for work in progress prior to its acceptance for publication. Policies and procedures for the publications are posted on www.sdss.org. The Ombudsman, Richard Kron, is responsible for resolving conflicts that arise on matters related to publications when they are brought to his attention.

SECTION 2. Work Plan and Cost Estimate

2.1. INTRODUCTION AND OVERVIEW

This section presents the scope of work and cost estimate to carry out the 5-Year Baseline Survey. The work plan is organized by a Work Breakdown Structure (WBS), and the tasks have been distributed amongst the Participating and Member Institutions based on logistics, skill requirements, and resource availability. The WBS structure has many branches, some of which extend out eleven levels; tasks at the lowest level of each branch are tracked in the SDSS Operations Schedule. Tracking costs to such low levels is unnecessary and would require a complicated accounting structure. We have avoided this by organizing the project budget into a Cost Control Structure (CCS) that has a one-to-one mapping of the WBS, to level 4. Level 5 of the CCS corresponds to agreements with Participating Institutions for well-defined tasks within each level 4 element. This allows us to track costs at the level at which work is assigned to the Participating Institutions and defined through formal agreements with ARC.

The major deliverables of the SDSS consist of two data sets: a calibrated five-color digital image of the Northern Galactic Cap and the Southern Outrigger Stripes; and the spectra of objects selected from the five-color image. These two data sets are organized into data products as described in the SDSS Archive Distribution Plan[1]. The data products are distributed to the astronomical community through the SDSS website (www.sdss.org) and the Space Telescope Science Institute (STScI) website (www.stsci.edu). Data that has not been fully calibrated and validated are available to the SDSS Collaboration through the SDSS web site.

Web-based interfaces to the Data Archive Server, the Catalog Archive Server, and the skyServer provide access to the data. The Data Archive Server provides access to the atlas images, spectra, corrected frames, compressed sky map, masks, and calibration data. The data for each object is on disk and may be retrieved through a web interface adapted from the STScI Multi-Mission Archive (MAST). The Data Archive Server provides the capability to download data on objects by RA, DEC, and object identification number to storage at the user's institution for subsequent use. The Data Archive Server also provides detailed supporting documentation for the data products and the SDSS project. The Catalog Archive Server provides access to the full object catalog and enables the user to carry out complex queries over all of the output quantities of the photometric and spectroscopic pipelines, plus the calibration parameters used in the processing. These queries are enabled through a Java-based query tool using a query language similar to standard SQL, but with some astronomy-specific extensions. Both the Data Archive and Catalog Archive servers rely on a commercial object-oriented database. The skyServer is built in the Microsoft Windows environment, using Microsoft's SQL Server database, and offers an interactive web-based interface that provides an integrated navigation of both images and the catalog. It provides access to the full object catalog, with redshifts and spectral lines, and a full set of color images in compressed (JPEG) format, plus GIF images of all of the spectra. The skyServer was jointly developed as a separate project by the Microsoft Bay Area Research Center (BARC) and JHU, with the goal of developing an interface that would provide easy-access to the SDSS data by the K-12 audience and the general public. Since it possesses features that might be useful to astronomers, it was included with the Early Data Release. Fermilab is providing support for the implementation of the skyServer and has made it available to the public through the SDSS web site. To date, the development and implementation costs have been borne by BARC, JHU, and Fermilab.

The three systems that produce and distribute the SDSS data sets are the Observing System, the Data Processing System, and the Data Distribution System. The first two are operational and have been used to obtain and process data. The work required to bring the operating efficiency and performance specifications of the Observing Systems and the Data Processing System to the level required for five years of sustained operation will be completed in early 2002. Beyond that, it is anticipated that further improvements in the operational efficiency of these systems will be made based on the experience of carrying out the survey. The development of the final photometric calibration system is scheduled for completion in mid-2002. When complete, the photometric system will define the survey calibration procedures and be used to calibrate the imaging data.

The initial data distribution system is a pioneering effort and its development is not complete. It will be upgraded as astronomers gain experience and propose improvements. We anticipate that improvements will be made between June 2001, the time of the Early Data Release, and January 2004, the time of the second data release. Roughly 50% of the entire SDSS Data Archive will be released to the astronomy community at that time.

The principal method of distributing the SDSS data products will be through the Catalog Archive and Data Archive Servers, which are accessible through the Internet. The Catalog Archive Server and Data Archive Server at Fermilab have been loaded with imaging data obtained during commissioning that meet survey requirements. This data set, which is referred to as the Early Data Release, consists of somewhat more than 500 square degrees of imaging data and 50,000 spectra. It provides the collaboration and the astronomy community with a large, uniformly processed and calibrated data set for end-to-end tests of the data. The collaboration will also test the performance of the user interfaces and verify the quality assurance tools that are currently available. The feedback from the end-to-end tests using this data set will be used to specify the final changes in the pipelines in the summer of 2001. The experience of the collaboration with the user interfaces and the servers will be used to improve these systems for subsequent data releases.

Details and the schedule for data releases to the SDSS collaboration are described in the SDSS Archive Distribution Plan. The Early Data Release was fully updated in the second quarter of 2001 and distributed simultaneously to the collaboration and astronomy community in June 2001. Over the ensuing six months, the efficacy of the data servers and the other data products will be fully evaluated by the collaboration and the community. It is expected that performance enhancements to the data servers will be incorporated in the last quarter of 2001. The scope of these enhancements will depend on the availability of funding for this work.

In the third quarter of 2001, the data servers and the other data products will be updated with all the data obtained prior to July 2001, and distributed to the collaboration. The July 2001 data set will be reprocessed and the best available quality calibrations will be applied uniformly to all of the data. It is anticipated that the experience that the collaboration gains using this data sample and the associated data products will be used to improve the data servers that were made available to the astronomy community in June 2001. After the fall of 2001, data releases to the collaboration will be made twice per year (in the spring and fall).

The SDSS Archive Distribution Plan also includes details and the schedule for data releases to the astronomy community. As noted, the EDR to the astronomy community occurred in June 2001. The EDR used the best calibrations available at the time of the release and contains some data that does not meet survey requirements. The first release of survey quality data to the astronomy community is scheduled to occur in January 2003. It will consist of data obtained prior to July 2001. After January 2003, additional data will be released to the astronomy community approximately once a year. The final release, with final calibrations will be made in July 2006.

The Observing phase of the Survey is scheduled to end on June 30, 2005. At that time, the support for Observing Systems, Observatory Support, and the maintenance of the data processing pipelines will end. The Fermilab Data Processing Team will complete the final processing of all data and will deliver it to the Space Telescope Institute (STScI) in time for the final release date of July 2006. This will be an in-kind effort that is not included in the 5-year Baseline Survey budget.

The SDSS and STScI have developed a plan for the long-term maintenance and distribution of the SDSS Science Archive. The intent is that the STScI will become the long-term steward of the SDSS Data Archive. Details of the arrangement are described in the SDSS Archive Distribution Plan. The STScI will require additional funding from NASA to accomplish the full execution of this plan beyond the EDR. The STScI has requested the required funding from NASA to support the distribution of the SDSS Archive through 2005. The plan is to request additional funds from NASA for the maintenance of the SDSS Archive after 2005, when the SDSS may no longer be able to assist the STScI. While NASA is supportive of this request, they have not awarded the funds to STScI.

In the fall, the Northern Galactic Cap is not visible from APO. During this period of the year, observations will continue with the same equipment that is currently in use. The plan is to observe three segments of the fall sky. The two outrigger stripes will each be observed once. The central segment, which lies on the Celestial Equator, will be observed many times. The software needed to properly exploit multiple images of the sky has not been developed and the cost to undertake this development is not included in the cost estimate presented in this document, nor has the cost to develop the servers to distribute multiple images to the community been included in this plan. ARC plans to seek additional funding to support the processing and distribution of the data from each fall observing season obtained between October of 2002 and April 2005. The proposal for additional funding may also include a request for funds to continue observing through the late spring of 2006, since the 5-year Baseline Survey does not completely achieve the original goals of the SDSS. At present, ARC is considering submitting such a proposal to NASA or a private foundation.

Finally, since a considerable effort has been expended in constructing and commissioning the 2.5-m telescope and its instruments, ARC intends to carefully consider its exploitation before making a decision on its future. During 2001, ARC expects to develop a plan for the utilization of the SDSS Observing Systems for the period beyond April 2005.

2.2. COST BASIS AND REPORTING FOR SURVEY OPERATIONS

The budget for Survey Operations is an estimate for operating an already-constructed system. A period of intense commissioning and development, which extended from March 1999 through March 2000, preceded regular operations and regular data collection and processing operations began in earnest in April 2000. This two-year period provided project management with the experience to determine the size and skills of the work force required to sustain steady-state operations. It also provided the knowledge to define the tasks to meet Survey Requirements.

The cost estimate for the 5-Year Baseline Survey was prepared using a bottoms-up approach that took advantage of the experience gained during the past two years of commissioning and operations. All known tasks required to complete the Survey were incorporated into the Operations WBS. Specific responsibilities, and deliverables, were then assigned to groups at the Participating Institutions. These groups then determined the resource requirements, developed cost estimates and schedules for their tasks, and submitted them to the Project Manager for his consideration. In nearly all cases, personnel costs are based on current salaries of the individuals who will do the work and they have been working on the SDSS for the past two years. In those instances where the work has not been assigned to a specific individual, the personnel costs have been estimated by using the average salary for the appropriate job classifications at the institutions where the work will likely be assigned. Time estimates for routine operations and maintenance tasks are based on the experience obtained in the past two years. Procurement, fabrication, and installation costs are based on solicited quotations or careful estimates based on prior experience. Cost estimates for the individual tasks in the WBS were incorporated into the SDSS Cost Control Structure (CCS) and provisionally assigned to an SSP. Tasks are assigned to the institutions working for the SDSS and the scope of work, schedule for deliverables, and the budget are defined in written agreements between ARC and these institutions. These agreements are called SSPs, which stands for Sky Survey Project. Each SSP has a unique identification number. The scope of work, budget, and schedule for deliverables for each SSP are determined through a negotiation with the Project Manager and the institutional contact responsible for managing the SSP; the latter is referred to as the SSP Manager. The SSPs are revised annually at the beginning of the fourth quarter. Based on the negotiated budgets and scope of work, the Project Manager assembles the draft annual budget, updates the cost estimate for the 5-Year Baseline Survey, and presents these to the Director and Project

Scientist for review. Once accepted, the Director presents the proposed annual budget to the Advisory Council for their consideration. The Advisory Council submits the budget with its recommendations to the Board for their consideration.

Table 2.1. SDSS Cost Control Structure (CCS)

- 1.0 Sloan Digital Sky Survey
  - 1.1 Survey Management
    - 1.1.1 ARC Administration
      - SSP51 – ARC Secretary Treasurer
      - SSP34 – ARC Business Manager
    - 1.1.2 Office of the Director
      - SSP60 – UW Support for Survey Management
      - SSP91a – Support for Public Affairs
    - 1.1.3 Office of the Project Scientist
      - SSP46 - Princeton Office of the Project Scientist
      - SSP62 - JHU Software Testing and Validation
      - SSP63 – UW Software Testing and Validation
    - 1.1.4 Office of the Project Manager
      - SSP48 – Fermilab Support for Survey Management
      - SSP59 – JHU Support for Survey Management
    - 1.1.5 Scientific Spokesperson
      - SSP47 – UC Project Spokesperson (1998-2001)
      - SSP65 – UC Scientific Spokesperson (2001-2003)
      - SSP91b – Future Spokesperson Support
  - 1.2 Collaboration Affairs
    - SSP91c - ARC Support for Collaboration Affairs
  - 1.3 Survey Operations
    - 1.3.1 Observing Systems
      - SSP42 – FNAL Observing Systems Support
      - SSP61 – FNAL Observing Programs and DA Support
      - SSP31 – UW Observing Systems Support
      - SSP32 – PU Observing Systems Support
      - SSP36 – JHU Observing Systems Support
      - SSP50 – JHU Photometric Telescope Commissioning
      - SSP33 – UC Observing Systems Support
      - SSP58 – LANL Observing Systems Support
      - SSP66 – JPG Observing Systems Support
      - SSP91d – ARC Observing Systems Support
    - 1.3.2 Data Processing and Distribution
      - SSP40 – FNAL Software and Data Processing
      - SSP38 – PU Software and Data Processing Support
      - SSP39 – UC Software and Data Processing Support
      - SSP57 – USNO Software and Data Processing Support
      - SSP54 – JHU Photometric System Definition
      - SSP41 – IAS Photometric System Definition
      - SSP64 – NYU Photometric System Definition
      - SSP37 – JHU Data Archive Development and Support
    - 1.3.3 Survey Coordination
    - 1.3.4 Observatory Support
      - SSP35 – APO Observatory Support
  - 1.4 ARC Corporate Support
    - SSP91e - Corporate Support
    - SSP91f - Additional Scientific Support
  - 1.5 Management Reserve
    - SSP91 - Management Reserve

Each SSP Manager submits a progress and budget report to the Project Manager, which describes the work completed in the preceding quarter, work planned for the coming quarter, actual costs incurred in the preceding quarter, and a revised forecast for the remainder of the calendar year. Since reports from the university financial systems tend to lag actual expenses by as much as two quarters, the Project Manager and the ARC Business Manager consult extensively with departmental budge officers to obtain accurate forecasts. The Project Manager uses this information to track and report on performance against the budget and report the project performance in the SDSS Quarterly Report. Any major change that significantly affects the annual budget of the SSP or increases the cost to complete the five-year Survey is submitted to the Change Control Board for action. Action is in the form of recommendations to the Director.

The budget for the 5-Year Baseline Survey is presented in Table 2.2. It should be noted that since survey operations started in April 2000, the budget for the year 2000 covers the 9-month period from April through December 2000, and the budget for 2005 covers the 6-month period from January through June 2005.

Table 2.2. Estimated Cost of Survey Operations ($K)

Calendar Year	2000 [1]	2001	2002	2003	2004	2005 [2]	Total
1.1. Survey Management							
1.1.1. ARC Administration							
ARC Secretary/Treasurer	14	19	18	20	20	5	96
ARC Business Manager	39	55	56	58	60	15	283
Sub-total ($K)	53	73	74	78	81	21	379
1.1.2. Office of the Director							
UW Support for Project Management	3	.4	0	0	0	0	3
ARC Support for Public Affairs	0	0	25	31	32	25	114
Sub-total ($K)	3		25	31	32	25	117
1.1.3. Office of the Project Scientist							
PU Office of the Project Scientist	80	51	121	58	40	6	357
JHU Photometric System Definition	23	28	0	0	0	0	51
IAS Photometric System Definition	9	0	0	0	0	0	9
NYU Photometric System Definition	0	19	4	0	0	0	22
UW Support for the Project Scientist	2	0	0	5	6	1	14
Sub-total ($K)	114	97	125	64	46	8	453
1.1.4. Office of the Project Manager							
FNAL Support for Survey Management	144	233	208	208	210	108	1,112
JHU Support for Survey Management	39	0	0	0	0	0	39
Sub-total ($K)	184	233	208	208	210	108	1,151
1.1.5. Scientific Spokesperson							
UC Spokesperson (1998-2001)	15	17	0	0	0	0	32
UC Spokesperson (2001-2003)	0	0	14	0	0	0	14
ARC Support for Project Spokesperson	0	0	0	23	24	6	53
Sub-total ($K)	15	17	14	23	24	6	99
Survey Management Sub-total ($K)	368	421	445	405	393	168	2,200
1.2. Collaboration Affairs							
ARC Support for Collaboration Affairs	0	0	16	16	16	17	65
Collaboration Sub-total ($K)	0	0	16	16	16	17	65
1.3. Survey Operations							
1.3.1. Observing Systems							
FNAL Observing Systems Support	421	664	686	338	335	166	2,610
FNAL Obs. Programs and DA Support	19	208	220	199	131	68	846
UW Observing Sy stems Support	232	331	325	346	335	123	1,692
PU Observing Systems Support	103	143	79	85	60	8	477
JHU Observing Systems Support	60	88	32	33	34	8	255
JHU PT Commissioning	127	42	0	0	0	0	169
UC Observing Systems Support	82	45	23	1	1	0	152
LANL Observing Systems Support	264	210	231	119	92	0	916
JPG Observing Systems Support	57	40	40	40	40	10	227
ARC Observing Systems Support	90	86	175	88	90	14	542
Sub-total ($K)	1,455	1,856	1,812	1,249	1,117	397	7,886
1.3.2. Data Processing and Distribution							
FNAL Software and Data Processing	793	1,046	1,124	1,164	1,195	574	5,896
PU Software and DP Support	258	273	203	188	173	5	1,099
UC Software and DP Support	86	70	37	38	39	20	291
USNO Software and DP Support	147	113	116	120	124	64	684
JHU Software Validation & Testing	0	14	31	0	0	0	45
UW Software Validation & Testing	0	50	61	0	0	0	111
JHU Data Archive Dev and Support	142	191	197	203	110	57	900
Sub-total ($K)	1,426	1,757	1,770	1,713	1,640	720	9,025
1.3.3. Observatory Operations							
APO Observatory Support	874	1,317	1,360	1,400	1,442	741	7,134
Sub-total ($K)	874	1,317	1,360	1,400	1,442	741	7,134
1.3.4. Survey Coordination	0	0	0	0	0	0	0
Sub-total ($K)	0	0	0	0	0	0	0
Survey Operations Sub-total ($K)	3,754	4,929	4,942	4,363	4,200	1,858	24,046
1.4. ARC Corporate Support							
ARC Corporate Support	107	88	70	68	70	12	415
ARC - Additional Scientific Support	114	0	18	106	109	84	429
Corporate Support Sub-total ($K)	221	88	88	173	179	96	845
1.5. Management Reserve [3]	0	170	200	360	366	179	1,275
Total ($K)	4,343	5,608	5,691	5,317	5,153	2,318	28,430

2.3. WORK BREAKDOWN STRUCTURE

The SDSS Operations WBS is organized to identify the effort, deliverables, services, and facilities necessary to successfully complete the Survey. The WBS is used to identify organizational and individual responsibilities for the various work elements and integrate project scope, cost, and schedule. Table 2.3 presents the organization of the SDSS Operations WBS to level four. The complete WBS can be found on the SDSS website (www.sdss.org) or accessed directly at: (http://tdserver1.fnal.gov/sdss/schedule/SDSS_OPS_WBS.pdf).

Table 2.3. Level Four SDSS Operations WBS

- 1.0 Sloan Digital Sky Survey
  - 1.1 Survey Management
    - 1.1.1 ARC Administration
    - 1.1.2 Office of the Director
    - 1.1.3 Office of the Project Scientist
    - 1.1.4 Office of the Project Manager
    - 1.1.5 Scientific Spokesperson
  - 1.2 Collaboration Affairs
    - 1.2.1 Collaboration Council
    - 1.2.2 Working Groups
    - 1.2.3 Publications
  - 1.3 Survey Operations
    - 1.3.1 Observing Systems
      - 1.3.1.1 2.5-meter Telescope
      - 1.3.1.2 Imaging System
      - 1.3.1.3 Spectroscopic Systems
      - 1.3.1.4 Photometric Telescope
      - 1.3.1.5 Observing Aids
      - 1.3.1.6 Data Acquisition
    - 1.3.2 Data Processing and Distribution
      - 1.3.2.1 Data Processing
      - 1.3.2.2 Data Distribution
    - 1.3.3 Survey Coordination
      - 1.3.3.1 Survey Strategy Tools
      - 1.3.3.2 Survey Planning
    - 1.3.4 Observatory Operations
      - 1.3.4.1 Site Administration
      - 1.3.4.2 Observing Operations
      - 1.3.4.3 Observatory Support
    - 1.3.5 Remaining Construction Tasks
  - 1.4 ARC Corporate Support
    - 1.4.1 Corporate Support
    - 1.4.2 Additional Scientific Support
    - 1.4.3 Capital Improvements
  - 1.5 Management Reserve

The Operations WBS was established to capture the tasks for operations and the limited set of improvement projects required to enable the survey systems to meet Survey Requirements. A construction WBS was used to manage the construction and commissioning phases of the Survey. It included all of the deliverables required to develop the hardware, software, and facilities required for survey operations. The construction WBS was closed out on March 31, 2000 as the Survey moved from construction to final commissioning and operations. The Operations WBS defines the maintenance and support tasks that define the steady-state level of effort and materials and services costs necessary to maintain the equipment; and support observations, data processing, and data distribution. The budgeted level of effort for maintenance and support is based on the operating experience gained during the last year of commissioning and the initial year of survey operations.

It also includes a limited set of improvement projects that must be executed in order to bring performance into compliance with survey requirements. The work in each of these tasks is organized as a separate project with well-defined deliverables and schedules. The responsibility for completing each project is assigned to a specific individual. Problems with existing systems are identified by members of the scientific and technical staff and filed in the on-line SDSS Problem-Reporting Database. Problems are then discussed in the appropriate SDSS teleconference and an individual is given an action to resolve it. If the resolution requires the definition of a new project, it is submitted to the Project Scientist and Project Manager for consideration and approval. New project requests may be submitted in the form of change-requests filed in the SDSS Problem-Reporting Database or through e-mail messages to the Project Scientist or Project Manager. When new project requests are received, the Project Manager consults with the Project Scientist to determine if the new project is necessary. If so, the Project Manager works with the appropriate individuals to develop a cost and schedule estimate. Once the cost and schedule estimate is prepared, it is reviewed against the current budget and schedule to consider if, when, and by whom the work will be done. New project requests with an estimated cost in excess of $3K are submitted to the SDSS Director for approval before they are incorporated into the WBS and work plan.

An important element of the approval process is to prioritize new work against the existing plan. The following criteria are used to prioritize new projects:

1. Projects that are required to mitigate a serious personnel safety concern receive the highest priority and are assigned and integrated into the schedule as soon as possible. These projects will interrupt operations if continuing operations is judged unsafe. We believe that all safety projects are complete. However, periodic external safety reviews, which are arranged by the Site Operations Manager to ensure a safe work environment, may uncover the need for additional work. If one of these reviews reveals a problem that is accepted by the Site Operations Manager, it will be incorporated in the WBS.

2. Projects that address serious equipment protection issues or are needed to maintain the availability of critical systems are given second highest priority. An

example of an equipment protection issue faced in 2000 was the need for a safer way to handle the spectroscopic corrector lens. Because of a near-miss incident, we initiated a new project to build a safe storage house and a handling cart dedicated to the lens. As of this writing, all Priority 2 projects are complete. Priority 2 projects may cause the suspension of normal operations if it judged that serious damage to observing systems could occur if operations continued.

3. Projects that will bring a system or sub-system into compliance with the SDSS Science Requirements, or with functional performance requirements flowing from the Science Requirements, receive third priority. Two major Priority 3 projects are currently underway. The first project will improve the thermal environment around the telescope, which is the major reason why image quality is failing to meet survey requirements. Measurements of the thermal environment made around the telescope in mid-2000 with an infrared camera showed that the telescope and its immediate environment were much hotter than planned. A thermometer system installed in the last two quarters of 2000 confirmed that the mirror was several degrees centigrade warmer than the ambient air. Additionally, ventilation measurements through the primary mirror cell indicated that the mirror ventilation system was not working as designed. The combined effect of these problems is that the telescope and mirrors begin the night many degrees above ambient and do not reach thermal equilibrium with the night air until late into the night. As a result it was not possible to acquire good imaging data during the first half of cold winter nights and so we have embarked on a series of tasks to improve the thermal environment and the performance of the mirror ventilation system. As of the time of the revision of this document, the problem is much improved.

   The second Priority 3 project is the development of a photometric calibration system that can meet the photometric accuracy requirements described in the Science Requirements. This work began in earnest in the summer of 2001, when it became clear that the requirements were not being met. A “tiger team” was appointed by the Director and the Project Scientist to investigate the photometric procedures and programs independently. Early results are favorable, but it is expected that this work will require at least another year of effort to really understand how well we are doing over the sky and whether we can in fact meet our specifications. The first of these projects is directed by Jim Gunn in his capacity as Head of Observing Systems. The second is under the direct supervision of Jim Gunn in his capacity as Project Scientist. The schedules are under the direct supervision of the Project Scientist.

4. Work that is necessary to improve the efficiency, reliability, or robustness of a system, sub-system, or procedure is ranked fourth in priority. Such work is undertaken to achieve and/or maintain operating uniformity and/or efficiency goals. An improvement in the efficiency of survey operations can increase the area of sky that can be observed. Inefficient data processing can delay the timeliness with which data is processed. If processed data were not available for

target selection it could delay the preparation of plate drilling files, and lead to an inadequate inventory of plates at the Observatory. An example of a Priority 4 engineering project is the telescope counterweight upgrade planned for 2001. The counterweight drive assembly has a weak component (a drive nut) that has failed more than once. While the repair only takes a few hours, the repair activity takes resources away from other work. More importantly, failure of the drive assembly during an observing night could keep the counterweight assembly from working properly, which would mean that the telescope could not be properly balanced should an instrument change occur. Ultimately, this translates to lost time on the sky. An example of a Priority 4 data processing project is the "automation" of the data processing operation at Fermilab. A significant effort is underway to automate data processing, quality assurance testing, and the loading of the Operational Database and the data servers. These improvements will ensure that data is processed quickly, that the processed data meets survey quality requirements, and that it will be loaded into the Operational Database and the data servers promptly, thereby making it available for use for target selection, plate drilling, and validation tests on schedule.

Since scheduled observations and data processing can be disrupted by priority three and four projects, all of the projects that can disrupt operations are reviewed by the Project Manager and Project Scientist. If the disruption is significant, they are considered by the Change Control Board and its recommendation submitted to the Director for approval. After new projects are approved, they are prioritized and assigned to an organization and individual, added to the Operations WBS, and integrated into the project schedule. Institutional budgets are adjusted to fund a new project whenever the new project reflects a change in the scope of work that was defined in the original agreement between the institution and ARC. Funding for new projects must come from within the approved annual operating budget, either by postponing planned lower priority work, or by tapping the management reserve that is controlled by the Director. The latter will occur only when the funds required for new work cannot be re-distributed amongst the allocated institutional budgets.

The WBS is defined by five top-level elements: Survey Management, Collaboration Affairs, Survey Operations, ARC Corporate Support, and Management Reserve. The following sections describe the various elements within the WBS.

2.3.1. Survey Management

The organization of work and costs associated with the management and oversight of the project are captured in WBS element 1.1, Survey Management. The following sections briefly describe the organization of work. Descriptions of the roles and responsibilities of each position can be found in Section 1, Management and Oversight. The total budget for Survey Management is $2,274K of the total cost estimate of $28,430K for the 5-Year Baseline Survey.

2.3.1.1. Survey Management WBS

WBS element 1.1.1: ARC Administration

The WBS for ARC Administration is where salary, travel, supply, and administrative support costs for ARC corporate personnel such as the Secretary/Treasurer and the Business Manager are captured.

WBS element 1.1.2: Office of the Director

The WBS for the Office of the Director captures the work and costs associated with the work performed by and for the Director. The Director is responsible for organizing and directing all aspects of the Survey, including the appointment of key personnel and the obtaining of funds to complete the Survey on behalf of ARC. The salary for the Director is provided by Fermilab as an in-kind contribution and its value is not included in the cost estimate for the 5-Year Baseline Survey.

The Director may request additional support for survey management from one of the Participating Institutions. When this occurs, the level of support is defined by written agreement between ARC and the institution performing the work and the funds necessary to support this work allocated accordingly. The work and costs for the additional survey management support are captured under the Office of the Director.

The WBS for Public Affairs, which captures the work and costs associated with education, public information, and outreach are contained in the WBS for the Office of the Director. It includes the development and maintenance of the SDSS web site (www.sdss.org). This web site will serve as a portal to the SDSS Data Archive for the collaboration and astronomy community. Public Affairs also includes the cost of building and staffing of exhibit booths at American Astronomical Society (AAS) meetings and travel support for SDSS speakers invited to present SDSS results at AAS meetings. These booths provide a flexible way to distribute current information about the project to the astronomy community.

WBS element 1.1.3: Office of the Project Scientist

The WBS for the Office of the Project Scientist captures the work and costs associated with work performed by the Project Scientist and his Deputy. This includes maintenance of the SDSS Science Requirements document and oversight of the lower-level requirements and specifications documents that flow from the Science Requirements. The Deputy Project Scientist is responsible for developing and executing tests to evaluate the ability of equipment and software to meet the scientific requirements of the Survey. The Deputy is responsible for generating reports that summarize test results and recommend remedial action when system performance could compromise science goals.

The Project Scientist tracks the progress made on the critical hardware and software systems that need to improve before they can be certified as meeting the Science Requirements. The items on the list fall into several categories, the most important of which are:

1. <u>Image quality</u> – The thermal environment around the telescope is the principle reason that the image quality fails to consistently meet the image quality requirement of 1.2" FWHM. The Project Scientist made a proposal to temporarily relax the seeing requirement until the thermal environment could be improved such that the seeing requirement can be regularly met. A concentrated engineering effort is underway to eliminate or relocate heat sources, improve the enclosure cooling system, and improve the telescope primary mirror ventilation system. Preliminary results are encouraging and show that the image quality requirements will be achievable once the thermal issues are properly addressed and managed.

2. <u>Survey Efficiency</u> – The efficiency of survey operations directly impacts the area of sky that can be observed and the timeliness with which data is processed and loaded into the Operational Database and the data servers. Performance metrics are used to closely monitor the efficiency of observing operations at APO and data processing operations at Fermilab. The information from the monitoring is used to focus effort on areas where improvement is needed. Sufficient quality assurance (QA) testing of the processed data has been identified as a weakness in the data processing operation. Development of quality assurance tests is now the focus of an intense effort by the data processing team at Fermilab and the programmers of the individual pipelines that process the data. Working directly from the Science Requirements, they are developing automated routines that will allow the data analysts to determine whether a given pipeline has successfully processed a given set of data and whether it can be passed onto the next step in the production process.

3. <u>Photometric calibration</u> - The scientific requirements on the photometric calibration are very stringent and are the focus of a great deal of effort by independent teams at Fermilab and Princeton. Reaching the 2% requirement in r' calibration requires exquisite care to such matters as subtle atmospheric transparency fluctuations on short time scales, the illumination of the flat field of the Photometric Telescope, and variations of the point spread function across individual detectors of the 2.5m imaging camera. Early results from the Fermilab and Princeton teams are promising, as the outputs from the independent analyses are producing similar results.

The Office of the Project Scientist is responsible for the oversight and coordination of testing to validate the performance of the data pipelines against written requirements and to verify the scientific integrity of the SDSS data products. Now that the pipelines have become stable, some of the pipeline developers have shifted their efforts to the development of quality assurance tools that will be used during data processing to continuously monitor the quality of the SDSS data products. In the course of developing these tools, the developers will be assessing the quality of the pipeline outputs. Members of the collaboration have also been engaged to do this work. Problems, questions, and inconsistencies brought to light by these efforts will be investigated in detail by the hardware and software developers. In some cases, ARC funding is provided to support the data validation work. Such support is approved by the SDSS Director and formalized through written agreements between ARC and the institution performing the work.

WBS element 1.1.4: Office of the Project Manager

The WBS for the Office of the Project Manager captures the work and costs associated with project management functions such as work planning, budget and schedule preparation, cost and schedule control, Survey Operations web site development and maintenance, and systems engineering. The Project Manager is responsible for developing and maintaining the project schedule and determining the schedule performance of Survey Operations. The Project Manager maintains the list of new work requests until each new project is approved, assigned, and integrated into the overall project plan; or rejected based on the lack of sufficient justification. Additional duties and responsibilities of the Project Manager are defined in Section 1.

The WBS for the Office of the Project Manager is where the costs were captured for the project management support that was provided by Johns Hopkins University prior to May 31, 2001. Following the creation of the Office of the Project Manager, no additional management support from JHU will be required and no funds have been budgeted for these services.

WBS element 1.1.5: Scientific Spokesperson

The Scientific Spokesperson is responsible for managing the affairs for the SDSS Collaboration and representing the SDSS to the scientific community. The duties of the Spokesperson are described in Section 1. The ARC-funded budget that provides support for the Scientific Spokesperson is held in this WBS element. The budget provides the cost of administrative support, travel, and supplies needed by the Spokesperson to carry out the duties of this office. The salary of the Spokesperson is provided as an in-kind contribution and is not included in the cost estimate for the 5-Year Baseline Survey.

In the spring of 2001, the Spokesperson position changed from an appointed position to an elected position with a 2-year term. With the inception of this change, active participants now select the Spokesperson through an election in which votes are collected and tallied by the ARC Business Manager. The first Spokesperson election occurred in July 2001 and the newly elected spokesperson took office on August 1, 2001.

A budget has been established to provide for Spokesperson support through the end of the observing period. This budget is held in the ARC corporate account, under the section “Support for Scientific Spokesperson.” On an annual basis, the level of ARC-funded support for the Spokesperson will be negotiated and then defined through a written agreement between ARC and the Spokesperson for the coming year. Once the level of support is defined, the funds for that support will be allocated from the ARC support budget to the Spokesperson’s institution through a formal agreement (SSP).

2.3.1.2. Institutional Support for Survey Management

ARC Administration

The SDSS is managed by ARC, a non-profit research corporation. Oversight of ARC operations is achieved through the Board of Governors, and the Board of Governors has delegated the management and oversight of the SDSS to the Advisory Council (the Council). Membership on the Council has been granted to those institutions that have made significant cash or in-kind contributions toward the construction, commissioning, and operation of the SDSS. ARC has obtained funding for the SDSS from federal, private, and international sources. These funds are administered by the ARC Secretary/ Treasurer and the ARC Business Manager. They disburse the funds through the formal work agreements known as SSPs. The SDSS budget supports a fraction of the salaries for the Secretary/ Treasurer and Business Manager and provides a modest amount for office support and supplies. The budget for the Secretary Treasurer is established through SSP21; the budget for the Business Manager is established through SSP34. In Table 2.2, these budgets have been summed together under the category "ARC Administration."

Princeton – Office of the Project Scientist

Princeton provides the Project Scientist and Deputy as an in-kind contribution during the academic year. The ARC budget provides a portion of the summer salary for the Project Scientist and funds for travel, equipment, and other miscellaneous expenses accrued in executing the duties of the Office of the Project Scientist. The budget and scope of work is established in SSP46.

Fermilab – Support for Survey Management

Fermilab provides the Director, the Project Manager, and the staff of the Office of the Project Manager as an in-kind contribution through a written agreement between ARC and Fermilab. The Director is responsible for organizing and directing all aspects of the Survey. The Project Manager is responsible for developing and maintaining the project schedule, negotiating and managing the institutional work agreements (SSPs), developing the survey operations budget, and overseeing the Project Office. The budget includes the value of the in-kind salaries of the Project Manager, cost/schedule specialist, and administrative assistant. It also includes the in-kind value of travel and incidental expenses associated with survey management activities. The travel costs of the SDSS Director and Project Manager are partially supported by ARC. The scope of work and the budget for these tasks is established in SSP48.

University of Chicago – Scientific Spokesperson

The first Scientific Spokesperson for the SDSS was Dr. Michael Turner, from the University of Chicago. UC provided the salary for the Scientific Spokesperson as an in-kind contribution from the time that the position was created in January 1998 through September 2001. The ARC-funded budget provides partial salary support for an administrative support person; along with travel and incidental supply costs for the Spokesperson. The scope of work and budget for these tasks is established in SSP47 and provides funds for these tasks through September 30, 2001.

In July 2001, the SDSS collaboration elected Dr. Richard Kron, from UC, to serve as Scientific Spokesperson for a 2-year term. UC will provide the salary for the new Scientific Spokesperson as an in-kind contribution to the SDSS, beginning in August 2001. The ARC-funded budget will provide partial salary support for an administrative support person; along with travel and incidental supply costs for the Spokesperson. The scope of work and budget for these tasks is established under agreement SSP65.

<u>University of Washington – Support for Project Management</u>

The University of Washington provided limited management support to the Director through 2000; this work was supported through SSP60. This work has been completed and no budget is provided after 2000.

<u>Johns Hopkins: Software Validation and Testing</u>

Johns Hopkins provides a part-time astronomer to support the validation of the quality of the processed data and testing the functionality of the Data Archive Server, and the Catalog Archive Server and the user interfaces to these servers. The astronomer is assisted in this effort by two graduate students. The budget provides limited support for salary, travel and supply expenses and is established under agreement SSP62.

<u>University of Washington: Software Validation and Testing</u>

The University of Washington provides two part-time astronomers to support the validation of the quality of the processed data and test the functionality of the Data Archive Server and the Catalog Archive Server and user interfaces to these servers. Limited travel and supply costs were provided under SSP31B in 2000. Since the scope of work was increased substantially in 2001, a new agreement, SSP63, was established to capture the expanded scope and cost for this work for the years 2001 and 2002. The budget provides limited support for salary, travel and supply expenses. A limited budget was established to support travel and supply expenses associated with software testing, data validation, and Working Group support for the period beyond 2003. The scope of work and budget for all of this work is now established under agreement SSP63.

2.3.2. Collaboration Affairs

2.3.2.1. Collaboration Affairs WBS

WBS element 1.2, Collaboration Affairs, describes the organization of work associated with collaboration activities such as the Collaboration Council, the Working Groups, and Publications. The roles of these organizations are defined in Section 1, Management and Oversight.

There is a limited budget set aside for Collaboration Affairs in the ARC Corporate budget, since it is anticipated that funds will be needed to coordinate the scientific effort of the collaboration, hold collaboration meetings, and provide limited support for travel for invited speakers when it is in the interest of ARC.

2.3.2.2. Institutional Support for Collaboration Affairs

There is no ARC-funded support for collaboration affairs, beyond that for the Scientific Spokesperson, allocated to any of the Participating Institutions. The support for individuals performing work associated with Collaboration Affairs is provided by their parent institutions as an in-kind contribution to the SDSS.

2.3.3. Survey Operations

WBS element 1.3, Survey Operations, is by far the largest of the three high-level work elements and encompasses all activities associated with the day-to-day operation of the Survey. The total budget for Survey Operations is $23,971K out of the $28,430K cost estimate for a 5-year Baseline Survey.

Survey Operations includes the Observing Systems, Data Processing and Distribution, Observatory Operations at Apache Point Observatory (APO), and Survey Coordination. The data flow through Survey Operations is shown in Figure 2.1. The following sections describe these major elements and the effort that will be provided by the various institutions supporting Survey Operations.

2.3.3.1. Observing Systems WBS

<u>WBS element 1.3.1: Observing Systems</u>

The WBS for Observing Systems captures the work and costs associated with the equipment that enables the collection of data at APO. This includes the 2.5-meter telescope, the photometric telescope, the imaging camera, the two multi-fiber spectrographs, the data acquisition system, and all ancillary equipment associated with their operation. It also includes the tasks required to fabricate the spectroscopic plug plates, ship them to APO, provide storage until they are used, and prepare them for spectroscopic operations at APO. It also includes the tasks for unplugging the plates and transferring them to long-term storage. Work activities for Observing Systems fall into two categories: maintenance/repair and improvements. A hierarchical system is used in the WBS to identify the engineering, fabrication, implementation, and maintenance tasks necessary to maintain the telescopes, instruments, data acquisition system, and ancillary support systems at the level required to achieve survey goals.

The Head of Observing Systems directs the work of the Observing Systems organization and is responsible for ensuring that the observing equipment and systems meet the Science Requirements and operational needs of the survey. A preventive maintenance program has been established to ensure system reliability. A spares inventory will be maintained through the end of survey operations to ensure system availability. A configuration management program has been implemented to manage improvements in a controlled manner and ensure maintainability. A quality assurance program is being established to track system performance. The SDSS Problem-Reporting Database is being used to report and track safety concerns and equipment problems.

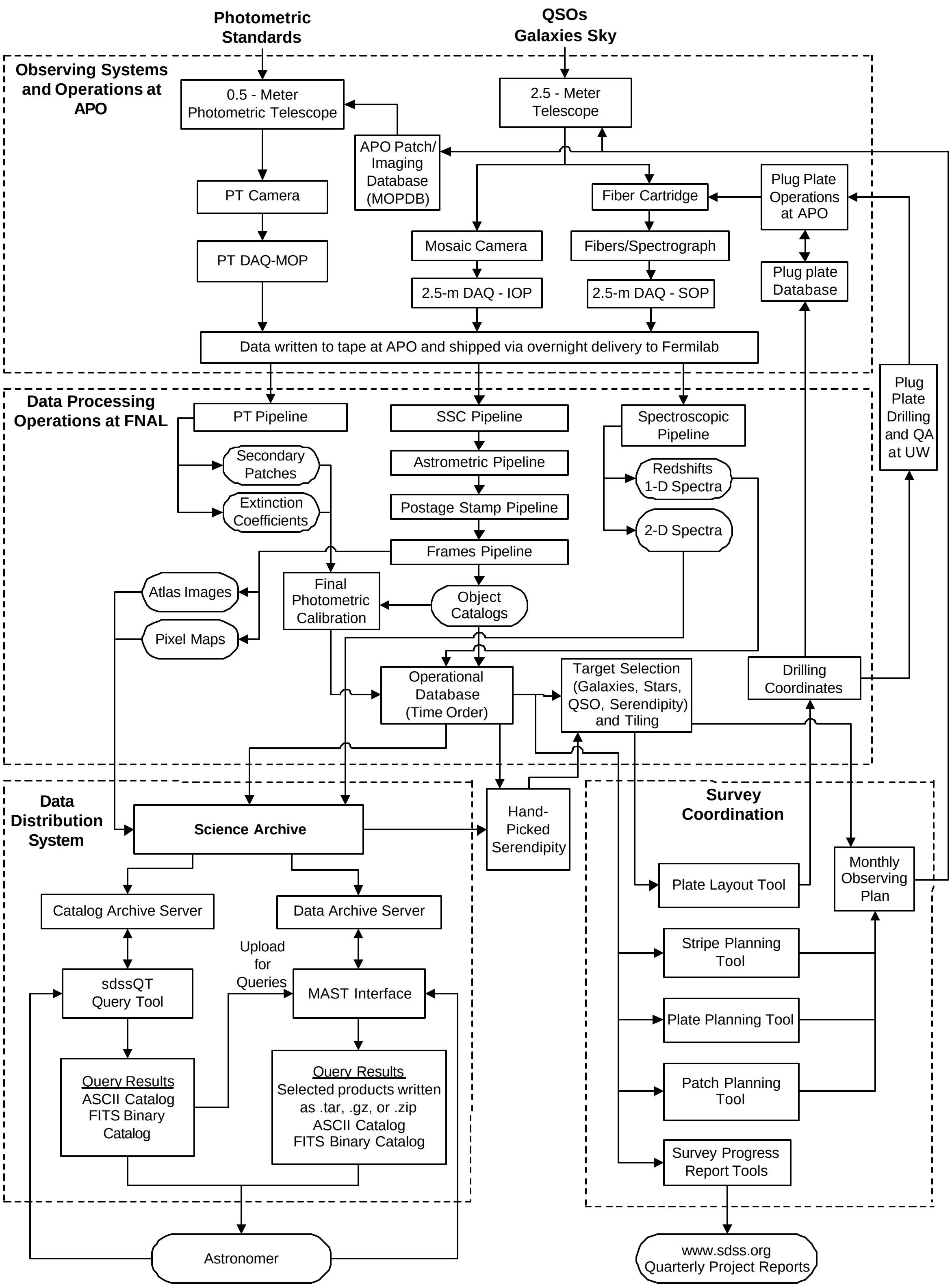
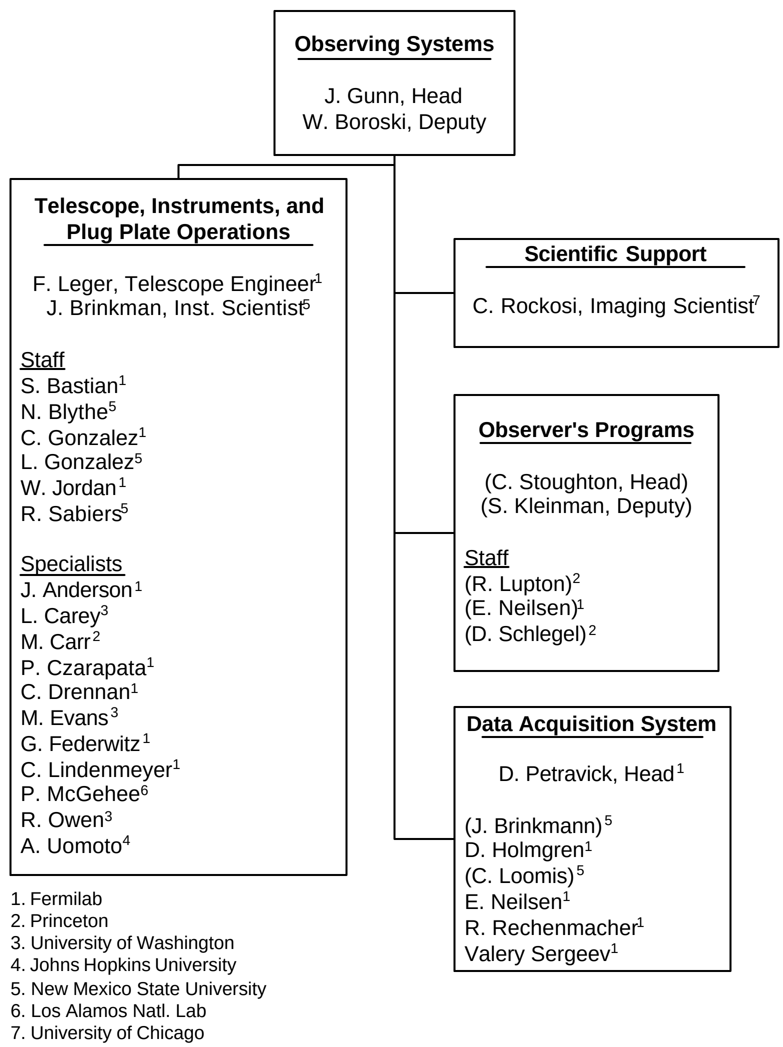


Figure 2.1. Data Flow for Survey Operations.

Figure 2.2 presents the organization chart for Observing Systems. The Telescope Engineer, Instrument Scientist, and staff shown in the Telescope, Instruments, and Plug Plate Operations (TIP) box comprise the group stationed at APO that is responsible for maintaining the telescope and instrument systems. They are also responsible for plug plate operations at APO. This group is herein referred to as the site technical staff.

Figure 2.2. Organization Chart for Observing Systems



The specialists in the TIP box define the personnel that work part-time for the SDSS and to whom specific projects are assigned. These projects produce deliverables that are implemented and tested at APO by the specialists in close coordination with the site technical staff. Once tested and implemented, the responsibility for maintaining and repairing these deliverables is given to the site technical staff.

The individuals shown in the Observers' Programs box are responsible for maintenance and improvements to the software programs that operate the telescopes and instruments at APO. As these individuals reside at several institutions, the Observers' Programs box defines a coordination mechanism. Chris Stoughton, the Head of Data Processing and Distribution, and Scot Kleinman, the Lead Observer, periodically review the status of the Observers' Programs, which are described in Section 2.3.3.1.3. The staff shown in the box are individually responsible for one or more of the Observers' Programs. Over time, it is anticipated that the primary responsibility for these programs will be concentrated in the Integrated System Development Department (ISDD) of the Fermilab Computing Division.

The individuals shown in the Data Acquisition System (DAQ) box are responsible for maintenance and improvements to the data acquisition system at APO, which is described in Section 2.3.3.1.4. Don Petravick, the Head of the Data Acquisition System Group, is also the Head of the Integrated Systems Development Department (ISDD) of the Fermilab Computing Division at Fermilab. The ISDD built and installed the DAQ system at APO and is now responsible for it maintenance. The ISDD is assisted in this responsibility by the APO Computing Systems Manager and the SDSS Instrument Scientist, both of whom are stationed at APO and provide the first line of response to problems and repairs with the system.

2.3.3.1.1. Telescopes and Instruments

Observing Systems includes the telescopes, instruments, and ancillary systems at APO that are used to acquire SDSS data. Although all of the critical systems necessary to acquire data were operational when survey operations began in April 2000, a number of engineering tasks remained to complete the less-critical systems and to bring all systems into compliance with performance requirements and operating specifications. Table 2.4 lists the more significant engineering tasks that were completed between April 2000 and April 2001, the first year of survey operations.

Table 2.4. Observing Systems Tasks Completed between April 2000 and April 2001

Task Completed	Month Completed
Imaging camera T-bar latch system installed and tested	Apr 2000
Plug plate marking station installed and made operational at APO	Apr 2000
Telescope Performance Monitor redesigned in EPICS	May 2000
Duplex air filters for PMSS installed and tested	May 2000
PT Cryotiger compressor recharged	Jun 2000
Engineering support building design documents and bid package finished	Jun 2000
Enclosure lightning protection upgrades completed	Jun 2000
MCP motion control code modified to improve robustness	Jun 2000
Windbaffle handling hardware installed and tested	Jul 2000
Telescope altitude and azimuth bump switches installed	Jul 2000
Interlock lightning protection upgrade completed	Jul 2000

Table 2.4. (continued)

Task Completed	Month Completed
Northwest fork emergency stop switch upgrade completed	Jul 2000
RS485 drivers and/or receivers for 8MHz circuit replaced	Jul 2000
Getter removed from all ten dewars on imaging camera	Jul 2000
Cartridge plug plate and slithead covers fabricated	Jul 2000
PT primary baffle tube modified	Jul 2000
M1 air support system duplex filter installed	Jul 2000
Photometric Telescope collimated using APO's auto collimator	Aug 2000
PT scattered light measurements completed and analyzed	Aug 2000
Cartridge cart igloo design drawings completed	Aug 2000
Secondary mirror and corrector lens optics measured at Lick Observatory	Sep 2000
Windbaffle LVDT replacement transducers installed	Sep 2000
Windbaffle azimuth cam followers pinned	Oct 2000
Telescope thermometer system electronics installed on telescope	Oct 2000
Ground-loop-pump cooling shroud installed	Oct 2000
Rotator removed, bearing disassembled and serviced, and rotator re-installed	Oct 2000
Primary mirror removed, re-aluminized, and re-installed	Oct 2000
Telescope and windbaffle thermometers assembled and calibrated	Oct 2000
M1 linear gage replacement for axial and transverse actuators completed	Oct 2000
Spectroscopic corrector cart and storage system fabricated and implemented	Oct 2000
Azimuth, altitude, and rotator axis fiducial tables implemented	Oct 2000
PT mirror removed, re-aluminized, and re-installed	Oct 2000
Common corrector cell purge system connected	Oct 2000
Camera de-icing heater improvements finished and tested	Nov 2000
Windbaffle scattered light baffles installed	Nov 2000
Primary and secondary mirror thermometers installed	Nov 2000
All cartridge guide fiber orientation ferrules installed and calibrated	Nov 2000
New rotator drive motor installed	Dec 2000
Telescope alignment clamp completed	Dec 2000
Enclosure air leaks plugged	Dec 2000
Moth and thermal barrier for windbaffle servo amp line filters installed	Dec 2000
Lower level light switches installed	Dec 2000
2.5-m telescope enclosure outside stair handrail installed	Dec 2000
Windbaffle wind sensors designed and approved	Jan 2001
PMSS monitoring system integrated with TPM and tested	Jan 2001
Finalized design requirements for instrument latch controller version 2	Jan 2001
PT Cryotiger enclosure heater installed and tested	Jan 2001
Telescope windbaffle shock absorbers installed	Jan 2001
Primary mirror cell and secondary mirror truss thermometers installed	Feb 2001
Rotating floor and enclosure hatch door air seals installed	Feb 2001
PMSS pump system replaced – new system installed and tested	Feb 2001
Primary support structure (PSS) air leaks found and plugged	Mar 2001
Telescope analog power supplies replaced with DC/DC converters	Mar 2001
Secondary mirror Galil power converter board installed and tested	Mar 2001
Spectroscopic Corrector Lens safety latch system installed and tested	Mar 2001
Instrument ID switch actuators for cartridges installed and tested	Mar 2001

The first year of operations provided the opportunity to assess system-level performance against requirements and identify areas in which system reliability and operating efficiency could be improved. As a result, a number of improvement projects have been identified that are required to bring the telescope systems into compliance with performance requirements and specifications such as image quality, equipment protection, system reliability, and operating efficiency. These projects are listed in Table 2.5 and planned for completion in 2001 or 2002.

Table 2.5. Observing Systems Improvement Project Milestones, as of September 2001

Task	Target/Actual Completion	% Complete
Thermal Environment Work (image quality)		
Flat field lamp heat removal plumbing installed	Apr	50%
Telescope liquid cooling loop installed and tested	Apr/May	100%
Windbaffle thermometers installed and tested	May/May	100%
Telescope 24 VDC distribution system installed and tested	May/May	100%
Enclosure HVAC ductwork modified to reduce stratification	May/May	100%
Instrument chiller plenum duct installed to improve inst. cooling	May/May	100%
Enclosure HVAC chiller system installed and tested	Jun/Aug	100%
Secondary mirror thermal radiation shield installed	Jul/Aug	100%
Primary mirror lateral gage power supplies fabricated	Jul/Sep	100%
Primary mirror vent tube discs removed to improve air flow	Jul/Oct	100%
Telescope drive amplifier replacements complete and tested	Jul/2002	0%
Equipment Protection		
Photometric telescope mirror handling equipment fabricated	Jun/Jun	100%
Slip detection system installed and tested	Oct	90%
Instrument change interlock system installed and tested	Dec	25%
System Reliability		
New Photometric Telescope filters installed	Jul/Jul	100%
Improved primary mirror retainer stops fabricated	Sep/Oct	100%
Secondary mirror flexure support system installed	2002	0%
Telescope counterweight system upgrade complete and tested	2002	0%
Cloud camera upgrade complete and tested	2002	0%
Operational Efficiency		
Camera safety latch system installed and tested	May/Jul	100%
Photometric Telescope lower shutter automated and tested	Jun/Aug	100%
DIMM telescope mounted on 2.5-m telescope pier	Jul/2002	15%
Cartridge cart storage house complete	Aug/2002	0%
Plug plate drilling fixture built and put into operation	Sep/2002	5%
Spectroreflectometer fabricated and tested	Sep	50%
Coordinate measuring machine for plug plate QA upgraded	Oct/2002	0%
Planned Maintenance		
Photometric Telescope mirrors re-aluminized	Jul/Jul	100%
2.5-meter telescope primary mirror re-aluminized	Oct/Oct	100%

Many of the tasks completed in 2001 were aimed at improving the thermal environment around the telescope, which is affecting observing efficiency and the ability to achieve the 1.2" seeing requirement for image quality. This work has been organized in two phases: the first phase addressed the more obvious problem areas and was completed during the summer of 2001. Planned Phase I work included completing the installation of thermometers to monitor telescope temperatures and the installation of blower fans in the telescope cone to improve airflow through the primary mirror ventilation system. The HVAC ductwork in the telescope enclosure was modified to eliminate stratification on the telescope level that was affecting the thermal equilibrium of the mirror, and an enhanced cooling system was installed in the enclosure to enable cooling of the enclosure to match outdoor winter temperatures. The scope and detailed cost of phase two activities will be determined based on the improvements realized as a result of the phase one work.

Preliminary flow measurements were made in the lab on a section of mirror cell comparable to the 2.5-m primary. The purpose of these measurements was to assess the impact of small discs at the ends of the vent tubes in the mirror ventilation system. Speculation was that the discs were severely impeding airflow through the mirror. While laboratory tests have shown this not to be the case, they have also shown that there is no distinguishable difference in airflow when the discs are in place or when they are removed. Since the discs complicate the installation procedure for the primary mirror, they were permanently removed when the mirror was removed for re-aluminizing in October 2001.

New handling hardware for the Photometric Telescope mirror was designed and installed in June 2001, and significantly improves the method by which the mirror is removed from the telescope for re-aluminization. Remaining equipment protection tasks planned for 2001 include the slip detection and PLC-monitored instrument change systems. The absence of the these systems is not severe enough to shut down operations, but their implementation will decrease the risk of damage to the telescope and sub-systems that could affect operations.

The slip detection system is designed to shut down telescope drive motors if a drive capstan slip is detected; it is currently being bench-tested to ensure that it works properly before being installed on the telescope. The PLC-monitored instrument change system will monitor the state of the hardware systems during instrument change and will prohibit unallowable actions that may damage an instrument or telescope sub-system. It was originally felt that a computer-controlled instrument change system was necessary to provide the proper level of equipment protection during instrument change. One of the suggestions of the Review Committee from the April 2000 review of Observing Systems was that the project reconsider the concept of an automated instrument change system. The concern was that an automated system would add a level of complexity that may not be necessary or justified. In response to this suggestion, the whole concept of the instrument change system was reviewed in the fall of 2000 by the Project Scientist, Project Manager, Telescope Engineer, observing staff, and the specialists who built the interlock system and programmed the telescope motion control computers. From this review, we concluded that a fully automated system would indeed be difficult and costly to implement, and the limited benefits could not justify the allocation of resources to such a project. Instead, we determined that a more appropriate approach would be to modify the interlock system to prohibit inappropriate actions during instrument change that could damage the instrument or telescope sub-systems. A requirements document was developed to define the functional requirements and specifications for a PLC-based instrument change interlock system, and the interlock system is being modified to achieve compliance with these requirements. The modifications will be implemented and tested during the fourth quarter of 2001.

Tasks such as the upgrades to the secondary support system, telescope counterweight system, and Cloud Camera, are planned to improve system performance and reliability, which translates directly to observing efficiency. Maintaining system reliability is critical to our ability to meet the observing efficiency specification for equipment uptime.

The Telescope Engineer is responsible for scheduling the re-aluminization of the telescope mirrors, including removal of the mirrors and preparation for shipping, and reinstallation into the telescopes after aluminizing. The Deputy Site Operations Manager coordinates aluminizing schedules with the Telescope Engineer, secures vendors for the aluminizing work, oversees transport of the mirrors to and from the vendor, and oversees the actual aluminizing process.

The Head of Observing Systems has delegated the maintenance and repair of Observing Systems to the SDSS Telescope Engineer and Instrument Scientist. They are assisted in performing maintenance and repair work by the TIP staff and the APO Computing Systems Manager. When work cannot be handled by the on-site staff, the Head of Observing Systems works with the Project Manager to assign work to the specialists at Fermilab, Princeton, Chicago, Johns Hopkins, Los Alamos National Laboratory, or the US Naval Observatory according to skill needs and availability. The specialists at these institutions include the people who built and commissioned the various systems at APO and who are available to assist with problems on an on-call basis.

2.3.3.1.2. Plug Plate Production and Preparations

In addition to the telescopes and instruments, Observing Systems includes the activities associated with the fabrication of the spectroscopic plug plates and their subsequent use in spectroscopic observations. The Head of Survey Coordination is responsible for coordinating and overseeing all activities associated with target selection, generation of drill files, drilling schedules, and inventory control at APO. In addition, the Head of Survey Coordination is responsible for providing the observing staff with tools and observing plans sufficient to ensure that the spectroscopic observing goals of the survey are met. To help achieve these goals, the Head of Survey Coordination has developed the Plug-Plate Database, which tracks the location and information on each plate fabricated and prepared for observing. The database also provides the observers with information needed to determine when specific plates should be selected for observing, and keeps track of which plates have been observed.

The Head of Observing Systems is responsible for plug plate operations at APO, which includes ensuring that adequate facilities exist at APO to meet the storage requirements requested by the Head of Survey Coordination, and that an adequate staff and facilities exist at APO to prepare plates for nighttime observing. The Head of Observing Systems has delegated the day-to-day management of APO plug plate operations to the SDSS Telescope Engineer.

Plate production begins with the delivery of plug-plate blanks to the University of Washington, where the blanks are inspected to verify conformance to specifications. On a monthly basis, target selection code is run at Fermilab on processed imaging data, thereby enabling the selection of stars, galaxies, quasars, and other objects that will be observed in the spectroscopic survey. The resulting drill files are posted on the Internet and subsequently downloaded at the University of Washington. These drill files instruct a numerically controlled milling machine at UW to drill holes in the spectroscopic plug plates that correspond to the selected objects in the sky and to engrave each plate with a unique ID number. After machining, each plate is sanded to dull the finish and remove burrs, and then thoroughly cleaned and rinsed. The cleaned plates are then inspected for conformance to design, in accordance with the plug plate QA program. The QA program is in place to monitor the quality of plug-plate production, with the complete set of QA records maintained at the University of Washington. After passing inspection, the plates are packaged and shipped to APO by high-quality carrier for storage, plugging and observing. The shipping method is chosen based on the required delivery schedule and the ability to track the shipment. Since each finished plate represents a significant investment in time and effort, the security provided by a high quality carrier is excellent and the cost reasonable.

The fiber plugging cycle begins after the drilled plates are received at APO. The plates are inspected for shipping damage and cleanliness by the APO plugging staff, logged in the plug plate database, and stored in the staging facility until they are ready to be plugged. Each morning during an observing run, the plugging staff receives instructions from the observing staff denoting which plates were successfully observed during the previous night and can be unplugged, and designating which plates need to be plugged for the coming night. When the observations for a plate have been declared complete, the observed plate is unplugged, removed from the fiber cartridge, and returned to the appropriate storage system. New plates are retrieved from the storage system, loaded into fiber cartridges, and plugged with optical fibers. Once plugged, the cartridge/plate assembly is scanned by the Fiber Mapper, which correlates fiber number with position on the plate. Once mapping is complete, the cartridge is placed in the storage rack in preparation for spectroscopic observation. Relevant information is loaded in the SDSS plug-plate database, INVENTORY, throughout the fabrication, plugging, and storage process.

The current operations process involves a monthly target selection run on recently acquired imaging data, followed by the creation of drill files that are used to fabricate the plug plates for subsequent observing periods. The UW shop is capable of fabricating approximately six plates per day, which could provide a peak capacity of 120 plates per month. To date, no more than 40 plates have been requested for a single drilling run. As operations become more efficient, the number of plates will increase to approximately 50 per drilling run. We do not expect this to occur until the fourth quarter of 2001. The driving requirement for the number of plates drilled per run is that spectroscopic observations should not be limited by an inadequate inventory of plates at APO. This requirement can be met with monthly drilling runs of 50 to 55 plates and the UW shop has demonstrated the capacity to meet the requirement easily.

The plug plate cycle was designed to achieve a one-month turn-around from the time that imaging data is collected at APO, to the time that plates drilled from that data are ready for observing at APO. While we have demonstrated this capability, the intent is to use it sparingly. Our original intent was to acquire sufficient imaging data during the first year of operations so that the appropriate areas of the sky could be processed a year in advance. Unfortunately, the weather in the first year of the survey limited the amount of good imaging data that was observed in the Northern Galactic Cap. Once there is an adequate inventory of imaging data, it will enable more efficient plate tiling over a larger contiguous area of the sky.

While the ability to run target selection code on data more than one month before the plates are needed relaxes the fabrication and delivery schedule for the plates and reduces shipping costs, the added costs are not large and have been budgeted. Ultimately, the turn-around time for the plug plate cycle is determined by the weather and seeing conditions at APO and the process must be able to accommodate a fast turn around time. Our process is designed so that weather is the only uncontrolled element in the schedule.

2.3.3.1.3. Observers' Programs

Observing Systems includes the Observers' Programs, which are used by the observers to control the telescopes and instruments. The Observers' Programs include the Imager Observer's Program (IOP), the Spectroscopic Observers' Program (SOP), and the Photometric Telescope Observer's Program (MOP). IOP provides the observer's interface to the systems used in imaging operations (telescope, imaging camera, and DAQ). SOP provides the observer's interface to the systems used in spectroscopic operations (telescope, multi-fiber spectrographs, and DAQ). MOP provides the observer's interface to the Photometric Telescope. The Observers' Programs have been developed and are maintained by the staff shown in the Observer's Program box in Figure 2.2. Planned tasks associated with the Observer's Programs include improvements to increase observing efficiency and track performance, and the development and improvement of on-line quality assurance tools for imaging, spectroscopy, and Photometric Telescope observations.

2.3.3.1.4. Data Acquisition System

Observing Systems includes the Data Acquisition System (DAQ) at APO, which consists of the hardware, and software programs, that collect data from the instruments and write it to tape for subsequent data processing at Fermilab. The Integrated Systems Development Department at Fermilab designed and installed the DAQ system and will support this system through the observing phase of the survey, with help from the APO site staff. The DAQ system consists of U.S. Government-owned property on loan to ARC for the duration of the survey. Upgrades to the DAQ system will be implemented as required to meet survey requirements and improve operational efficiency. A major upgrade to the DAQ system was completed in the fall of 1999. The need for future upgrades will be reviewed in the first half of 2002.

A spares plan has been established for the DAQ system and spare components procured to ensure that an adequate supply of critical parts is available to keep processing activities on-line. The Fermilab Computing Division ISDD is responsible for specifying and maintaining the on-site spares inventory and is assisted by the APO site staff. The ISDD also manages commercial hardware and software support contracts for DAQ system components.

Data acquisition activities include the maintenance and support of the data acquisition hardware at the observatory. They also include the development and maintenance of the Observers' Programs, the suite of software programs used by the observing staff to acquire data with the telescopes and instruments and record it on tape for processing at Fermilab.

2.3.3.2. Institutional Support for Observing Systems

The systems that comprise Observing Systems were built and delivered by many of the Participating Institutions. The following sections describe the support that will be provided by the institutions sustaining Observing Systems. They also include brief summaries of their contributions during the Construction and Commissioning phase.

2.3.3.2.1. Fermilab Support for Observing Systems

<u>SSP42 - Fermilab Observing Systems Support</u>

Fermilab built and delivered the telescope motion control system, drive amplifiers, Motion Control Processor (MCP), Telescope Performance Monitor (TPM), interlock system, instrument handling equipment, and numerous small sub-systems. Fermilab is providing the SDSS Telescope Engineer, a mechanical technician, and an electronics technician to support on-site engineering and maintenance activities associated with SDSS operations. A second electronics technician will be provided in 2001 and 2002 to help address and troubleshoot electronic problems, and reduce the backlog of incomplete electrical tasks. The SDSS Telescope Engineer will oversee all plug plate activities at APO, including the supervision of technicians provided by APO and maintenance activities required to ensure system readiness or improve efficiency. System specialists at Fermilab who built and installed sub-systems at APO will provide support to the Telescope Engineer for problems with these systems that cannot be handled by the on-site technical staff. The scope of work and budget is established under agreement SSP42.

SSP61 - Fermilab Observing Software and DA Support

The Integrated Systems Development Department (ISDD) of the Fermilab Computing Division built and now maintains the DAQ system at APO, along with its maintenance plan. This department has extensive experience with large high-speed data acquisition systems and can rapidly provide considerable resources to promptly resolve DAQ problems when they arise. Personnel from ISDD provide rapid responses to problems encountered during nighttime observations. They routinely answer urgent questions from observers during the night and provide consultation during the day to the APO Computing Systems Manager. ISDD built a test stand in 1995 and now maintains it to facilitate problem solving. ISDD established the spares plan for the DAQ system and is responsible for specifying and maintaining the on-site spares inventory. ISDD also manages the hardware and software support contracts for DAQ subsystems.

Beginning in November 2000, Fermilab increased the level of support for the maintenance and improvement of the DAQ systems and the observers programs by one person. This person is primarily responsible for the maintenance and improvement of the suite of software known as the Observer's Programs, and the software associated with the DAQ system. The Observers' Programs provide the software interface to the telescopes and instruments and include the Imaging Observers' Program (IOP), Spectroscopic Observers' Program (SOP), and the Photometric Telescope Observers' Program (MOP). A fourth software program, Astroline, writes the acquired data to tape and disk and provides feedback to the observers through the Observer's Programs. This same person also serves as the primary liaison between the observing team and the ISDD, and will serve as a half time observer at APO. The scope of work and budget is established under agreement SSP61.

2.3.3.2.2. APO Support for Observing Systems

SSP35 - Apache Point Observatory Support for Observing Systems

APO provides technical personnel to the Telescope Engineer to assist him in the preparation of the 2.5-meter and Photometric Telescopes for daily operation. APO provides cleaning procedures for the optics and assist with the cleaning of the optics. They perform routine maintenance and repair activities when requested. APO provides the SDSS Instrument Scientist, who reports to the SDSS Telescope Engineer and is responsible for ensuring that all instruments are operational and that cryogens and other consumables are available to support observations and checkout activities. APO also maintains the instruments that monitor seeing and weather conditions, including the Cloud Camera, the DIMM, and the instruments on the site meteorological tower.

APO provides qualified technicians to the SDSS Telescope Engineer for plug plate handling and plugging activities. APO also maintains on-site storage and staging facilities for approximately 300 plates and contracts for off-site facilities for long-term storage of the remaining plates.

The APO Computing Systems Manager and the SDSS Instrument Scientist provide the first level of maintenance and support to the Fermilab-provided DAQ system at APO. These individuals diagnose DAQ problems and replace parts as required. Personnel from the Fermilab ISDD assist with the troubleshooting and repair of problems that require detailed knowledge of the DAQ system. Problems that require attention from vendors for systems under maintenance contracts are reported to the Head of Data Processing and Distribution for resolution. The budget for APO support of Observing Systems is included with the APO budget for Observatory Operations that is established under agreement SSP35.

2.3.3.2.3. Princeton Support for Observing Systems

SSP32 - Princeton University Observing Systems Support

Princeton built and delivered the imaging camera and its mechanical and support systems, the detector systems for the spectrographs and the Photometric Telescope, the cryogen and temperature control systems for all of the instruments, the flat-field and wavelength calibration systems for the spectrographs, throughput monitoring systems for the optical surfaces, and software for the Fiber Mapper. Princeton is maintaining and improving these systems during operations as required to meet the Science Requirements. Princeton also provides technical support for other telescope-related tasks as needed. The scope of work and budget are established under agreement SSP32.

SSP38 – Princeton Observing Software Support

Princeton developed portions of the Observer's programs, including the focus loop, parameter watcher, Imaging Observers' Program (IOP), Spectroscopic Observer's Program (SOP). Princeton also developed the Motion Control Processor (MCP) and the interlocks graphical display. Princeton will provide support to maintain these systems through the five-year observing period, although the level of support will decrease over time as these programs become mature and require only occasional maintenance. Beginning in 2002, the major responsibility for IOP and SOP will be transferred to Fermilab, with Princeton providing consulting support on an as-needed basis. The budget for observing software support provides for salary, travel, and supplies and is included with the Princeton budget for data processing support that is established under SSP38.

2.3.3.2.4. University of Washington Support for Observing Systems

SSP31 - University of Washington Observing Systems Support

The University of Washington oversaw the procurement of the 2.5-meter telescope and its enclosure, provided oversight for the delivery of the telescope optics, developed and implemented the Telescope Control Computer (TCC), built and delivered optical support and control systems, and designed and delivered the fiber cartridges with their associated optical fiber assemblies. The development group was disbanded in 1999 and those staff members with operations experience were retained.

During operations, UW provides technical support to maintain and upgrade as necessary the TCC, the 2.5-m telescope guiding system, and telescope optical support and control systems, and provides technical support for other areas on an as-needed basis. UW is also responsible for plug plate fabrication. The baseline plan is for all plug plate production to occur at UW. However, a second vendor could be qualified and used if production demands exceed the UW shop capacity. Fermilab produced prototype plug plates during the plug plate R&D phase and could serve as a back up vendor in short notice. The budget and scope of work for UW support for Observing Systems is established under agreement SSP31.

2.3.3.2.5. Johns Hopkins Support for Observing Systems

<u>SSP36 - Johns Hopkins University Observing Systems Support</u>

The Johns Hopkins University built and delivered the spectrographs and managed the installation and commissioning of the Photometric Telescope (PT) at APO. During operations, the astronomer who was the Principal Investigator (PI) for the spectrographs will assist the SDSS Instrument Scientist with maintenance and required improvements on the spectrographs. This astronomer will also oversee and support new tasks and projects that are required. The JHU Center for Astrophysics will provide engineering and technical support for the specific projects assigned to it by the SDSS Project Manager. The scope of work and budget are established under agreement SSP36.

<u>SSP50 - Johns Hopkins University Photometric Telescope Commissioning</u>

Johns Hopkins provided one person through March 2001 to help staff PT observations at APO and perform data reduction and analysis tasks at JHU associated with the photometric calibration effort and spectroscopic data reduction. The budget provided funding for salary, travel, and incidental supplies and was covered under agreement SSP50. This agreement will be closed in early 2002, once final costs for this effort have been received.

2.3.3.2.6. University of Chicago Support for Observing Systems

<u>SSP33 - University of Chicago Observing Systems Support</u>

The University of Chicago (UC) provided management oversight for the construction of the 2.5-meter telescope and its optics and provided significant technical support for the construction of the imaging camera. During operations, UC will provide the Imaging Scientist to support the operation of the imaging camera through September 2001. After September, the Imaging Scientist will continue this work at another Participating Institution. It is noted that the Imaging Scientist has worked on the camera since 1992 and has supported its operation effectively since its commissioning in June 1998. The UC budget provides for salaries, tuition, travel, and miscellaneous expenses to support the Imaging Scientist through September 2001. After September, the budget for this support will move with the Imaging Scientist to her new institution.

UC also provides occasional engineering support for optics design and analysis, and electronics support for the imaging camera and other telescope systems. This support is provided on an as-needed basis, with work organized in the form of projects. The budget for UC engineering support provides for a limited amount of base support and will be augmented as needed to support projects that the UC group will be asked to complete. The budget and scope of work for UC support of Observing Systems are established under agreement SSP33.

2.3.3.2.7. Los Alamos Support for Observing Systems

SSP58 - Los Alamos National Laboratory Observing Systems Support

In 2000, LANL accepted responsibility for the development and maintenance of the Telescope Performance Monitor (TPM), which monitors, displays, and archives telescope engineering and thermal data. LANL also provides one astronomer to serve as a half-time observer on the Photometric Telescope and assist with bright-time photometry as needed. Continued support beyond 2002 is under review by LANL management; it is anticipated that LANL will continue to provide technical and observing support beyond 2002. The budget and scope of work are established under SSP58.

2.3.3.2.8. Japan Participation Group Support for Observing Systems

Japan Participation Group

The Japan Participation Group (JPG) provided the CCDs for the imaging camera. The CCDs are JPG property on loan to ARC for the duration of the survey. JPG engineers and scientists contributed to the fabrication of electronic components and systems for the imaging camera. They built and installed a 50 Å resolution monochrometer to measure, through the corrector plate and filter, the sensitivity of every CCD on the imaging camera. They designed, built and installed the flat field system for the Photometric Telescope.

During operations, the JPG will provide operations, engineering, and maintenance support for these systems as needed. They will also provide new filters for the Photometric Telescope, and will periodically calibrate the imaging camera using the 50 Å monochrometer. This work is currently not defined under an SSP agreement, but in a formal Memorandum of Understanding between the JPG and ARC. The budget to support this work is provided by the JPG as an in-kind contribution to the SDSS.

2.3.3.2.9. ARC Support for Observing Systems

SSP91 - ARC Observing Systems Support

Larger procurements associated with Observing Systems are frequently managed directly by the ARC Business Manager, since it is often more cost-effective for him to place these large orders directly. Examples of on-going procurements paid directly from the ARC corporate account include the annual aluminization of the primary mirror and the annual usage fee for the vertical mill used in plug plate production at UW. Funds to cover large one-time expenses are also captured here. Examples of such expenses include the costs for the profilometry measurements of the secondary mirror and Common Corrector lens at Lick Observatory, and the costs of the on-going effort to improve the thermal environment around the 2.5-m telescope. Since the latter is being done by personnel from several institutions, we have elected to capture the costs in place in order to more easily capture the total cost for this critical project. The costs for these procurements are budgeted in the ARC Corporate Account under agreement SSP91.

Funds have also been set aside to provide support for salary, travel, and incidental supply costs for the Imaging Scientist after she moves to the University of Washington in the fourth quarter of 2001. These funds will provide support from October 2001 through the end of the 5-year observing period. The budget for the effort will be transferred from the ARC Corporate Support account and allocated to the University of Washington once the level of support for the Imaging Scientist is negotiated and a written agreement prepared. The budget and scope of work for ARC Corporate Support for Observing Systems are established under agreement SSP91.

2.3.3.3. Data Processing and Distribution WBS

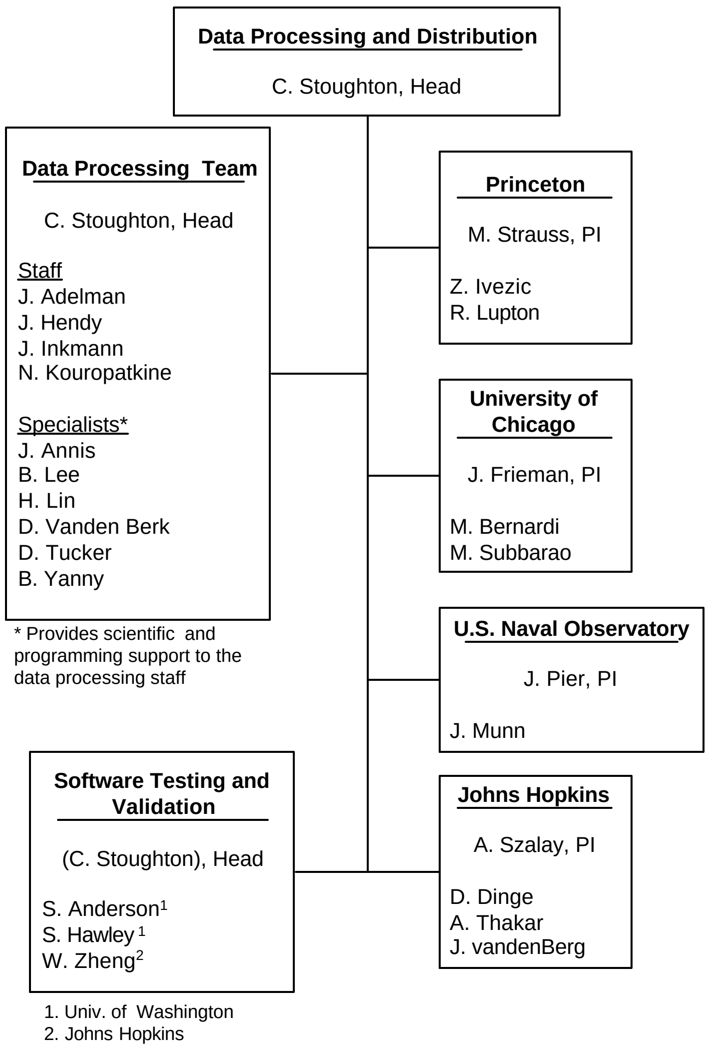
WBS element 1.3.3, Data Processing and Distribution, captures the work associated with collecting, processing, and distributing data to the collaboration and astronomical community. As with Observing Systems, work is divided into two categories: maintenance/repairs and improvements. Data processing activities include all work associated with the development and maintenance of the data processing pipelines by various institutions, and the organization, operation, and maintenance of the data processing “factory” at Fermilab. Data distribution activities include the development and deployment of five data servers: the Chunk Database, the Rerun Database, the Catalog Archive Server, the Data Archive Server, and the skyServer. These last three servers and their interfaces will be used to distribute the SDSS Archive to the astronomy community as well as the SDSS collaboration. The other servers are used for data validation and will be used in the plug-plate operation. Data distribution activities also include support for the development of interfaces between the servers and the data users. The implementation plan for the distribution of SDSS Archive to the astronomy community, including the role of the STScI, is described in the SDSS Archive Distribution Plan[3]. Data processing and distribution activities are carried out by staff and specialists at the Participating and Member Institutions. The Space Telescope Science Institute (STScI) also provides support for data distribution as described in section 2.3.3.5. The organization chart for Data Processing and Distribution is shown in Figure 2.3.

<u>WBS element 1.3.2.1: Data Processing</u>

SDSS data processing is carried out by members of the Fermilab Computing Division Experimental Astrophysics Group (EAG), using Computing Division facilities. During observing operations, the following types of data are recorded: 2.5-meter imaging data, 2.5-meter spectroscopic data, and PT calibration data.

During imaging observations, the data is written in real-time to disk and from disk it is written to two sets of tape simultaneously. One set of tapes serves as the primary copy of the data; the second is a redundant set that serves as a back up of the night's data. Each set consists of seven tapes: one tape for each of the six dewars on the imaging camera, and one tape with the gang and log files associated with the observations.

Figure 2.3. Organization Chart for Data Processing and Distribution



During spectroscopic observations, data from the spectrographs are written to disk in real-time. At the end of the observing night, this data is written sequentially to two tapes. The first tape serves as the primary copy of the data; the second is a redundant copy that serves as the back up.

During observations with the PT, data is written to disk in real-time and then copied to tape in the morning following the observations. At the same time, data from the previous night's observations is also copied from disk to tape, and then the data from the previous night purged from disk. This process ensures that PT data is always recorded on two different tapes: one serves as the primary copy, the second is the redundant back up.

After a night's observing, the full set of primary tapes are packaged at APO and shipped to Fermilab for processing. The tapes are shipped via overnight carrier, so that the data arrives promptly at Fermilab and so that each shipment can be tracked if necessary. During the workweek, tapes are shipped overnight to arrive one day after the data was collected. Data collected on weekend and holiday nights are shipped on the first business day following the night of observing, for arrival at Fermilab the following day. The APO Site Operations Manager is notified by the Head of Data Processing and Distribution when the primary data tapes are successfully processed at Fermilab, and then sends the back-up copies to Fermilab for long-term storage. The smaller data files such as PT data files, Spectroscopic Data Files, and reports are frequently transferred over the Internet for immediate use. The size of imaging data file and the bandwidth of the APO Internet connection do not permit this.

Data processing operations at Fermilab run in a "factory" production mode. Under the Head of Data Processing and Distribution, the goal of the Data Processing Team at Fermilab is to process new imaging data within two weeks after it is collected and to process spectroscopic data with one day of acquisition. When necessary, selected imaging runs can be processed in less than a week and an evening of spectroscopic data can be processed on one day.

Once received at Fermilab, each type of data is processed by its own set of pipelines. Photometric Telescope data are processed through MTpipe, which defines the primary network of photometric standards, calculates extinction and color terms, and produces calibrated secondary patches. Imaging data are processed through the imaging pipelines, which produce catalogs of calibrated objects, corrected frames, and atlas images. Object lists from individual imaging runs are merged together and targets selected for subsequent spectroscopic observations. Using the target selection data, drill files are designed for use in the fabrication of the spectroscopic plug-plates. Results from target selection, and the corresponding drill files, are loaded into the Operational Database and made available via the Internet for plate drilling at UW and plugging and mapping operations at APO. Spectroscopic data are processed through the spectroscopic pipelines to produce calibrated spectra, identifications, redshifts, and other spectral parameters. Data from special runs are processed on an as-needed basis to obtain calibration files (electronic calibrations, CCD positions, etc.) or check the imaging and spectroscopic data. After each stage of processing, the results are loaded into the Operational Database. Data quality is verified and checked in summary form to determine which segments of data are ready for the next stage of processing. Global tests are performed on calibrated outputs. Problems and their solutions are tracked in the SDSS Problem Reporting Database to allow trending analysis on system performance.

The full set of processed data is stored temporarily on disk and permanently archived in an online tape robot. A facility is provided to access the tape robot and disk at Fermilab so members of the SDSS collaboration have ready access to these files. As the cost of disk continues to decline, the intent is to place essentially all of the processed data on disk in the future. This will allow efficient use of the Data Archive Server at Fermilab by the collaboration and the astronomy community. Portions of the processed data that meet Survey Requirements are also loaded in the various data servers for use by the collaboration and community as described in the SDSS Archive Distribution Plan.

All of the software used in the data processing operation is controlled by the CVS configuration management system. The introduction of new versions of data processing code into the production operation is done under the direction of the Head of Data Processing and Distribution. Upgrades of the pipelines are planned and implemented only when it is established that a pipeline does not meet Survey requirements. At this time, there are several planned upgrades, which should be completed by the end of 2001. Beginning in 2002, efforts associated with the pipelines will consist of responding to bugs and change requests in the SDSS Problem-Reporting Database to correct problems and improve operating efficiency. Version 5.3 of the photometric pipeline is being developed at Princeton with the expectation that it will be introduced into the factory in the third quarter of 2002. Work is also in progress at Chicago, Fermilab and Princeton to develop quality analysis tools for the imaging and spectroscopic pipelines. These tools will be used during data processing to monitor the quality of the pipeline outputs. There is also a significant effort underway at Fermilab, Princeton, and New York University to improve the photometric calibration of the imaging data. One of the deliverables of this effort will be a new pipeline, which will process special 2.5-m imaging data and provide inputs to the calibration pipeline. This work will be coordinated by the Head of the Data Processing and Distribution and will be completed in 2001.

WBS Element 1.3.2.2: Data Distribution

Data distribution tasks include the development and deployment of the catalog Archive Server, Data Archive Server, and skyServer databases, and the development of the user interfaces to enable the SDSS collaboration and the astronomy community to use these servers. The set of data products that constitute the SDSS Data Archive, along with the plan and schedule for data releases, are described in the SDSS Archive Distribution Plan. Data distribution tasks also include the development and deployment of the Chunk and Rerun databases, which are used by the SDSS staff for target selection, the evaluation of pipeline performance, and the validation of processed data. Table 2.6 shows the WBS for Data Distribution.

A major effort was mounted for the release of the high quality commissioning data to the astronomy community at the beginning of 2001. This release is called the "Early Data Release to distinguish it from the first release of survey quality data on January 2003. The initial distribution of the commissioning data is scheduled for June 2001 and is fully described in the SDSS Archive Distribution Plan. The work associated with this effort was developed in the past three months and is included in the WBS for the first time.

Table 2.6. WBS for Data Distribution

- 1.3.3.2 Data Distribution
  - 1.3.3.2.1 Science Database Development
  - 1.3.3.2.2 Science Database Support
  - 1.3.3.2.3 Data Release Preparation
    - 1.3.3.2.3.1 Early Data Release
      - 1.3.3.2.3.1.1 SDSS Public Archive
      - 1.3.3.2.3.1.2 Catalog Archive Server
      - 1.3.3.2.3.1.3 Data Archive Server
      - 1.3.3.2.3.1.4 SkyServer
      - 1.3.3.2.3.1.5 Data Release Documentation
      - 1.3.3.2.3.1.6 Data Release System Administration at STScI
      - 1.3.3.2.3.1.7 User Groups and Usage Stats
      - 1.3.3.2.3.1.8 Early Data Release AJ Publication
      - 1.3.3.2.3.1.9 Data Processing for Early Data Release
      - 1.3.3.2.3.1.10 Early Data Release Event
    - 1.3.3.2.3.2 Data Release 1
    - 1.3.3.2.3.3 Data Release 2
    - 1.3.3.2.3.4 Data Release 3
    - 1.3.3.2.3.5 Data Release 4
    - 1.3.3.2.3.6 Data Release 5

The development of the Catalog Archive, Data Archive, and skyServer databases and the preparation of the data release with these servers are being carried out by groups at Johns Hopkins, Fermilab, and the Space Telescope Science Institute (STScI), under the direction of the Head of Data Processing and Distribution. Johns Hopkins is responsible for developing, loading and testing the servers and responding to problems. While processed data is loaded into the Catalog Archive Server, the Data Archive Server actually points at data products stored on disk at each Data Archive Server site. Fermilab is responsible for installing and commissioning the database systems at Fermilab. Fermilab is also responsible for preparing the data products for loading into the servers. STScI is responsible for installing and commissioning the Data Archive Server at STScI, developing user web interfaces to access the data through the Internet, and developing web pages that will facilitate easy access to the SDSS data. The SDSS collaboration is responsible for validating the data that can be accessed by these servers and providing feedback to the data processing and distribution teams through the SDSS Problem Reporting Database. Early Data Release coordinators have been appointed and they are responsible for carrying out specific tests under the direction of the Head of Data Processing and Distribution.

2.3.3.4. Institutional Support for Data Processing

SSP40 - Fermilab Software and Data Processing

The SDSS data processing effort is the responsibility of the Fermilab Experimental Astrophysics Group (EAG), which is located in the Fermilab Computing Division and reports to the Head of the Computing Division. The Head of the Data Processing Team directs the efforts of the data analysts who carry out routine operations. The EAG scientists support them by diagnosing problems and implement solutions when every they are encountered. This team processes data through the pipelines, performs QA checks, archives the processed data on a disk or tape as appropriate, stuffs the appropriate files of processed data in the Operations Database and the other data servers, and prepares the processed data for export to the data distribution servers at each institution. They rely on the support from the Operating Systems Support Department and the Computing Services Departments of the Computing Division for computer hardware maintenance, operating system maintenance, networking, and tape handling. Fermilab provides the support necessary to maintain all Fermilab-provided computer systems for data processing and distribution. Computer hardware and operating systems are monitored and problems repaired as they arise by personnel from the Fermilab Computing Division as part of its normal support function for elements of the Fermilab experimental program.

Each of the SDSS collaborating institutions is required to have a point-of-contact, a data "guru", with the Fermilab Data Processing Team in order to access data through Fermilab. They coordinate transfers of data to their local institution. The Data Processing Team maintains the software infrastructure for the SDSS and coordinates software updates at the collaborating institutions with the institutional data gurus. The data gurus assist astronomers with all data products and data servers.

During the survey, Fermilab will maintain the following data processing pipelines and code:

1. Photometric Telescope Pipeline (mtPipe);
2. Final Calibration Pipeline (nfcalib);
3. Target Selection Pipeline (target);
4. Plate Design Pipeline (plate);
5. Tiling Pipeline (tiling);
6. Set Quality Pipeline (setQuality);
7. Operational Database (opdb); and
8. DP (data processing production system infrastructure code).

Maintenance of data processing pipelines at Fermilab includes fixing bugs; adding improvements to accommodate hardware or operating system changes; and making code enhancements to improve operational efficiency. Currently, Fermilab and Princeton are responsible for the development and maintenance of the Spectro 2D Pipeline. The development is coordinated by Princeton. Bug fixes and improvements will be made as necessary to meet Survey Requirements and/or improve operational efficiency. Fermilab also provides scientific analysis of the photometry to verify that scientific goals are met. The budget and scope of work are established under agreement SSP40.

SSP38 - Princeton Pipeline Maintenance/QA and Photometric Calibration Support

Princeton provides support for the maintenance and improvement of the Photometric Pipeline to meet the Science Requirements. This includes SSC (Serial Stamp Collection), PSP (Postage Stamp Pipeline) and Frames. Princeton develops and maintains pipeline quality analysis code and diagnostics and works jointly with Fermilab to maintain and improve the Spectro 2D Pipeline. Princeton is responsible for coordinating the development of the Spectro 2D Pipeline. Princeton also provides scientific analysis, software development, and observing support to the photometric calibration effort. The budget and scope of work are established under agreement SSP38.

SSP39 - University of Chicago Pipeline Maintenance and QA Support

The University of Chicago will maintain and improve the Spectro 1D Pipeline as necessary to meet the Science Requirements and will develop and maintain quality analysis code in support of Spectro 1D pipeline automation at Fermilab. The budget and scope of work are established under agreement SSP39.

SSP57 - United States Naval Observatory Pipeline Development and Support

The U.S. Naval Observatory (USNO) maintains the astrometric pipeline (ASTROM) and provides limited support for the maintenance of the Operational Database. USNO monitors the performance of the ASTROM pipeline and makes modifications as required to meet the Science Requirements. USNO will continue to provide the SDSS with the best available astrometric catalogs for use in the pipeline as they become available. The budget and scope of work are established under agreement SSP57.

SSP54 - Johns Hopkins University Photometric System Support

Through September 2001, JHU will provide scientific analysis support for the photometric system development effort. This effort is largely associated with documenting the standard star network developed using the USNO 40-inch telescope. The budget and scope of work are established under agreement SSP54.

SSP64 - New York University Photometric Calibration Support

The Institute for Advanced Study (IAS) led an independent effort through January 2001 to evaluate the photometry. They were responsible for providing a set of tools that can be used to assess the quality of photometry over the duration of the Survey. In February 2001, the effort and budget was transferred from the IAS to New York University (NYU). Salary support for this work, which was provided by the IAS, is now provided by NYU as an in-kind contribution to ARC. ARC will provide funds for travel and incidental supplies. The work at IAS was covered under agreement SSP41; the work at NYU is covered under agreement SSP64.

2.3.3.5. Institutional Support for Data Distribution

SSP40 - Fermilab Support for Data Distribution

Fermilab provides the Head of Data Processing and Distribution, who directs data distribution tasks at Fermilab and JHU and integrates these with the tasks carried out by STScI. A Catalog Archive Server, Data Archive Server, and skyServer have been assembled and will be maintained by Fermilab. Fermilab will augment the data contained or associated with these servers at lease twice a year, typically in the spring and fall. Fermilab is also responsible for loading and maintaining the Chunk database and the Rerun database. In the second quarter of 2001, these databases and servers were loaded with data reprocessed with the current version of the pipelines and calibrated with the best available calibrations. The data products distributed to the astronomy community will be augmented in accordance with the SDSS Archive Distribution Plan. The final release of the data products to the astronomy community will be made in July 2006. Table 2.7 reproduces the schedule for SDSS data releases that is included as Table 3 in the Archive Distribution Plan.

Table 2.7. Dates for the SDSS Data Releases

	Release	Photometry	Spectroscopy
Early Release	1-July-2001	5%	0%
Release 1	1-Jan-2003	15%	7%
Release 2	1-Jan-2004	47%	33%
Release 3	1-Oct-	68%	60%
Release 4	1-July-2005	88%	85%
Final Release	1-July-2006	100%	100%

The estimated number of FTEs required for this task is estimated to be 2.5 for the period January 2001 to July 2006.

Fermilab will be responsible for partitioning the Data Archive Server into a public section and Collaboration section. The Collaboration section will contain data that is not ready for distribution to the astronomy community. Fermilab, working in close collaboration with STScI and JHU, will contribute to with the development of web-based user interfaces that allow the collaboration and the astronomy community easy access to the SDSS data servers. Fermilab will oversee the collection of documentation necessary to support the exploitation of the Archive by the collaboration and the community. It will provide this documentation in their web-based documents to the STScI for inclusion in their web based documentation pages. While most documents exist, substantial editing may be needed to put them into HTML format. These tasks are included in the scope of work of each participating institution contributing documentation, including Fermilab. The estimated effort to develop the web pages for the status reports, documentation, and data distribution is one FTE during the performance period.

The budget that provides for salaries, travel, and supply costs associated with data distribution is included with the budget for data processing that is established under agreement SSP40.

SSP37 - Johns Hopkins Data Archive Development and Support

Johns Hopkins developed and now maintains the software for the Chuck database, the rerun database, Data Archive server, Catalog Archive Server and the skyServer. Upgrades and enhancements will be made as required to support database product and operating system upgrades. In addition JHU will be responsible for migrations to different operating system platforms, should that be required. JHU also provides support for the development of user interfaces and documentation associated with collaboration and public access to the servers, as noted in the SDSS Archive Distribution Plan. The budget and scope of work are established under agreement SSP37.

Space Telescope Science Institute Support for Data Distribution

The Space Telescope Institute (STScI), working in collaboration with Fermilab and JHU, will adapt its MAST user interface for use with the Data Archive Server and the Catalog Archive Server. The SDSS Archive will be made available to the astronomy community through the STScI Multi-Mission Archive (MAST). STScI has and is developing this interface, which will allow easy access to the SDSS Archive. Development and testing of the web pages and the MAST interface for the SDSS Archive began at the end of the first quarter of 2001. An extensive test of the MAST interfaces and the servers at Fermilab was successfully carried out by the collaboration at its March 2001 meeting at Fermilab. The www.sdss.org and www.stsci.edu websites are providing access to the data through the MAST interface. Once these websites are fully developed, they will provide the astronomy community access to the Early Data Release in June 2001. Feedback from the user community will be used to plan improvements of the functionality of the websites.

STScI will build the web pages that will provide the collaboration and astronomy community with sufficient documentation to utilize the data servers. These web pages will be mirrored at Fermilab and other SDSS sites. STScI will also operate a help desk to be used by the astronomy community when accessing the SDSS Archive. They will publish and maintain an online user's guide, including examples and Frequently Asked Questions (FAQs). It is anticipated that e-mail will be the primary means of communication.

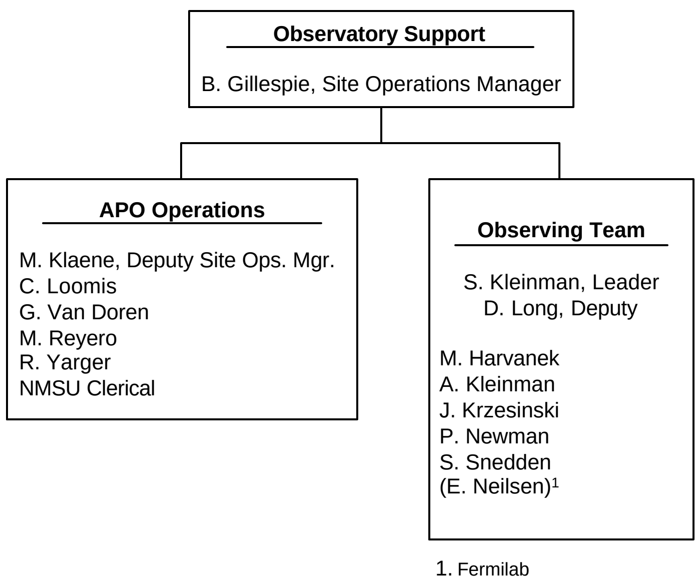
STScI will also install and run copies of the Data and Catalog Archive Servers at the STScI. At the time of the Early Data Release, the Data Archive Server will be installed and operational. The Catalog Archive Server will be installed as resources allow.

The STScI provided a level of effort of 0.75 FTEs in support of the Early Data Release as an in-kind contribution, which is not included in the SDSS 5-Year Baseline Survey budget. The STScI has requested funds from NASA to support their continued involvement in subsequent data releases during the observing and data processing phases of the survey, as long-term stewards of the SDSS Data Archive. They intend to request funds after the ARC support for the SDSS has ended. Although NASA has authorized the participation of the STScI in the Early Data Release, NASA has not yet awarded funds to permit the STScI to support the effort beyond the Early Data Release. It is the intent of the STScI to propose additional funding to support the long-term stewardship of the SDSS Archive after the completion of the SDSS Project. The budget for the 5-Year Baseline Survey does not include the cost of the support provided by the STScI.

2.3.3.6. Observatory Support WBS

WBS element 1.3.3, Observatory Support, captures the work and costs associated with staffing and maintaining the observatory at the level required to sustain survey operations over the 5-year observing period. In addition to capturing the level of effort necessary to maintain the observing systems and observatory infrastructure, this WBS element also contains the work scope and schedule for upgrades to the observatory infrastructure when required to maintain effective operations. The budget to support observatory operations provides for technical and observing staff salaries, building and grounds maintenance, utilities and consumables, and other related services. The organization chart for Observatory Support is shown in Figure 2.4.

Figure 2.4. Organization Chart for Observatory Support



2.3.3.7. Institutional Support for Observatory Support

SSP35 - APO Observatory Support

APO site management provides managerial and administrative support for observatory operations. The APO Site Operations Manager is responsible for staff recruitment and training, budget, and procurements. These activities are developed in concurrence with the SDSS Director and Project Manager to ensure that SDSS needs are met. APO is implementing procedures to ensure data quality and consistency through the 5-year observing period. The SDSS Problem Reporting Database is used to report and track safety issues and system problems. The Site Operations Manager provides status reports to the Project Manager and has implemented programs for publishing night and day site activity logs.

The Site Operations Manager is responsible for providing a safe work environment for all activities at the site. Appropriate policies and procedures have been formulated and implemented to ensure that work is done in a safe and efficient manner and in accordance with applicable rules and regulations. This includes developing a site safety plan and designating a Site Safety Officer. Additional policies and procedures will be developed as needed. To ensure the adequacy of the site safety program, external safety officers are called upon to perform periodic site audits.

APO provides a staff of seven observers for the 2.5-m telescope. One observer has been appointed the Lead Observer and another the Deputy Lead Observer. The Lead Observer is responsible for preparing the schedule and activities of the observing staff. The Lead Observer is also responsible for interfacing with the technical staff to ensure good communication between management, technical, and observing personnel. The Lead Observer works with the Head of Survey Coordination to prepare monthly observing plans and is responsible for the execution of those plans. The Deputy Lead Observer assists the Lead Observer in these responsibilities and assumes them in the Lead Observer's absence.

The observing staff is responsible for the safe and efficient use of the telescopes and instruments to collect data that meets the survey requirements. They develop and use documented procedures that ensure data quality and uniformity; and implement and use performance metrics to track observing efficiency and performance against goals. Short, on-line QA analyses are done to verify data quality; data passing these tests are sent to Fermilab for processing. The observing staff publishes observing logs to document observing activities and records problems in the SDSS Problem Reporting Database.

APO maintains the ARC-provided real property and equipment necessary to support data collection activities at the observatory. APO maintains ARC-provided facilities and equipment necessary to operate and maintain the instruments, including vacuum equipment and a Class-100 clean room for maintenance and repair activities associated with the SDSS imaging camera. APO maintains the site telecommunication system and all on-site SDSS computer systems and associated spare parts. These consist of Fermilab-provided DA systems as well as ARC-provided instrument and telescope control computers. APO also maintains the basic site services and facilities necessary to carry out operations in an efficient manner. Critical equipment and sub-systems have been placed on Uninterruptible Power Supplies and an automatic backup diesel generator is available for emergencies.

The APO operations staff maintains the site facilities, roads, grounds, and housing used by visitors working on SDSS activities at APO. A small machine shop is in operation at APO. The shop is outfitted with tools and equipment suitable for performing small machining jobs. Larger machining jobs are done under contract with local shops. Fermilab provided the machine tools in this shop and will maintain these tools through the 5-year observing period. The budget and scope of work associated with APO Observatory Support are established under agreement SSP35.

2.3.3.8. Survey Coordination

WBS element 1.3.4, Survey Coordination, captures the work associated with planning and executing the observing strategy for the Survey. This includes the development of strategy planning tools that are used to determine the optimum time(s) when specific regions of the survey area should be imaged and when specific spectroscopic plug plates should be exposed. These tools are critical to achieve efficient observing operations and meeting survey performance goals.

The start and end dates for each monthly observing run during the 5-year observing period, as well as the summer shutdowns for planned maintenance, are listed under the WBS for Survey Coordination. They are also published on the SDSS website (www.sdss.org). Defining and publishing the dates for observing runs and shutdowns allows for the efficient planning and scheduling of resources and the identification of periods, which are called "bright times", during which engineering and maintenance work can be integrated with observing activities.

The budget for Survey Coordination is included in the SSP budgets that also support data processing and distribution at Fermilab (SSP40) and observatory operations at APO (SSP35). The organization chart for Survey Coordination is shown in Figure 2.5.

Figure 2.5. Organization Chart for Survey Coordination

Survey Coordination

S. Kent, Head
(S. Kleinman, Deputy)

J. Annis[1]
R. Kron[2]
B. Lee[1]
D. Vanden Berk[1]
B. Yanny[1]

1. Fermilab
2. University of Chicago

2.3.3.9. Institutional Support for Survey Coordination

Fermilab Support for Survey Coordination

Fermilab provides the Head of Survey Coordination, who is responsible for developing the 5-year observing strategy and the monthly observing plans to acquire the data necessary to achieve the Survey goals. The Head of Survey Coordination is responsible for developing and implementing survey planning and strategy tools to ensure efficient survey operations and measure observing performance. Fermilab provides additional support from the Experimental Astrophysics Group to the Head of Survey Coordination to help develop these tools. Finally, the Head is responsible for coordinating the steps in the production of plug plates, from target selection to plate inventory at APO. This includes scheduling and oversight of target selection, determining the number of plates required per drilling run, overseeing the generation and delivery of drill files to the UW, and overseeing plate delivery to APO. The Head of Survey Coordination is responsible for maintaining the on-line plug plate database (INVENTORY), which tracks the location and observing status of all plug plates. The budget to support this effort is included in the Fermilab budget for data processing and distribution and is covered under SSP40.

Apache Point Observatory Support for Survey Coordination

The Lead Observer at APO also serves as the Deputy Head of Survey Coordination, and is responsible for implementing the monthly observing plans at APO. The Deputy Head is responsible for developing the planning and tracking tools necessary to efficiently conduct observing operations at APO. The Deputy Head is responsible for implementing a tracking system to log and monitor observing performance against the established baseline plan. The budget to support this effort is included in the APO budget for Observatory Operations and is covered under SSP35.

2.3.3.10. Remaining Construction Tasks

WBS element 1.3.5, Remaining Construction Tasks, captures the carry-over deliverables that were not completed during the construction phase of the project. While these deliverables were not critical to beginning routine observing operations, they are necessary to achieve the level of equipment protection, performance, and operating efficiency necessary to meet established performance requirements. It is expected that all remaining construction deliverables will be completed by the third quarter of 2001. Table 2.8 lists the outstanding carry-over tasks from the construction schedule. The budget for this work is included in the institutional SSP budgets.

Table 2.8 Carry-over Tasks from the SDSS Construction Schedule

Task	Estimated Completion	% Complete
Common Corrector Cell Purge System	May 2001	90%
Windbaffle LVDT Replacement	Jul 2001	100%
Slip Detection System	Jul 2001	90%
Instrument ID Actuators for the Imaging Camera	Jul 2001	100%

2.3.4. ARC Corporate Support

WBS element 1.4, ARC Corporate Support, is where costs associated with miscellaneous corporate-level expenses are captured and funds for management reserve and capital improvements are held. The total budget for ARC Corporate Support is $953K of the $26,740K cost estimate for the 5-year Baseline Survey.

2.3.4.1. ARC Corporate Support WBS

<u>WBS element 1.4.1: Corporate Support</u>

The WBS for Corporate Support captures the costs for financial audits, insurance, Advisory Council meetings, external project reviews, and one-time events such as the SDSS Dedication ceremony. The Corporate Support budget is administered by the ARC Business Manager.

<u>WBS element 1.4.2: Additional Scientific Support</u>

The WBS for Additional Scientific Support is where funds are set aside to cover the cost of scientific support that may be needed on an occasional basis. When a need for additional support is identified, a scope of work is defined and cost estimate prepared and submitted to the Change Control Board and then SDSS Director for consideration and approval. Once approved, a written agreement describing the scope of work and budget is established between ARC and the institution, and the funds to support the work are allocated from the ARC Corporate budget to that institution.

<u>WBS element 1.4.3: Capital Improvements</u>

Capital improvements are treated as line items in the baseline budget and must be approved by the Advisory Council. At present, there are no approved capital improvement projects in the 5-year baseline budget.

2.3.5. Management Reserve

Management reserve funds are treated as a line item in the budget and are shown as element 1.5 in the WBS. Management reserve funds are held under ARC Corporate and are managed and controlled by the SDSS Director in consultation with the ARC Secretary/Treasurer. Management reserve is used to cover the cost of unanticipated but required expenses that arise during the course of survey operations. Management reserve funds are allocated only after it is clear that the costs cannot be covered by adjusting priorities, postponing procurements, or rearranging work.

2.4. SUMMARY OF RESPONSIBILITIES, BY INSTITUTION

As described in the previous section, work associated with the SDSS is spread across many institutions and defined by Statements of Work (SOW) or Memoranda of Understanding (MOU) between the institutions and ARC, the legal entity overseeing the SDSS. These SOWs and MOUs are referred to as "agreements" and are indexed by unique agreement numbers. The SSPs are used to allocate budgets at the institution level and track project costs. As shown earlier in Table 2.1, project costs are tracked at level 4 in the WBS.

This section is a recanting of the work described in the previous section, but here the work is organized by institution rather than WBS. This recanting is included in the Management Plan to make the institutional responsibilities more transparent. Table 2.9 summarizes the distribution of work among the various institutions, by SSP agreement number. Subsequent paragraphs describe the distribution of work and summarize institutional responsibilities in detail.

2.4.1. Astrophysical Research Consortium (ARC)

The SDSS is managed by ARC, a non-profit research corporation. The Board of Governors (the Board) is responsible for the oversight of all ARC programs, the formulation of policies that govern the programs, and the approval of all budgets for these programs. The Board of Governors has delegated the oversight of the SDSS to the Advisory Council (the Council). Membership on the Council has been granted to those institutions that have made significant cash or in-kind contributions toward the construction, commissioning, and operation of the SDSS. ARC has obtained funding for the SDSS from federal, private, and international sources, and these funds are administered by the Secretary/Treasurer and the Business Manager. They disburse the funds through the SSPs.

The SDSS budget supports a fraction of the salaries for the Secretary/Treasurer and Business Manager and provides a modest amount for administrative support, travel, and office supplies. The budget and scope of work for the Secretary/Treasurer is defined in SSP51. The budget and scope of work for the Business Manager is defined in SSP34.

Table 2.9. ARC Work Agreements, by Institution

Institution	Agreement	Description	Manager
ARC	SSP51	ARC Secretary/Treasurer	D. Baldwin
	SSP34	ARC Business Manager	D. Baldwin
Fermilab	SSP48	Survey Management	J. Peoples
	SSP42	Observing Systems Support	W. Boroski
	SSP40	Data Processing and Distribution	S. Kent
	SSP61	Observing Programs and DA Support	D. Petravick
New Mexico State	SSP35	NMSU Site Support	B. Gillespie
Princeton	SSP46	Office of the Project Scientist	J. Gunn
	SSP32	Observing Systems Support	J. Gunn
	SSP38	Software and Data Processing Support	M. Strauss
Univ. of Washington	SSP63	Software Testing and Validation	C. Hogan
	SSP60	Support for Project Management	Closed
	SSP31	Observing Systems Support	C. Stubbs
Johns Hopkins	SSP62	Software Testing and Validation	W. Zheng
	SSP36	Observing Systems Support	A. Uomoto
	SSP50	Photometric Telescope Operations Support	A. Uomoto
	SSP54	Photometric Calibrations	A. Uomoto
	SSP37	Data Archive Development and Support	A. Szalay
Univ. of Chicago	SSP47	Project Spokesperson (1998-2001)	M. Turner
	SSP65	Project Spokesperson (2001-2003)	R. Kron
	SSP33	Observing Systems Support	R. Kron
	SSP39	Software and Data Processing Support	J. Frieman
Institute for Advanced Study	SSP41	Photometric System Definition	Closed
New York University	SSP64	Photometric System Definition	D. Hogg
United States Naval Observatory	SSP57	Software and Data Processing Support	J. Pier
Los Alamos National Laboratory	SSP58	Observing Systems Support	P. McGehee
Japan Participation Group	No SSP #	Observing Systems Support	S. Okamura

2.4.2. Fermilab

Fermilab provides support for Survey Management, Observing Systems, Data Processing and Distribution, and Survey Coordination through signed SSP agreements with ARC.

<u>SSP48 – FNAL Support for Survey Management</u>

Fermilab provides the Director, Project Manager, and Project Office as an in-kind contribution through a written agreement between ARC and Fermilab. The Director is responsible for organizing and directing all aspects of the Survey. The Project Manager is responsible for developing and maintaining the project schedule, developing the survey operations budget, and overseeing the Project Office. The budget includes the value of the in-kind salaries of the Project Manager, cost/schedule specialist, and administrative assistant. It also includes the in-kind value of travel and incidental expenses associated with survey management activities. The travel costs of the SDSS Director and Project Manager are partially supported by ARC. The scope of work and budget are established under agreement SSP48.

<u>SSP42 – FNAL Observing Systems Support</u>

Fermilab provides engineering support for the Observing Systems at APO by providing a full-time staff of three individuals who will reside full-time near the observatory through the end of the 5-year observing period. One of these individuals serves as the SDSS Telescope Engineer and is responsible for ensuring that all telescopes and instruments are available for operations. The two remaining individuals are technicians who support the Telescope Engineer with engineering and maintenance work at APO.

The level of effort to support on-site engineering and maintenance activities has been increased by one FTE for the period April 2001 through the March 2003. The additional support is being provided by an electronics technician who resides near APO and works under the direction of the SDSS Telescope Engineer to address and troubleshoot electronic problems and reduce the backlog of incomplete electrical tasks.

Fermilab also provides part-time engineering support at Fermilab for systems and components that were built and installed by Fermilab. This support is provided by system specialists, who not only support the SDSS, but also work on and provide support for many other projects at Fermilab.

In summary, Fermilab will provide 3.0 FTEs of on-site support and approximately 0.5 FTEs of off-site technical specialist support as an in-kind contribution through the end of the observing period. Fermilab will also provide 1.0 FTE of additional electronic technician support at APO during 2001 and 2002. ARC will reimburse the salary costs for the 2-year term position, as well as all travel, material, and supply costs associated with maintaining and improving the Observing Systems. The scope of work and budget are established under agreement SSP42.

SSP61 – FNAL Observing Programs and DA Support

Fermilab designed, built, and delivered the data acquisition system at APO. Fermilab is responsible for the long-term maintenance and support of the hardware and software components that make up this data acquisition system. Fermilab is also responsible for the long-term maintenance of the software programs used to acquire data from the telescopes (the Observers' Programs).

The level of support provided by Fermilab for observing program and DA support is 2.0 FTEs. One FTE will consist of specialists from the ISDD and will be provided as an in-kind contribution. The second FTE is the computer professional-observer position, which will be funded by ARC from November 2000 through September 2003. The ARC-funded budget also supports the costs of travel, materials, and services. The scope or work and budget are established under agreement SSP61.

SSP40- FNAL Data Processing and Distribution

Fermilab is responsible for processing the SDSS data, loading the final data products into the Science Archive, and operating the Science Archive through the duration of the Survey. Fermilab provides the Head of Data Processing and Distribution (DP&D), who works with the software Pipeline Coordinators at the various institutions to ensure that data processing software is properly maintained and that outputs meet survey requirements. The Head of DP&D also works with the Science Archive development team to ensure that the database remains functional and available to the SDSS collaboration.

During the survey, Fermilab will maintain the following data processing pipelines and code:

1. Photometric Telescope Pipeline (mtpipe);
2. Final Calibration Pipeline (nfcalib);
3. Target Selection Pipeline (Target);
4. Plate Design Pipeline (plate);
5. Tiling Code (Tiling);
6. Operational Data Base (opdb);
7. DP (data processing production system infrastructure code); and
8. Set Quality Pipeline (setQuality)

Maintenance of data processing pipelines at Fermilab includes fixing bugs; adding improvements to accommodate hardware or operating system changes; and making code enhancements to improve operational efficiency. Additionally, Fermilab jointly maintains with Princeton the Spectro 2D portion of the Spectroscopic Pipeline. Bug fixes will be implemented and improvements made as necessary to meet Survey requirements and/or improve operational efficiency. This work will be coordinated with the Spectroscopic Pipeline development effort on Spectro 1D at the University of Chicago.

Fermilab provides scientific analysis of the photometry to verify that scientific goals are met, and supports the development and maintenance of the Photometric Telescope Pipeline to ensure that Science Requirements and operational efficiency goals are met.

Fermilab also provides the Survey Coordinator, who among other things is responsible for managing the long-term observing strategy of the Survey.

The level of support provided by Fermilab to support data processing and distribution is 11.2 FTEs and is provided along with materials and supply expenses as an in-kind contribution. The ARC-funded budget supports Fermilab travel costs. The scope of work and budget are established under agreement SSP40.

2.4.3. Apache Point Observatory

New Mexico State University (NMSU) operates APO for ARC. It provides the personnel who maintain the site and technical infrastructure for the SDSS program. The Site Operations Manager is responsible for providing a safe work environment for all activities at the site. Appropriate policies and procedures have been implemented to ensure that work is done in a safe and efficient manner and in accordance with applicable rules and regulations. This includes the development of a site safety plan and a designated Site Safety Officer. To ensure the adequacy of the site safety program, external safety officers perform periodic site audits.

APO maintains ARC-provided facilities and equipment necessary to operate and maintain the instruments, including vacuum equipment and a Class-100 clean room for maintenance and repair activities associated with the SDSS imaging camera. APO also maintains the instruments that monitor seeing and weather conditions.

APO provides technical personnel to the Telescope Engineer to assist him in the preparation of the 2.5-meter and Photometric Telescopes for daily operation. APO provides the SDSS Instrument Scientist, who is responsible for ensuring that all instruments are fully operational and that consumables are available at the levels necessary to support observing activities. APO makes qualified technicians available to the SDSS Telescope Engineer to perform plug plate handling and plugging activities. APO also provides storage space for the plug-plates, including on-site storage and staging facilities for approximately 300 plates and off-site facilities for long-term storage of the remaining plates.

The APO Computing Systems Manager and the SDSS Instrument Scientist respond to DA problems and diagnoses hardware failures and replaces parts as required. Members of the Fermilab ISDD will be contacted as necessary to assist with the troubleshooting and repair of more difficult problems.

APO provides a staff of seven observers for the 2.5-m telescope. One observer serves as the Lead Observer and another the Deputy. The Lead Observer is responsible for preparing the schedule and activities of the observing staff for review and approval by Survey management and for interfacing with the technical staff to ensure good communication between management, technical, and observing personnel. The Lead Observer works with the Survey Coordinator to prepare monthly observing plans and is responsible for the execution of those plans. The observing staff is responsible for the safe and efficient use of the telescopes and instruments to collect data that meets Survey requirements. They develop and use documented procedures that ensure data quality and uniformity and use performance metrics to track observing efficiency and performance against goals. The observing staff publishes observing logs to document observing activities and record problems in the problem-reporting database.

APO maintains the site telecommunication system and all on-site SDSS computer systems and associated spare parts. These consist of Fermilab-provided DA systems as well as ARC-provided instrument and telescope control computers. APO maintains the basic site services and facilities necessary to carry out operations in an efficient manner, including maintenance of the site facilities, roads, grounds, and housing used by visitors working on SDSS activities at APO.

The total level of effort associated with APO observatory operations is 14.6 FTEs. Of this, 7.0 FTEs represent the observing team, 4.0 FTEs represent the technical staff dedicated to the SDSS, 3 FTEs represent the level of effort provided for observatory support, and 0.6 FTEs represent the level of administrative support required at NMSU to support observatory operations. The three FTEs that comprise observatory support are made up of six individuals who support both SDSS and 3.5-m telescope operations. These include the Site Operations Manager, Deputy Site Operations Manager, and four members of the observatory support staff. Accordingly, the budget provides 50% of the salary for these individuals. The balance is provided by ARC to support 3.5-meter telescope operations. The SDSS budget provides full salary support for the observing and technical staff working on the SDSS, as well as travel, equipment, supply, and indirect costs. The scope of work and budget are established under agreement SSP35.

2.4.4. Princeton University

Princeton provides support for Survey Management, Observing Systems, and Data Processing and Distribution.

<u>SSP46 – Office of the Project Scientist</u>

Princeton provides the Project Scientist and Deputy as an in-kind contribution during the academic year. The ARC budget provides a portion of the summer salary for the Project Scientist and funds for travel, equipment, and other miscellaneous expenses accrued in executing the duties of the Office of the Project Scientist. The scope of work and budget are covered under SSP46.

<u>SSP32 – PU Observing Systems Support</u>

Princeton built and delivered the imaging camera and its mechanical and support systems, the detector systems for the spectrographs and Photometric Telescope, the cryogen and temperature control systems for all of the instruments, the flat-field and wavelength calibration systems for the spectrographs, and throughput monitoring systems for the optical surfaces. During operations, Princeton maintains and upgrades these systems as required to meet Science Requirement and efficiency goals. Princeton also supplies technical support for other telescope-related tasks as needed. The total level of technical support will initially be 1.0 FTE and will decline as needs for further improvements diminish. The level of support is planned to be 0.5 FTE by the end of the five-year observing period. The budget for technical support provides for salary, travel, materials, and supplies. The budget and scope of work are established under SSP32.

SSP38 – PU Software and Data Processing Support

Princeton developed portions of the software programs used for observing operations, including the focus loop, parameter watcher, Imager Observer's Program (IOP), Spectroscopic Observer's Program (SOP). Princeton also developed the Motion Control Processor (MCP) and the interlocks graphical display. By 2002, the responsibility for maintaining IOP and SOP will be handled primarily by Fermilab, with Princeton providing support on an as-needed basis. Princeton will maintain full responsibility for the focus loop, Watcher, MCP, and interlock watcher display.

Princeton also provides support for data processing operations at Fermilab. Princeton is responsible for maintenance and improvement of the Photometric Pipeline as required to meet the Science Requirements. This includes SSC (Serial Stamp Collection), PSP (Postage Stamp Pipeline) and Frames. Princeton also develops and maintains pipeline quality analysis code and diagnostics and works jointly with Fermilab to maintain and improve the Spectro 2D Pipeline. This work is coordinated with the Spectro 1D Pipeline effort at the University of Chicago. Finally, Princeton provides scientific analysis and software development support to the photometric calibration effort.

The level of effort for Princeton software support was 3.1 FTEs in 2000 and 2001, and will be 2.5 FTEs in 2002, 1.5 FTEs in 2003, and 1.25 FTEs in 2004. The scope of work and budget are established under agreement SSP38.

2.4.5. University of Washington

The University of Washington (UW) provides astronomer support to the Project Scientist for software testing and validation, and technical services to the Observing Systems. The UW had provided limited survey management support to the Director prior to 2001, but no further support is required in this area.

SSP60 – Support for Survey Management

The University of Washington (UW) provided limited survey management support to the Director on an as-needed basis through 2000; the need for additional support is not evident and so there is no budget for this effort beyond 2000. This work had been supported through SSP60.

SSP60 – Software Testing and Validation

UW provides end-to-end testing to validate the quality of the data processing pipelines and test the functionality of the Science Archive databases and user interfaces. The budget provides limited support for travel and supply expenses. The scope of work and budget are established under agreement SSP63.

SSP31 – UW Observing Systems Support

UW oversaw the construction of the 2.5-meter telescope and its enclosure, provided oversight for the delivery of telescope optics, developed and implemented the Telescope

Control Computer (TCC), built and delivered optical support and control systems, and designed and delivered the fiber cartridges with their associated optical fiber assemblies. During operations, UW provides technical support to maintain the TCC, the 2.5-m telescope guiding system, and telescope optical support and control systems, and provides engineering and technical support for other areas on an as-needed basis. UW also oversees plug plate fabrication. The baseline plan calls for all plug plates to be fabricated at UW, with a second vendor qualified as a back up in the event that production demands exceed the UW shop capacity. The level of Observing Systems support at UW will be 1.75 FTEs. The staff consists of a mechanical engineer, controls software specialist, and procurement support. The budget provides for supports salaries, travel, supplies, and plug plate fabrication costs. The scope of work and budget are established under agreement SSP31.

2.4.6. Johns Hopkins University

The Johns Hopkins University (JHU) provides astronomer support to the Project Scientist for software testing and validation, technical services to the Observing Systems, and software development and support for the Science Archive and data distribution effort.

<u>SSP62 – Software Testing and Validation</u>

JHU will assist the Project Scientist by providing end-to-end testing to validate the quality of the data processing pipelines and test the functionality of the Science Archive databases and user interfaces. The level of astronomer effort will be 0.25 FTEs in 2001 and 2002. In addition, two graduate students will provide additional testing support in 2001, in support of the Early Data Release effort. The budget provides limited salary support as well as travel and supply expenses associated with this work. The scope of work and budget are covered under agreement SSP62.

<u>SSP36 – JHU Observing Systems Support</u>

JHU built and delivered the spectrographs and oversaw the installation and commissioning of the Photometric Telescope at APO. During operations, JHU assists the SDSS Instrument Scientist with maintenance and required improvements on the spectrographs. Technical support for other areas of observing systems is provided on an as-requested basis. The budget provides for partial scientist salary, limited engineering support and machine shop services, and software maintenance costs. The scope of work and budget are established under agreement SSP36.

<u>SSP50 – Photometric Telescope Operations Support</u>

JHU provided one postdoc through March 2001 to help staff observing activities with the Photometric Telescope and perform data analysis in support of the photometric calibration effort. This work was covered under SSP50 and the agreement will be closed in mid-2001, after final costs have been received.

<u>SSP54 – Photometric Calibrations</u>

JHU will provide limited scientific analysis support to the photometric calibration effort. The budget provides salary, travel, and incidental supply costs for scientific analysis support at 0.25 FTE through September 2001. The scope of work and budget are established under agreement SSP54.

SSP37 – Data Archive Development and Support

JHU developed and now maintains the Science Archive databases and associated software. Upgrades and enhancements will be made as necessary to support database product and operating system upgrades and migrations to different operating system platforms. JHU will also assist with the preparation of the SDSS data releases as described in the SDSS Archive Distribution Plan, and will support the implementation of mirror sites of the Science Archive at Participating and Member Institutions. JHU, in close coordination with the STScI and Fermilab, will assist in the development of user interfaces and documentation associated with collaboration and public access to the SDSS data. The JHU development team will also be responsible for adapting the Science Archive software and the SDSS Data Model to the STScI Multi-Mission Archive (MAST) framework, since they are the only members in the SDSS-STScI collaboration with extensive experience with the Science Archive software.

The level of effort will be 3.6 FTEs through 2001, 2.6 FTEs in 2002 and 2003, and 1.25 FTEs from 2004 through the end of the 5-year observing period. The budget supports salary, travel, and supply costs. The scope of work and budget are established under agreement SSP37.

2.4.7. University of Chicago

SSP47 – Project Spokesperson

The University of Chicago (UC) will provide the Project Spokesperson through mid-2001 as an in-kind contribution by written agreement between ARC and the University of Chicago (UC). The ARC-funded budget provides for part-time support of a staff person, travel, supplies, and other miscellaneous items. This is covered under SSP47.

SSP33 – UC Observing Systems Support

UC provided management oversight for the construction of the 2.5-meter telescope and its optics and provided significant technical support for the construction of the imaging camera. During operations, UC will provide the Imaging Scientist to support the operation of the imaging camera through September 2001. The budget provides for salaries, tuition, travel, and miscellaneous expenses associated with this support. UC also provides occasional engineering support for optics design and analysis, and electronics support for the imaging camera and other telescope systems. This support is provided on an as-needed basis, with work organized in the form of projects. The budget for UC engineering support provides for a limited amount of base support and will be augmented as needed to support projects that the UC group will be asked to complete. The scope of work and budget are established under agreement SSP33.

SSP39 – UC Software and Data Processing Support

UC developed the Spectro 1D pipeline and will maintain and improve this pipeline as necessary to meet the Science Requirements. UC will also develop and maintain quality analysis code in support of pipeline automation at Fermilab. The level of effort will be

1.5 FTEs through 2001 and will decrease to 0.5 FTEs from 2002 through the end of the 5-year observing period. The budget provides for salary, travel, and supply costs. The scope of work and budget are established under agreement SSP39.

SSP65 – Project Spokesperson (2001-2003)

The University of Chicago (UC) will provide Dr. Richard Kron as the Project Spokesperson through mid-2003 as an in-kind contribution by written agreement between ARC and the University of Chicago (UC). The ARC-funded budget provides for travel, supplies, and other miscellaneous items. This is covered under SSP65.

2.4.8. Institute for Advanced Study / New York University

The Institute for Advanced Study (IAS) led an independent effort through January 2001 to investigate the photometry for the SDSS and provide the Survey with a set of tools that can be used to assess the quality of photometry over the duration of the Survey. In February 2001, the individual leading this effort moved from the IAS to New York University (NYU) and the budget subsequently moved as well. Salary support for this work is provided by NYU as an in-kind contribution to ARC. ARC will provide funds for travel and incidental supplies. The work and budget at IAS was covered under agreement SSP41; the work and budget at NYU are covered under agreement SSP64.

2.4.9. United States Naval Observatory

The U.S. Naval Observatory (USNO) maintains the astrometric pipeline (ASTROM) and provides limited support for the maintenance of the Operational Database. USNO monitors the performance of the ASTROM pipeline and makes modification as required to meet Science Requirements. USNO will continue to provide the Survey with the best available astrometric catalogs for use in the pipeline as they become available. The level of effort will be 2.0 FTEs in 2000 and will reduce to 1.0 FTE from 2002 through the end of the 5-year observing period. The budget provides for salary, travel, and supply costs as an in-kind contribution from the USNO to ARC. The scope of work and budget are covered under agreement SSP57.

2.4.10. Los Alamos National Laboratory

Los Alamos is responsible for developing and maintaining the Telescope Performance Monitor (TPM), which monitors, displays, and archives telescope engineering and thermal data. Los Alamos also provides one postdoc to augment the observing staff for the Photometric Telescope and assist with bright-time photometry as needed. The budget provides for salaries, travel and supplies, and is provided by Los Alamos as an in-kind contribution to ARC. Although continued support is subject to review by Los Alamos management, it is anticipated that Los Alamos will continue to provide technical and observing support beyond 2002. The scope of work and budget are covered under SSP58.

2.4.11. Japan Participation Group

The Japan Participation Group (JPG) provided the CCDs for the imaging camera. These CCDs are on loan to ARC through the duration of the survey. The JPG built and installed a 50 Å resolution monochrometer to measure, through the corrector plate and filter, the sensitivity of every CCD on the imaging camera. JPG engineers and scientists were also heavily involved in the fabrication of electronic components and systems for the imaging camera, and designed and installed the flat field system for the Photometric Telescope. During operations, the JPG will periodically use the 50 Å monochrometer to perform calibration measurements on the imaging camera and will provide operations, engineering, and maintenance support for this system as needed. JPG will provide new filters for the Photometric Telescope in 2001 and will serve as a resource for the maintenance and repair of JPG-provided components and systems on an as-needed basis through the 5-year observing period. The JPG effort is provided as an-kind contribution to ARC. Additionally, the JPG has committed to provide ARC with a cash commitment of $985K.

2.5. PERFORMANCE METRICS

2.5.1. Observing and Data Processing Statistics

One of the significant recommendations from the Readiness Review of Observing Systems held in April 2000 was for the SDSS to develop a set of baseline performance goals for the imaging and spectroscopic surveys. In particular, the review committee recommended that a set of minimum performance goals be developed such that if the SDSS failed to meet them, strong measures would have to be taken to address the failure to meet the goals. These baseline performance goals have been developed and are being used to provide a baseline against which survey progress is being measured. The baseline performance goals realistically take into account such factors as the number of dark hours available per observing period, percentage of time allocated for imaging and spectroscopy, percentage of time weather conditions at the observatory should be suitable for observing, percentage of time that the observing systems will be available to support observing, and the anticipated overall efficiency of imaging and spectroscopy operations. These parameters were factored together to obtain the number of hours per quarter that should be available for imaging and spectroscopy. Considering the number of square degrees that can be imaged per hour and the nominal time required to observe a spectroscopic plate, we were able to establish observing performance goals for the number of square degrees imaged and the number of spectroscopic plates observed per quarter. We were also able to establish measurable observing efficiency goals. These will be tracked closely, for if we are not using observing time efficiently, then we will certainly not be able to meet the survey progress goals.

The survey progress and efficiency goals were described in the 2000-Q1 SDSS Quarterly Project Report that was submitted to the A.P. Sloan Foundation, the Advisory Council, and the SSP managers. We review our performance at the end of each observing period to monitor performance against the baseline plan. We look at the number of hours spent imaging and doing spectroscopy and compare those against the goals for that period. We also look at how and where time was spent during the hours we should have been on the sky in order to understand whether we met our goals for operating efficiency, equipment readiness, etc. After the data from a run are processed, we review the number of unique square degrees imaged and number of unique spectroscopic plates exposed that meet survey quality acceptance criteria. These numbers are added to the running totals to obtain cumulative performance to date, which is compared against the baseline. We report these results in our quarterly reports. We also provide the status of survey progress with the collaboration through the SDSS web site (www.sdss.org). The SDSS web site contains links to pages that graphically show the amount of survey area imaged to date, the number of spectroscopic plates observed to date, and the number of photometric patches obtained to date. We intend to begin posting the quarterly project progress reports on the web in the near future, as an additional means of keeping the collaboration and others informed on survey progress and performance.

Figure 2.5 compares the cumulative imaging data collected in the Northern Survey Region through July 2001 against the baseline plan. Figure 2.6 compares the total number of spectroscopic plates observed in the North through this same period against the baseline.

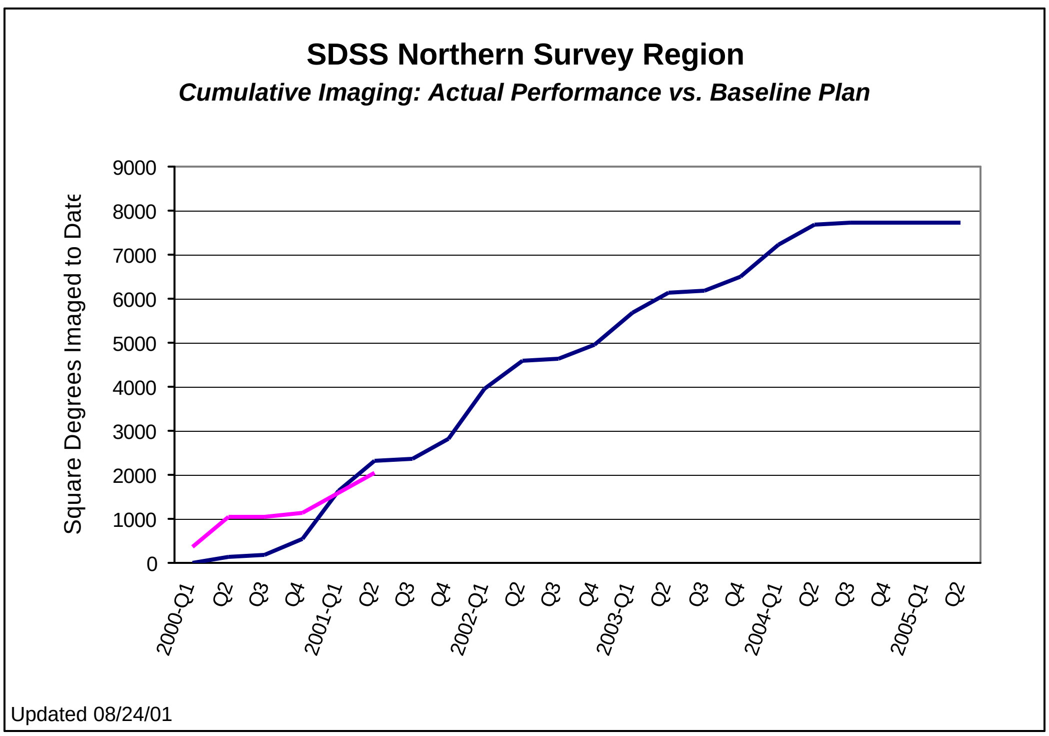


Figure 2.5. Photometric Survey Progress Against the Baseline Plan for the Northern Survey Region.

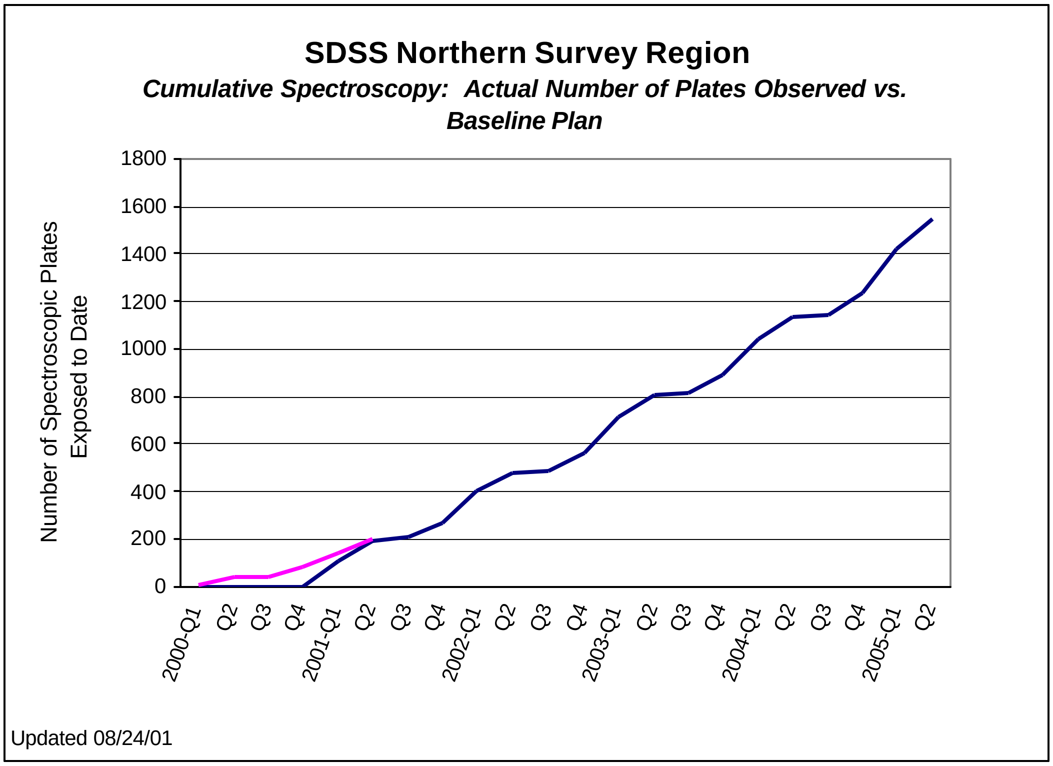


Figure 2.6. Spectroscopic Survey Progress against the Baseline Plan for the Northern Survey Region.

In the months of September, October, and most of November, the North Galactic Cap is not accessible and so observations are concentrated instead on the South Galactic Cap; we refer to this as the Southern Survey Region. Survey strategy for the Southern Survey Region is different than for the Northern Survey Region, because these are in fact distinct surveys.

The Southern Survey will consist of three stripes. Two of the stripes flank the equatorial stripe and are called the "Outrigger" stripes. The outrigger stripes comprise 475 square degrees and are observed in a manner similar to the stripes in the Northern Survey Region. This is, they are imaged once and targeted for spectroscopy with the same selection criteria. The equatorial stripe is 108 degrees long and has a footprint of 270 square degrees. The baseline plan calls for imaging the southern equatorial stripe once, although we intend to seek additional funding that will allow the equatorial stripe to be imaged many times. Co-adding these multiple imaging scans will achieve a correspondingly deeper image of the sky in this area.

Figure 2.7 compares the cumulative imaging data collected on the outrigger stripes, through July 2001, against the baseline plan. Figure 2.8 compares the number of times that the equatorial stripe as been imaged against the baseline plan, for this same period.

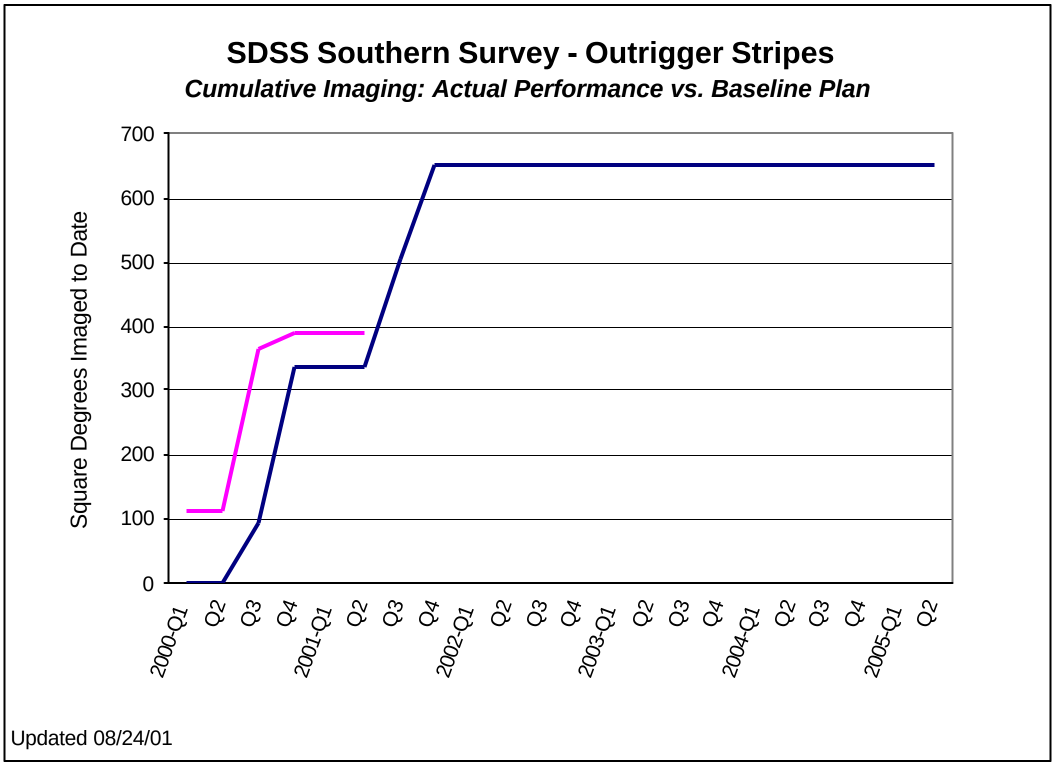


Figure 2.7. Photometric Survey Progress against the Baseline Plan for the Southern Outrigger Stripes.

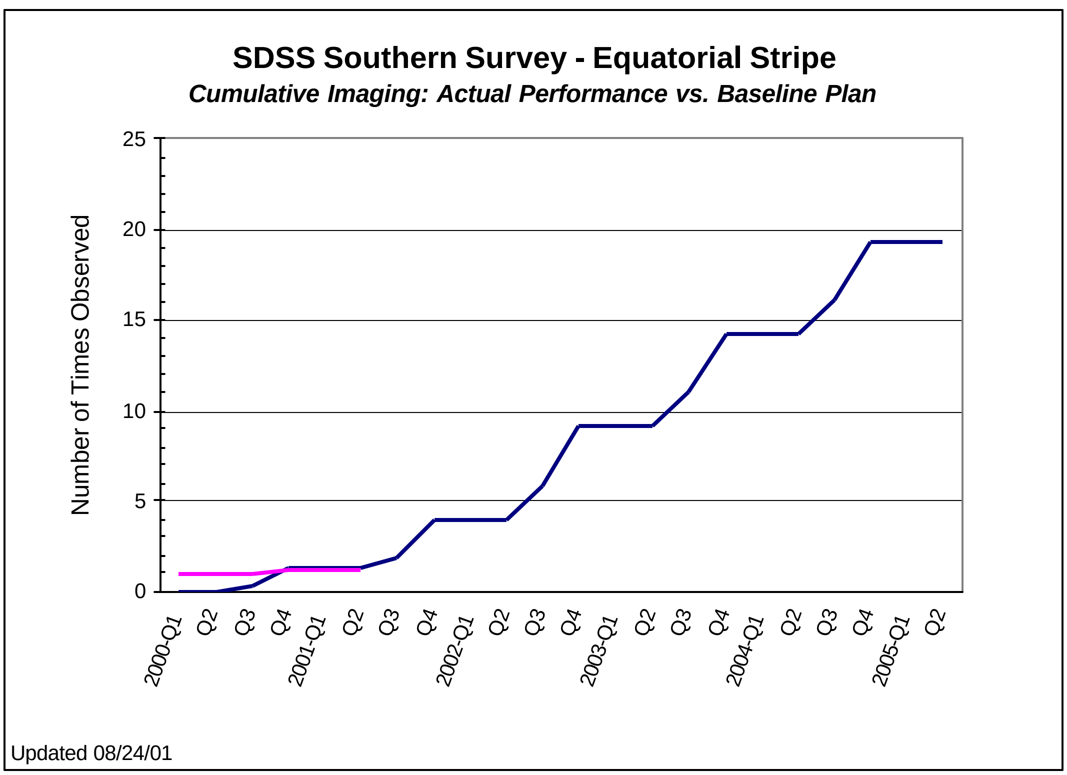


Figure 2.8. Photometric Survey Progress against the Baseline Plan for the Southern Equatorial Stripe.

2.5.2. Schedule Performance for Observing Systems and Data Processing

Schedule performance is reviewed on a monthly basis by comparing work performed in the previous month against work planned for that period. We consider the number of tasks completed according to plan and review why some of the planned work was not completed on time. In many cases, we still fall prey to overestimating our ability to get work done and underestimating the time required to maintain the systems already in place. To improve our performance in the former area, we are in the process of reviewing our schedule and work plan to develop a more realistic and achievable schedule. To help strengthen our performance in the latter area, we have begun to focus more heavily on identifying areas in which system reliability is low and taking corrective action to remedy problems. Focusing effort on improving system reliability should result in an increase in the uptime of observing systems during observing runs.

In the first year of operations, our scheduling efforts focused primarily on the hardware work necessary to bring the observing systems to the state where we could efficiently support observing operations. We have now focused efforts on developing the plan and schedule for the remaining development efforts associated with the pipelines and software packages that support data processing. This plan and schedule is being developed so that we have a clear understanding of when pipelines must be frozen in order to allow sufficient testing time before data is re-processed in time for the planned data releases.

2.5.3. Public Distribution Performance

The Archive Distribution Plan presents the schedule for releasing SDSS data to the astronomy community. The schedule for data releases is shown in section 2.3.3.3 of this document, in Table 2.7. Figure 2.11 shows the planned rate of accumulation of the two main data components, the photometric data and the spectroscopic data. The intermediate milestones occur on July 1, in each year starting in 2001. Two other critical milestones are the beginning of the survey, and the end of survey observations. The planning assumptions that determined these milestones are: observations of the northern sky can be made during the first two quarters of every year, the third quarter is largely lost to the monsoon season, and the northern galactic cap can be observed for only about one month during the fourth quarter. The data obtained prior to the "points-of-no-return" is quantized by the mid-year milestones and will be released at the times shown by the tip of the arrows. Somewhat arbitrarily, the date of January 1, 2000 was shown as the effective starting date of the survey in Figure 2.11, because it simplifies the graphical presentation. It also reflects our expectation that some of the commissioning data will meet the Science Requirements after it is properly calibrated.

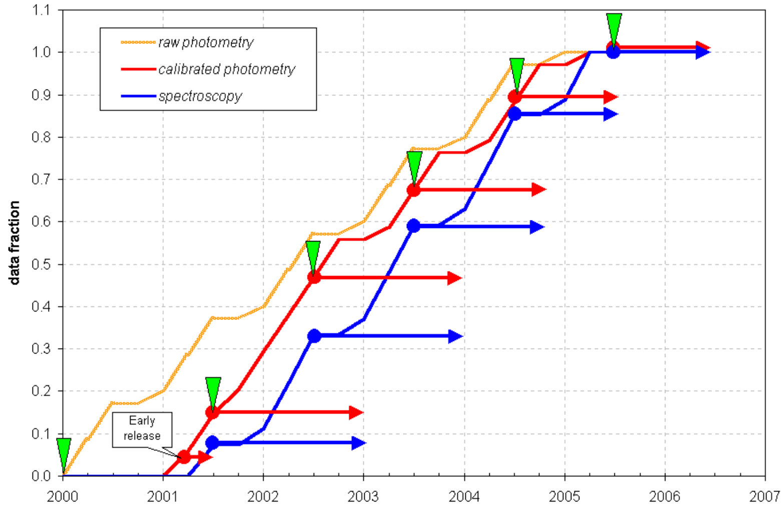


Figure 2.11. Milestones and Data Fractions for Archive Distribution

The data release dates are hard milestones and the schedule for tasks associated with data distribution are established and closely monitored so that these milestones will be met.

2.5.4. Cost Performance

The operations budget for the 5-year Baseline Survey is formally reviewed on an annual basis and presented to the Advisory Council for approval. At the same time, the budget for the next ARC fiscal year is submitted to the Council for consideration. Once approved by the Board of Governors, the annual budget serves as one of the baselines against which cost performance is measured. The other cost baseline is the overall cost to complete the observing and data processing phases of the survey. Cost performance is tracked with respect to the budget on a quarterly basis by the Project Manager. The cost performance is included in the quarterly project report.

The Project Manager is responsible for submitting a quarterly financial report that tracks cost performance to the Director. A summary of the report is included in the quarterly project report that is provided with the Advisory Council, funding sponsors, and institution SSP managers. The quarterly financial report compares the actual expenses of each institution against the plan for the quarter, based on input received by the SSP managers. Each SSP manager is responsible for submitting a quarterly report to the Project Manager that summarizes the work that was completed, work planned for the following quarter, and cost performance for the quarter just ended. By reviewing these quarterly progress and budget reports, the Project Manager is able to assess cost performance and understand the cause of significant deviations from the baseline plan. When significant deviations occur or are forecast, adjustments are made in the overall plan for the remainder of the year and forecast for the remainder of the year to ensure that critical work is completed and the project remains within the approved budget. When new work is added to the baseline plan, the work is either funded by allocating undistributed contingency or by eliminating other planned work that is of lower priority.

This more stringent review and control process was started late in 1999 and used extensively to monitor cost performance against the 2000 budget.

REFERENCES

1. Sloan Digital Sky Survey website: www.sdss.org

2. Direct links to the SDSS Operations WBS in either HTML or PDF file format:
   http://tdserver1.fnal.gov/sdss/schedule/SDSS_OPS_WBS.htm
   or
   http://tdserver1.fnal.gov/sdss/schedule/SDSS_OPS_WBS.pdf

3. SDSS Archive Distribution Plan:
   http://tdserver1.fnal.gov/sdss/SurveyDocs/datadistplanr2.htm

Appendix A – SDSS Acronyms

APO	Apache Point Observatory
ARC	Astrophysical Research Consortium
DAQ	Data Acquisition System at APO
IOP	Imaging Observers' Program
JPG	Japan Participation Group
MCP	Motion Control Processor
MOP	Photometric Telescope Observer's Program
PT	Photometric Telescope
SDSS	Sloan Digital Sky Survey
SOP	Spectroscopic Observers' Program
TCC	Telescope Control Computer
TPM	Telescope Performance Monitor
WBS	Work Breakdown Structure