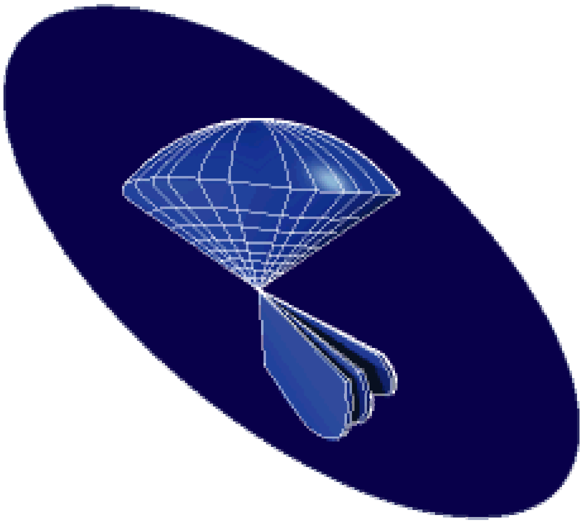
Sloan Digital Sky Survey Project
Annual Report 2001

27 February 2002



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Sloan Digital Sky Survey
Annual Report for 2001

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Sloan Digital Sky Survey Annual Report for 2001

1. Introduction

This annual report reviews our progress toward the SDSS goals that we established more than a decade ago. The two primary goals of the SDSS are the creation of a uniform, five-band, digital photometric map of the Northern Galactic sky to faint magnitudes, and the creation of a large, homogeneous spectroscopic survey of objects selected from this photometric map. The goals include extending the photometric map to three stripes of the southern sky and a spectroscopic survey of objects selected from these three stripes. The two constitute the Southern Survey. Collectively the maps and surveys are the survey product. A final goal is their distribution in a useful form to the astronomical community. This is the SDSS Archive and it will enable astronomers to address many of the unanswered questions about the structure of the universe and its constituents, from stars through galaxies to quasars.

The observation phase of the Sloan Digital Sky Survey began nearly two years ago. The data that we obtained in the past 21 months, together with the commissioning data that met survey requirements, have already had an impact on the disciplines of astronomy, astrophysics and cosmology. In June of 2001, we made good on our commitment to distribute the SDSS Archive to the astronomical community when we delivered the Early Data Release (EDR) to the public. This first installment of the Archive can be accessed through the Space Telescope Science Institute connection to the world-wide-web. We have also released our catalog of distant quasars, including the most distant quasars, to the public. The discoveries that emerged from our data during the past year are very strong testimony for its quality. Astronomers are already using the public SDSS data to follow up on a variety of interesting objects through observations with Chandra, the Hubble Space Telescope, KECK and VLT.

As the year began, the SDSS faced multiple challenges. In particular, the telescope did not always deliver an image quality that met survey requirements. This was traced to a poor thermal environment around the telescope. We steadily attacked a multitude of small problems that degraded the image quality and our observing efficiency and when the year ended both were significantly improved. Sections 2, 3, 4 and 5 describe how we met these challenges and present the current status of each of these activities.

Section 6, Science Highlights in 2001, shows convincingly that our Archive will answer many of the unanswered questions that we posed when we began the Survey. Section 7, Outreach and Communication, describes what we have done to train the next generation of astronomers and to share our excitement with the public. Section 8 outlines our responsible stewardship of the funds we received. Sections 9 and 10 point to our financial plans for the year 2002 and our outlook for progress in 2002 respectively. We had a busy and successful year and we look forward to accomplishing much more in 2002.

2. Observing Statistics for 2001

We have imaged 32% of the baseline area of the Northern Galactic Cap and 99% of the baseline area of the Southern Survey. All of these data have been processed and calibrated and meet survey quality requirements. We more than doubled the area of survey quality images from the Northern Galactic Cap. Even with this progress, we fell short of our baseline goals for the Northern Galactic Cap, which were to accumulate a total of 2845 square degrees of image data by the end of 2001 and to obtain 2281 square degrees of image data during 2001. As shown in Figure 2.1, we accumulated a total of 2448 degrees through the end of December, of which 1286 square degrees were obtained during 2001.

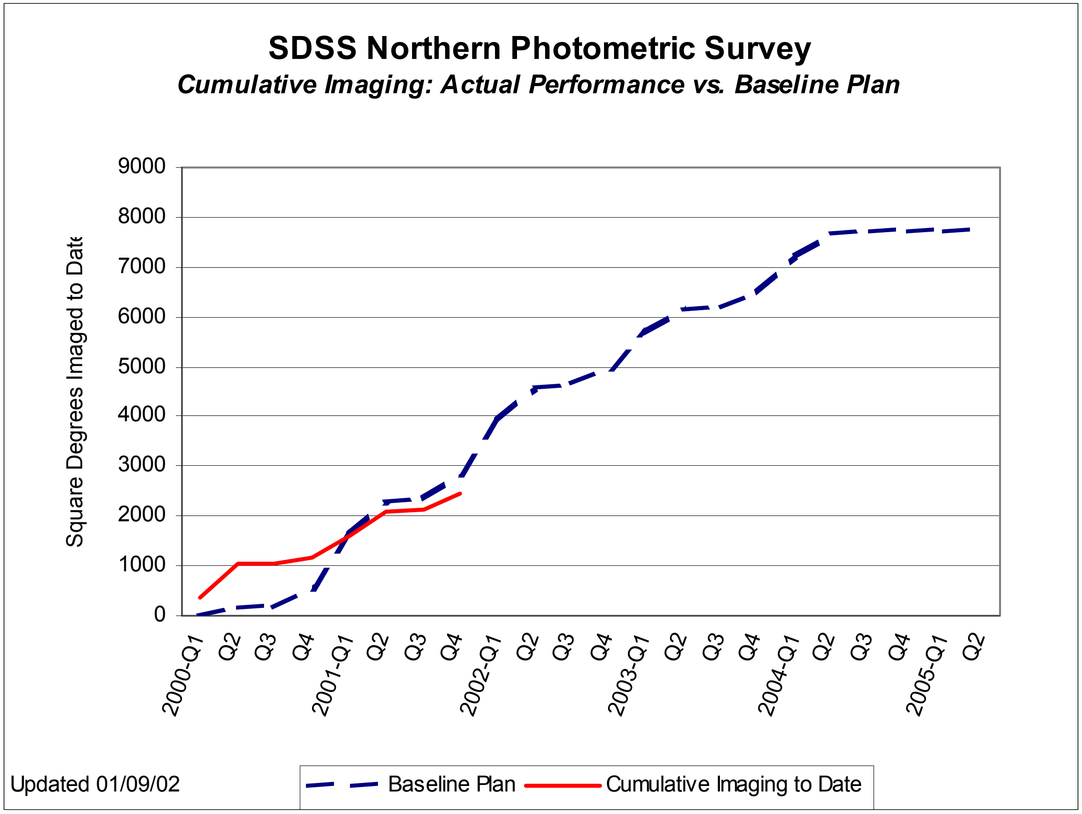

Figure 2.1. SDSS Northern Survey

We reached our 2001 goals for the Southern Survey, which consists of three separate, non-overlapping, 2.5-degree wide stripes in the southern galactic hemisphere. The two "outrigger" stripes have a collective area of 475 square degrees and the central stripe, the Southern Equatorial Stripe, has an area of 270 square degrees. Figure 2.2 shows the status of the Southern Survey. At the end of the fourth quarter, we had imaged and processed 737 square degrees of the three stripes. We declared the imaging phase of the Southern Survey complete, even though 7 square degrees of one of the outrigger stripes had not been imaged. We chose to obtain additional images of the Southern Equatorial Stripe, since a significant investment of set up time would be required to obtain this last thirty minutes of data.

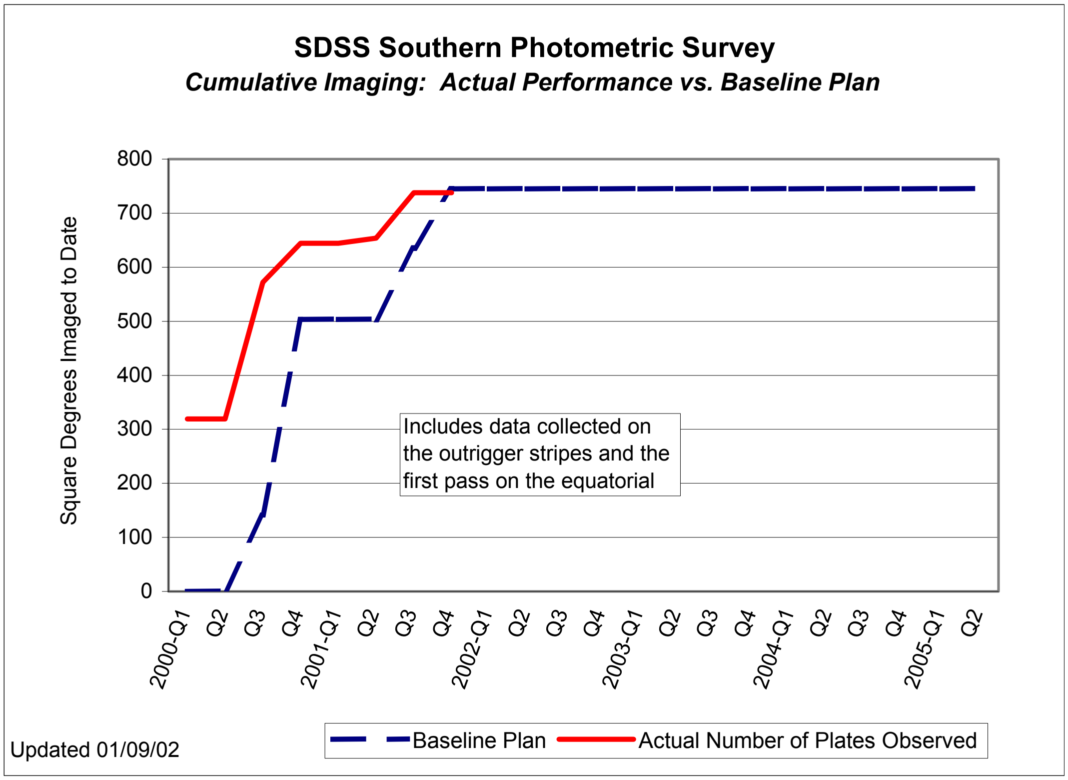

Figure 2.2. SDSS Southern Survey

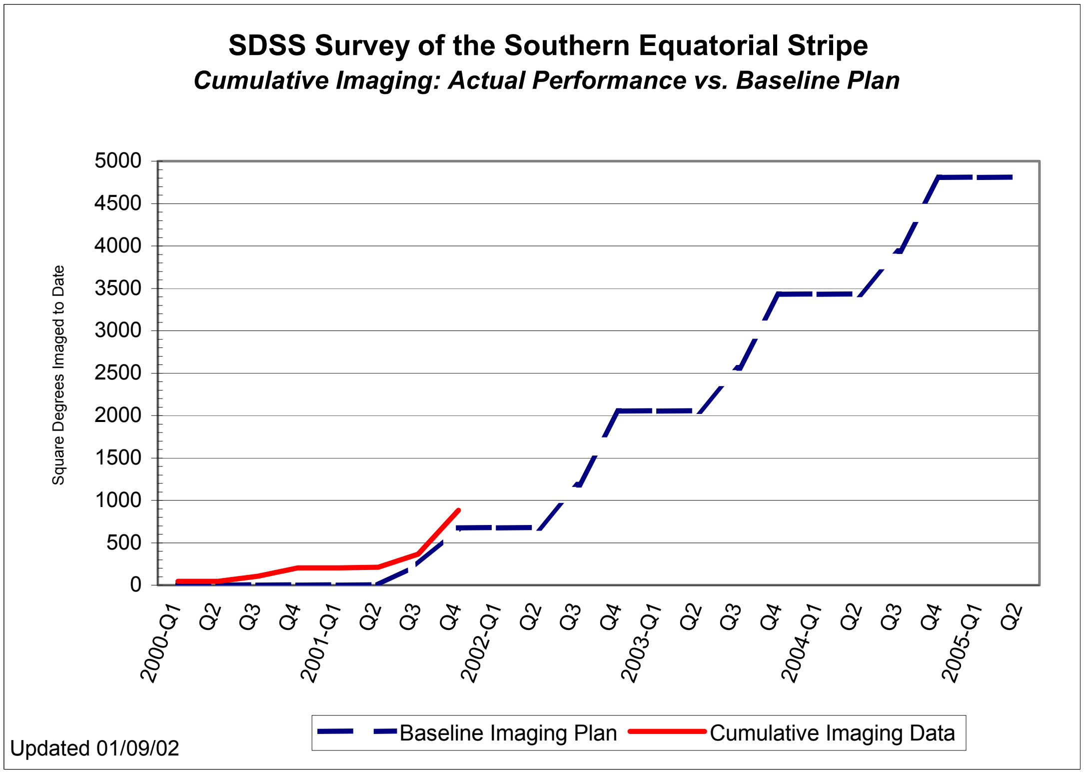

Figure 2.3. SDSS Survey of the Southern Equatorial Stripe

We fell short of our goals for the Northern Galactic Cap for two reasons: the efficiency of our observations did not meet the baseline plan and the amount of good seeing fell below our expectations. Our efficiency, when measured relative to the baseline efficiency, was less than 40% in the fourth quarter of 2000 and it was 80% of the baseline efficiency in the fourth quarter of 2001. The steadily improving efficiency allowed us to image 36% more area of the Northern Galactic Cap than we did in 2000, it allowed us to complete the imaging phase of the Southern Survey during the third quarter of 2001, and it allowed us to make an excellent start on the imaging phase of the Survey of the Southern Equatorial Stripe.

We also made steady progress on the spectroscopic surveys during 2001. We have observed 228 plates in the Northern Galactic Cap and 129 plates in the Southern Survey. We also observed an additional 36 special plates. Since each plate yields 640 spectra, we have obtained a little more than 240,000 unique spectra that meet survey requirements. This number includes roughly 170,000 galaxy spectra and 19,000 candidate quasar spectra. The goals for the spectroscopic phases of the survey of the Northern Galactic Cap and the Southern Survey were to observe 264 plates and 148 plates in each area of the sky respectively through the end of 2001. The main reason that the number of spectra fell short of our goals was our inability to obtain images of the Northern Galactic Cap during the months of December, January and February in previous years. We did not obtain any imaging data in 1998 and 1999 during those months. Moreover, we obtained very little data during the month of December in 2000 and 2001 because of inefficiency and poor seeing. Our ability to provide targets for spectroscopy of objects in the Northern Galactic Cap will continue to be compromised until we build up an inventory of five-color images suitable for target selection in this part of the sky. Nevertheless we expect that we will catch up and meet the baseline goals for spectroscopy before the middle of 2005, when the Survey is scheduled to end.

3. Performance of Observing Systems in 2001

The biggest challenges that we faced at the beginning of 2001 were the need to significantly improve the image quality and the efficiency of observations. Since they are tightly coupled, a brief history of how these challenges arose provides the background to the strategy that we are following to meet them. Soon after regularly scheduled observations began in April 2000, we learned that the thermal environment of the telescope was severely degrading the image quality and thus our ability to collect survey quality data. The extent of the problem did not become clear until after we had gathered sufficient telescope performance data to characterize its essential features. With the data that we obtained during the last three quarters of 2000, we were able to identify two major contributors to the poor thermal environment and many small but collectively significant contributors. First, the flow of outside air over the primary mirror was not sufficient to maintain the primary mirror at the outside temperature. Second, the heat dissipated in the lower enclosure, which is immediately below the telescope and instruments, was far greater than planned and the air handling system did not have the capacity to remove it. These factors made the lower enclosure much warmer than the outside, ambient air causing heat to flow from the lower enclosure to the telescope and the instruments.

Measurements made during the last quarter of 2000 showed that the equipment in the lower level dissipated nearly 10 kW of waste heat. This is a factor of 10 larger than planned and is the reason why the lower enclosure was about 10° C warmer than the outside during observations. While the insulation between the lower level enclosure and the telescope was excellent, heat was conducted from the lower enclosure along the steel azimuth support cone, through the telescope fork and into the outside telescope support structure. As a result, parts of the telescope exposed to the night sky, particularly the primary mirror, were several degrees warmer than the outside air. The warm air in the lower enclosure also made the CCD camera and the spectrographs warmer than the outside air. The heat generated by these instruments is transported by a glycol loop to a thermoelectric chiller in the lower enclosure and the chiller can only lower the glycol temperature relative to the temperature of the lower enclosure by about 3°C. The coolant, as delivered to the camera and spectrographs, was about 7°C warmer than ambient air around the telescope because of all of these unwanted heat sources. Collectively these factors were responsible for the degradation of the image quality.

While we quickly gained a qualitative understanding of these factors, we lacked the fundamental information on the temperature distribution over the mirrors and their support systems, the temperature of the glycol coolant delivered to the instruments, and the temperature of the lower enclosure to devise a comprehensive plan for fixing the problems. Moreover, we did not have a quantitative measure of the temperature and volume of the air exhausted from the lower enclosure. Since we had anticipated that we would encounter problems of this nature we had begun the fabrication of an extensive system of thermometers to provide this information early in 2000. It began to provide the needed detailed information during the third quarter of 2000 and first quarter of 2001. It consists of 120 solid-state current-mode temperature sensors and a small microprocessor-based data acquisition system. The data from this system has enabled us to set priorities on the work that was underway, inform the design of additional improvements, and evaluate the effectiveness of the improvements as they were completed. As 2001 began, we had developed a plan of action to fix the thermal problems, we had the tools to guide the work and we had begun to address the two major problems in parallel.

The temperature of the primary mirror is controlled by drawing outside air into the mirror cell and then in turn through the mirror vent tubes, the altitude bearings, the support fork, and finally through openings in the azimuth support cone in the lower enclosure. The airflow was to be established by reducing the air pressure in the lower enclosure below the outside air pressure. We found that the airflow was only about two percent of the design value because of leaks, incorrect flow calculations, and a number of other problems. As a result, the primary mirror was much warmer than the outside ambient air and there were unacceptably large temperature gradients across the mirror.

The flow was increased by installing a pair of high-speed centrifugal fans in the telescope fork that drew the outside air into the lower cone and by plugging the leaks that allowed air to bypass the intended airflow path. The airflow is now approximately the design value and the time required to bring the primary mirror temperature into thermal equilibrium with the outside air at the start of nightly observations has been reduced to about one hour. Prior to these changes, the mirror never really reached thermal equilibrium with the outside air. The improved airflow has also eliminated the unacceptable temperature gradients across the primary mirror.

An unplanned proliferation of small electronic devices in the space behind the primary mirror support system, such as power supplies, added undesirable sources of heat in a sensitive location. We removed these power supplies and replaced them with a high-efficiency industrial 24V DC distribution system, which now powers all the major electronic equipment on the telescope except the instruments.

We reduced the temperature of the lower enclosure both by moving equipment that dissipated large amounts of heat in the lower enclosure to distant locations and by improving the cooling of equipment that could not be relocated. The pumps and the associated UPS for the primary mirror support system, which dissipated about 4 , collectively made the biggest single contribution to the heat load in the lower enclosure. They were replaced with higher capacity screw pumps that were installed in the operations building. The previous system was left in place as a backup in case of a power failure. The pressure in the return leg is now maintained by a venturi mounted on the air plenum mounted on top of the thermoelectric chiller. The plenum is part of newly installed ductwork that draws outside air through a grating on the rotating platform and into the plenum. This was done to provide a flow of cool air over the thermoelectric chiller. The compressed air that exits the venturi flows into the plenum and provides about a of cooling as it expands.

The motors for the high-speed centrifugal fans, which were installed in the azimuth cone support, dissipate about 1 kW of heat in a critical location. The impact of this additional source of heat is minimized by cooling the motors with a flow of glycol that transports the excess heat into the ground loop for the air conditioner. In addition, several other electric motors, which had previously dissipated quite a bit of heat in the lower enclosure, are cooled in the same way and the unwanted heat is dumped into the ground loop, which has sufficient capacity to dissipate the unforeseen heat loads. These changes removed about 5.5 kW of heat that was previously dissipated in the lower enclosure. The collective effect of all of these changes has reduced the temperature of the lower enclosure by about 5°C. It has also reduced the temperature of the thermoelectric chiller coolant by about 3°C. However, the instruments are still about 4°C above the outside air temperature. While the situation is vastly superior to that of a year ago, further work is needed. We will do more to reduce the temperature in the lower enclosure in 2002, and his work is described in Section 10.

The telescope was much warmer than outside air when nightly observations began because it was stowed in an unintentionally warm enclosure during the day. Once the enclosure was removed, it took many hours for the telescope to cool down and during that time imaging was not possible. The air conditioner that was intended to bring the temperature of the rollaway enclosure and the telescope to the temperature forecast at the start of observations could not operate when the outside temperature was below 10° C. We have replaced this air conditioner with a low-temperature refrigeration unit that can cool the roll away enclosure even when the outside air temperature is as low as –20° C. We are now able to bring the telescope to the appropriate temperature before the roll away enclosure is removed and the telescope is ready to be used for science observations at twilight.

As the thermal environment was brought under control at the beginning of the third quarter of 2001, we began to work on another set of less severe problems, which included rotator misalignment, poor pointing, and inadequate tools for checking pointing. While each problem made a small impact on efficiency, collectively they contributed to the slow startup of science observations. The specifications for pointing accuracy and rotator accuracy for imaging are very tight, and must be achieved without feedback. The erratic performance of the telescope, particularly at the beginning of the night, forced the observers to adopt very conservative procedures. Before we could adopt more success-oriented procedures, we had to fix the worst of these problems.

The rotator misalignment was traced to the way we used the pointing model software package. We found a simple and nearly exact workaround and it has been in place since June. One of the sporadic pointing errors was caused by a procedural error in the creation of the pointing model and this was fixed once it was recognized. Part of the remaining problem may be a very intermittent loss of synchronization of the telescope drive with the control system. While this has been very difficult to track down, it was receiving considerable attention as the year ended. The automatic focusing routine was not fast enough to meet our needs. The problem was traced to the way calculations were made by Astroline, a software package in the data acquisition system. They have been streamlined and the start-up time is now significantly shorter. In addition, the improved thermal environment makes it possible to predict the focus setting from temperature data and with better starting values the observers quickly acquire a good focus. There are still some further improvements that can be made to the Astroline code and we expect the new code to be fully operational in the first quarter of 2002.

When all the planned improvements are completed, the necessary startup time will be decreased to about two chip crossing times, or two minutes (for focus), plus the seven minute camera ramp time. If we can achieve this, our efficiency will be better than the baseline target of 86%. During the first two quarters of the year we typically spent forty-five minutes to an hour establishing a good pointing and focus. By the middle of the third quarter the pointing, even with the remaining sporadic timing problems, was good enough for imaging and in November we put success-oriented observing procedures in place. The observers have obtained excellent results with the new procedures. They were able to consistently start imaging runs with only enough lead to focus. Since the time spent setting up a run is an inescapable overhead, long runs are more desirable than short runs. Unfortunately, we are forced to make the length of imaging runs shorter than we had planned, in order to optimize the total time spent on imaging and spectroscopy. This problem is clearly eased by streamlining the setup.

The telescope pointing and rotator alignment problems that affect imaging also affect spectroscopy, since the guide fibers are only 7 arc seconds in diameter, except for two 'large' 12-arcsecond fibers. If the selected guide stars are not in the fibers, a time-consuming search technique must be initiated. If only a few of the stars in the field are found because the rotator is misaligned, the complicated interaction between pointing and rotator position makes corrections difficult. On some occasions in the past, the observers needed as much as an hour to acquire a field. Since the nominal duration of a science exposure is only forty-five minutes, the efficiency of spectroscopy was quite poor. The pointing and rotator improvements made to date have already eliminated most of these long delays.

The time estimate used in the operations model for exposure of a single plate omitted two essential operations. One was the readout of the CCDs by the DA and the other was the dedicated observation for spectrophotometric calibration. The omitted steps add 11 minutes to the time required to mount, expose and dismount a plate. Fortunately, the observers are changing cartridges in four minutes, faster than the time allocated in the operations model and the omission is partially compensated by their skill. Nevertheless, the overhead for spectroscopic observations is still greater than we planned. We believe that we will reach baseline goal for the efficiency of spectroscopic observations because there are still opportunities to reduce the time required to acquire a field through software and guider improvements.

SDSS Site Operations at Apache Point reached the desired level of completeness and capability in 2001. The SDSS Observing team is now fully staffed and trained. They have implemented observing and change control procedures, they gained expertise in all of the various observing systems, and they took responsibility for the routine operation of the PT. They also assisted the SDSS site-engineering group with the characterization of the 2.5-m telescope thermal environment, and with other various efficiency improvement studies. The SDSS site-engineering group developed methods and protocols for providing support of shutdowns, bright-time upgrades and repairs, and 24/7 standby engineering support, all geared toward improving on-sky efficiency and performance. The Lead Observer worked closely with the Project Manager and Project Scientist to establish the coordination of the work of the observers and the site-engineering group. He also developed the monthly observing plans for the SDSS program with the Head of Survey Coordination. The technical support staff at APO improved the routine support services for survey operations, including the handling and processing of spectroscopic plug plates, cryogenic provisioning and data tape shipping. Overall, SDSS Site Operations have become an effective production operation, which can handle both the routine aspects of survey observing operations and cope carefully and constructively with changes. We made steady progress in increasing the efficiency of our observations throughout 2001. The problems in both imaging and spectroscopy that are still limiting our operating efficiency are relatively well understood. We now know that in some instances we can do better than the operations model and thus can fully compensate for those steps that were omitted.

4. Status of Data Processing and Data Distribution

We completed the Data Processing Factory in the first quarter. During the year, we acquired six Linux machines and an additional six terabytes of RAID disc. The imaging, spectroscopic, and photometric pipelines have been automated, so that data taken during a dark run is generally processed and entered into the operational data base before the start of the next dark run. The high level of automation and the millisecond access of data from disc have enabled us to increase the speed with which data are processed. The Factory was used throughout the year to process all imaging and spectroscopic data.

We are continuing to make the Factory more efficient by using only fully validated pipelines and automated routines to process and archive the data that we deliver to the SDSS collaboration and the astronomical community. Since the Factory is not an appropriate place for development, we built separate platforms to test the development versions of the pipelines in a factory environment. There is a separate test bed for processing data with code that is under development in a production environment and a test operations database for archiving data processed with this code. This latter step was necessary since some of the planned changes require data model changes, which in turn require additional features in the test operations database. These test facilities allow production processing and development to proceed in parallel without interference. Of course with a limited staff our priorities must be carefully managed.

During the year we developed new code for the target selection pipeline, the photometric telescope pipeline, the astrometric pipeline, the monitor telescope pipeline, the final calibration pipeline, and the spectroscopic pipelines. The major development effort was focused on the photometric pipeline (Photo v5_3). The improvements to this pipeline will enable better photometric calibration, as described in the section entitled Status of Photometric Calibration. They will minimize the impact of the inevitable problems with the instruments and seeing that arise during observations. The coding and initial testing of Photo v5_3 was largely completed during the year. An evaluation of the performance of the code in an environment that replicates the production environment was begun as the year ended. Once Photo v5_3 has been thoroughly tested and certified ready for production it will be used to process all data obtained to date and all future data. As these data are processed, QA tests are performed and then an end-to-end test is performed in order to fully validate the code and the data. Priority will be given to processing the data that will be distributed in Data Release 1 (DR1), which will be the first large release of data to the public.

We made our first public release of SDSS data to the astronomical community in June 2001 with the help of the Space Telescope Science Institute (STScI). This release, the Early Data Release (EDR), was officially announced at the AAS meeting in Pasadena and it has already substantially increased our credibility with the community. It consists of 460 square degrees of images and a little more than 50,000 spectra. The STScI brought considerable experience and expertise in distributing data to the astronomical community to this partnership, while we, the SDSS, brought a deep knowledge of the Science Archive, its limitations and its opportunities. The NSF and NASA have endorsed this partnership and encouraged us to develop a detailed plan. If NASA provides the STScI with the required support, the STScI will distribute the data over the web (http://archive.stsci.edu/sdss/index.html) through their Multi-mission Archive (MAST) to the U.S. astronomical community.

The EDR is presented through two scientific databases, the Catalog Archive Server and the Data Archive Server, which we have been developing for the past five years. The Catalog Archive Server contains all of the attributes of each object (found by the imaging pipelines) that were calculated during processing and calibration. The Data Archive Server provides access to all of the processed data for every object and all of the attributes that were calculated during processing. A user can present a complex query to the Catalog Archive Server and it will return the objects that satisfy the query with all of their attributes. The user can also obtain Atlas images, sky backgrounds, the corrected imaging frames, and, when available, the flux-corrected spectra for each object from the Data Archive Server.

The SDSS collaboration and the astronomical community have used these databases during the past six months. Both communities found them to be very useful tools for mining the SDSS Archive and creating catalogs. However, the reliability and availability of the database servers left much to be desired. The SDSS data distribution team found loading the databases to be very time consuming and system crashes frequently occurred during loading. Much of the difficulty can be traced to problems encountered with integrating the commercial object oriented database into the framework that we chose five years ago. While we have had a lot of difficulty, we have established that the basic concept of our science database is sound. We had to build the framework with our own limited resources. This experience has given us the guidance that we need to improve the usability and performance of the science databases.

Three years ago, we recognized this was a potential problem and we began a search for an alternative. At the same time, we had begun an informal collaboration with the Microsoft Bay Area Research Center (BARC) to develop a data server that could be used for public outreach. The development of this server, which uses a Microsoft relational database (SQLServer), was surprisingly rapid and it became the SkyServer. It serves the same data to the public that is contained in the Catalog Archive Server. As an added bonus, it also provides color images of the corrected frames. Astronomers found the SkyServer to be very useful in spite of its relatively limited query tool, which we had developed to enable the public to mine the data. The SkyServer includes several tools that make the data more intuitive, such as the Navigation tool, which is a point-and-click interface to the sky, and the Object Explorer, which provides full SDSS data on single objects. SkyServer also includes full data documentation, a glossary of terms, and articles that give background information on astronomy. The astronomers found these features very valuable.

Since the customer is never wrong, we realized that it might be feasible to develop it into a competitive alternative. Since then we have improved the query tool and added other features that are needed by astronomers. We found that the SkyServer architecture provides a far faster Catalog Archive Server than what we had developed on our own. It also proved to be much easier to load and operate in the Fermilab environment, the place from which the data are downloaded onto the Internet. For these reasons, we started a thorough comparison of the two approaches. As the year ended, we had shown quantitatively that the SkyServer, with an improved query tool, outperformed the Catalog Archive Server in almost every instance. We found no instance in which the SkyServer was slower than the existing system in returning a query. Shortly after the year ended we completed the performance comparison of the two servers and decided that we would terminate development of the object-oriented Catalog Archive Server and put our entire development effort on a Catalog Archive Server that uses the Microsoft SQL Server. The object-oriented Catalog Archive Server will be maintained for the collaboration until the development of the SkyServer has reached a satisfactory state. Although no new features will be added to the object-oriented version of the Catalog Archive Server, bugs that cause it to crash will be fixed.

At the beginning of the third quarter we began the planning for Data Release 1 (DR1) the first large scheduled data release, which will provide the astronomical community with six times more data than was contained in the EDR. A detailed task list was developed and a preliminary schedule was drafted. As part of the planning effort, we specified two significant improvements to the contents of the Catalog Archive Server. The first will provide information about the area of the sky that is "masked" due to the satellite trails of bright stars. The second will provide bookkeeping information on the spectroscopic targets and tiling operations. These features will allow the Catalog Archive Server to be used for statistical studies.

5. Status of Photometric Calibration

The photometric accuracy is quite good when compared to previous surveys, particularly those done with photographic plates. Typically, we have achieved a relative photometric accuracy of 3% in the r, g, and i bands and roughly 5% in the other bands. In some instances, the u band is poorer than 5%. The requirements for global accuracy that we established at the beginning of the survey were 2% in r, g, and i, and 3% in the other bands. During the past year, we reassessed the accuracy of our photometric calibrations and concluded that they were good enough for target selection, but that they did not meet the requirements for the final, global calibrations. In July of 2000, we significantly increased the level of effort dedicated to understanding the problems that were limiting the accuracy of the calibrations. This effort was continued throughout this year, though it was given a lower priority than the improvement of image quality and efficiency. We chose to give this work lower priority because we felt, and still feel, that we can improve the calibration of the image data after they have been processed. The creation of a consistent photometric map across the entire Northern Survey, which consists of 45 stripes, is the big challenge that we must meet. We are confident that the calibration within a strip is quite good and our QA tests bear this out. We have not completed the development of the calibration techniques to make the calibrations that link widely separated stripes, nor have we developed the QA tools to test the global calibration. Since target selection depends primarily on the photometric accuracy in the r, i, and g bands within a single stripe, we are confident that we are meeting the requirements for target selection. Five problem areas were identified during the year. Their description and status are as follows:

1. Flat fields. On the eve of the EDR it became clear that our flattening procedure did not work as well as required, particularly in the ultraviolet. Prior to the reductions for the EDR we had used the median sky values in columns to construct the (1-dimensional because of the TDI scanning) flat field vector. The comparison of a large number of secondary standards, obtained with PT observations, with 2.5-m CCD column data showed systematic discrepancies in some of the u chips in excess of ten percent. This was traced to reflection paths between the CCDs and filters. While the PT data did not yield sufficiently accurate data to make the corrections, oblique scans with the 2.5-m, specially taken for this purpose, have produced excellent flats. They will be incorporated in Photo v5_3, the version of the Photometric Pipeline that will be used to reduce data for DR1. It is anticipated that Photo v5_3 will be used for production data processing before the end of the first quarter of 2002.

2. Aperture corrections. These are corrections to the magnitudes derived from the point spread function (PSF) fitting, which is used throughout the photometric pipeline, to those derived from measurements of bright stars in large apertures. The data have informed us that we need to apply more sophisticated techniques to the data reduction. Errors of up to 0.1 magnitudes have been introduced when the PSF is changing rapidly because the seeing is changing magnitude or

character. We now use Karhunen-Loewe variable PSF fitting and more sophisticated interpolation to determine these corrections. We have added several refinements to Photo v5_3 that will reduce these errors to about a third this size. Moreover, there is considerable promise that these errors can be reduced further using locally measured image moments.

3. Filters. We ordered identical filter sets for the USNO 40-inch telescope, the PT and the 2.5-m telescope. In 2000, we discovered that because they all operate in different environments, their bandpasses are slightly different. This is because the interference coatings, which are used for the short-pass (red) edge on the g, r, and i filters, are hygroscopic and their optical properties depend on humidity and its history. During the year, a considerable effort was made to understand and resolve this problem. The filters used in the 2.5-m camera are in a hard vacuum and thus are stable. They differ from the designs and the laboratory measurements, since the red edges of g, r, and i filters are shifted blueward by an amount that is accurately proportional to the cutoff wavelength. The shift in the red filter is about 15 nm. The filters used in the USNO 40-inch, which were kept in ambient air, are stable but different, since the range of humidity encountered at Flagstaff does not cause variations. The PT filters present a more difficult problem. They were kept in a box filled with dry air during routine use. When filters were being serviced they were exposed to moist air. Under these conditions the PT filters were not stable. New PT filters were made that are stable and insensitive to humidity. We decided not to replace the 2.5-m filters because of the complicated nature of the task and the time that would be lost to observations.

This has several unfortunate scientific consequences. For example, there are 'dead bands' in photometric redshifts when features fall in the gaps between filters. We have three photometric systems rather than one. This is further complicated by the small manufacturing differences among the different CCDs and filters in the six columns in the 2.5-m camera. Our standards are on a system defined by the USNO telescope, for which the filters are close to design. Unfortunately, this system is not very useful for trying to understand the survey data, which must be on the natural system of the camera if the colors belonging to objects with arbitrarily peculiar energy distributions at arbitrary redshift are to be understood. During the year, we devoted considerable effort to determine robust transformations between the systems.

The determination of these transformations to the required accuracy has been difficult, and we are still studying why similar but not identical techniques have yielded different answers. The effort has been further complicated by the fact that until the filters were replaced the PT was not stable. We have concentrated on tying the USNO and PT systems together in order to be able to report the PT observations of secondary ‘patch’ standards on the USNO system. Once that is done, we can take the step of transforming the stellar standards, a mix of stars of quite ordinary colors and spectral properties, between the USNO system and the native 2.5-m survey system. Until this is done, our photometry is provisional. While these effects are smaller than those in items 1 and 2, they are systematic with color and should be included in the calibration. A proper treatment of the photometry in which we explicitly use the fact that there are two fundamental systems awaits these results.

4. CCD Linearity. The response functions of the CCDs that we are currently using were derived from measurements made at the vendor during acceptance testing. Since the camera

electronics did not exist when the tests were made, different electronics were used. Near saturation, the nonlinear response of each CCD and its electronics can lead to errors of up to two percent. During 2001, we initiated a program to measure the response functions of the 2.5-m CCDs and their electronics in situ at Apache Point. The work should be completed in the first quarter of 2002. This will provide a far better characterization of the camera. The linearity corrections for the 2.5-m system will be incorporated into Photo v5_3. The new CCD chip for the PT was measured in 2001, and the corrections are being applied in the PT reductions.

5. Cross-scans. Since imaging data is taken in long, narrow strips the control of errors along the strip is fundamentally better than the control errors from one strip to another and from one stripe to another. The CCDs in the imaging camera are arranged in six columns and the CCDs in each column are separated by somewhat less than the width of a CCD. When the sky passes over the CCD array, there are gaps in the coverage. A second pass displaced by roughly the width of the CCD is made and this fills the gap in the coverage and provides overlap. Each pass is called a strip and the two strips are called a stripe. A stripe has a width of 2.5 degrees and the overlap of the two strips in a stripe is about 10%. The six columns of a strip are tied to one another using the sky and one strip of a stripe is tied to the other strip using the overlap of the edges of the strips. These data are used to make the photometry homogeneous across the stripe and for considerable extent along the stripe. The overlaps of the edges of stripes are also used to tie stripes together, although they do not control gradients across many stripes very well. Oblique scans with the 2.5-m will cross many stripes and thus, will be used to connect many widely separated stripes together. This calibration process can only be used sparingly since it can consume quite a bit of imaging time. We are developing the Apache Wheel technique that will allow the 2.5-m to acquire data with scans that are at several large angles with respect to the regular survey stripes. The hub of the wheel is near the north celestial pole. It will make use of a binned scan in order to reduce the time required to acquire the data.

We plan to produce a final global calibration using the 2.5-m scans, the PT patches, and the Apache Wheel data in an optimum way toward the end of the survey.

6. Science Highlights in 2001

The large amount of high quality five-color image data and the large number of high quality, medium resolution spectra of objects selected from the image data, have provided the more than two hundred SDSS collaborators with extraordinary opportunities. During 2001, they discovered the three most distant quasars found to date, they performed the first analysis of large-scale structure of the galaxy sample in the SDSS Archive, and they investigated the properties of an extraordinary array of unusual stars. They submitted 50 papers to the *ApJ* and/or *AJ* and of these 30 have already been published and another 10 had been accepted for publication. The remainder will appear in publication during 2002. The full citation list of these papers may be found in Appendix B. The rate at which scientific publications are being prepared and submitted for publication grew steadily during this year. Each of these papers was posted on the SDSS collaboration web site for three weeks before it was submitted to one of the journals. This gives the entire collaboration opportunity to comment on each paper.

The early release of data in June (the EDR) gave the entire astronomical community opportunities to look at the public SDSS Archive and this resulted in the preparation of another 11 papers that were accepted for publication by peer reviewed journals. Since the scientists who wrote these papers were not part of the SDSS collaboration, it is an indication of the value of the SDSS Archive to the astronomical community. In addition, another five papers that used published SDSS data and included SDSS collaborators among the list of authors were accepted for publication by peer reviewed journals.

It needs to be noted that the impressive level of research productivity put forth by the SDSS Collaboration is not supported by the project funds that enable the project team to create the SDSS Archive. However, the participating institutions were able to provide the support that allowed the researchers to do this work. In some instances, the researchers had grants to support their work. The support from the participating institutions has also enabled their faculty to contribute to the training of the next generation of scientists. In particular, collaboration scientists are mentoring a significant number of Ph.D. students. The SDSS Archive directly enabled this research and it will enable the research of many more as it becomes public.

The Spokesperson asked the chairs of the working groups to provide highlights of the science carried out by SDSS collaborators in the areas of science covered by their working groups. The working groups are responsible for refining the spectroscopic target selection criteria and providing the data processing team with the target selection code that uses these criteria. The target selection code automatically selects the objects found in the five-color image data for spectroscopic observations. In response to this request the chairs and the spokesperson assembled the following impressive account of the scientific investigations that were undertaken by SDSS collaborators during 2001. Much of the work was presented for the first time at collaboration meetings by the youngest members of the collaboration, graduate students and post docs.

Galaxy Working Group

The SDSS has obtained redshifts for over 170,000 galaxies, and has five-color photometry for of order 100 times as many galaxies. The redshift survey comes in two parts: a magnitude-limited sample to $r = 17.8$ with a median redshift of 0.1, and a color-selected sample directed at the most luminous red galaxies at each redshift, which extends to $z = 0.45$ (Eisenstein et al. 2001).

There has long been a mismatch between galaxy counts at the bright and faint end, giving rise to claims of a “local hole” in the galaxy distribution, namely a lower-than-average density to $z = 0.1$. The SDSS commissioning data cover enough area to allow a measurement of galaxy counts (in five bands) over ten magnitudes, from $r = 12$ to 22 (Yasuda et al. 2001). This shows no evidence for a local hole, and puts the bright and faint counts on a common system for the first time.

With redshifts, one can measure the galaxy luminosity function. This has been done in the five SDSS bands by Blanton et al. (2001), who show that the galaxy luminosity density is appreciably higher than inferred from the Las Campanas Redshift Survey due to the much fainter surface brightness limits of the SDSS sample. The luminosity function is studied as a function of color, surface brightness and concentration index. This work looks forward to the eventual exploration of the full distribution of galaxies in parameter space, which will constrain models of galaxy formation.

The physical properties of galaxies are a function of environment, as shown by Castander et al. (2001): using the very first SDSS spectroscopic plates, taken of galaxies in the Coma cluster, one sees enhanced star formation at the periphery of the cluster, but essentially none in the interior.

There are strong correlations between the morphologies of galaxies and their other physical properties. Shimasaku et al. (2001) show that galaxy color and concentration index are effective proxies for morphology. Strateva et al. (2001) show further that the galaxy color distribution is strongly bimodal in u - r; moreover, the division between the two modes is essentially independent of magnitude to at least r = 21, allowing a clean color separation of these two types of galaxies to quite faint magnitudes.

McKay et al. (2001) have used the weak lensing signature of faint background galaxies to make statistical measurements of the masses of galaxies in the SDSS spectroscopic sample. They find evidence of constant mass-to-light ratio as measured separately in the g, r, i, and z bands. Especially in the reddest bands, these results appear independent of environment or galaxy morphology.

Cluster Working Group

The Cluster Working Group used commissioning data to identify clusters of galaxies in a ~400 square-degree area using several independent cluster selection methods. These methods include:

1. The Matched Filter methods and the Voronoi-Tesselation method (Kim et al. 2001a). The MF methods use radial and luminosity filters to select rich clusters as a function of redshift and obtain a best estimate of each cluster's redshift and richness. The VT method finds high-density regions that correspond to typical clusters of galaxies. These methods, by design, select the richer clusters, finding hundreds candidates to redshift z ~ 0.5.

2. The MaxBCG method (Annis et al. in prep). This method identifies clusters based on the color and the magnitude typical for the Brightest Cluster Galaxy (BCG), plus a density enhancement of red galaxies around the BCG. This method identifies poor clusters and groups of galaxies and thus identifies thousands of clusters and groups to redshift z ~ 0.5.

3. Cut and Enhance method (Goto et al. 2001). The CE method uses the typical red color cuts for clusters as a function of estimated redshift, followed by a density enhancement selection method. This method also finds thousands of clusters and groups to redshift of z ~ 0.5.

4. The Color-4 method (Miller et al. in prep). This method identifies clusters by a multi-color selection method.

The comparison of these methods (including the estimated positions, redshifts, and richnesses of the clusters, the distribution of clusters as a function of redshift and richness, and the calibration of cluster richnesses versus observed cluster luminosity and velocity dispersion) was carried out by Bahcall et al. (in prep). The comparison reveals a good agreement among the derived parameters using these independent algorithms after allowing for the different selections.

Several cluster science results has been derived from these clusters:

1. Cluster Alignments. We find a strong alignment of the orientation of the dominant cluster galaxy, the BCG, with orientation of the cluster itself (the 'Binggeli effect'). We find this alignment to be strong for clusters with a highly dominant BCG; clusters with less dominant BCGs do not exhibit an alignment. We also find the alignment effect exists to redshift of z ~ 0.5 (Kim et al. 2001b), enabling comparisons with cosmological simulations.

2. The Luminosity Function of galaxies in clusters has been determined for a sub-sample of clusters identified by the CE method (Goto et al. 2001). The luminosity function has been studied as a function of galaxy type, and as a function of cluster surface density (dense versus sparse clusters). As expected, the luminosity function for elliptical galaxies is not as flat as that of spiral galaxies.

Quasar Working Group

The project announced the discovery of the three most distant quasars yet known, the most distant at a redshift of 6.28 (Fan et al. 2001c). These objects were found in a survey of i-dropout objects selected from ~1550 deg^2 of imaging data. Objects with $i - z > 2.2$ and $z < 20.2$ are selected, and follow-up J-band photometry is used to separate L and T type cool dwarfs from high-redshift quasars. Spectra of the remaining high-redshift candidates were obtained with the APO 3.5-m and Keck telescopes. The four quasars at $5.7 < z < 6.3$ found in this survey (including the $z = 5.74$ object found in Spring 2000) form a complete color-selected flux-limited sample. We find that at $z = 6$, the comoving density of luminous quasars is a factor of ~ 2 lower than that at $z \sim 5$, and is consistent with an extrapolation of the observed quasar evolution at $z < 5$. The existence of strong metal lines in the quasar spectra less than a billion years after the Big Bang suggests early metal enrichment in the quasar environment.

Subsequent high S/N spectroscopy of these quasars using Keck (Becker et al. 2001) and VLT (Pentericci 2002) reveals that the Lyman alpha absorption in the spectra of these quasars evolves strongly with redshift. In the highest redshift object the flux level drops by a factor of more than 300 from longward to shortward of Lyman α and is consistent with zero flux in the Lyman alpha forest region immediately blueward of the Lyman α emission line. A similar break is seen at Lyman β; because of the decreased oscillator strength of this transition, this allows us to put a considerably stronger limit on the optical depth. This is a clear detection of a complete Gunn-Peterson trough, caused by neutral hydrogen in the diffuse intergalactic medium. It suggests that the mean ionizing background along the line of sight to this quasar is significantly lower at $z = 6$ than at $z = 5$, and the universe is approaching the reionization epoch at $z \sim 6$.

In addition to finding the four quasars at redshifts near six, the SDSS has discovered over 450 quasars with z > 3.6, including over 200 with z > 4, and ten of the twelve published quasars with z > 5. The vast majority of these objects were discovered “automatically”: imaging data were reduced, spectroscopic targets were selected based on their colors, and spectra taken, all by the SDSS hardware and software. Many of these objects appear unusual: of order 10-15% of the quasars show evidence for broad absorption lines (Menou et al. 2001, Hall et al. 2001), indicative of ejected clouds of relativistic gas, and several quasars have been found with essentially no emission lines.

The photometric errors of the SDSS imaging data are sufficiently small that we can resolve the color distribution of quasars, and we are able to study the intrinsic scatter in their colors for the first time. The color distribution of quasars is found to be surprisingly tight at a given redshift, and their strong emission lines cause distinctive variations in color as a function of redshift. These variations allow for the determination of redshifts of quasars based purely on their photometry (Budavari et al. 2001, Richards et al. 2001b), a feat never before accomplished. Although most quasars follow a tight redshift-color relation, approximately 4% of the quasars are much redder than the mean, and there is no equivalent population on the blue side. It is likely that these red quasars suffer from internal dust extinction.

The large wavelength coverage, good spectral resolution, and high signal-to-noise ratio of the SDSS spectra have permitted the construction of a composite quasar spectrum of unprecedented quality (Vanden Berk et al. 2001). The initial composite, formed by the summation of approximately 2000 individual SDSS quasar spectra, has permitted the detection of 80 emission lines. In the near future it will be possible to form similar-quality composites of subsamples of quasars (e.g., by redshift, radio properties, and continuum slope).

The Quasar Working Group constructed the first edition of the SDSS Quasar Catalog from the EDR (Schneider et al. 2001). The catalog contains 3814 quasars, 3000 discovered by the SDSS, and is available at a public web site. We anticipate that future editions of the catalog will coincide with project data releases, and that the next edition of the catalog will contain more than 20,000 new quasars.

Stars Working Group

1. Cataclysmic variables and white dwarf/M dwarf pairs: Szkody et al. (2002) identified 22 CVs in the first year of SDSS spectra; 19 are new and 3 are recoveries of known systems. Follow-up photometry and spectroscopy of three of the new CVs revealed two as short orbital period dwarf novae and one as an unusual eclipsing magnetic CV. An exciting result is that we are picking up the faint, low mass-transfer systems missed in previous surveys that sampled only brighter objects. We have also isolated a sample of about 100 white dwarf/M dwarf pairs. We fit these pairs with white dwarf and M dwarf models to obtain temperatures and spectral types of the components. Velocity information is being used to determine which are close pairs that could be precursors of CVs and also to relate the rotation rate to the H alpha activity level.

2. White dwarfs: White dwarfs hotter than 8000K and cooler than 4000K have distinctive colors. Spectra of hot WDs give excellent spectral types and initial determination of surface gravities and atmospheric compositions. Numerous unusual white dwarfs have been discovered already from the SDSS spectra, including several magnetic stars with lines split by the Zeeman effect, a peculiar DQ star with very strong carbon bands, and several unusual DZ stars. One extremely cool DC star with strong absorption from molecular hydrogen has been found (Harris et al. 2001).

3. Carbon stars: Recent work (Margon et al. in prep) reports the discovery of 39 faint high-latitude Carbon stars, doubling the number of previously known such objects. They show a diversity of temperatures as judged by both colors and NaD line strengths. Proper motions indicate that the sample is a mixture of extremely distant (>100 kpc) halo stars and nearby dwarf carbon (dC) stars. The observed kinematics suggest that the dwarfs occupy distinct halo and disk populations.

4. An object with a bizarre spectrum: A serendipitous spectroscopic discovery of an unusual star showed that redward of 7000A, the spectrum appears to be a normal mid-M dwarf, while the blue spectrum is characterized by two giant humps centered near 4600A and 6000A, each approximately 1000A wide. Anderson et al. (in prep) found that the object exhibits a periodic, nearly sinusoidal, light curve with a period of about four hours, and that the humps in the spectra vary in cadence with the light curve. This may be a highly magnetic type of CV known as a polar, with a magnetic field exceeding 60 MG, resulting in cyclotron humps that change throughout the orbit due to viewing angle. However, there are aspects of the spectra that have not been seen in other polars (e.g. extreme amplitude of the humps).

5. Emission line stars: Low- and very-low-mass stars exhibit UV excess and Balmer emission due to magnetic activity. Such stars include the classical T Tauris that undergo magnetospheric accretion, the chromospherically active flare stars (dMe), and weak-lined T Tauris. We have determined photometric selection criteria based on reddening-invariant combinations of the SDSS passbands suitable for use within the Orion star formation region and the high-latitude translucent and dark molecular clouds found in the survey. Follow-up spectroscopy has been successful in the identification of a number of T Tauri candidates (McGehee et al. 2001).

6. Low mass stars and brown dwarfs: Hawley et al. (in prep) characterized the Sloan colors and spectra of M and L dwarfs in the EDR. The color-color and color-spectral type plots provide the means to compare Sloan data with other infrared and optical photometry and spectroscopy. In addition we present photometric and spectroscopic parallax relations and find that either the spectral type, or a combination of optical and infrared colors, are most useful to obtain reliable distances.

Several other important results from Sloan data were published in the past year. These include a combination of infrared photometry (Leggett et al. 2001) and spectroscopy (Geballe et al. 2001) leading to a definition of the T dwarf spectral sequence. The majority of T dwarfs known have been discovered with the SDSS, and preliminary results indicate that the space density of T dwarfs is about 1 object per 100 cubic parsecs, consistent with a declining IMF, assuming current evolutionary models. Late L dwarfs (later than L5) have a magnitude-limited surface density approximately four times higher than that of T dwarfs, corresponding to a volume density about 1.5 to 2 times higher than that of T dwarfs (Knapp et al. in prep).

7. Supernovae: Two supernovae were recently detected (IAU Circulars 7731 and 7440) in repeated imaging scans. These objects were detected within a few days of the acquisition of the images. Sophisticated image subtraction techniques allowed suppression of sources that had not varied while enhancing those that had brightened. The depth of the SDSS allows us to find supernovae at redshifts between 0.1 and 0.3, which is presently under-represented on the SN Hubble diagram.

8. Thick Disk and Halo: Using star count analyses, Chen et al. (2001) showed a clear difference in the turnoff color between thick disk and halo populations. The best-fit model gives a thick disk scale height between 580 and 750 pc, lower than the original proposal of Gilmore and Reid. The thick disk may have formed through the heating of a preexisting thin disk, created through merger of a satellite galaxy with the Milky Way.

9. Halo Substructure: Newberg et al. (2001) analyzed star counts of a larger section of SDSS data. They found significant spatial substructure in the bluer turnoff stars that Chen et al. had assigned to the halo population. One over-dense region is expected to be a cross-section through a halo streamer, near the previously discovered Sagittarius dwarf streamer. The proximity to the Sagittarius dwarf streamer raises the question of whether this new streamer is also associated with the disruption of the Sagittarius dwarf galaxy, but the color of the turnoff stars does not support this.

   The SDSS finds many more stars near the Galactic plane at the anti-center than are expected from standard models of the thin disk, thick disk, and halo populations. These stars could be part of a previously undiscovered, tidally disrupted dwarf galaxy hiding in the plane of the Milky Way, or the stars could be a manifestation of a metal-weak thick disk, with scale height close the 2 kpc and scale length nearly 10 kpc. If all of the stars near the Galactic center are attributed to a smooth component of the Galactic halo, then a very flattened halo with c/a ~ 0.5 is implied, consistent with results of Chen et al. (2001). However, power-law stellar distributions are not very good fits to the data.

10. Tidal Tails: We are also studying streams in the halo by looking for tidal signatures in and around globular clusters and dwarf spheroidal companions of the Milky Way. These studies constrain cluster and satellite orbits, their mass-loss history, their dark matter content, and the Galactic potential as a function of radius. The observed stellar populations of the targets are used to define an efficient multi-color filter that reduces the density of Galactic field contaminants by more than an order of magnitude. With this technique Odenkirchen et al. (2001a) discovered two extended, well-defined tidal tails emerging from the sparse halo cluster Palomar 5. At least one third of the cluster mass is contained in its tails, indicative of substantial mass loss and impending destruction. The orientation of the tails led to an improved determination of the tangential motion and orbit of Pal 5. New scans have been used to trace the tails out to an angular distance of 4 degrees from the cluster and to

determine their curvature. Rockosi et al. (2002) find that, of the total number of Pal 5 stars detected both within the cluster's tidal radius and in the tails, 45% of the total are out in the tails. The annular-averaged density of stars along the tails is fit to a power-law in radius with best-fit index -1.58, significantly steeper than that predicted from a constant orbit-averaged mass-loss rate.

The same technique used by Odenkirchen et al. for Pal 5 was applied to the Draco dwarf spheroidal galaxy and revealed a highly regular structure without any indication of extratidal features (Odenkirchen et al. 2001b). The surface density profile is well described both by a King model and an exponential Sersic profile. The deeper SDSS data show Draco to be 40% larger and twice as massive than measured in previous studies. The results strengthen the case for a strongly dark-matter dominated, bound stellar system.

Large-Scale Structure Working Group

A series of papers has analyzed a rectangular stripe with dimensions 2.5 degrees x 90 degrees.

Results on the angular two-point correlation function were reported by Scranton et al. (2001) and Connolly et al. (2001). The form of the correlation function over the magnitude range 18 to 22 was shown to be consistent with results from wide-field photographic surveys and narrower CCD surveys. On scales between 1 arc minute and 1 degree the correlation function is well described by a power-law with an exponent of -0.7. The amplitude of the correlation function within this angular interval is smaller at fainter magnitudes, in good agreement with analyses from existing galaxy surveys. There is a characteristic break in the correlation function on scales of 1 to 2 degrees. On scales of less than one arc minute, the correlation function does not appear to be consistent with the power-law form fitted to the $1 \text{ arcmin} < \theta < 30 \text{ arcmin}$ data. Because of the limited area and the highly correlated nature of the error covariance matrix, these initial results do not yet provide the definitive characterization of departures from the power-law form at smaller and larger angles.

The first measurements of clustering in the SDSS galaxy redshift survey were reported by Zehavi et al. (2001). Their sample consists of 29,300 galaxies with redshifts $0.019 < z < 0.130$, distributed in several long but narrow (2.5 to 5 degree) segments. For the full, flux-limited sample, the redshift-space correlation length is $8h^{-1}$ Mpc. The two-dimensional correlation function shows clear signatures of both the small-scale, "fingers-of-God" distortion caused by velocity dispersions in collapsed objects, and the large-scale compression caused by coherent flows, though the latter cannot be measured with high precision in the present sample. The inferred real space correlation function is well described by a power law with slope -1.75. The galaxy pairwise velocity dispersion is ~ 600 km/s for projected separations from $0.15\ h^{-1}$ Mpc to $5\ h^{-1}$ Mpc. When the sample is divided by color, the red galaxies exhibit a higher and steeper real space correlation function and a higher pairwise velocity dispersion than do the blue galaxies. The relative behavior of subsamples defined by high/low profile concentration or high/low surface brightness is qualitatively similar to that of the red/blue subsamples. The most striking result is a clear measurement of scale-independent luminosity bias at separations less than 10 h^{-1} Mpc: subsamples with different absolute magnitude ranges have different real space correlation functions in the sense of having shorter correlation lengths at lower luminosity.

The large-scale angular power spectrum C_ℓ was computed from 1.5 million galaxies on angular scales $\ell < 600$ (Tegmark et al. 2001).The data set covers about 160 square degrees, with a characteristic depth of order 1 h^{-1} Gpc in the faintest ($21 < r < 22$) of four magnitude bins. Cosmological interpretations of these results were presented in Dodelson et al. (2001). The data in all four magnitude bins are consistent with a simple flat "concordance" model with nonlinear evolution and linear bias factors of order unity. Nonlinear evolution is particularly evident for the brightest galaxies. A series of tests suggest that systematic errors related to seeing, reddening, etc., are negligible, which bodes well for the much larger sample that the SDSS is currently collecting.

In Dodelson et al. (2001), Limber's equation was inverted to extract the 3D power spectrum from the angular results. This was accomplished using an estimate of the redshift distribution of galaxies in each of the four magnitude bins. The resulting 3D power spectrum estimates from $w(\theta)$ and C_ℓ agree with each other and with previous estimates over a range in wave numbers $0.03 < k\ h\ \mathrm{Mpc}^{-1} < 1$. The galaxies in the faintest magnitude bin ($21 < r < 22$, which have median redshift $z = 0.43$) are less clustered than the galaxies in the brightest magnitude bin ($18 < r < 19$ with median $z = 0.17$), especially on scales where nonlinearities are important. The derived power spectrum agrees with that of Szalay et al. (2001), who go directly from the raw data to a parametric estimate of the power spectrum. The strongest constraints on the shape parameter Γ come from the faintest galaxies ($21 < r < 22$), from which we infer $\Gamma = 0.14 + 0.11 - 0.06$ (95% C.L.).

Szalay et al. (2001) expanded the projected galaxy distribution on the sky over a set of Karhunen-Loeve eigenfunctions, which optimize the signal-to-noise ratio in the analysis. A maximum-likelihood analysis was used to estimate parameters that set the shape and amplitude of the three-dimensional power spectrum. This analysis gives a best estimate for $\Gamma = 0.188 \pm 0.04$ for a flat universe with a cosmological constant. The measurements contain signal from scales at or beyond the peak of the 3D power spectrum.

Counts-in-cells statistics of the angular distribution of galaxies were presented by Szapudi et al. (2001). The third and fourth moments of the cell counts, s_3 and s_4, constitute the most accurate measurements to date of these quantities (for $r < 21$) over angular scales from 0.015 deg to 0.3 deg. The statistics display the approximate hierarchical scaling expected from non-linear structure formation models and are in reasonable agreement with the predictions of Λ-dominated cold dark matter models with galaxy biasing suppressing higher order correlations at small scales. The results are in general consistent with previous measurements in the APM, EDSGC, and Deep-range surveys.

Other Results

The parallax of a main belt asteroid is several arc seconds in the roughly five minutes it takes an object to traverse the five filters of the SDSS imaging camera. This is large enough to be recognizable by the photometric pipeline, and this is explicitly taken into account in doing object photometry. Thus we can measure the colors, apparent magnitudes, and (by the size of the parallax) distances of many thousands of asteroids. Ivezic et al. (2001) have studied the properties of roughly 10,000 asteroids seen in the SDSS commissioning data. SDSS photometry is good enough to show the color distinction between the two main classes of asteroid, carbonaceous and rocky; the latter tend to have orbits with smaller semi-major axes. Assuming the albedos of these two classes allows the inference of their sizes. The size distribution is well-fit by a broken power-law. The numbers of smaller asteroids (which are numerically the majority, of course) are lower than previous estimates.

Gamma-ray bursts (GRBs) are among the most enigmatic events in the heavens. They are often accompanied by afterglows seen in optical bands, observations of which give tight constraints on the physical nature of the GRBs. The SDSS photometric and 2.5-m telescope observed the optical afterglow of BRG010222 (Lee et al. 2001). The photometry shows a power-law decline with time, and a power-law spectral energy distribution. There is an intriguing deviation from this power-law; the u band shows 20% less flux than the power-law would provide. This is a new feature, not previously seen in GRB spectra, which was enabled by the superb SDSS photometric calibration.

7. Outreach and Communication

The SDSS collaboration is engaged in a broad, widely dispersed outreach effort, which reflects the extended geographic distribution of the participating institutions and the participants. This effort has major components for graduate education, communication of the findings derived from the Archive within the collaboration and to the scientific community, and communication of the excitement of the discoveries in astronomy, astrophysics, and cosmology made with the Archive to the public through its closely linked websites, http://www.sdss.org/ and http://skyserver.fnal.gov/en/. The SkyServer provides readily understandable material about the SDSS and current developments in astronomy, astrophysics, and cosmology to K-12 and college students and their teachers. As noted in Section 4, it also gives the public access to the SDSS Archive. The SDSS web site provides the status of the survey, information on research topics submitted for publication, policies for governance and publication, and access to the Archive. It also provides the most recent press releases on research results obtained by the SDSS Collaboration.

Graduate and Undergraduate Education

In the short time since the project delivered the first SDSS commissioning data to the collaboration, seven students have completed their PhD and begun careers in the disciplines that the SDSS touches. During the past year, Drs. Xiaohui Fan, Rita Kim, and Constance Rockosi defended their dissertations and joined astronomy and astrophysics departments at SDSS institutions. Drs. Fan and Rockosi were awarded Hubble Fellowships this year. The three recent graduates, together with four others who completed their dissertations prior to 2001, were awarded Builder Status and Participant Status for their exceptional contributions to the building of the SDSS project infrastructure. The former is an honor that recognizes two years of exceptional service to the project. The latter allows them to have access to the complete SDSS

Archive, irrespective of their future institution, and entitles them to give their future students access to the Archive as well. They are actively exploiting the SDSS Archive and many have been lead authors on papers that were published in peer-reviewed journals. There has been a renaissance of all-sky surveys brought on by vastly improved technology and extraordinary science opportunities. The current and future SDSS graduates are well trained and in an excellent position to emerge as leaders of this next generation of surveys. Already some of them are among the pioneers who are creating the framework for the National Virtual Observatory.

As the year ended, 25 students were working on PhD dissertation topics based on SDSS data. The list of these topics, which is posted on the SDSS collaboration website, is presented in Appendix C. In the context of outreach, it is noteworthy that almost half of these are students working with External Participants, scientists who are not on the staff of participating institutions.

The large quantities of superb, reduced SDSS data allow students, including undergraduates, to dive into real research with little or no overhead. Undergraduates have carried out significant research projects while working with groups in the SDSS institutions as well as with groups led by SDSS External Participants. Undergraduate students have also made key contributions to the SDSS instrumentation and software. The total number of undergraduates that have participated in SDSS activities is at least 25. At present count, 25 undergraduate students and one high school student are among the authors of SDSS papers.

The Role of the Collaboration Council in the Communication of Findings

The Collaboration Council (CoCo), under the leadership of the Scientific Spokesperson, plays an important role in the dissemination of the research findings derived from the Archive to the scientific community. The membership of CoCo consists of one person from every participating institution and one person selected from the External Participants by the Spokesperson. Given that there are more than two hundred people in the collaboration who are actively working with the Archive and that the locations of the participating institutions span the northern hemisphere from Germany to Japan, coordination is essential. Many venues are used to communicate the activities of the collaboration; including collaboration meetings and workshops, meetings of learned societies, and our websites. CoCo establishes publication policies, organizes collaboration meetings, and assists the Scientific Spokesperson in the selection of topics and speakers for major scientific meetings.

Collaboration Meetings

Collaboration meetings are held twice a year, rotating among the participating institutions. Typically, about one hundred people participate in each meeting. CoCo selects the meeting location and serves as the scientific organizing committee for the meeting. The host institution is responsible for the scientific program and the organization of the meeting. In 2001, the spring meeting (March 30 – April 2) was held at Fermilab. The collaboration meeting featured tutorials on the use of the Catalog Archive Server interface and its query tool, because the Early Data Release was scheduled to be delivered to the public at the June meeting of the AAS. It also provided opportunities for collaborative work prior to the EDR. The fall meeting (October 23 –

25) was held in Kyoto, Japan. This meeting featured special working sessions on the status of photometric calibration, planning the Survey of the Southern Equatorial Stripe, and discussions of potential connections with the Subaru and LAMOST projects. Both meetings included Working Group sub-meetings and plenary presentations of current research. The project management team also presented the status of the project at each meeting. The participating institutions and ARC made a special effort to provide support for graduate students and younger members of the collaboration so that they could attend these meetings and make presentations of their work. The spring 2002 meeting will be held in Heidelberg (March 21-23) under the auspices of the Max Planck groups and the 2002 summer meeting will be held at Princeton University (July 22-28).

American Astronomical Society Meetings

The SDSS was represented at both AAS meetings in 2001: January (San Diego) and June (Pasadena). At the January meeting, we organized a Special Session on early results from the SDSS, and at the June meeting, we organized a Special Session more specifically on Quasars. The June meeting also featured a press conference (and associated press release) on some of the most topical discoveries, as well as the EDR, the first formal release of SDSS data to the public. The use of the SDSS databases and the mining tools were demonstrated at the SDSS exhibit booth.

SkyServer and Education

One of the most important outreach elements of the SDSS is the SkyServer http://skyserver.fnal.gov/en/, which is an ambitious undertaking to provide astronomy education materials to students and their teachers. It was created under the leadership of Alex Szalay of Johns Hopkins and Jim Gray of the Microsoft Bay Area Research Center and unveiled to the public at the June AAS meeting. Since then it has served the EDR data to the public as well as to astronomers. It has served about 2.4M web hits, about 970K web pages, via 89K sessions to 68K "users" (ip addresses), since 5 June 2001. The site is under active development and it has evolved through 3 web interface designs (the newest design went live 3 January 2002).

SkyServer is more than an access portal for SDSS data – it is a complete resource for educators. The educational material is being developed by Robert Sparks, a high school teacher who is the Fermilab Teaching Fellow for the academic year 2001-2002, and Jordan Raddick, a science writer at Johns Hopkins. They have prepared more than 15 lesson plans on topics in astronomy, astrophysics, and cosmology for intermediate school, high school and undergraduate students. In each lesson, students look at and analyze SDSS data to learn interactively. Each lesson includes a teacher's page, with sample student responses, teaching advice, and correlations to national education standards. In the past six months, more than 70 teachers have signed up for access to the teacher's part of the site, and several high schools have elected to be test sites for the web-based educational material. SkyServer has become a way of mining the SDSS Archive as mentioned in Section 4.

SkyServer has been promoted at several conferences attended by teachers. Robert Sparks and Jordan Raddick exhibited SkyServer at last summer's Astronomical Society of the Pacific meeting in St. Paul. They presented a poster and a talk on educational uses of SkyServer at the American Association of Physics Teachers Winter meeting in Philadelphia. Plans are underway for presentations at future conferences and workshops, including invited presentations at two workshops for teachers: one at the Wright Center for Science Education at Tufts University, and one at the University of Texas at Brownsville.

8. Financial Performance: 2001 Budgets and Costs

The operating budget that the Advisory Council approved in November 2000 for the year 2001 consisted of $1,938K of in-kind contributions from Fermilab, US Naval Observatory (USNO), and Los Alamos National Laboratory (LANL); and $4,000K for ARC funded expenses. In November of 2001 we confirmed our earlier tentative conjecture that we could contain the cash funded expenses to $3,400K, well below the planned level. The SDSS Management requested that the ARC funded budget for 2001 be reduced to $3,400K and that the 2001 budget for in-kind contributions be increased to reflect the actual contributions. The sources of funds for the revised 2001 budget are shown in Table 8.1.

Table 8.1. Sources of Funds for the 2001 Budget ($K)

Sources of Funding	Cash	Actual In-Kind	Total
A. P. Sloan Foundation	2,000		2,000
Japan Participation Group	185	40	225
National Science Foundation	618		618
Prior year funds	515		515
New partner funds	82		82
Fermilab		1,831	1,831
Los Alamos National Laboratory		225	225
United States Naval Observatory		106	106
Total	3,400	2,202	5,602

The initial ARC-funded cash budget of $4,000K included $447K for management reserve. Since our review of our cost performance through October 2001 showed that the estimated expenses for 2001 would be $3,230K, the management reserve was reduced to $170 K and $600K of the unused funds from the original 2001 budget were allocated to the management reserve in calendar years 2003 and beyond. In January 2002 the actual cash-funded expenses for all of 2001 were reviewed again and found to be slightly lower than had been forecast in November. Table 8.2 shows the actual cost performance by project area for ARC-funded cash expenses in 2001.

Table 8.2. Summary of ARC-Funded Cash Expenses for 2001, by Project Area ($K)

Category	Baseline Budget (Nov 2000)	Revised Budget (Nov 2001)	Actual Expenses

Survey Management	274	220	221
Observing Systems	1,095	956	967
Data Processing and Distribution	696	648	640
Observatory Support	1,320	1,318	1,336
ARC – Corporate Expenses	168	88	82
Sub-total	3,553	3,230	3,246
Management Reserve	447	170	0
Total	4,000	3,400	3,246

After the final books for 2001 are closed, any remaining unspent management reserve funds will be placed in the management reserve for 2002.

Table 8.3 compares the budgeted and actual in-kind contributions in 2001 by institution and Table 8.4 shows the distribution of in-kind contributions by project area. The estimated value of the in-kind contributions in 2001 was $2,202K. In-kind contributions exceeded the 2001 budget by $264K for the following reasons: Fermilab was required by the Department of Energy to revise the way it accounted for vacation and sick leave. Previously, these costs were included in the overhead, which was not included in the in-kind costs. We also made a more accurate accounting of the administrative support that Fermilab had directly assigned to the project, but had not been included in the in-kind costs. Although these changes increase the cost of the in-kind support, they do not represent an increase in the Fermilab scope of work. Since Fermilab did not complete the slip detection system and the interlock systems in 2000 as planned, the costs of this work were accrued in 2001. The in-kind contributions were also larger because the full level of in-kind contributions made by LANL in 2001 had not been included in the 2001 in-kind budget. LANL provided engineering support to expand the capability of the telescope performance monitor and an astronomer for photometric telescope observations throughout the first half of 2001. The USNO group was able to reduce the level of effort that it provided to the project while delivering the scope of work that they had agreed to provide. Finally, the in-kind contribution for work performed by the JPG was not included in the 2001 budget when it was prepared in November 2000.

Table 8.3. Budget and Costs for the 2001 In-kind Contributions, by Institution ($K)

Institution	Baseline Budget (Nov 2000)	Revised Budget (Nov 2001)	Actual In-kind Contribution
Fermilab	1,540	1,845	1,831
Los Alamos National Laboratory	180	210	225
United States Naval Observatory	218	113	106
Japan Participation Group	0	40	40
Total	1,938	2,208	2,202

Table 8.4. Summary of In-kind Contributions, by Project Area ($K)

Category	Baseline	Revised	Actual

	Budget (Nov 2000)	Budget (Nov 2001)	In-kind Contribution
Survey Management	284	218	229
Observing Systems	419	767	810
Data Processing and Distribution	1,235	1,223	1,163
Total	1,938	2,208	2,202

The costs for 2001 are preliminary, since the actual costs incurred by some institutions will not be reported until the end of the first quarter of 2002. The preliminary costs are based on our review of requisitions and other commitments made by the participating institutions through December. In the past this provided an accurate guide for the actual cost. Details on the use of funds obtained from the Sloan Foundation and the National Science Foundation are provided in Appendix A.

9. Financial Planning: 2002 Budget

On November 20, 2001, the ARC Board of Governors approved a budget of $5,716K for the year 2002. The 2002 budget is fully funded. It consists of $3,425K in cash provided by ARC, including a management reserve of $200K, and in-kind support from the MOU Partners with an estimated value of $2,291K. The sources of funds for the 2002 budget are shown in Table 9.1.

Table 9.1. Sources of Funds for the 2002 Budget ($K)

Sources of Funding	Cash	In-Kind	Total
A. P. Sloan Foundation	2,000		2,000
National Science Foundation	955		955
Japan Participation Group	200		200
Prior year funds	270		270
Fermilab		1,903	1,903
Los Alamos National Laboratory		231	231
United States Naval Observatory		117	117
Japan Participation Group		40	40
Total	3,425	2,291	5,716

The funds from the A.P. Sloan Foundation are from a commitment to award ARC $10,000K for the observation phase of the Five-Year Baseline Survey. The initial award was made in December 1999 and to date the A.P. Sloan Foundation has awarded ARC $7,000K for the Five-Year Baseline Survey. The award of the remaining $3,000K is subject to making satisfactory progress on the survey. The funds from the National Science Foundation shown in table 9.1 are in expectation of the receipt of $955K from a multiyear grant of $4,000K awarded to ARC in August of 2001. The amounts anticipated in 2002 and beyond are subject to fulfilling the terms of the grant. The funds from the Japan Participation Group represent their commitment to purchase $200K in supplies (primarily finished plug plates).

With regard to in-kind contributions, Fermilab will provide support for observing, data processing, and data distribution operations, and for survey management. Los Alamos will provide support for observing software maintenance and data quality assurance. The U.S. Naval Observatory will provide support for data processing software, and the Japan Participating Group will provide technical support for the imaging camera.

Table 9.2 shows the allocation of the 2002 cash funds by project area and compares the 2002 budget to the actual 2001 cash expenditures in each category.

Table 9.2. Allocation of 2002 Cash Funds, by Project Area ($K)

Category	2001 Actual Expenses	Approved 2002 Cash Budget
Survey Management	221	265
Observing Systems	967	868
Data Processing and Distribution	640	644
Observatory Support	1,336	1,360
ARC – Corporate Expenses	82	88
Sub-total	3,246	3,225
Undistributed Contingency	0	200
Total	3,246	3,425

Table 9.3 shows the distribution of anticipated in-kind contributions by project area, along with a comparison of the estimated value of actual 2001 in-kind contributions.

Table 9.3. Distribution of 2002 In-kind Contributions, by Project Area ($K)

Category	2001 Actual Expenses	Approved 2002 Budget
Survey Management	229	196
Observing Systems	810	836
Data Processing and Distribution	1,163	1,259
Total	2,202	2,291

Financial Planning: Funding Requirements

In order to complete the five-year survey and to pay outstanding invoices from the construction phase of the project, we will need to raise an additional $2.5 million. The estimate of $28 million for the five-year observing phase of the Survey does not include project closeout costs. We will develop a closeout plan and a cost estimate for the closeout during the first half of 2002 and submit it to the Advisory Council for their consideration. The Advisory Council has authorized the SDSS Director to develop options for a six-month extension of the survey from July 1, 2005 to December 31, 2005. The major purpose of the extension would be to obtain additional 5-color images of the Southern Equatorial Stripe and to obtain spectra of some special targets, which would enhance the quality of the data taken during the first five years of observations. This proposal will be prepared during the second quarter of 2002 and submitted to the Advisory Council for their consideration, with the expectation that it will be submitted to one of the funding agencies in the fall of 2002.

During 2001, our fundraising efforts were largely limited to responding to the questions raised by the NSF on the proposal that we submitted to them for $5M. Following an extensive review of the proposal during the last quarter of 2000 and the first quarter of 2001, the NSF asked us to revise our management plan and to prepare a detailed data release plan. This was done and the NSF accepted these plans and subsequently informed us in June that we would be awarded $4 million spread over four fiscal years beginning in FY2001. It is important to note that the NSF award makes no provision for funding the Survey of the Southern Equatorial Stripe during the third quarters of 2003, 2004, and 2005. This is the time when the Northern Galactic Cap is not visible at APO. We must seek funds for operations, data processing and data distribution for this part of the survey.

We continued to seek new partners when it made sense. We anticipate reaching an agreement on an MOU with Los Alamos in the first quarter of 2002, which will give a limited number of Los Alamos scientists access to the SDSS data prior to its release to the astronomical community in exchange for the valuable in-kind contribution that Los Alamos has made over the last several years and their commitment to continue to provide this in-kind support at its current level. Negotiations have begun with the University of Pittsburgh to join the SDSS as an Affiliate Member. While these discussions began nearly two years ago, there is a now good prospect that Pitt will be able to meet our financial requirements. At this time, there is no plan to seek additional new partners.

The fact that the attention of SDSS Management is now turning to closing out the project is actually a positive sign, since it means that the long and difficult struggle to build and operate the survey is in hand. It is now time to think about what lies beyond the five-year survey. The prospects for funding the complete project are excellent.

10. Outlook for 2002

Our goals for 2002 are to bring the efficiency for the acquisition of new data to the baseline efficiency goals, to complete the reliability and equipment protection improvements that will improve observing efficiency, to bring the photometric calibrations up to the final accuracy requirements, and to deliver DR1 to the astronomical community as scheduled in January 2003.

The New Observing Plan

We have formulated a two-step recovery plan that will enable us to achieve the goals of the five-year baseline plan. The first step will bring the efficiency up to the level that is needed to reach the baseline rate for the acquisition of new data. We will do this by completing the program of improvements, which was begun in 2001, for Observing Systems and our observing procedures. The second step will compensate for the accumulated loss of observing time during the first eighteen months of scheduled operations and any additional loss of observing time that might occur because of inefficient operations or poor weather in 2002. We will do this by allocating more time to imaging than was allocated in the baseline plan while maintaining the amount of time allocated to spectroscopy. We can do this because the amount of time allocated to imaging in the baseline plan decreases after the third quarter of 2002. While we will have to decrease the amount of time allocated to spectroscopy during dark time, the time when the moon is down, we can maintain the overall amount of time allocated to spectroscopy by allocating most or all of the gray time to spectroscopy, the time when the moon is up and limited observations are feasible. Gray time was not included in the five-year baseline plan. Prior to the summer shutdown of 2001, some of the gray time was used for engineering tests and much of the rest was used to test bug fixes to the operations software. Since then, we have been able to decrease the amount of time that we allocate to engineering tests and the number of software bugs is declining.

We plan to allocate the same number of hours per year to imaging between Q4 2002 and Q4 2004 as we allocated to imaging between Q4 2001 and Q4 2002. This can increase the amount of imaging data relative to the baseline plan by 1,400 square degrees. Of course, we must reach the baseline efficiency in 2002 in order to take full advantage of the added imaging time. Furthermore, we must demonstrate that gray time can be effectively used for spectroscopy and that this time can compensate for the decrease in the dark time allocated to spectroscopy. We demonstrated in the fourth quarter of 2001 that we could obtain survey quality spectroscopic data during gray time by making the exposures longer, thereby providing the desired signal-to-noise ratio in the presence of moonlight. While the efficiency of spectroscopic operations is poorer during gray time than in dark time, there is sufficient gray time to meet our goals. Since the baseline plan allocated only 10% of the dark time in 2004 and 2005 to imaging, a modest increase in imaging time will have a small impact on the much larger spectroscopic budget. While the uncertainty of the weather makes it difficult to forecast our performance for the next three and a half years, we plan to reach the baseline goals for data acquisition before the survey ends on June 30, 2005.

In order to reach our efficiency goals for 2002, we will complete the program of improvements to Observing Systems that was underway in 2001. We also plan to increase the reliability of operations and equipment protection, since poor reliability or the failure of a critical piece of equipment could derail our recovery plan. We will continue to identify and eliminate the factors that degrade the image quality, much as we did in 2001. The close coupling of the efficiency of observations with image quality demands that we do this. Finally, we will continue to review potential workplace hazards and make improvements that provide a safe working environment for the SDSS staff at APO.

The highlights of the hardware and software improvements to Observing Systems planned for 2002 are described in the text that follows.

Observing Systems Hardware Improvements

The needed hardware improvements that were identified during the past year were reviewed and prioritized at an engineering planning meeting held in December 2001. Of these tasks, six deserve a description since they were not mentioned earlier.

1. Enclosure Stair Upgrade. The stairs leading from the telescope level to the lower level, through the floor hatch, pose a hazard. A new staircase is being designed to replace the existing temporary staircase with a permanent structure that will reduce the angle of the stairs and incorporate better handrails. The design will also allow gas cylinders to be lowered through the hatch opening in a safer manner. We plan to install the new staircase in the second quarter of 2002.

2. Instrument Change Interlocks. While the observers have been able to make instrument changes routinely, their procedures do not adequately protect the instruments. We had planned to obtain the desired equipment protection system through a computer-assisted instrument interchange system, since we thought that it would also decrease the time for instrument change. Since the observers had become quite skilled in changing instruments, we realized that the computer assisted instrument change system would not bring a significant reduction in the time required to change instruments. We chose to substantially descope the proposed system by relying exclusively on interlocks, which minimize mistakes. The new hardware consists of more and better status-gathering sensors and a programmable interlock system. The hardware was installed in the last quarter of 2001 and firmware was changed to implement the new model for instrument changes. The first version of the new code was tested in December 2001. The tests revealed the need for minor revisions, which will be made during bright time in the first quarter of 2002. We expect that the system will be fully operational by the end of the first quarter of 2002.

3. Emergency Power for closing the 2.5-m Telescope Enclosure. There is a risk that it will not be possible to move the roll-away enclosure onto the telescope in the event of a site power failure. While there is a backup generator at the site, it has not been as reliable aw we need to protect the camera. Since power failures and bad weather are highly correlated, we concluded that a small generator capable of moving the enclosure would be excellent insurance. The generator will be procured and installed in the first quarter of 2002.

4. Thermal Environment Improvements. Although we removed a significant number of heat sources from the lower enclosure, it is still several degrees above the temperature of the outside air. We plan to install louvers in one of the lower enclosure walls to provide a flow of cool outside air through the enclosure, thereby reducing its temperature. We will also finish installing the plumbing that will provide a flow of cool glycol to the flat field lamp assemblies, which are located in the telescope. Since they get quite hot when used and they have a thermal time constant of approximately 30 minutes, they can degrade image quality even after they have been turned off. This cooling system will be operational in the first quarter of 2002.

5. Spectrograph Radiator Replacement. The aluminum radiators, which are used to extract heat generated by the spectrograph electronics, are becoming corroded. Since the plumbing that

delivers the glycol to the radiator is copper, replacing the aluminum units with copper units will eliminate the problem.

6. Relocation of the DIMM. The Differential Image Motion Monitor (DIMM) at the site is functional, but its location was poorly chosen. The data derived from its measurements did not provide useful predictions of the 2.5-m seeing. The DIMM will be moved to the pier of the 2.5-m telescope building and this new location will permit measurements at several points around the sky. These measurements will provide much better predictions of the 2.5-m seeing, thereby allowing the observers to make more informed decisions on whether to do imaging or spectroscopy. As the year ended, design requirements were being reviewed. The conceptual designs will be completed during the first quarter, with the expectation that the DIMM installation and commissioning will be completed by the end of the 2002 summer shutdown.

Table 10.1 presents all of the significant tasks that we plan to complete in 2002. They include those that we deferred a year ago in order to give priority to completing the most critical thermal improvements. We developed this list by allocating the resources that will be available in 2002 to these tasks and prepared a preliminary schedule for their completion as part of the December planning meeting. A more detailed schedule that will allow us to track our progress will be completed in the first quarter of 2002.

Table 10.1. Scheduled Observing Systems Tasks for 2002.

Task	Responsible	Driver	Priority
Instrument change interlocks (completion)	Anderson	Equip. Prot.	High
Imager non-linearity measurements	Kleinman	Data quality	High
Enclosure stair upgrade	Carey	Safety	High
Photometric Telescope enclosure platform	Klaene	Safety	High
Flat field screen arc lamp cooling system	Leger	Efficiency*	High
Spectrograph radiator replacement	Leger	Reliability	High
Secondary mirror actuator bellows upgrade	Carey	Reliability	High
2.5-m lower enclosure louvers	Klaene	Data quality	High
Azimuth fiducial read-head mount upgrade	Leger	Efficiency	High
Science fiber curvature modification	Carey	Reliability	High
Aluminize PT, secondary, and primary mirrors	Leger	Data quality	High
Execute PM program for telescope systems	Leger	Reliability	High
Procure and install emergency closing generator	Leger	Equip prot.	High
Design/fab/install telescope counterweight upgrade	Carey	Reliability	High
Install secondary latch improvements	Gunn	Equip. Prot.	Medium
Design/fab/install DIMM telescope mount	Gunn	Data quality	Medium
Telescope Performance Monitor 2-CPU upgrade	McGehee	Reliability	Medium
Design/fab/implement cloud camera upgrade	Gunn	Data quality	Medium
Design/fab improved plug plate QA fixture	Carey	Efficiency	Medium
Finish implementation of slip detection system	Czarapata	Equip prot.	Medium
Design/fab improved plug plate drilling fixture	Carey	Efficiency	Medium

*Also affects data quality.

Observing Systems Software Improvements

The observers are able to use the software for observing systems to carry out observations, although they typically encounter small problems during the evening, which decrease the efficiency of observations. Through operating experience, they have identified a number of bugs that would improve efficiency if fixed. As noted earlier, there are opportunities to reduce the time to establish the initial focus, pointing and rotator alignment, by improving the software that manages these processes.

All but one of the observers' programs is under formal change control, and all are under version control. The outstanding program will be placed under change control in the first quarter of 2002, when the development work is completed. A thorough review and control process was put in place in the last quarter of 2001 to prioritize, plan, and schedule near-term development work on this software. Needs are reviewed and prioritized on a monthly basis. The process has worked well and has limited software changes to fix bugs or improve efficiency and reliability.

We have identified additional improvements that can be made to the guider software that will reduce the time to acquire a field. These include the implementation of a centroiding algorithm that can handle guide stars when they fall near the edges of a fiber and a better but still simple image correction for the guider images. Increasing the reliability and functionality of the guider camera hardware and image handling software will improve the efficiency of spectroscopic observations. We have also noticed that there is a substantial amount of diagnostic chatter over the slow communication links during the preparations for a spectroscopic observation and that may be slowing the startup. It should be possible to move the chatter in time so that it takes place during exposures when the system is relatively quiescent and is not waiting for instructions. It may be possible to find further reductions in time by carrying out certain operations in parallel that are currently done serially for the sake of modularity. We believe that this can be accomplished with relatively minor code changes.

A software planning meeting will be held in the first quarter of 2002 to allow management, software developers, and representatives of the observing staff to review the status of all observing system software. They will assess each area to determine if improvements are required to meet science requirements or efficiency goals, and then develop appropriate plans and schedules for long-term development efforts. Since the monthly review tends to react to short-term software problems, the planning meeting will give the participants an opportunity to create a strategy and vision that balances long-term code development and maintenance needs.

Photometric Calibration Improvements for 2002

We will have made substantial improvements in the photometry by the time the DR1 processing begins in earnest, but there will still be some tasks which may not have been completed, or at least not fully completed.

There are extensive QA tools to check the photometry, which are executed after the reductions. However, they do not feed back into the photometric solution. We plan to make changes so that the sky levels in the six scan lines of a strip are incorporated in the solution. There is strong evidence that their ratios are highly reproducible. By using the sky levels, we should obtain a more accurate relative calibration than the very sparse calibrations from stars in the PT patches. The method that we will use needs more study, but certainly will be applied before DR2, and there is some chance that it will be incorporated into the DR1 reductions. We plan to use the strip overlaps to tie the calibrations of the two strips of a stripe together, thereby creating a "monolithic" calibration for a stripe. The goal of these two together is to make the photometry within a stripe self-consistent across the whole stripe, although, it may vary slowly along the stripe. We must understand the new flattening procedure much better before this can be applied reliably. The flat fields have not been well behaved at the edges of the chips, where the overlaps occur, and we do not know whether the new procedures overcome these difficulties or not.

Finally, we will implement a system of binned cross scans, the ‘Apache Wheel’, to tie stripes together and pin the slowly varying calibration along stripes. The Apache Wheel consists of a series of scans that cross the regular drift scan strips at several different angles. They are intended to provide cross calibrations across many stripes. We have not been able to test this approach successfully because of hardware difficulties in the data acquisition system. These problems are being addressed and we hope to run a small pilot test in the spring. To take proper account of this technique will require writing a global calibration package, which takes account of the calibration at each step and its errors to produce a homogeneously calibrated product. Only the barest outlines of this code exist at the moment, and development will not proceed far without test data.

Preparations for Data Release 1

During 2002, we will reprocess and recalibrate all data taken to date in preparation for delivering DR1 to the astronomical community. This release will include all survey quality image data obtained prior to July 1, 2001 and the spectra of objects that were found in that data and obtained prior to January 1, 2002. It will consist of 2810 square degrees of unique image data, including complete coverage of the three stripes in the Southern Survey. It will include the spectra from 379 plates. The provisional classification of the 242,165 unique spectra from those plates includes: 168,911galaxies, 24,541 QSO candidates, 1,437 high-z QSO candidates, 31,709 stars, and 15,567 unknown. This data will be released to the astronomical community in January 2003.

DR1 is one of our primary goals for 2002 and a major effort is being undertaken to assure the quality of the data in this release. We developed a plan to improve the photometric calibrations, which was described earlier, and we expect to complete work in this plan during the first half of 2002. This will provide an improved calibration process that will be used to process the data for DR1. In addition, a data testing plan has been developed and we will use it to test the data quality in DR1. As noted earlier, we decided to implement the Catalog Archive Server using Microsoft SQLServer, provide query mechanisms for this database, and streamline the operation of the Data Archive Server. During 2002, we will prepare the DR1 data for the astronomical community using these new tools. As we continue to collect data, we will process it and provide it to the collaboration with these same tools.

Quality control and testing are vital phases in our preparations for DR1. Once we complete this testing, we expect to be able to define the requirements for the “final” set of data processing pipelines. We have always planned to reprocess the SDSS data, since we anticipated that we would learn from the data and use that knowledge to improve the pipelines.

Conclusions

We have an excellent plan to reach the objectives of the survey. In 2001, we substantially improved the telescope image quality and the efficiency of our observations. The image quality consistently meets, but not always, survey quality requirements. The efficiency of our observations is approaching the level we need. We will continue to improve the thermal environment of the telescope so that the image quality meets survey requirements more often. The level of this effort will be incorporated into our routine maintenance and repair effort since the big improvements have been made. We will also continue to work on improving the efficiency and we expect that we will reach our efficiency goals during 2002. We plan to put more emphasis on routine maintenance and repair in order to improve the reliability of the telescope and the instruments. At this time, our reliability is acceptable but small improvements will help to increase the efficiency. We are adopting a formal approach to maintenance in anticipation of the day when parts need to be replaced as they age.

The SDSS is now the second-largest galaxy redshift survey. As of the end of the year, we had obtained spectra of 170,000 galaxies and the number was increasing by 15,000 per month. The 2dF survey is the largest survey and it has obtained nearly 220,000 galaxy redshifts. The third largest is the Las Campanas Redshift Survey, which has about 50,000 redshifts. These surveys are complete. The SDSS redshift survey will exceed 250,000 redshifts by the middle of 2002 and it will grow to more than 800,000 redshifts by the end of the five-year survey. The two largest redshift surveys will complement one another since they observe different regions of the sky. The science will benefit greatly from the expanded coverage.

The number of redshifts is not the only measure of the quality of a redshift survey. The current uniformity of the SDSS redshifts survey is already substantially better than previous surveys. As a rule, most of the targets for the other surveys were selected from images obtained with photographic plates, which have inherently larger systematic errors than data obtained with a CCD camera. The SDSS spectroscopic targets are selected from the calibrated SDSS imaging data. Even with the present accuracy, we have obtained some stunning scientific results that eluded earlier surveys. It was the prospect of obtaining a high-quality, uniform sample of spectra of galaxies and QSOs was one of the motivations for the SDSS in the first place.

We will give photometric calibration and data distribution greater emphasis in 2002. The accuracy of our photometry is quite good when judged by older standards and the quality of the science that we produced in 2001 from the imaging data provides ample evidence for that statement. Nevertheless, our careful scrutiny of the imaging data during the past year and a half has shown us that we can make improvements. The plan that we described earlier in the report will allow us to reach the very demanding survey goals that we set for photometry and the improved photometry will allow us to get more science out of the photometric maps. When we make our first major release of data in January 2003, we want the data quality to be superb.

We now have a clear idea on what we need to do in order to release the data to the public in a useful form. The experiences that we gained with databases and data mining tools, show that we are on the right track. In 2001, we learned what we had to change to reach our objectives for data distribution and created a plan to meet these objectives. In 2002, we will implement that plan and reach our objectives.

The observing and data gathering phase of the five-year Baseline Plan has a duration of 63 months. By the end of 2002, we will have just passed the half way mark in this phase. Survey Operations will be mature and the first major release of the SDSS data barely a week away as 2003 begins. We are looking forward to an exciting year in 2002, now that we are confident that we can reach our goals.

Appendix A. Use of Funds from the A.P. Sloan Foundation and the National Science Foundation in 2001.

The funds from the A.P. Sloan Foundation and NSF were expended in 2001 on the project areas shown in Table A1.

Table A1. Expenditure of Sloan and NSF Funds on 2001 Costs ($K)

Category	A.P. Sloan Funds	NSF Funds
Survey Management	196	22
Observing Systems	724	85
Data Processing and Distribution	606	176
Observatory Support (APO/NMSU)	1,164	274
ARC Corporate Expenses	229	13
Total Expenditures of A.P. Sloan Funds	2,919	570

The expenditures in Table A1 are for payments made by ARC prior to January 1, 2002. All of the NSF funds awarded to ARC in 2001 were fully committed by the end of calendar year 2001. Details of the payments from the A.P. Sloan and NSF accounts between January 1, 2001 and December 31, 2001 are shown in Table A2. Each line lists the funds paid to a particular institution for the specific scope of work defined in the annual agreements between each institution and ARC. Each agreement has a specific SSP number and provides an initial budget for that SSP. During the year, the Project Manager and the Business Manager track the costs incurred by each SSP. They review all new commitments with the appropriate budget officer from each institution. All commitments in excess of $3,000 require the approval of the Director and the ARC Business Manager. Any changes in the personnel supported by ARC require a revision to the Agreement.

Some of the items deserve a few comments. The costs incurred by Fermilab for SSP48 and SSP40 are for travel, primarily between Fermilab and APO. The costs incurred by Fermilab for SSP42, Observing Systems Support, are primarily for parts and materials, including spares, for the 2.5-m telescope and for all other hardware systems in Observing Systems except the DAQ system. SSP42 also provides funds for travel expenses for the Fermilab employees stationed at APO. The costs associated with SSP22/25/55 were for work performed by the University of Pittsburgh in the fourth quarter of 2000. They appear in Table A2 because final invoices were not submitted and paid until April 2001.

Table A2. Payments from NSF and Sloan Accounts during 01/01/01 through 12/31/01
(Cash Basis)

SSP No.	Description	Inst	NSF Acct	Sloan Acct
Project Management and Survey Coordination				
SSP18/48	Survey Management	FNAL	0	15,455
SSP17/47	Project Spokesperson	UC	0	17,460
SSP16/46	PU Support for Project Management	PU	0	70,710
SSP14/59	JHU Support for Project Management	JHU	0	855
SSP15/60	UW Support for Project Management	UW	0	1,572
SSP62	JHU Software Testing and Validation	JHU	3,762	13,997
SSP63	UW Software Testing and Validation	UW	18,548	26,694
SSP64	NYU Software Testing and Validation	NYU	0	15,488
SSP22/25/55	CMU/UPitt Spectroscopic Scientist	CMU/UPITT	0	33,535
	Sub-total		22,310	195,766
Observing Systems				
SSP01/31	UW Observing Systems Support	UW	41,955	251,856
SSP02/32	PU Observing Systems Support	PU	33,237	100,565
SSP12/42	FNAL Observing Systems Support	FNAL	0	197,536
SSP03/33	UC Observing Systems Support	UC	0	48,447
SSP06/36	JHU Observing Systems Support	JHU	9,616	66,205
SSP19/20/50	JHU Photometric Telescope Commissioning	JHU	0	59,593
	Sub-total		84,808	724,202
Data Processing and Distribution				
SSP08/38	PU Software and Data Processing Support	PU	96,049	248,489
SSP09/39	UC Software and Data Processing Support	UC	13,143	52,850
SSP10/40	FNAL Software and Data Processing Support	FNAL	0	113,894
SSP61	FNAL Observing Software and DA Support	FNAL	0	0
SSP07/37	JHU Data Archive Development and Support	JHU	66,403	138,869
SSP24/54	JHU Photometric System Definition	JHU	0	32,444
SSP13/43	UMich Photometric System Support	UMICH	0	12,640
SSP41	IAS Photometric System Definition	IAS	0	6,406
	Sub-total		175,595	605,592
Observatory Support				
SSP05/35	NMSU Site Support	NMSU	274,050	1,164,440
	Sub-total		274,050	1,164,440
ARC Corporate Expenses				
SSP91	ARC Misc Corporate Expenses (see Table A3)	ARC	13,176	152,535
SSP04/34	ARC Business Manager	ARC	0	57,738
SSP21/51	ARC Secretary/Treasurer	ARC	0	17,798
SSP23	SDSS Dedication	UW	0	998
	Sub-total		13,176	229,069
Account Totals			**569,940**	**2,919,069**
Combined Total				**3,489,009**

Table A3. Details of 2001 Corporate Expenses Paid with NSF and Sloan Funds

Details of Misc Corporate Expenses		**Inst**	**NSF**	**Sloan**
SSP91	May & Nov AC Mtg	ARC	0	5,999
SSP91	V-Mill use fee	ARC	0	24,175
SSP91	AAS Meeting Booth Panels & Brochures	ARC	0	12,843
SSP91	Audit & Federal Reports	ARC	0	5,276
SSP91	Realuminize M1	ARC	11,000	0
SSP91	Site Petty Cash Account	ARC	0	19,906
SSP91	External review meetings	ARC	0	2,060
SSP91	Insurance	ARC	0	4,840
SSP91	Young Astonomer's Travel Assistance Fund	ARC	0	10,000
SSP91	AAS Travel expenses	ARC	0	6,244
SSP91	Thermal mitigation	ARC	0	28,225
SSP91	Compressed Air System Upgrade (split w/3.5m)	ARC	0	14,579
SSP91	Storage container rental	ARC	0	2,633
SSP91	Two SDSS computers for APO	ARC	0	2,193
SSP91	EMS Donation	ARC	0	3,600
SSP91	Hygrothermometer (split w/ 3.5m)	ARC	0	3,304
SSP91	Spectrometer (split w/3.5m)	ARC	2,176	0
SSP91	Page charges	ARC	0	6,562
SSP91	Misc small expenses	ARC	0	93
	Subtotal		13,176	152,535

Appendix B. List of SDSS Publications

Technical Papers

Chris Stoughton, et al. (2002), “Sloan Digital Sky Survey: Early Data Release”, *AJ*,123,485.

Daniel Eisenstein, et al. (2001), “Spectroscopic Target Selection for the Sloan Digital Sky Survey: The Luminous Red Galaxy Sample”, *AJ*,122,2267.

J. Allyn Smith, et al. (2001), “The u'g'r'i'z' Standard Star Network” *AJ* accepted

Science Papers

Anderson, S., et al., (2001), “High-Redshift Quasars Found in Sloan Digital Sky Survey Commissioning Data VI.”, *AJ*,122,503

Becker, Robert H., et al., (2001), “Evidence for Reionization at z~6: Detection of a Gunn-Peterson Trough in a z=6.28 Quasar”, *AJ*,122,2850

Bernardi, Mariangela, et al., (2002), “Early-type galaxies in the SDSS”, *AJ* submitted

Blanton, Michael, et al. (2001), “The Luminosity Function of Galaxies in SDSS Commissioning Data”,*AJ*,121,2358

Budavari, Tamas, et al., (2001), “Photometric Redshifts From Reconstructed Quasar Templates” *AJ*,122,1163

Castander, Francisco et al. (2001), “The First Hour of Extra-galactic Data of the Sloan Digital Sky Survey Spectroscopic Commissioning: The Coma Cluster”, *AJ*,121,2331

Chen, B., et al., (2001), “Stellar Population Studies with the SDSS I. The Vertical Distribution of Stars in the Milky Way”, *ApJ*,553,184

Connolly, Andrew, et al., (2002), “The Angular Correlation Function of Galaxies from Early SDSS Data”, *ApJ* submitted

Dodelson, Scott, et al., (2002), “The 3D Power Spectrum from Early SDSS Angular Clustering “, *ApJ* submitted

Fan, Xiaohui, et al., (2001), “A Survey of z > 5.8 Quasars in the Sloan Digital Sky Survey I: Discovery of Three New Quasars and the Spatial Density of Luminous Quasars at z~6”, *AJ*,122,2833

Fan, Xiaohui, et al., (2001), “High-Redshift Quasars Found in Sloan Digital Sky Survey Commissioning Data IV: Luminosity Function from the Fall Equatorial Stripe Sample”, *AJ*,121,54

Fan, Xiaohui, et al., (2001) “High-Redshift Quasars Found in Sloan Digital Sky Survey Commissioning Data III: A Color Selected Sample at i*<20 in the Fall Equatorial Stripe” *AJ*, 121,31

Geballe, T. R., et al., (2002), “Towards Spectral Classification of L and T Dwarfs: Infrared and Optical Spectroscopy and Analysis”, *ApJ*,564,466

Goto, Tomotsugu, et al., (2002), “The Cut & Enhance Method: Selecting Clusters of Galaxies from the SDSS Commissioning Data”, *AJ* accepted

Hall, Patrick B., et al., (2002), “Unusual Broad Absorption Line Quasars from the Sloan Digital Sky Survey”, *ApJ* submitted

Harris, Hugh, et al., (2001), “A New Very Cool White Dwarf Discovered by the Sloan Digital Sky Survey”, *ApJ*,549,L109

Infante, Leopoldo, et al., (2002), “The Angular Clustering of Galaxy Pairs”, *ApJ* accepted

Ivezic, Zeljko, et al., (2001), “Solar System Objects Observed in the Sloan Digital Sky Survey Commissioning Data”, *AJ*,122,1104

Kim, Rita S. J., et al., (2002), “Detecting Clusters of Galaxies in the Sloan Digital Sky Survey I: Monte Carlo Comparison of Cluster Detection Algorithms”, *AJ*,123,430

Kim, Rita S. J., et al., (2001), “The Alignment Effect of Brightest Cluster Galaxies in the SDSS”, in Conference Proceedings, “Where's the Matter? Tracing Dark and Bright Matter with the New Generation of Large-Scale Surveys”, June 2001, eds: M. A. Treyer and L. Tresse, Frontier Group

Lamb, Don Q., et al., (2002), “LOTUS, Super-LOTIS, SDSS, and Tautenburg Observations of GRB 010921”, *ApJ* Lett accepted

Lee, Brian C., et al., (2001), “Sloan Digital Sky Survey Multicolor Observations of GRB010222”, *ApJ*,561,183

Leggett, S.K., et al., (2002), “Infrared Photometry of Late M, L, and T Dwarfs”, *ApJ*,564,452

McGehee, Peregrine, et al., (2001), “Star Formation Studies with Sloan Digital Sky Survey”, in ASP Conference Series, “Astrophysical Ages and Timescales”, Vol 245, eds: Ted von Hippel, Chris Simpson and Maxine Manset, ISBN 1-58381-083

McKay, Timothy, et al., (2002), “Dynamical Confirmation of SDSS Weak Lensing Scaling Laws”, *ApJ* Lett submitted

McKay, Timothy, et al., (2002), “Galaxy Mass and Luminosity Scaling Laws Determined by Weak Gravitational Lensing”, *ApJ* submitted

Menou, Kristen, et al., (2001), “Broad Absorption Line Quasars in the Sloan Digital Sky Survey with VLA-FIRST Radio Detections”, *ApJ*,561,645

Newberg, Heidi, et al., (2002), “The Ghost of Sagittarius and Lumps in the Halo of the Milky Way”, *ApJ* accepted

Odenkirchen, M., et al., (2001), “New Insights On The Draco Dwarf Spheroidal Galaxy From SDSS: A Larger Radius And No Tidal Tails”, *AJ*,122,2538

Odenkirchen, Michael, et al., (2001), “Detection of Massive Tidal Tails around the Globular Cluster Pal 5 with SDSS Commissioning Data”, *ApJ*,548,L165

Pentericci, Laura, et al., (2002), “VLT optical and near-IR observations of the $z=6.28$ quasar 1030+0524”, *AJ* submitted

Richards, Gordon T., et al., (2001), “Photometric Redshifts of Quasars”, *AJ*,122,1151

Richards, Gordon T., et al., (2001), “Colors of 2625 Quasars at $0 < z < 5$ Measured in the Sloan Digital Sky Survey Photometric System”, *AJ*,121,2308

Rockosi, Connie, et al., (2002), “A Matched-Filter Analysis of the Tidal Tails Around the Globular Cluster Palomar 5”, *AJ* submitted

Schneider, D. P., et al., (2002), “The Sloan Digital Sky Survey Quasar Catalog I. Early Data Release”, *AJ* accepted

Schneider, D. P., et al., (2002), “L Dwarfs Found in Sloan Digital Sky Survey Commissioning Data II. Hobby-Eberly Telescope Observations”, *AJ*,123,458

Schneider, D. P. et al., (2001), “High-Redshift Quasars Found in Sloan Digital Sky Survey Commissioning Data V. Hobby-Eberly Telescope Observations”, *AJ*,121,1232

Scranton, Ryan, et al., (2002), “Analysis of Systematic Effects and Statistical Uncertainties in Angular Clustering of Galaxies from Early SDSS Data”, *ApJ* submitted

Sheldon, Erin Scott, et al., (2001), “Weak Lensing Measurements of 42 SDSS/RASS Galaxy Clusters”, *ApJ*,554,881

Shimasaku, K., et al., (2001), “Statistical Properties of Bright Galaxies in the SDSS Photometric System”, *AJ*,122,1238

Strateva, Iskra, et al., (2001), “Color Separation of Galaxy Types in the Sloan Digital Sky Survey Imaging Data”, *AJ*,122,1861

Szalay, Alexander S. et al., (2002), “ KL Estimation of the Power Spectrum Parameters from the Angular Distribution of Galaxies in Early SDSS Data” *ApJ* submitted

Szapudi, Istvan, et al., (2002), “Higher Order Moments of the Angular Distribution of Galaxies”, *ApJ* accepted

Szkody, Paula, et al., (2002), “Cataclysmic Variables from SDSS I. The First Results”, *AJ*,123,430

Tegmark, Max, et al., (2002), “ The Angular Power Spectrum of Galaxies from Early SDSS Data”, *ApJ* accepted

Vanden Berk, Daniel E., et al., (2002), “SDSS J124602.54+011318.8: A Highly Luminous Optical Transient at a Redshift of 0.385”, *AJ* submitted

Vanden Berk, Daniel E., et al., (2001), “Composite Quasar Spectra From the Sloan Digital Sky Survey”, *AJ*,122,549

Willman, Beth, et al., (2002), “An SDSS Survey for Resolved Milky Way Satellite Galaxies I: Detection Limits”, *AJ* accepted

Yasuda, Naoki, et al., (2001), “Galaxy Number Counts from the Sloan Digital Sky Survey Commissioning Data”, *AJ*,122,1104

Zehavi, Idit, et al., (2002), “Galaxy Clustering in Early SDSS Redshift Data”, *ApJ* accepted

Appendix C. List of Approved SDSS Collaboration Thesis Topics

Student Email Advisor
Andrea Stolte (stolte@mpia-hd.mpg.de) Hans-Walter Rix, Rodrigo Ibata
Galactic Halo Substructure and Tidal Streams

Daniel Harbeck (dharbeck@mpia-hd.mpg.de) Eva K. Grebel
Modelling of the SDSS Photometric System Through Synthetic Colors and Application to Stellar Population Studies

Vandana Desai (desai@astro.washington.edu) Julianne Dalcanton
An Empirical Measure of Galaxy Evolution in Clusters

Beth Willman (willman@astro.washington.edu) Julianne Dalcanton
A Survey for Resolved LSB Stellar Populations in the Local Group

Bart Pindor (pindor@astro.princeton.edu) Ed Turner
Identifying Strongly-Lensed Quasars in the SDSS Imaging Data

Tomo Goto (ss96068@mail.ecc.u-tokyo.ac.jp) Maki Sekiguchi
Finding Galaxy Clusters in Sloan Data Using Color Cut And Enhancement Method.

Michael Weinstein (maw@astro.psu.edu) Don Schneider
Photometric Redshifts for SDSS Quasars

Erin Sheldon (esheldon@umich.edu) Timothy Mckay
Measuring the Correlation between Luminous Matter and Mass with Weak Gravitational Lensing

Lei Hao (haol@astro.princeton.edu) Michael Strauss
Emission-Line Properties Of Galaxies: Large-Scale Structure, Active Nuclei, and Metallicity.

Liam O'Connell (l.a.o-connell@sussex.ac.uk) Jon Loveday
Constraining Cosmological Models with SDSS

Katsuko T. Nakahira (nakahira@a.phys.nagoya-u.ac.jp) Satoru Ikeuchi
Candidate Selection for Moderately Distant Clusters of Galaxies Using Matched Filter Method

Randall R. Rojas (rrojas@mercury.physics.drexel.edu) Michael S. Vogeley
Voids and Void Galaxies in the SDSS

Brice Ménard (menard@MPA-Garching.mpg.de) Matthias Bartelmann
Angular Cross-Correlations between Background Quasars and Foreground Galaxies

Student email Advisor
Shiyin Shen (shen@mpa-garching.mpg.de) Wolfgang Voges and Houjun Mo
Statistical Analyses of X-Ray Emissions from SDSS Agns and Galaxies

Brigitte Koenig (bkoenig@mpe.mpg.de) Ralph Neuhaeuser and Wolfgang Voges
Search For Post-T Tauri Stars and Young Zero-Age Main-Sequence Stars Among SDSS Stars

Jacek Guzik (guzik@feynman.princeton.edu) Uros Seljak
Measuring Scale Dependence of Bias Using Galaxy-Galaxy Lensing and Galaxy Clustering

Tara Murphy (tm@roe.ac.uk) Avery Meiksin
Spectral Properties of Galaxies

Iskra Strateva (iskra@astro.princeton.edu) Michael Strauss
Physical Correlations Between Quasars and Inactive Galaxies

Ryan Scranton (scranton@oddjob.uchicago.edu) Scott Dodelson
Expected Biasing Model Constraints from SDSS Galaxy Angular Clustering

Christy Tremonti (cat@pha.jhu.edu) Tim Heckman & Guinevere Kauffmann
The Nature of Star Forming Galaxies in the SDSS

Yeong-Shang Loh (yeongloh@astro.princeton.edu) Michael Strauss
The evolution of Brightest Cluster Galaxies from SDSS Data

Gajus Miknaitis (gm@astro.washington.edu) Christopher Stubbs
Constraining Cosmological Parameters with Type Ia Supernovae

Brian Wilhite (wilhite@oddjob.uchicago.edu) Richard Kron
Spectral Variability of Quasars in the SDSS