

The ARCS Project Execution Plan

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Abstract. A large construction project, built at the SNS but managed through a university with personnel at national laboratories, is a challenge to manage and execute. The plan for doing so is presented here.

Keywords: project execution plan, ARCS, SNS, management, schedule, cost, baseline design, project controls

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1. Introduction

This document outlines the plan of the Principal Investigator to execute a project to construct the wide Angular-Range Chopper Spectrometer (ARCS). It was written in November 2004 in partial response to the ARCS Construction Progress Review of August 2004. It is a revision and update of the first Project Execution Plan for ARCS that was written in November 2002. Some of its text originated from the ARCS proposal itself [1], and from a management plan that was prepared for the ARCS Baseline Review of March 2002 [2].

2. Mission Need

To date, inelastic neutron scattering experiments have been constrained by low neutron flux, forcing experimental compromises in energy resolution, momentum resolution, and in the number of spectra that can be measured. Low neutron flux has suppressed the quality of research in the U.S. on dynamical processes in materials, molecules, and condensed matter, research fields for which inelastic neutron scattering is well-suited. The high neutron fluxes from the moderators of the Spallation Neutron Source (SNS) will provide qualitatively new opportunities for inelastic neutron scattering research, if suitable instrumentation is built for use at the SNS. ARCS will be one such SNS instrument that will open new fields of research in condensed matter physics and materials science.

3. Project Description

3.1. SCIENTIFIC GOALS

ARCS will be a wide Angular-Range, direct-geometry, time-of-flight Chopper Spectrometer at the SNS. It will be optimized to provide a high neutron flux at the sample, and a large solid angle of detector coverage. With its high detection efficiency and its location at the high-power target station of the SNS, ARCS will free experimenters from many of today's restrictions caused by low neutron flux. The uncompromising hardware and advanced software of ARCS will enable new experiments with a sophistication not yet achieved with chopper spectrometers. A thorough documentation of the national need for ARCS is provided in the proposal to DOE BES [1].

ARCS will advance the science of dynamical processes in materials. It is designed to measure excitations in materials and condensed matter having energies from a few meV to several hundred meV, with an efficiency better than any existing high-energy chopper spectrometer. Research topics include: (i) studies of vibrational excitations and their relationship to phase diagrams and equations of state of materials, including materials with correlated electrons, and (ii) studies of spin correlations in magnets, superconductors, and materials close to metal-insulator transitions.

Table I. Milestones Level 4

Receive LPSD detectors	December 2004
Award scattering chamber contract	February 2005
Detector array design approval	February 2005
Award guide contract	February 2005
Award T0 chopper contract	March 2005
Beamline shielding design approval	April 2005
Receive Fermi chopper	June 2005
Award internal vessel shielding contract	July 2005
Data analysis software alpha release	July 2005
Poured-in-place shielding installation complete	September 2005
Receive T0 chopper	January 2006
Neutron guide installation complete	February 2006
Ready for SNS CD-4 measurement	March 2006
Scattering chamber installation complete	April 2006
Detector array installation complete	June 2006
Data acquisition installation complete	July 2006
Data analysis software release 1.0	July 2006
Readiness review complete	August 2006
ARCS project complete	September 2006

3.2. KEY PARAMETERS

Key operational parameters for ARCS are:

- primary flight path to include a tapered neutron guide and a method for efficiently changing the Fermi chopper and other user-specified optics,
- secondary flight path of 3.0 m,
- a full complement of position-sensitive ^3He detector tubes mounted nearly adjacent to each other, offering tight coverage from angles through the forward beam to $+140^\circ$ in scattering angle,
- a release of modern object-oriented software that provides data acquisition, visualization, and some capabilities for data analysis.

3.3. PROJECT MILESTONES

Project milestones at level 4 are presented in Table I. The meanings of most level 4 milestones are straightforward. The Instrument Readiness Review is intended to review the mostly-completed instrument for safety and other issues that pertain to opening the shutter for first beam.

Table II. Budget Periods and Funds for the ARCS Project

Fiscal Year	Operating Funds	Duration	Dates
FY2001	\$0,500,000	6 months	09/15/01 - 03/15/02
FY2002	\$4,500,000	18 months	03/15/02 - 09/15/03
FY2003	\$1,750,000	6 months	09/15/03 - 03/15/04
FY2004	\$2,430,000	12 months	03/15/04 - 03/15/05
FY2005	\$2,530,000	9 months	03/15/05 - 12/15/05
FY2006	\$3,269,000	9 months	12/15/06 - 09/15/06

4. Resource Requirements

4.1. BUDGET PERIODS

Authority and responsibility for managing DOE programs resides with the Secretary of Energy. Specific authority for managing DOE Science programs has been delegated to the Director of the Office of Science. Within the Office of Science, the ARCS project falls under the authority of the Office of Basic Energy Sciences, and the Program Monitor of the ARCS Project is within the Materials Sciences and Engineering Division. The DOE will provide funding for the ARCS Project, and has delegated to the ARCS Principal Investigator the responsibility for the design, fabrication, installation, and the initial stages of commissioning of the ARCS instrument. These funds are provided in six budget periods presented in Table II.

4.2. DISBURSEMENTS OF FUNDS

Funds will be made available to the DOE through legislation passed by the U.S. Congress. Budgets adequate to support the project baseline will be submitted from Caltech to the Materials Sciences and Engineering Division of BES, DOE following the schedule of Table II, or revisions to this schedule decided by DOE. The funds will be disbursed to Caltech as a university research grant, with Brent Fultz as Principal Investigator, and to Argonne or Oak Ridge as Field Work Proposals with Kent Crawford or Ian Anderson as Principal Investigator.

Figure 1 shows the channels for financial disbursements within the ARCS project. The Principal Investigator, Brent Fultz, is responsible for directing all funding in the ARCS project, and for reporting all costs and financial status to DOE. This includes coordination with Dr. Helen Kerch of DOE BES to direct the funds into DOE field work proposals to Argonne and Oak Ridge for support of engineering services and assembly, for example. An alternative channel allows transfers of funds directly from Caltech to Oak Ridge through Caltech purchase orders and a Work for Others Agreement between Oak Ridge and Caltech. This WFO agreement allows quick responses to the needs at Oak Ridge. The sum of the budgets to Caltech, Argonne, and Oak Ridge will equal the total budget authorized by DOE BES for

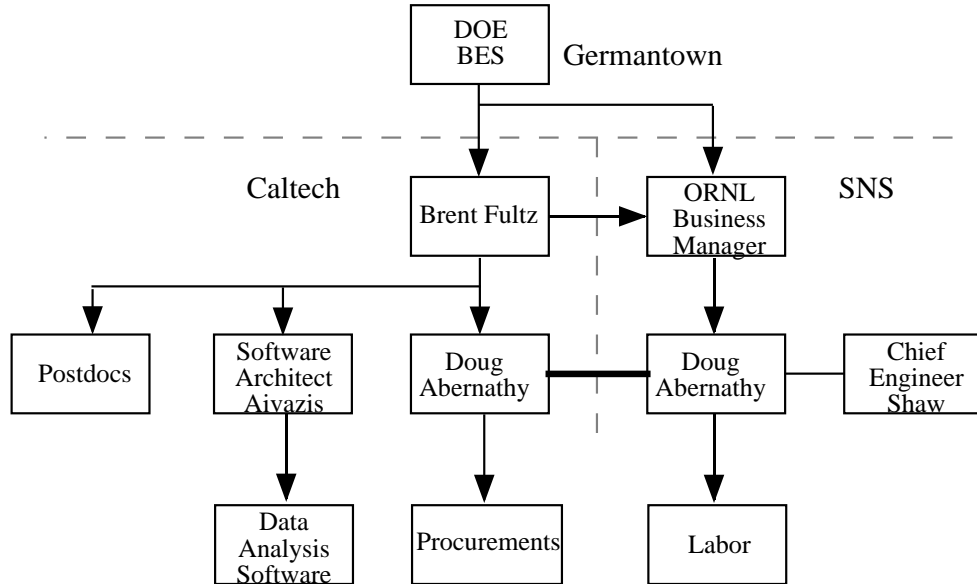


Figure 1. Funding channels for the ARCS project.

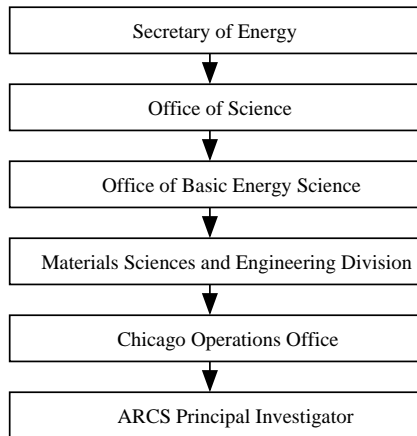


Figure 2. ARCS Project Organization Relationships.

each budget period. Funds for the FWP's are allocated by fiscal year, however, and do not follow the budget periods of Table II.

5. Management Structure

5.1. MANAGEMENT OVERVIEW

The ARCS Project Management Organization is shown in Fig. 2. The responsibilities of each group follows below.

5.2. DOE: MATERIALS SCIENCES AND ENGINEERING DIVISION

Within the Office of Basic Energy Sciences, the Materials Sciences and Engineering Division is responsible for monitoring the ARCS Project. The Materials Sciences and Engineering Division shall:

- Review and approve the technical, cost, and schedule baselines at the Work Breakdown Structure (WBS) level 4.
- Monitor the technical, cost, and schedule milestones at level 3.
- Review the ARCS Project. This includes the Construction Progress Review and an Instrument Readiness Review. It also includes a technical and financial report submitted at the end of each budget period.
- Verification of compliance with ES&H requirements.
- Provide funds on a timely basis, and provide timely information on changes in the funding profile. Work with ARCS team to ensure a suitable funding profile, and work with the team to arrange appropriate distributions of funds between the three institutions: Caltech, Argonne, and Oak Ridge.
- Coordination with other DOE offices.

5.3. DOE: CHICAGO FIELD OPERATIONS OFFICE

Specific responsibilities of the Chicago Field Operations Office are:

- Legal support.
- Contract Support.

Similar functions are performed by the Oak Ridge field office for funds sent from DOE BES to the field work proposals of Oak Ridge National Lab.

5.4. CALTECH: PRINCIPAL INVESTIGATOR

Figure 3 shows the organizational structure of the ARCS project. DOE BES interacts directly with the Principal Investigator, Brent Fultz, who is responsible for executing the project. Besides his role as project coordinator, other specific responsibilities of the Principal Investigator are:

- Ensuring the measurement of project performance against established goals, including technical performance, cost levels, and schedule milestones.
- Organizing meetings to monitor and coordinate the hardware and software efforts.
- Monitoring monthly project costs, and providing this information to DOE as requested.
- Approving and disbursing project funds.

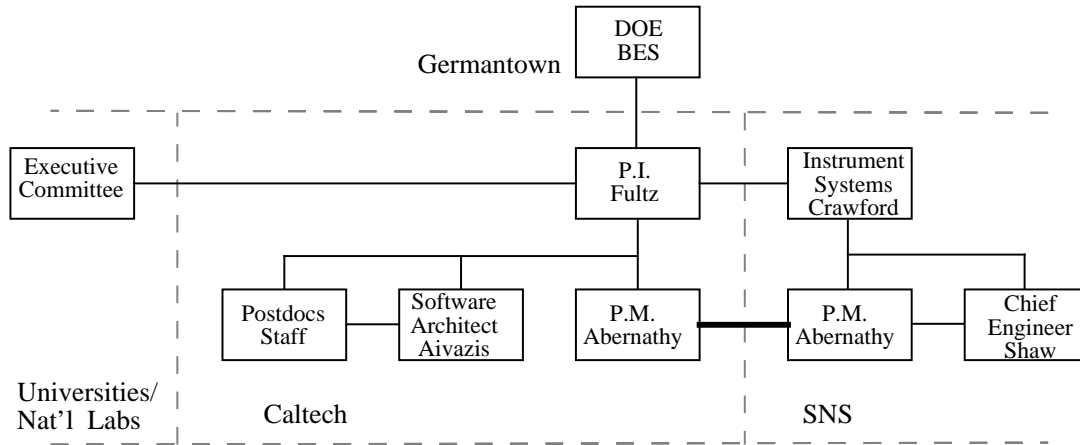


Figure 3. Organizational chart of the ARCS project management. Light dashed lines bound geographical locations.

5.5. SNS: INSTRUMENT SCIENTIST AND CHIEF ENGINEER

The person serving in the central position as Project Manager, Doug Abernathy, is an Instrument Scientist at the SNS. He has been appointed as a Visiting Associate at Caltech,¹ an arrangement that allows him to use the purchasing and accounting systems at Caltech. It is understood that DOE BES will later support this Instrument Scientist position through the SNS operations budget. Technical support for the completed ARCS instrument, befitting a world-class neutron spectrometer, will be provided by the SNS operations budget.

The Chief Engineer, Kevin Shaw, is responsible for the technical systems integration for the ARCS spectrometer. He is located at the SNS where he interacts closely with the technical support personnel and can oversee the instrument construction.

5.6. INTERFACE BETWEEN THE ARCS PROJECT AND THE SNS PROJECT

The ARCS Project will utilize a number of services provided through the SNS. In particular, the ARCS Project will coordinate with the Experimental Facilities Division (XFD) of the SNS to ensure that appropriate staffing levels are maintained to perform the necessary engineering and design work for the instrument development and installation. All services will be appropriately charged to ARCS project accounts, funded either by direct DOE funding at ORNL or by a work-for-others agreement between Caltech and ORNL. Other SNS resources that will be used by the ARCS project include quality assurance (QA) staff, environment, safety, and health (ES&H) staff, document control, project controls, installation labor, and information technology (IT) services. Although most of the ARCS procurements are arranged through Caltech, SNS procurement services are used for items intimately connected to the target area of the SNS, or for some purchases that involve components for other instruments.

¹ This flexible appointment is presently without a salary, but a Caltech salary is possible if this is desired later.

The physical interface between the ARCS hardware and the SNS will be maintained and documented according to SNS policies. The ARCS team is working with the SNS Space Allocation and Safety committees, for example, to ensure that the ARCS instrument will conform to all requirements for operation at the facility. Particular attention is needed for coordination with the SEQUOIA instrument on SNS beamline 17, which is part of the SNS Instruments – Next Generation (SING) project. As provided by XFD procedures, the detailed interface is being negotiated and documented between the ARCS and SEQUOIA instrument teams.

5.7. INTERFACE BETWEEN THE SNS AND CALTECH

Both the Spallation Neutron Source and the California Institute of Technology are committed to the success of the ARCS Project. A signed Memorandum of Agreement between the California Institute of Technology and the Spallation Neutron Source delineates the interactions between the ARCS Project and the SNS Project, and the roles and responsibilities of all participants. This document explains the type of SNS oversight of the ARCS Project that is needed to ensure safe construction practices, good engineering design, and safe operation after the instrument is complete. This Memorandum of Agreement explains allocation of resources of the SNS Project to the ARCS Project.

5.7.1. *Hardware Effort Coordination*

Doug Abernathy is authorized to access and review the ARCS financial records in the Oracle database at Caltech. He has regular contact with the Caltech Administrator and Buyers who support the ARCS project.

All purchases and contracts for ARCS hardware are made through the Financial Services Office of Caltech. The SNS Central Receiving Office is alerted to ARCS purchases, and in turn provides proof of receipt to Caltech. Vendor invoices are sent to Caltech. Paper and electronic records of purchases and reconciliations are maintained at Caltech, with electronic copies at the SNS.

Doug Abernathy will coordinate with the SNS Instrument Group on the installation plan for the ARCS project. In some cases, coordination will involve changes to the ARCS or SNS project schedules, sometimes without additional cost. When coordination does affect costs to either the SNS or ARCS projects, costs will be shared equitably between the SNS and the ARCS projects. Travel costs for meetings are shared as appropriate.

5.7.2. *Software Effort Coordination*

A major piece of the Caltech effort in the ARCS project is the development of scientific software. The software architecture is being coordinated by a software engineer, Dr. Michael Aivazis, Member of the Professional Staff at the Center for Advanced Computing Research at Caltech. Steve Miller of the SNS is informed and involved in all major decisions, such as data storage, data standards, software architecture, programming languages, and user interfaces. The software, like the hardware, will be maintained by the SNS in its operations phase after the ARCS instrument is commissioned.

Table III. The ARCS hardware project WBS

ARCS on BL18	2.18		
Integrated Design, System Integration	2.18.1		
	Design 2.18.2	Procurement and Fabrication 2.18.3	Installation 2.18.4
Detectors	2.18.2.1	2.18.3.1	2.18.4.1
Optical components	2.18.2.2	2.18.3.2	2.18.4.2
Choppers	2.18.2.3	2.18.3.3	2.18.4.3
Sample Environment	2.18.2.4	2.18.3.4	2.18.4.4
Shielding	2.18.2.5	2.18.3.5	2.18.4.5
Data Acquisition and Software	2.18.2.6	2.18.3.6	2.18.4.6
Instrument Specific Support Equipment	2.18.2.7	2.18.3.7	2.18.4.7
Instrument Infrastructure	2.18.2.8	2.18.3.8	2.18.4.8

6. Project Baseline

6.1. ACCEPTANCE CRITERION

The ARCS project ends on September 14, 2006. It is not possible to fully evaluate the performance of the ARCS instrument without extensive measurements using an intense and reliable neutron beam, and this may not be possible in 2006. Furthermore, optimizing the signal-to-noise ratio will occur for some time after the ARCS instrument is commissioned. The CD4 acceptance criterion for ARCS shall be the same as for the other instruments being constructed in the SING Project. These are [3]:

1. demonstrating the capability to achieve the technical parameters in Section 3.2, either by acceptance testing, calculations, or some combination of testing and calculation, and
2. successful completion of an Instrument Readiness Review, including completion of all pre-beam closeout items, i.e., approved as ready for beam, prior to commissioning with the SNS neutron beam.

6.2. WORK BREAKDOWN STRUCTURE

All work required for the completion of the ARCS hardware project is organized into a Work Breakdown Structure (WBS). The WBS contains a complete definition of the scope of the project and forms the basis for planning, execution and control of the hardware project². A high-level rollup of the WBS is presented in Table III.

The Integrated Design and System Integration activity, WBS 2.18.1, includes the overall instrument design, prototyping, project management tasks, review, external

² The plan for the ARCS software project was developed in January, 2003

drivers and milestones. The other activities can be viewed by the major tasks of design, procurement and installation, or by components at WBS levels 2.18.2, 2.18.3, and 2.18.4, respectively. These are:

1. *Detectors*

The ARCS instrument will utilize linear position-sensitive detectors filled with pressurized ^3He . Operation of the detector tubes and their electronics inside the instrument vacuum offers the advantages of better coverage of solid angle, safety of operation (no thin windows required), shielding from the neutron background inside the Target Building, and electrical shielding.

2. *Optical Components*

This includes the neutron guide with a long, tapered straight section in the primary flight path. The core vessel insert, shutter, apertures, and collimators are also included.

3. *Choppers*

ARCS will use a T_0 chopper to suppress fast neutrons and γ -rays. A Fermi chopper for energy selection will also be used.

4. *Sample Environment*

A modest budget was provided for the design and construction of a goniometer for single crystal manipulations at cryogenic temperatures.

5. *Shielding*

The shielding includes neutron and photon absorbing material both inside and outside the instrument. Besides shielding personnel from radiation exposures, the shielding will protect the detectors from extraneous counts. A substantial calculational effort for optimizing the shielding is included in the project plan.

6. *Data Acquisition and Software*

To ensure that the ARCS instrument has a data acquisition system that can be maintained over the long term during the SNS operations, a design for the ARCS data acquisition system will be adapted from the generic designs developed by the SNS. (Data analysis software is not included in this WBS activity.)

7. *Instrument Specific Support Equipment*

This includes the scattering chamber with integrated sample isolation system.

8. *Instrument Infrastructure*

This effort includes the installation of utilities.

6.3. PROJECT SCHEDULE

Approximately, the years 2001 and 2002 included project initiation tasks such as staffing and planning. The years 2002 and 2003 included design work. The year 2004 included further design and issuing subcontracts for procuring some major components. Installation in the Target Building begins in 2005. Instrument commissioning begins in 2006. The Project Schedule has been rebaselined in the summer of 2004,

and will be rebaselined in February 2005 after assessing the vendor proposals for fabrication of the scattering chamber with integrated sample isolation system.

7. Project Controls

7.1. MANAGEMENT OF CONTINGENCY

At any time, the project contingency will be defined as the difference between the Total Estimated Cost (total cost of construction including contingency), and the sum of current baseline costs summed over tasks at level 4 of the WBS. Contingency funds are allocated as needed to complete the tasks of level 4 of the WBS in excess of the baseline budgeted costs.

The principles of contingency management for the ARCS project are:

- The actual allocations of contingency at all levels of the WBS will be reflected in a new Estimate at Completion to be updated annually.
- The ARCS Principal Investigator has the authority to assign the contingency available during each budget period³ in accordance with the Project Change Control Procedures.
- The sum of these contingency allocations may not exceed the total contingency available.
- All changes from the baseline shall be traceable. The ARCS Principal Investigator shall report to the DOE ARCS Project Monitor in the Materials Sciences and Engineering Division of DOE how the contingency funds were used during the budget period.
- The contingency included in each budget period is under the authority of the Principal Investigator. Subject to the conditions above, the Principal Investigator can approve cost change requests without further approval by the ARCS Change Control Board, or the DOE ARCS Project Monitor in the Materials Sciences and Engineering Division.

7.2. CHANGE CONTROL

Table IV presents the thresholds for changes to technical characteristics, schedule, and cost, for which reporting is required to the DOE Materials Sciences and Engineering Division, or which trigger an action of the ARCS Change Control Board. The Change Control Board is organized to be small and engaged so it can evaluate efficiently potential changes to the scope, cost, and schedule of the ARCS project. It includes the Principal Investigator, Project Manager, Chief Engineer, and another member as appropriate. The Change Control Board:

³ The contingency available during the budget period is defined as the pro-rated part of the total project contingency.

Table IV. Change Control Thresholds

	DOE MSE Div.	Change Control Board
Technical	Changes in Key Parameters: > 2.5 m secondary flight path detectors to 135° guide in primary flight path	Changes in Design Parameters (not affecting the Key Parameters): e.g., deletion of frame overlap chopper, switching of Fermi choppers
Schedule	Any Delay in Level 3 Milestone	Any Delay in Level 3 or 4 Milestone
Cost	Any Increase in Total Project Cost	Any Increase > k\$ 75 at WBS Level 4 Any Increase > k\$ 200 at WBS Level 3

- Convenes to discuss any delays in milestones listed in Table I, and recommend action to the Principal Investigator and Project Manager. Members of the Change Control Board follow the progress of tasks at level 4 of the Work Breakdown Structure.
- Convenes to discuss any changes to the costs of tasks at level 4 of the Work Breakdown Structure in excess of k\$ 75, or in excess of k\$ 200 at level 3.
- Convenes to discuss any major changes to the configuration of the instrument listed as tasks at level 5 of the Work Breakdown Structure.

7.3. EARNED VALUE REPORTING SYSTEM

The ARCS project is using the same earned value management processes and procedures as the SING (SNS Instruments – Next Generation) Project. This system uses a state-of-the-art project management software system to analyze and report technical, cost, and schedule progress on a monthly basis. The Project Manager transmits monthly cost and schedule performance data to the SNS Project Controls group, who enter this information in the project controls software. Monthly earned value reports are available to the Project Manager and Principal Investigator. A teleconference with the Program Monitor at DOE BES is scheduled on a monthly basis to discuss this cost and schedule performance information.

7.4. MANAGEMENT OF RISK AND CONFIGURATION

7.4.1. *Risks*

The design philosophy of the ARCS instrument is to use best engineering practices, and minimize the use of components that push present technology. All individual components for the ARCS instrument have been constructed and operated previously, although not necessarily in similar configurations. This design philosophy minimizes technical risks to the project cost and schedule, and allows better planning for the instrument performance and maintenance. In 2004 we perceive the greatest technical risks as:

- The biggest time and budget risk today is the fabrication of the ARCS scattering chamber with its integrated sample isolation system. A request for proposals was issued in September, 2004, and vendor proposals are expected by early January 2005.
- Radiation shielding design has remained a risk throughout the project, both for biological shielding and for minimizing instrument background. Shielding calculations have been underway throughout the project.

7.4.2. *Risk Documentation*

The project controls system includes provisions for risk monitoring and documentation. “Risk Items” are identified each month in a category that can be quantified. “Gut feel” items are identified each month as risks that cannot be expressed in money or time. These items are collected by the Principal Investigator into a Risk Watch List, and are discussed as needed in the ARCS weekly conference call involving Caltech and Oak Ridge personnel. This teleconference has proved to be an effective forum for team members to report quickly any newly-identified risks. Minutes of these meetings are prepared by the Chief Engineer, Kevin Shaw, and issued as SNS controlled documents as part of the ARCS project. Although the project controls system includes brief records of risk mitigation plans, the teleconference minutes are a more detailed record of the risk mitigation plans and actions.

7.4.3. *Risk Mitigation and Configuration Management*

Risk mitigation actions often involve rearranging the project schedule, or changing dependencies among tasks. Coordinating these actions is the responsibility of the Risk Control Board. The Risk Control Board is composed of the same individuals as the Change Control Board, ensuring informed decisions on risk mitigation and how these affect the configuration of DANSE. Responsibilities of the Risk Control Board are:

- Document the risks through the risk watch list, with updates at least monthly.
- Maintain risk mitigation plans and contingency plans.
- Plan and request changes to scope or configuration after risks undergo large changes.

Documentation of the risk mitigation actions is through the monthly responses of the Project Manager, Doug Abernathy, to issues flagged by the Earned Value Reporting system. These responses are SNS controlled documents.

8. Quality Assurance

The ARCS instrument will join the suite of neutron scattering instruments operated by the SNS. As such, the engineering, fabrication, and installation of the ARCS instrument must follow the Quality Assurance procedures of all SNS instruments, developed by the SNS Experimental Facilities Division.

9. Environment, Safety, and Health

The ARCS instrument will join the suite of neutron scattering instruments operated by the SNS. As such, the engineering, fabrication, and installation of the ARCS instrument must follow the Environment, Safety, and Health plan for all SNS instruments, developed by the SNS Experimental Facilities Division.

10. Transition to Operations

A schedule for commissioning and transferring the ARCS instrument into SNS Operations will be presented at the Instrument Readiness Review, to occur towards the end of the ARCS project. A smooth transition from commissioning to operations will be facilitated by the fact that Doug Abernathy will make the transition from Project Manager in the ARCS construction phase to Instrument Scientist in the ARCS operations phase. Documentation of the ARCS hardware design will be kept in the SNS document control system. Electronic materials from the ARCS software project will be turned over to the SNS to maintain.

Near the conclusion of the project, the Principal Investigator and Project Manager will document their “lessons learned,” “what went right,” and “what went wrong” as a part of the CD4 acceptance procedure.

Acknowledgements

I thank Doug Abernathy and Kevin Shaw for contributing sections of text to this document, and for correcting some errors. The work at Caltech was supported by the U. S. DOE under contract DE-FGO3-01ER45950.

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3. J. Haines and L. Radcliffe, Project Execution Plan for the SNS Instruments – Next Generation (SING) Project, SNS Document SINGPRJ-10-PN0001-R00, October 2004.

Appendix A: Instrument Development Team Members

The members of the ARCS IDT have contributed to the ARCS Proposal to DOE, and have been willing to attend meetings of the IDT. This group and others receives regular e-mail communications about the ARCS project. An asterisk (*) denotes the present members of the ARCS Executive Committee.

- * D. Abernathy, Argonne National Laboratory
- M. Aivazis, California Institute of Technology
- * W. Beyermann, University of California, Riverside
- C. Broholm, Johns Hopkins University
- O. Bruno, California Institute of Technology
- * T. Egami, University of Pennsylvania
- * B. Fultz, California Institute of Technology
- B. Gaulin, McMaster University
- B. Hudson, Syracuse University
- T. Kelley, California Institute of Technology
- C-K. Loong, Argonne National Laboratory
- M. Manley, Los Alamos National Laboratory
- * R. McQueeney, Iowa State University
- H. Nakotte, University of New Mexico, Las Cruces
- F. Mezei, Los Alamos National Laboratory
- S. Nagler, Oak Ridge National Laboratory
- * R. Osborn, Argonne National Laboratory
- J. L. Robertson, Oak Ridge National Laboratory
- P. Sokol, Pennsylvania State University
- J. Tranquada, Brookhaven National Laboratory

