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THE CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY: CEBAF Quality Assurance Program[1]

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I. LABORATORY MISSION

Purpose

At the Continuous Electron Beam Accelerator Facility (CEBAF) being built in Newport News, Virginia, a continuous, high-energy, high-intensity beam of electrons will enable nuclear physicists to explore the quark structure of the nucleus and advance understanding of the nuclear strong force. By directing this beam at nuclear targets under precisely controlled and observed conditions, they will study nuclear structure down to distances of a fraction of a proton or neutron diameter. The scientific need for an accelerator to support such study has been recognized since the 1970s. Construction of such a machine has been endorsed as nuclear physics' highest priority in the DOE/NSF Long Range Plan for Nuclear Science (1979, 1983, and 1989).

Accelerator Design

A superconducting recirculating linear accelerator will produce the 100%-duty-factor, 4-GeV, 200-microampere beam for use in three end stations. Enclosed in a racetrack-shaped tunnel 1200 meters in circumference, this machine will cycle the beam through a segment of linear accelerator in each straightaway. Recirculation arcs will transfer the beam between straightaways. The beam will gain 800 MeV in each of five complete circuits. To allow continuous-beam operation at an acceptable level of power consumption, the niobium accelerating cavities in the linac segments will be superconducting. They will be kept immersed in liquid helium inside insulated cryostats at 2 Kelvin.

Progress and Future Plans

Construction started in February 1987; given the budget profile in the President's FY 1990 budget request, the project will be completed in FY 1993 at a total estimated cost of $265 million. In CEBAF's test lab, prototyping and assembly of accelerator components also began in 1987. In 1988, major elements of the accelerator control system were assembled and used for cavity-cryostat tests and early tests of the injector. The cavity-cryostat tests are supported by liquid helium produced in a cryogenic test facility. Also in 1988, tunnel construction, fabrication of the central helium refrigerator, and construction of the CEBAF Center building began, and the accelerator commissioning plan was formulated.

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By late 1989, a production-version cryomodule (containing four cavity pairs) had been tested successfully, key components had been ordered from industry, the central helium refrigerator was being installed, and CEBAF Center was in use.

A scientific program is being planned in full collaboration with the potential scientific users of CEBAF. Conceptual designs for detectors are nearing completion. A Program Advisory Committee advises CEBAF on scientific program development, and Technical Advisory Panels periodically review the evolving designs of the experimental equipment. Operations for physics are to begin in 1994.

II. LABORATORY QA MODEL

It is the policy of CEBAF that all activities be performed at a level of quality appropriate to achieving scientific, technical, operational, and administrative objectives of the laboratory. Each CEBAF manager is responsible and accountable for the quality and reliability of the scientific, technical, and administrative output in his/her area of responsibility. The bottom line is that quality is a line responsibility.

An Institutional Quality Assurance Officer was hired at the start of construction to coordinate and develop QA activities. In addition, Associate Directors have assigned quality assurance officer responsibilities to staff members. The Institutional and Division QA Officers meet periodically to set and evaluate lab-wide QA policy.

The essential elements to CEBAF's QA model are:

Staffing
Meetings
Reviews
General Quality Control Mechanisms
Specific Quality Assurance Plans
Documentation
Audits

These topics are discussed more fully in section III, QA Program Architecture.

III. QA PROGRAM ARCHITECTURE

QA Standard

CEBAF's QA standard is based on good management practices which have been important and effective in designing, building, and operating similar accelerator facilities that work reliably, achieve their performance goals, and support forefront physics research. NQA-1 is used as a reference source, but not as a standard.

Management And Organization

CEBAF is managed by the Southeastern Universities Research Association (SURA), an organization of 39 universities in 13 southeastern states and the District of Columbia.

SURA appoints the CEBAF Directorate, which comprises a Director and Scientific Director. Together, they have expertise in nuclear physics and the accelerators and detectors required to perform frontier research in the field. The Directorate is responsible for appointing Associate Directors with recognized expertise in their respective fields to head each of the divisions.

The divisions at CEBAF have been structured to comprise comparable levels of complexity and responsibility, and have also been structured to minimize the communications overhead among them. (See Figure 1).

To ensure an appropriate distribution of resources and adequate communications during the construction phase of CEBAF, an Associate Director and Project Manager has been appointed to coordinate the activities of the groups engaged in construction of the Project. Reporting to the Project Manager is a Deputy Project Manager with specific responsibility to ensure technical coordination and interface compatibility. Within the project, six Associate Project Managers have been appointed to oversee one or more of the Work Breakdown Structure (WBS) level 2 areas into which the construction project is divided. The Associate Project Managers are selected to have a high degree of competence in the area for which they are responsible. Each Associate Project Manager has appointed technically qualified people to serve as Cost Account Managers within the WBS. The Cost Account Managers have the principal responsibility for accomplishing their assigned part of the project with a suitable level of quality, consistent with the cost and schedule constraints faced by the entire project. Additional technical staff work under the direction of the Cost Account Managers.

Staffing

Competent, dedicated personnel are CEBAF's key to obtaining and maintaining quality. Strong consideration is given to the quality of performance of employees in establishing merit pay increases and in establishing eligibility for promotion. These practices provide further incentive for employees to maintain a high degree of quality.

It is customary practice at CEBAF to have at least three qualified people interview each interviewee, to reduce the likelihood that someone who will not or cannot perform a job adequately will be hired. CEBAF's probationary policy permits new employees who do not exhibit the required level of quality in their work to be terminated without complex procedures to demonstrate inadequate performance.

One of CEBAF's most powerful tools for ensuring that a high degree of quality is maintained is CEBAF's structure, in which the group of people responsible for designing and implementing some portion of the laboratory is the same group of people who are responsible for commissioning, operating, maintaining, and/or using it. These people therefore have a very strong incentive to do a job properly, to avoid substantial difficulties they will need to remedy later.

Meetings

CEBAF has a number of meetings for project and laboratory activities which:

A. Maintain an adequate level of communication to avoid excessive interface incompatibilities;

B. Present information on work in progress, permitting others to contribute constructive suggestions and help anticipate and prevent problems;

C. Permit problems which do occur to be addressed and methods of solving them initiated;

D. Provide minutes which provide documentation and further enhance communication.

Reviews

A number of types of reviews are held which consider quality, and provide feedback to appropriate people at CEBAF. Some of these reviews are initiated by CEBAF, others are held by DOE. They include programmatic reviews, construction project reviews, administrative reviews and numerous audits. They are often held at a stage where valuable expertise has significant leverage in producing a quality product or activity that reliably serves its intended use.

General Quality Control Mechanisms

CEBAF has implemented a number of mechanisms to assist in the assurance of quality. Important examples include the following:

A. Design Handbook. The Design Handbook describes the required specifications of CEBAF, and was written by the Associate Directors and Associate Project Managers, with input from the Cost Account Managers.

B. CEBAF Standards. CEBAF has an Electrical Standards Subcommittee and a Mechanical and Vacuum Standards Subcommittee of the Standards Committee.

C. Procurement procedures. These procedures assure quality by requiring adequate specifications and drawings, with appropriate levels of approval.

D. Property Management procedures. These procedures require inspection of incoming materials and equipment for obvious damage, require approval of the requisitioner, and describe methods for short or long term storage of items in such a manner as to minimize the likelihood of damage or loss.

E. Accounting procedures. These procedures insure the integrity and quality of financial information and activities.

F. Personnel procedures. These procedures describe personnel practices.

G. Civil Construction Standards. These standards describe the process for developing, reviewing, and approving designs and managing and inspecting subcontractors performing civil construction work.

H. Prototyping, Development And First Article Demonstrati
which involve unknown processes to be developed, which
print items, or which are items involving non-trivial in-h
have prototyping, development, and/or first article der
quality assurance steps, as decided by the Cost Acco
concurrence of the Associate Project Manager or Associat
of these cases, if a Specific Quality Assurance Plan is tc
plan will normally be generated following the prototypi
work, since the development work will help establish wha
steps are appropriate.

Specific QA Plans

QA requirements specific to a unique type of item are descril
Plans. Each Associate Director determines which specific activities in
responsibility require a written quality assurance plan and who
preparing it. This determination is based on the Associate Director's
complexity and importance of the activity, the risk and consequences c
and labor costs, the cost and benefit of developing and implementin
technical factors specific to the item. Associate Directors have
decisions, and the activities which require a Specific QA Plan are liste
to the Quality Assurance Plan. Associate Directors will review the
as necessary and at least annually beginning in January 1991. T
annual review will be documented in the form of a signed and dated r
or a statement that the list is unchanged.

Specific QA Plans are to be prepared and reviewed in accorda
which is included as an appendix to the Quality Assurance Plan. Be
of quality and quality assurance is content rather than form, CEBA
Specific QA Plans emphasizes substance more than format.

Quality is defined as "fitness for use"; therefore the perso
responsible for the QA plan is also the person responsible for deliveri
having it satisfy its intended use with appropriate reliability. In prepa
QA Plan, this person shall think about, describe, and plan the actions
sure that the end product will be acceptable for its intended use, such

- To what requirements is the item being prepared?
- How is it ensured that only satisfactory materials and comp
in preparing the item?
- What needs to be done to minimize the probability of p
and/or installing unsatisfactory or defective items?
- What tests are required of the product and at what intermed
critical to check aspects of quality, performance, materials, o
What are pass-fail criteria?
- How are the quality of tests results and data assured?
- What documentation should be retained related to the pedigre
the item?

Specific QA Plans must be reviewed and approved by the author, who is the person responsible for the item and its quality, and the cognizant Associate Director. For items which relate to the Project, the Associate Project Manager and the Project Manager review and approve Specific QA Plans. The review and approval process provides a quality check on the content of the Specific QA Plans.

Revision of Specific QA Plans is controlled. The process of building, testing and using items provides a feedback loop that indicates whether the QA plan is satisfactory or should be revised. Revisions have the same review and approval process as an original plan. Timely implementation of the revision is the responsibility of the author.

Documentation

A Divisional Quality Assurance Officer is appointed by each Division to ensure that the documentation is safely maintained and complies with the requirements of CEBAF's QA Manual. Documentation shall be kept in locked files in a location equipped with sprinklers.

A copy of all QA plans will be provided to the Quality Assurance Officer, who will maintain these copies in a central location. Further documentation, as required by the Specific Quality Assurance Plans, is to be maintained by each division in a location central to that division.

Audits

The CEBAF Quality Assurance Officer conducts audits of selected parts of the Quality Assurance Program at least quarterly to ensure quality.

All documentation required by the QA Manual is made available to the DOE for auditing at established storage locations.

Summary

The Quality Assurance Program at CEBAF, as manifested in the QA Manual and Specific QA Plans, is designed to establish a supportive framework in which physicists, engineers and administrators can work effectively and efficiently to produce hardware, systems, services, and data at an appropriate level of quality. We believe we are on the right track.

IV. LABORATORY QA ISSUES

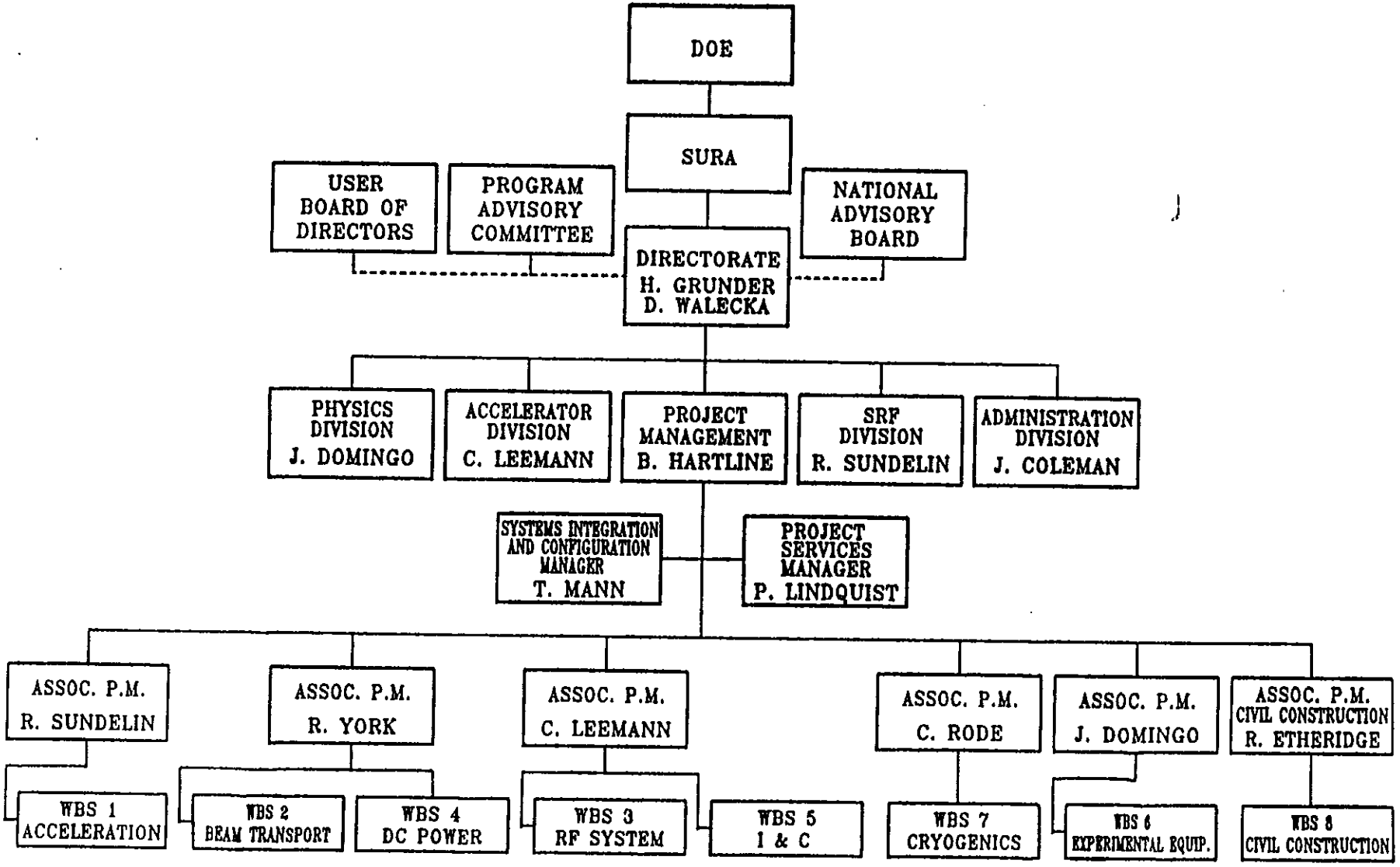
1. Selecting and implementing an appropriate QA standard. DOE provides a lot of pressure for us to follow NQA-1 which is not well matched to the approach or training of CEBAF staff. There is in effect a language barrier between CEBAF staff and DOE QA auditors. Two attempts at developing internal procedures based on an NQA-1 approach were unsuccessful because the documents produced did not meet lab needs and imposed unnecessary and counter-productive constraints. An NQA-1 approach tends toward Theory X management, which assumes that employees are not motivated to achieve organizational objectives, must be given explicit and detailed direction for every activity, and must be closely watched. This is not the case at CEBAF.

Fortunately, CEBAF's M&O contract with DOE does not require us to use NQA-1 as a QA standard.

2. Selecting an appropriate level of quality. CEBAF uses the responsible individual's best technical judgment, but cost and schedule factors inevitably enter in. Only in retrospect does one learn whether or not the right level was implemented.

3. How can low bid contracting policies be reconciled with appropriate quality needs?

QA:msl



WBS = PROJECT WORK BREAKDOWN STRUCTURE ELEMENT
R = PRECONSTRUCTION R&D ELEMENT

11/13/89

Figure 1