Management Plan
for the
Large-Area Time-of-Flight System
for STAR

at
Brookhaven National Laboratory

For the U.S. Department of Energy
Office of Science
Office of Nuclear Physics

December 1, 2005

STAR Large-Area Time-of Flight (TOF) Management Plan
Signature Page

STAR Collaboration approval:
Geary Eppley
Project Manager

Timothy Hallman
STAR Spokesman

Brookhaven National Lab approval:
Thomas Ludlam
BNL Project Oversight Manager

Samuel Aronson
BNL Assoc. Laboratory Director, HENP

DOE approval:
Michael Butler
Federal Project Director

Jehanne Simon-Gillo
Program Manager

Concurrence of STAR TOF Collaborators in China:
Yu-Gang Ma
Chinese Academy of Sciences

1 INTRODUCTION

STAR proposes to install a 23k-channel multi-gap resistive plate chamber (MRPC) time-of-flight (TOF) system at the outer radius of the time projection chamber (TPC), the area now occupied by the central trigger barrel (CTB). The detector will cover the full azimuth and from $-0.9 < \eta < 0.9$. MRPC technology is a major new detector technology developed at CERN for the ALICE experiment. STAR has been conducting successful R&D for STAR-specific MRPC detectors since 2000. The technology and test results are described in the proposal. Prototype detectors operated successfully in STAR in Runs 3, 4, and 5 (2002-2005).

The parallel plate detectors are made from 2, 0.7 mm and 5, 0.55 mm-thick glass plates separated by 6, 0.22 mm gaps. An electric potential of 14 kV is applied across the plates. The chambers operate in a highly electro-negative gas, primarily Freon r134a. Charged particles traversing the plates create electron avalanches in the gas gaps which are seen in 3.15 cm x 6.3 cm copper pick-up pads. The signals are amplified, discriminated, then recorded by the CERN HPTDC chip with a 25 ps least-significant-bit precision.

The proposed TOF system will double STAR's particle identification (PID) reach to 95% of all charged particles within the acceptance of the TOF detector. Seamless hadron particle identification from 0.1 < pT <~10 GeV/c over the full azimuth and $-0.9 < \eta < 0.9$ by the combination of time of flight and dE/dx at relativistic rise from the TPC will provide a crucial tool for the detailed study of the equation of state, hadronization, and jets in heavy-ion collisions. The enhanced PID capability is essential for STAR's heavy flavor physics program and for investigations of chiral properties of resonance particles in dense matter through measurement of their leptonic decays. For example, the proposed TOF detector will allow STAR to make a precise measurement of the D^0 production cross section in a normal running period. The identification of electrons below 2 GeV/c, by combining the TOF and the TPC dE/dx measurements, is critical for the measurement of resonances such as ρ, ϕ, and J/Ψ. The proposed TOF system will enable studies of identified-particle correlations and fluctuations over broad scales of pT, rapidity, and azimuth. These studies will open new opportunities in STAR event-by-event analysis, possibly addressing the nature of the fluctuations induced by temperature variations and mini-jet scattering in the dense medium. Details of the physics reach of the proposed TOF system are described in the proposal.

The new detector will be realized in two parallel fabrication projects, one in China and one in the U.S. Six Chinese universities and research institutions joined the STAR collaboration in 2001. The Chinese STAR Collaboration will take the responsibility for MRPC production in China. The Chinese group will manufacture and test 4032, 6-channel MRPC modules using Chinese funds, and will be responsible for delivering MRPC modules to the U.S. The U.S project will install the modules in aluminum trays, 32 per tray, build and install the read-out electronics, and test the completed detector trays. Both Chinese and U.S institutions will be responsible for installing and commissioning the detector in STAR. Some of these activities are outside the scope of the project described in this management plan.

2 FUNCTIONAL REQUIREMENTS

The principal functional requirement of the TOF system to meet the physics goals is to provide a timing measurement with a resolution of 100 ps or better after all corrections.

Other general requirements that provide input for the definition of deliverables at project completion are:

- The system must fit into the integration envelope for the present 120-tray CTB system, which it would replace.

- The system must be able to operate inside the 0.5 Tesla magnetic field.

- The system must meet BNL C-AD safety requirements.

- The system must not impair the physics capability of other STAR detector subsystems.

- The *noise rate* is a performance measurement of MRPC detectors that specifies the signal rate above operating threshold at operating high-voltage in the absence of beam. In general, this measurement is an indication of how well the MRPC will perform as a “trigger” detector. The requirement on the system, included in Table 1 below, is that the noise rate for all channels be below 50 Hz.

- The TOF system will also function as a trigger detector in STAR and will provide information on event multiplicity to the Level 0 trigger processor. The bunch-crossing rate, also called the experimental clock rate for STAR, is 9.4 MHz. Multiplicity information must be delivered to Level 0 at this frequency with a latency of 700 ns following the collision. The TOF system will provide a multiplicity in the range of 0 – 12 for each one-half tray.

- The TOF system must read out data when “Level 0 Accept” commands that include readout of the TPC are issued by the STAR trigger system. The TOF system must readout data at a maximum event rate of 10 kHz to meet this requirement. The TOF system will also provide a 23k bit map of hit channels that can be sent to the Level 2 trigger at this 10 kHz rate.

- The TOF system must be able to transfer information to STAR DAQ at the “Level 2 Accept” command (including TPC readout) rate. The TOF system must transfer event information to the DAQ at an event rate of 2 kHz to meet this requirement.

A summary of the functional requirements that will verified at project completion for the TOF system is shown in Table 1.

Table 1. System Functional Requirements to be demonstrated at project complete.

Number of stop detector channels	23040 total, 192 per tray
Number of "live" channels	>175 per tray
Number of start detector channels	38
Noise rate per channel (stop-side)	<50 Hz
Tray high-voltage current (no beam)	<50 nA
System overall timing resolution	<100 $\pm$ 15ps, in Au+Au collisions
Electronic overall timing resolution, single channel	<45 ps
Total power consumption	<40 kW
Average single hit efficiency	>90%
Level 0 trigger multiplicity rate	9.4 MHz
Level 0 trigger multiplicity latency	700 ns
Pre-Level 0 time-stamp buffer size	128 time-stamp pairs per 2 channels
Average dead time per hit	<50 ns
Maximum time stamp acquisition rate per channel	2 MHz
Bandwidth from pre-level 0 buffer to pre-Level 2 Buffer	80 M-bit/s/tray: >10k events/s/tray
Bandwidth from pre-Level 2 buffer to DAQ	5 G-bit/s: >2k events/s

3 TECHNICAL SCOPE

The STAR TOF project is divided into three major subsystem groups: (a) MRPC Modules, (b) Detector and Mechanical Systems, and (c) Electronics. The Chinese institutions are responsible for the following technical scope:

- Production of 4032 MRPC modules
- Testing of 4032 MRPC modules relative to approved QA procedures. The QA procedures and performance specifications will be documented by the China TOF project.

The U.S. Institutions are responsible for the following technical scope:

- Mechanical support of MRPC detectors and electronics (tray)
- Gas system
- High Voltage System
- Start Detector
- Associated Infrastructure
- Electronics Boards (TINO, TPMT, TDIG, TCPU, THUB)
- Low Voltage System
- Configuration and calibration software

3.1 MRPC MODULES

The system consists of 3840, 6-channel MRPC modules housed in 120 aluminum trays. Each tray covers about 0.9 units of pseudorapidity and 1/60th of the azimuth. The production and testing of the MRPC modules is the responsibility of the Chinese collaborating institutions in STAR. This represents an in-kind contribution of approximately $2.3M and the costs are not included in the cost of the U.S. construction project. Quality assurance parameters and procedures will be established by the Chinese institutions in collaboration with the U.S. TOF project to insure that all modules meet the design goals of the project.

3.2 DETECTORS AND MECHANICAL SYSTEMS

The **tray** is the mechanical support for the MRPC detectors and the electronics. It is also the gas containment vessel for the MRPCs. There are 120 trays in the system. They are roughly the same size as CTB trays and are installed in STAR in the same manner. The feet of the tray latch on to rails glued to the TPC outer field cage. The aluminum trays will be fabricated by the same vendor that built the CTB trays. The MRPC modules will be installed in trays at the University of Texas, Austin (UT). The read-out electronics are then mounted on the tray. Quality assurance procedures and tests will be established at UT to insure that all tray assemblies are ready for successful operation in STAR when they are delivered to BNL.

The **gas system** provides a mixture of 18 parts r134a to 1 part isobutane to the detector trays. The isobutane content is analyzed and monitored to insure an accurate mixture. The isobutane content is also monitored to insure that a flammable gas mixture is not introduced into the detector and to insure the safe operation of the STAR detector. The oxygen content is monitored and maintained at less than 30 ppm. The water content is monitored and maintained at less than 10 ppm. The design and installation of the TOF gas system will be under the supervision of L. Kotchenda (MEPHI) who designed and maintains the STAR TPC gas system.

The **high-voltage system** (HV) delivers +7000V and –7000V to each tray. Each pair of high-voltage channels will serve 10 trays. The high-voltage system will be procured and fabricated at UCLA.

The **start detector** is a separate subsystem similar to the existing 3-channel start detector in STAR, the pVPD (pseudo vertex position detector). The system will consist of two, 19-detector assembly arrays on each side of STAR positioned very close to the beam pipe at a distance of ~5.5 meters from the center of STAR. Each detector assembly will consist of a 1 X_0 -thick layer of Pb, a plastic scintillator or quartz radiator, and a mesh dynode PMT. The front-end and digitization electronics are the same as that used on the stop side. This detector provides the start time and the MRPCs the stop times which determine precisely the time of flight of particles. The time of flight together with the path length and momentum determines the mass and allows particle identification. This detector could also provide information for a low-level (Level 0) trigger on the primary vertex location as well. The start detector will be built at Rice University.

The BNL STAR operations group will be responsible for the design and installation of the required **infrastructure** for the TOF system. The principal requirements are racks and cooling for the low voltage power supplies, a chilled-water delivery system to cool the TOF tray electronics, and a support structure to support the TPC during insertion of the TOF trays behind the TPC support arms.

3.3 ELECTRONICS

The TOF electronics system records the time of signals in the start detector and the MRPC "stop" detectors and delivers the information to the STAR DAQ (data acquisition) system. It also interfaces with the STAR trigger system and provides multiplicity information to the Level 0 trigger, similar to the information now provided by the CTB, and detailed hit information to the Level 2 trigger. A schematic tray-level diagram of the electronics is shown in Figure 1.

The following electronics boards will be produced:

TINO. The *TINO* card is the interface between the MRPC tray and the *TDIG* read-out card (see below). It amplifies and discriminates the MRPC signals using the ALICE *NINO* analog ASIC. Each *TINO* card handles 4, 6-channel MRPC modules. There are 960 *TINO* cards.

TPMT. The *TPMT* interfaces the start detector PMTs to the *TDIG* card. Each *TPMT* handles 8 PMT signals, provides input over-voltage protection. There are 6 *TPMT* cards.

TDIG. The *TDIG* card receives the input signals and records the signal times using CERN *HPTDC* chips. Each *TDIG* handle 24 signal channels. There are 966 *TDIG* cards.

TCPU. The *TCPU* card concentrates the data from 8 *TDIG* cards and sends it to *THUB* (see below). It distributes the 40 MHz clock to the *TDIG* cards. It also sends multiplicity information to the Level 0 trigger. There are 122 *TCPU* cards.

THUB. The *THUB* card interfaces 30 or 31 *TCPU* cards to STAR trigger and DAQ. It creates a low-jitter 40 MHz clock for the *HPTDC* chip and distributes it to the *TCPU* card on the tray. There are 4 *THUB* cards, each in a chassis mounted on the magnet steel. Each *THUB* card has a CERN/ALICE *SIU* daughter card that provides a dual-fiber interface to STAR DAQ. The TOF DAQ receiver is a Linux pc with a PCI based CERN/ALICE *D-RORC* optical interface and a Myrinet interface.

The following 5 deliverables are involved in implementing the electronics subsystem:

- electronics board purchase and board testing,
- electronics integration and system testing: engineering redesign, firmware debugging and modification,
- electronics installation and commissioning,
- electronics configuration and calibration software and control software, and
- low-voltage systems.

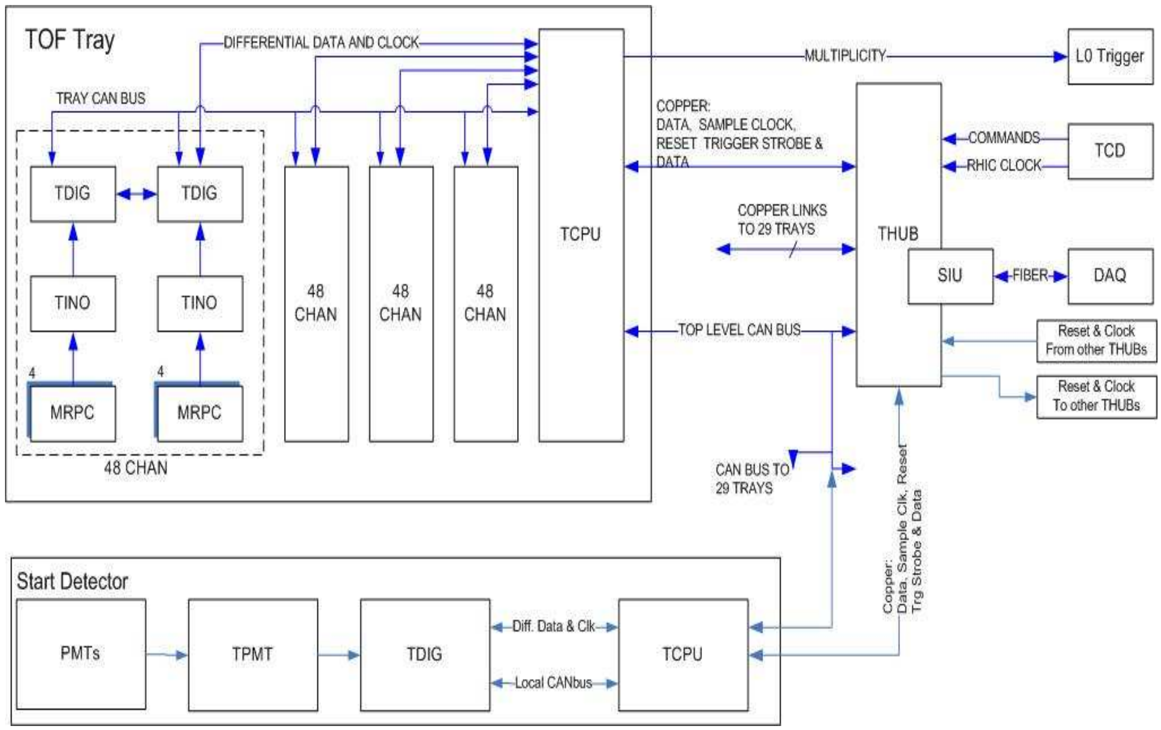


Figure 1. A tray-level schematic diagram of the TOF electronics boards.

The electronics board purchase and testing will be managed at Rice University.
The low voltage system will be designed, procured, and fabricated at UCLA.

The *TINO*, *TDIG*, and *TCPU* cards are mounted on the detector trays as part of the assembly process at UT. The trays are then tested at UT as complete detector units including the integral on-board read-out electronics. The trays are shipped to BNL as complete detector units including the electronics. The **installation** at BNL will include the mechanical installation of the tray on the TPC rails and connection to the HV, gas, and cooling system. The electronics installation includes the connection to trigger, *THUB*, and low voltage, and the connection from *THUB* to trigger and DAQ. The electronics commissioning of the detector consists primarily of integrating the detector electronics into the STAR trigger and DAQ systems.

3.4 DELIVERABLES

The STAR TOF project shall be completed in the first quarter of FY2009 when all component deliverables specified in Table 2 have been assembled, tested, and received at BNL and functional requirements specified in Table 1 have been demonstrated. It is estimated that 48 of the120 trays will be installed in STAR by project completion and will be used for demonstrating the functional requirements shown in Table 1.

Table 2. Component Deliverables of TOF

Item	Number	Spares
Mechanical Systems		
TPC support structure	1	
Gas system	1	
Detector Trays		
32 modules/tray, 6 channels/module	120	6 sets of parts
Electronics		
TINO 24-channel	960	5%
TDIG 24 channel	966	5%
TPMT	6	2
TCPU	122	8
THUB	4	2
Low voltage supplies	128 channels	8
High voltage supplies	24 channels	4
Configuration software	1	
Electronics calibration software	1	
Start Detector		
Detector assemblies	2	

3.5 ALTERNATIVE TECHNOLOGY

Low momentum hadronic particles are now identified by energy loss in the TPC. Time-of-flight particle identification can identify most of the particles not currently identified, except those at high momentum. It has a substantial momentum overlap with energy-loss particle identification in the TPC allowing cross checks between the two methods. RICH detectors can identify high momentum particles but there is a momentum gap in the particle identification between RICH detectors and the TPC. There is also no integration volume available in STAR for installing RICH detectors. The known alternative to MRPC technology for TOF is scintillator-PMT. It is not possible shield PMTs from the large magnetic field in STAR where the time-of-flight detector must be located. Therefore, it is necessary to use mesh-dynode PMTs. A small TOF detector was built and operated in STAR for three years using mesh-dynode PMTs and scintillator and the performance was excellent. However, the mesh-dynode PMTs cost $1.9k each so a large-area system is not affordable.

4 MANAGEMENT ORGANIZATION

4.1 GENERAL

This document provides the proposed management organization and delineates responsibilities within the project. Figure 2 shows the proposed management structure for the STAR TOF fabrication project.

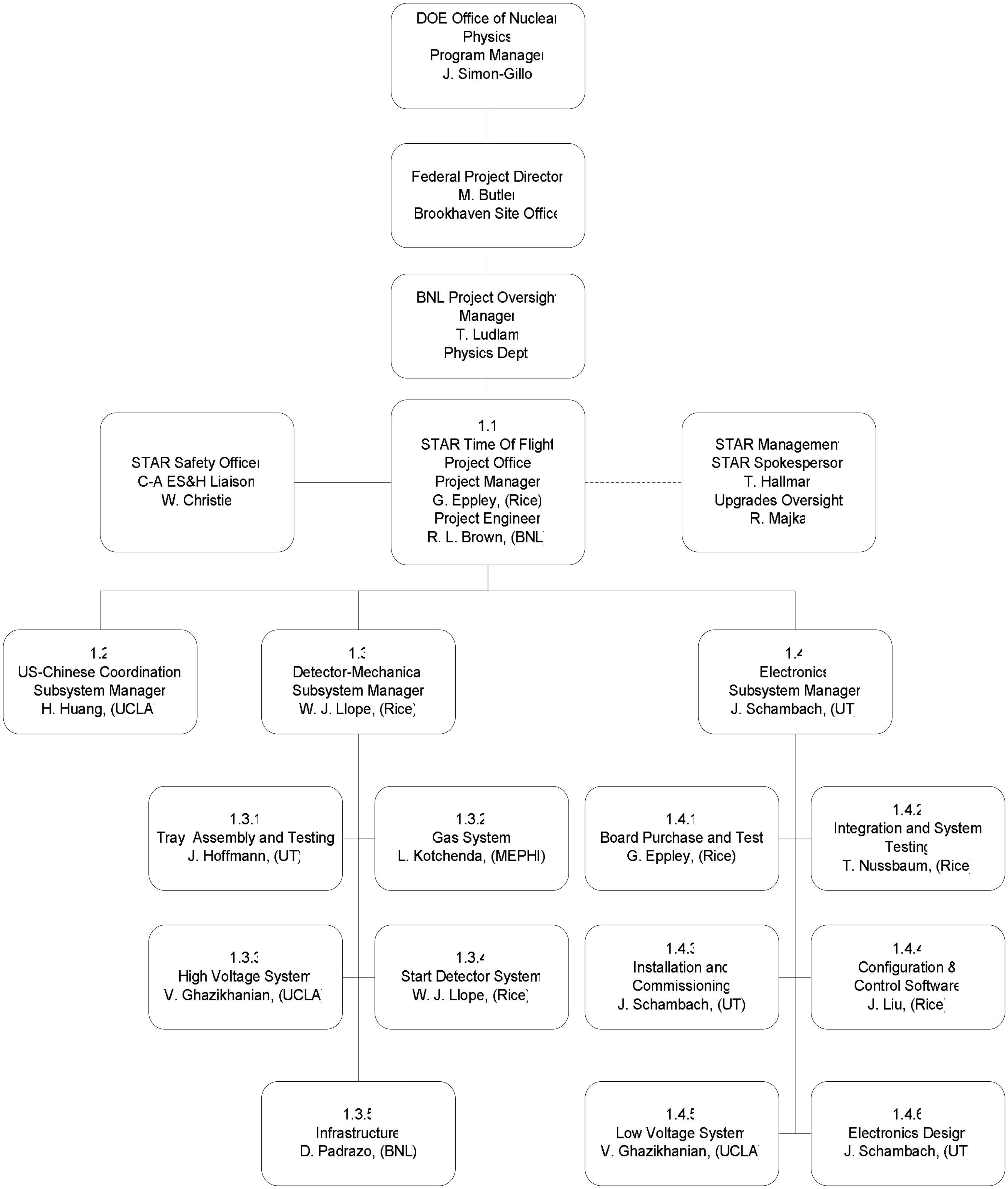


Figure 2. Management chart for the STAR TOF fabrication project.

4.2 PROJECT MANAGEMENT RESPONSIBILITIES

4.2.1 DOE project management

The DOE Office of Nuclear Physics (NP) has overall DOE responsibility for the project. Jehanne Simon-Gillo is the Program Manager for the project.

- Provides programmatic direction.
- Functions as DOE headquarters point of contact for the project.
- Budgets for funds to execute the project.
- Approves Level 1 baseline changes.

Michael A. Butler is the Federal Project Director at the Brookhaven Site Office (BHSO)

- Provides overall management oversight for the project.
- Submits key project documents to DOE and reports project progress.
- Approves Level 2 baseline changes.
- Ensures that the project complies with applicable ES&H requirements.

4.2.2 BNL project oversight

The BNL Project Oversight Manager is T. Ludlam, BNL.

Responsibilities

The BNL Project Oversight Manager will be administratively and fiscally responsible for the project. In particular he will:

- Provide overall management oversight for all aspects of the project.
- Approve key personnel appointments made by the Project Manager.
- Approve major subcontracts recommended by the Project Manager.
- Manage the distribution of contingency funds for the project.
- Ensure that the project has demonstrated that it meets the functional requirements.
- Review quarterly status reports.
- Schedule and organize external reviews of the project.
- Ensure the work is performed safely and in compliance with the ISM rules.

The BNL Project Oversight Manager will keep the BNL management and the DOE informed about the technical goals and progress of the project. He will conduct annual reviews, in coordination with the DOE Office of Nuclear Physics, to insure that the project continues to serve the long-term interests of the laboratory's research program through the related upgrades of the detectors and the RHIC collider.

4.2.3 STAR Collaboration Management

The STAR Collaboration Management has overall responsibility for the successful execution of the scientific operation of the STAR detector. Timothy Hallman (BNL) is the STAR Spokesperson. Richard Majka (Yale University) is the STAR Upgrades Manager, and has direct responsibility within STAR for oversight of the TOF project. The STAR Management is responsible for the integration of the TOF detector into STAR, and provides the technical support for the commissioning and operation of the completed detector. The STAR Management reviews and approves any changes to the baseline performance parameters of the TOF.

4.2.4 Project management office

The TOF project office consists of the Project Manager and the Project Engineer. The Project Manager is responsible for the overall management of the project and the Project Engineer who reports to the Project Manager is responsible for the technical management of the project.

The Project Manager is G. Eppley, Rice University.

Responsibilities

The Project Manager reports to the BNL Project Oversight Manager. The Project Manager will have the following responsibilities:

- Responsible and accountable for the successful execution of the project.
- Delivers project deliverables.
- Keeps the STAR spokesperson and Advisory Board informed on the progress of the project.
- Implements a performance measurement system .
- Identifies and ensures timely resolution of critical issues.
- Approves distribution of fabrication funds and awarding of contracts according to approved procedures.
- Allocates the contingency funds following approved procedures.
- Appoints subsystem managers with the approval of STAR management.
- Submits quarterly status reports to BNL Oversight Project Manager.
- Ensures the work is performed safely and provides necessary ES&H documentation, with the project engineer and STAR safety manager.
- Responsible with the Project Engineer and subsystem managers for providing documentation and presentations for project reviews.
- Responsible with the Project Engineer and subsystem managers for developing and maintaining project documentation meeting STAR documentation standards.

The Project Engineer is R. Brown, BNL.

Responsibilities

The Project Engineer reports to the Project Manager The Project Engineer will have the following responsibilities:

- Under the direction of the Project Manager, supplies the project deliverables on time and within budget.
- Identifies and ensures timely resolution of critical issues within the project engineers control.
- Ensures the work is performed safely and provides necessary ES&H documentation, with the STAR safety manager.
- Ensures the project integrates properly into the STAR detector and with existing subsystems.
- Responsible for the technical direction of the TOF.
- Responsible for developing the system design requirements, including interfaces with other subsystems, and achieving these requirements.
- Communicates functional requirements to the subsystem managers.
- Controls changes in the system design requirements, including interfaces between subsystems.
- Maintains the project files and identifies critical paths and project risks.
- Conducts regular meetings (monthly) and reports results to the project manager.
- Responsible with the project manager and subsystem managers for providing documentation and presentations for project reviews.
- Responsible with the project manager and subsystem managers for developing and maintaining project documentation meeting STAR documentation standards.

The project engineer will meet regularly with TOF project and STAR management to assure that the project meets the performance and budget goals.

4.2.5 Subsystem managers

Subsystem managers are responsible for each of the three major groups of subsystems: MRPC Modules, Detectors and Mechanical Systems, and Electronics. The subsystem managers are:

- H. Huang, UCLA, project coordination with the China STAR TOF project which will produce MRPC detector modules,
- W.J. Llope, Rice, Detectors and Mechanical Systems, and
- J. Schambach, UT, Electronics.

The subsystem managers report directly to the Project Engineer and will be responsible for the design, construction, installation, and testing of their subsystem, in accordance with the performance requirements, schedule, and budget.

Responsibilities for subsystem managers of U.S. performed work

- Collaborate with the Project Engineer to assemble the staff and resources needed to complete the subsystem.
- Develop and follow the system design requirements.
- Ensure that subsystems meet the system design requirements, including interfaces
- Responsible for carrying out the design, construction and assembly of the subsystem in accordance with the scope, schedule and budget.
- Provide regular reports on the status of the subsystem to the project engineer.
- Ensure the work is performed safely and provide necessary ES&H documentation.
- Responsible for providing documentation and presentations for project reviews.
- Develop and maintain project documentation.

Responsibilities of subsystem manager for China project coordination

- Develop, in collaboration with the Chinese and U.S. project management, system design requirements and plans for their implementation.
- Develop, in collaboration with the Chinese and U.S. project management, MRPC QA procedures.
- Monitor progress to see that the subsystem meets the system design requirements, including interfaces.
- Provide regular reports on the status of the subsystem to the project engineer and project manager.
- Provide necessary ES&H documentation for components delivered to the US project.
- Responsible for providing documentation and presentations for project reviews.
- Develop and maintain project documentation.

5 SCHEDULE AND BUDGET

The STAR TOF project has been organized into a work breakdown structure (WBS) for purposes of planning, managing and reporting project activities. Work elements are defined to be consistent with discrete increments of project work.

5.1 SCHEDULE

Figure 3 is a Gantt chart of the project schedule, consistent with the WBS. The project begins in first quarter FY06 and ends in first quarter FY09. The full barrel TOF system is delivered and ready for installation by October 2008. The MRPC module construction bar line, line 4, is displayed as an open bar rather than solid to indicate that the MRPC module fabrication project is a Chinese project not funded by the U.S. fabrication project.

The MRPC modules are shipped to UT and assembled into trays with the onboard electronics. The completed trays are tested at UT as complete detector units with the integral electronics before they are shipped to BNL. Except for the 4 *THUB* cards and the 6 cards for the start detector readout, the rest of the several thousand electronic cards produced for the project will arrive at BNL as part of pre-assembled and tested detector units.

A milestone that states for example, 24 trays complete, requires that the requisite modules were produced and tested in China and received at UT. It also requires that the requisite on-board electronics have been manufactured and the individual boards tested. It requires that the detector trays have been assembled with modules and electronics and tested with cosmic rays at UT for ~3 weeks as complete detector units. Finally, it requires that the modules have been shipped and received at BNL.

The milestones for the delivery of MRPC modules to the U.S. were developed by the China MRPC construction project. The construction of electronics and the assembly and testing of detector trays in the US, and the associated milestones, have been matched to this schedule.

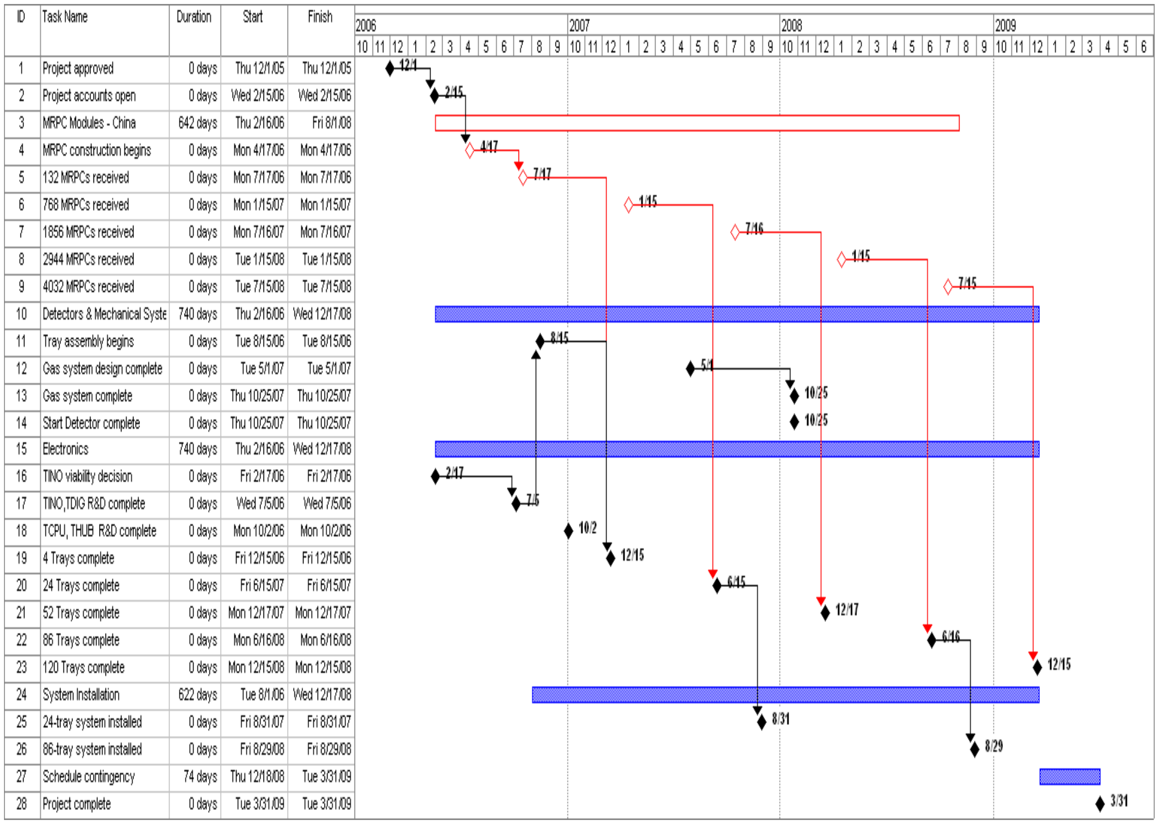


Figure 3. High level schedule of the STAR TOF construction project. MRPC module production, line 3, and the associated milestones, lines 4-9 are the responsibility of the China TOF MRPC construction project.

5.1.0 Control Milestones

Table 3 shows the project management and control milestones, WBS level 3.

Table 3. Project Milestones. Milestones for the China MRPC fabrication project are shown in blue with completion dates in italics.

WBS	Milestone Description	Completion Date
1.1.2	Project approved	**FY06 Q1**
1.1.3	Preliminary design and safety review	**FY06 Q2**
1.1.4	Project accounts open	**FY06 Q2**
1.1.5	Final design review: Trays	**FY06 Q2**
1.4.7	Decide viability of NINO chip	**FY06 Q2**
1.1.6	Final design review: Modules	**FY06 Q3**
1.2.2	Module production begins in China	***FY06 Q3***
1.4.8	Order *HPTDC* and *NINO* chips	**FY06 Q3**
1.4.9	*TINO*, *TDIG* R&D complete	**FY06 Q4**
1.1.7	Final design review: Electronics	**FY06 Q4**
1.2.3	128 modules received from China	***FY06 Q4***
1.3.7	Tray assembly begins	**FY06 Q4**
1.4.10	*TCPU*, *THUB* R&D complete	**FY07 Q1**
1.2.4	384 modules received from China	***FY07 Q1***
1.1.8	Final design review: Gas system, Start detector, Infra.	**FY07 Q1**
1.3.8	4 trays complete	**FY07 Q2**
1.2.5	768 modules received from China	***FY07 Q2***
1.1.9	Final design review: Low & High voltage systems	**FY07 Q1**
1.3.9	14 trays complete	**FY07 Q3**
1.2.6	1312 modules received from China	***FY07 Q3***
1.3.10	24 trays complete	**FY07 Q4**
1.2.7	1856 modules received from China	***FY07 Q4***
1.3.11	38 trays complete	**FY08 Q1**
1.2.8	2400 modules received from China	***FY08 Q1***
1.3.12	52 trays complete	**FY08 Q2**
1.3.13	Start detector complete	**FY08 Q1**
1.3.14	Gas system complete	**FY08 Q1**
1.2.9	2944 modules received from China	***FY08 Q2***
1.3.15	68 trays complete	**FY08 Q3**
1.2.10	3488 modules received from China	***FY08 Q3***
1.3.16	86 trays complete	**FY08 Q4**
1.2.11	4032 modules received from China	***FY08 Q4***
1.3.17	106 trays complete	**FY09 Q1**
1.3.18	120 trays complete	**FY09 Q1**
1.1.10	Project complete	**FY09 Q2**

5.2 BUDGET

Figure 4 shows the cost summary for the TOF project at WBS level 4 in FY05 kilo-dollars and the required annual funding profile in actual year kilo-dollars. It should be noted that the planned DOE funding profile is $2,400,000 in FY 2006 and $2,400,000 in FY 2007, which is more aggressive than planned expenditures. This DOE funding profile will eliminate cost and schedule risks from potential Continuing Resolutions.

		WBS 4	Cont. rate	Contin.	Sum	Actual yr:	FY06	FY07	FY08	Total
Detectors and Mech. Systems										
	Tray									
1.3.1.1	Tray structure	62.8	0.21	13.3	76.0		77.6			
1.3.1.2	Tray assembly fixtures	11.9	0.30	3.6	15.4		15.9			
1.3.1.3	Tray storage rack	6.4	0.30	1.9	8.4		8.6			
1.3.1.4	Prepare work area	3.4	0.30	1.0	4.5		4.7			
1.3.1.5	Other materials	47.5	0.22	10.5	58.0		59.1			
1.3.1.6	Tray assembly	257.0	0.21	52.8	310.0		74.5	147.0	114.0	
1.3.1	Tray	389.0	0.21	83.1	472.0		240.0	147.0	114.0	501.0
	Gas system									
1.3.2.1	Gas system design	5.8	0.24	1.4	7.2		7.5			
1.3.2.2	Gas system component	38.5	0.12	4.6	43.1		22.0	22.4		
1.3.2.3	Gas system installation	2.4	0.16	0.4	2.8			3.0		
1.3.2.4	Gas system MSTC	12.0	0.24	2.9	14.9		7.6	7.8		
1.3.2	Gas system	58.7	0.16	9.3	68.0		37.1	33.2		70.3
	High voltage system									
1.3.3.1	High voltage supplies	33.3	0.09	3.1	36.4			37.9		
1.3.3.2	HV distribution system	80.3	0.20	16.2	96.4		96.3	2.1		
1.3.3.3	HV slow controls	4.6	0.18	0.8	5.4		5.6			
1.3.3	High voltage system	118.0	0.17	20.1	138.0		102.0	40.0		142.0
	Start detector									
1.3.4.1	Detector assemblies	23.3	0.11	2.6	25.9			27.2		
1.3.4.2	Mounting structure	2.7	0.20	0.5	3.2			3.5		
1.3.4.3	Installation	0.5	0.05	0.1	0.6			0.6		
1.3.4	Start detector	26.5	0.12	3.2	29.7			31.3		31.3
	Infrastructure									
1.3.5.1	Water system,trays	19.9	0.20	4.0	23.9		24.4			
1.3.5.2	Interlock, water, tray	3.4	0.20	0.7	4.0		4.1			
1.3.5.3	TPC support	39.2	0.36	14.1	53.3			55.5		
1.3.5	Infrastructure	62.5	0.30	18.8	81.3		28.5	55.5		84.0
1.3	**Detectors and mech.**	**655.0**	**0.21**	**134.0**	**789.0**		**408.0**	**307.0**	**114.0**	**829.0**
	Electronic board purchase and testing									
1.4.1.1	TINO	532.0	0.29	154.0	687.0		412.0	294.0		
1.4.1.2	TPMT	8.1	0.20	1.6	9.7		9.9			
1.4.1.3	TDIG	994.0	0.26	258.0	1252.0		766.0	521.0		
1.4.1.5	TCPU	182.0	0.20	37.0	219.0		133.0	92.4		
1.4.1.6	THUB	81.0	0.36	28.8	110.0		112.0			
1.4.1.7	Board test components	14.4	0.11	1.6	16.0		16.3			
1.4.1.8	Board testing	232.0	0.31	71.9	304.0		144.0	106.0	76.3	
1.4.1	Board Purchase and tes	2044.0	0.27	553.0	2597.0		1593.0	1013.0	76.3	2683.0
	System testing and integration									
1.4.2	System testing and inte	213.0	0.30	63.9	277.0		147.0	89.5	58.9	296.0
	Electronics installation									
1.4.3	Electronics installation	149.0	0.30	44.6	193.0		44.8	86.8	78.6	210.0
	Low voltage system									
1.4.5.1	LV power supplies	125.0	0.11	13.9	139.0		12.0	133.0		
1.4.5.2	LV power cables	77.7	0.10	7.8	85.5		7.4	81.4		
1.4.5.3	Control and monitoring	9.6	0.25	2.4	11.9		12.3			
1.4.5	Low voltage system	212.0	0.11	24.1	236.0		31.8	214.0		246.0
	Electronics Design									
1.4.6.1	TDIG	27.2	0.30	8.2	35.4		36.8			
1.4.6.2	TCPU	54.4	0.30	16.3	70.7		73.5			
1.4.6.3	THUB	32.6	0.30	9.8	42.4		44.1			
1.4.6	Electronics design	114.0	0.30	34.3	149.0		154.0			154.0
1.4	**Electronics total**	**2732.0**	**0.26**	**720.0**	**3452.0**		**1972.0**	**1404.0**	**214.0**	**3589.0**
1.1.1	MSTC	165.0	0.05	8.3	173.0		58.9	60.0	61.3	180.0
1.1.2	BNL Management	172.0	0.03	5.6	178.0		94.7	43.2	45.0	183.0
1	**Project Total**	**3724.0**	**0.23**	**869.0**	**4592.0**		**2533.0**	**1814.0**	**434.0**	**4781.0**

Figure 4. The cost summary for the STAR TOF fabrication project. Amounts are in FY05 kilo-dollars. Actual year kilo-dollars are shown for the funding profile for FY06 through FY08. An inflation factor of 0.02 compounded is used for materials and 0.04 compounded for labor.

5.2.0 Contingency

The BNL Project Oversight Manager will manage the distribution of contingency funds for the project. Contingency is allocated under the change control procedures described in the next section. The average contingency is 23%.

This section describes how the contingency for a given WBS element was calculated. Risk is a function of the following factors: the sophistication of the technology, the maturity of the design effort, the accuracy of the cost sources and the impact of delays in the schedule. Risk analysis is performed for each WBS element at the lowest level estimated. Results of this analysis are related to a contingency which is listed for each WBS element. The goal is to make the method of contingency determination uniform for all project WBS elements.

Definitions

Base Cost Estimate – The estimated cost of doing things correctly the first time. Contingency is not included in the base cost.

Cost Contingency – The amount of money, above and beyond the base cost, that is required to ensure the project's success. This money is used only for omissions and unexpected difficulties that may arise. Contingency funds are held by the Project Manager.

Risk Factors

Technical Risk – Based on the technical content or technology required to complete the element, the technical risk indicates how common the technology is that is required to accomplish the task or fabricate the component. If the technology is so common that the element can be bought "off-the-shelf", i.e., there are several vendors that stock and sell the item, it has very low technical risk, therefore a risk factor of 1 is appropriate. On the opposite end of the scale are elements that extend the current "state-of-the-art" in this technology. These are elements that carry technical risk factors of 10 or 15. Between these are: making modifications to existing designs (risk factor 2-3), creating a new design which does not require state-of-the-art technology (risk factor 4 & 6), and creating a design which requires R&D, and advances the state-of-the-art slightly (risk factor 8 & 10).

Cost Risk – Cost risk is based on the data available at the time of the cost estimate. It is subdivided into 4 categories.

The first category is for elements for which there is a recent price quote from a vendor or a recent catalog price. If the price of the complete element, or the sum of its parts, can be found in a catalog, the appropriate risk factor to be applied is 1. If there is an engineering drawing or specification for the element, and a reliable vendor has recently quoted a price based on these, the cost risk factor to be applied is 2. Similarly, if a vendor has quoted a price based on a sketch that represents the element, and the element's design will not change prior to its fabrication, the appropriate cost risk factor would be 3.

The second category is for elements for which there exists some relevant experience. If the element is similar to something done previously with a known cost, the cost risk factor is 4. If the element is something for which there is no recent experience, but the capability exists, the cost risk is 6. If the element is not necessarily similar to something done before, and is not similar to in-house capabilities, but is something that can be comfortably estimated, the risk factor is 8.

The third category is for elements for which there is information that, when scaled, can give insight into the cost of an element or series of elements. The cost risk factor for this category is 10.

The fourth category is for elements for which there is an educated guess, using the judgment of engineers or physicists. If there is experience of a similar nature, but not necessarily designing, fabricating or installing another device, and the labor type and quantity necessary to perform this function can be estimated comfortably, a cost risk factor of 15 is appropriate.

Schedule Risk – If a delay in the completion of the element could lead to a delay in a critical path or near critical path component, the schedule risk is 8. If a delay in the completion of the element could cause a schedule slip in a subsystem which is not on the critical path, the schedule risk is 4. Only elements where a delay in their completion would not affect the completion of any other item have schedule risks of 2.

Design Risk – is directly related to the maturity of the design effort. When the element design is nearly complete, quantity counts and parts lists finished, the risk associated with design is nearly zero; therefore a risk factor of 0 is applied. This is also the case when the element is an "off-the-shelf" item and the parts counts and quantities are finalized. When the element is still just an idea or concept, with crude sketches the only justification for the cost estimate, the risk associated with design state is high or 15. Between these two extremes are the stages of conceptual design and preliminary design. In conceptual design, when layout drawings of the entire element are approaching completion, some preliminary scoping analyses have been completed, and parts counts are preliminary, the design risk factor is 8. During preliminary design, when there are complete layout drawings, some details worked out, complete parts counts, and some analysis for sizing and showing design feasibility, the appropriate design risk is 4.

Weighting Factors

The weight applied to the risk factors depends on whether there are multiple or single risks involved in completing an element.

The weights applied to technical risk depend upon whether the element requires pushing the current state-of-the-art in design, manufacturing, or both. If the element requires pushing both, the weight to be applied is high, or 4; if either the design or manufacturing are commonplace, the weighting factor is 2.

For weights applied to cost risk, the two factors are material costs and labor costs. If either of these are in doubt, but not both, the weight to be applied to cost risk is 1. If they are both in doubt, the weight applied is 2.

The weight factor given to schedule risk is always 1.

The weight factor given to design risk is always 1 and so is not shown explicitly.

Procedure

The following procedure is used for estimating contingency.

Step 1 – The conceptual state of the element is compared with Table 4 to determine risk factors. A technical risk factor is assigned based on the technology level of the design. A design risk factor is assigned based upon the current state (maturity) of the design. A cost risk factor is assigned based on the estimating methodology used to arrive at a cost estimate for that element. Similarly, a schedule risk factor is identified based on that element's criticality to the overall schedule.

Step 2 – The potential risk within an element is compared with Table 5 to determine the appropriate weighting factors.

Step 3 – The individual risk factors are multiplied by the appropriate weighting factors and then summed to determine the composite contingency percentage.

Step 4 – This calculation is performed for each element at its lowest level.

Step 5 – The dollar amount of contingency for an element is calculated by multiplying the base cost by the composite contingency percentage.

Table 4: Technical, cost, and schedule risk factors.

Risk Factor	Technical	Cost	Schedule	Design
0	Not used	Not used	Not used	Detail design > 50% done
1	Existing design and off-the-shelf H/W	Off-the-shelf or catalog item	Not used	Not used
2	Minor modifications to an existing design	Vendor quote from established drawings	No schedule impact on any other item	Not used
3	Extensive modifications to an existing design	Vendor quote with some design sketches	Not used	Not used
4	New design; nothing exotic	In-house estimate based on previous similar experience	Delays completion of non-critical subsystem item	Preliminary design >50% done; some analysis done
6	New design; different from established designs or existing technology	In-house estimate for item with minimal experience but related to existing capabilities	Not used	Not used
8	New design; requires some R&D but does not advance the state-of-the-art	In-house estimate for item with minimal experience and minimal in-house capability	Delays completion of critical path subsystem item	Conceptual design phase; some drawings; many sketches

10	New design of new technology; advances state-of-the-art	Top-down estimate from analogous programs	Not used	Not used
15	New design; well beyond current state-of-the-art	Engineering judgment	Not used	Concept only

Table 5: Technical, cost, schedule, and design weighting factors.

Risk Factor	**Condition**	**Weighting Factor**
Technical	Design OR Manufacturing	2
	Design AND Manufacturing	4
Cost	Material Cost OR Labor Rate	1
	Material Cost AND Labor Rate	2
Schedule	Same for all	1
Design	Same for all	1

6 CHANGE CONTROL

All changes to the technical, cost and schedule baselines shall be identified, controlled, and managed through a traceable, documented change control process, which will have been approved.

Changes to the technical, cost and schedule baselines will be controlled using the thresholds described in Table 6.

Over the term of the TOF fabrication project, it is expected that the design or definition of components will evolve. When components of a system of the complexity of the TOF detector change without a system of checks and balances, confusion may occur; this would affect the technical, cost or schedule outcome of the TOF fabrication project. The following procedure is meant as a simple means of controlling this natural evolution and is intended to reduce or eliminate change as a source of problems.

Items that fall under this Change Control Procedure include the following:

TOF Engineering Drawings and Schematics with revision “A” or higher.
Controlled TOF Notes with revision “A” or higher.
Statements of Work.
Specifications.
Memorandum of Understanding.
Requirements Documents.
Lists of Deliverables.
WBS Dictionary.
Project Schedule.

Interface/Integration Specifications.
Integration Envelopes.
Documented Work Procedures.
Rigging Procedures.
Operations Procedures.
TOF Detector Baseline Configuration.

TOF change control will follow a graded approach with three (3) levels of project impact. All changes are reportable to the TOF Project Management Office for tracking, but it is only Levels 1, 2, & 3 which require project management approval. Changes which only affect a single subsystem; do not impact the subsystems interfaces, overall performance, cost, or schedule goals, will be managed and controlled by the subsystem managers. Level 1, 2, & 3 changes will possess one or more of the following attributes:

- Physical interface: the envelope within which the element will be contained.

- Utilities interface: the location, size, and rate of “flow” of utilities supplied.

- Signal interface: the location, number and size of input/output signal cabling.

- Structural interface: the location, number, shape, size, hole pattern, etc., of the element component from which the subsystem is supported or aligned.

- Parameters, function, and requirements which are used to define the technical scope and specification of the element component.

- Significant cost or the possibility of affecting the subsystem delivery schedule.

Table 6 defines the three categories of changes and the method of review and approval level required for each.

Table 6: Change approval levels.

Level	Cost, Schedule, and Technical Impact	Review/Approval
1	Deviation from total project cost or cumulative allocation of contingency > $500k; WBS level 3 milestone delay >3-months; Technical deviation that impact baseline performance parameters.	DOE NP Program Manager, STAR Management, BNL Oversight Manager, TOF Project Office
2	Deviation from Level 2 project cost or cumulative allocation of contingency > $250k; WBS level 3 milestone delay >2-months; Technical deviation with impact on other subsystems but doesn't affect baseline performance parameters.	DOE BHSO Federal Project Director, STAR Management, BNL Oversight Manager
3	Deviation from Level 2 project cost or cumulative allocation of contingency > $50k; WBS level 3 milestone delay >1-month; Technical deviation with minor impact on other subsystems and doesn't affect baseline performance parameters.	TOF Project Office

7 RISK

The Project Engineer and the Project Manager will mitigate risk through routine monitoring of the progress and performance of the project.

The final responsibility for risk management will rest with the project manager. However, effective risk management requires the involvement of all project members.

The risks associated with the electronic board design and the mechanical structure are estimated to be low due to successful R&D and the installation and successful use of prototype detectors in the STAR detector for three years prior to the start of construction.

The largest known source of risk to the project at the moment is the availability and successful performance of the CERN HPTDC chip. If the chip fails to perform adequately in longer term tests or in long-term equivalent testing, or if CERN is not able to produce the chips in sufficient quantity to sell chips to STAR, there would not be sufficient time between now and the scheduled start of electronics board production to develop an alternative solution. However, we used 30 HPTDC chips in RHIC Run 5 for data readout and they worked adequately.

There is a similar risk associated with the purchase of the NINO chip. These are reported to have been produced in sufficient quantity so that STAR may purchase an adequate supply. We have completed the design for a prototype TINO board using the NINO chip but have not yet successfully assembled and tested any boards. If this design fails to perform adequately, we can fall back to component amplifiers and discriminators that performed adequately in Runs 3, 4, & 5 at slightly higher cost, but well within contingencies.

Another source of R&D related risk is the electronic board design and testing. If those prototype electronic boards that are still undergoing design or revision have not been tested successfully by the milestones set out in the project schedule, the project could be delayed and an additional budget and schedule for electronics R&D might need to be added to the project. Periodic evaluations of the R&D status will minimize this risk. The risk is considered low since most of the elements of the final design were used successfully in the prototype electronics for Run 5.

A source of risk during the project will be due to the construction and testing of MRPC modules in China. This will be a Chinese contribution to STAR and not under the control of the U.S. project. The U.S. project management will closely monitor progress and QA in China and include the status of the Chinese construction project in reports and reviews to minimize this risk. The U.S. project management will also make frequent visits to China to facilitate the integration of the Chinese effort into the U.S. project.

8 ASSESSMENTS

8.1 ENVIRONMENT, SAFETY AND HEALTH

8.1.0 Integrated Safety Management Plan

Environment, safety and health (ES&H) will be integrated into all phases of planning and implementation through to the final design and production processes of the project. The project engineer will interface through the STAR safety manager to BNL C-AD safety management. The project will conform to BNL’s Integrated Safety Management policies.

8.2 QUALITY ASSURANCE

“Quality” is defined as the “fitness of an item or design for its intended use” and Quality Assurance (QA) as “the set of actions taken to avoid known hazards to quality and to detect and correct poor results.” The project engineer and project manager will work with the subsystem managers and STAR operations management to assure that performance goals are met.

9 PROJECT CONTROLS AND REPORTING SYSTEMS

Technical performance will be monitored throughout the project to insure conformance to approved functional requirements. Design reviews and performance testing of the completed systems will be used to ensure that the equipment meets the functional requirements.

For each main subsystem of the TOF project: MRPCs, tray assembly and test, gas system, high-voltage system, start detector, infrastructure,, electronics board purchase and test, and low-voltage system there will be the following reviews:

- preliminary design review including detailed concept for the system, detailed cost and schedule, QA and testing procedures
- pre-production review, all details settled. A small number of units will be produced and tested, and the performance reported.
- final design review, final cost and schedule, production QA and testing procedures,
- STAR and BNL safety reviews,
- STAR operations readiness review.

A single preliminary design and safety review for the project will be held approximately one month after the project is approved. A final design review will be held for each subsystem prior to initiating any large procurement or fabrication work.

Technical information concerning the project that is of interest to the TOF collaboration and the STAR collaboration will be published and archived in the existing STAR Note system.

In general STAR Notes are documents about a topic of general interest and of a technical subject. These documents should be of an archival nature, that is they should not need frequent revision. STAR Notes concerning TOF can document requirements, specifications, procedures or policies, and are controlled and approved, under change control procedure, by the TOF Project Office. The reason for issuing a STAR Note is to insure that members of the collaboration and project are aware of its content and are made aware of changes when they occur. Practically this is accomplished by the project office announcing to the collaboration/project that a new STAR Note has been issued or a STAR Note has been revised.

10 INSTITUTIONAL PARTICIPATION

Several institutions will participate in the TOF project. The institutions and their anticipated project responsibilities are listed in Table 7 for the US TOF project. The MRPC modules are produced by the China STAR TOF Collaboration and the institutional participation for that project is shown in Appendix 1.

Table 7. US TOF Project Institutional Participation

Institution	**Project Responsibility**
Brookhaven National Laboratory	Detector infrastructure Project management E, S, H, & Q
Rice University	Electronics board production and test Start detector Project management
UCLA	US-China project coordination Low voltage system High voltage system
University of Texas	Tray assembly and test Electronics systems management *THUB* design and production

APPENDIX 1: CHINA TOF PROJECT MANAGEMENT RESPONSIBILITIES

Project Manager

The Chinese project manager is Yugang Ma from Shanghai Institute of Applied Physics (SINAP), Chinese Academy of Sciences. The deputy project managers are Hongfang Chen from USTC and Jianping Cheng from Tsinghua.

Responsibilities

The Chinese Project Manager reports to the STAR TOF project manager and Advisory Board of the Chinese STAR TOF Collaboration. The Chinese Project Manager will have the following responsibilities:

- Responsible and accountable for the successful execution of the Chinese STAR project
- Delivers Chinese project deliverables
- Identifies and ensures timely resolution of critical issues in China
- Allocates the contingency funds following approved procedures
- Appoints Subsystem Managers
- Acts as the spokesperson for the Chinese STAR TOF Collaboration and maintain effective communication with the STAR management and the rest of the STAR collaboration
- Submits quarterly status reports
- Ensures the work is performed safely and provides necessary ES&H documentation.
- Develops functional requirements with the subsystem managers
- Responsible with the subsystem managers for the technical direction of the project
- Controlling changes in the system design requirements, including interfaces between subsystems
- Responsible with the subsystem managers for developing and maintaining project documentation.

Subsystem Managers

Subsystem managers are responsible for each of the three major tasks of the Chinese STAR project: MRPC module production, quality assurance and control, and Chinese STAR physics analysis. The subsystem managers are:

- Jianping Cheng, Tsinghua, MRPC module production
  Yuanjing Li, Tsinghua, 70% of MRPC module production at Tsinghua facility
  Cheng Li, USTC, 30% of MRPC module production at USTC facility
- Xiaolian Wang, USTC, Quality control and assurance for MRPC production
  Yi Wang, Tsinghua, Quality control and assurance for MRPC production at Tsinghua
  Xiaolian Wang, USTC, Quality control and assurance for MRPC production at USTC
  Ming Shao, USTC, TOF off line software
- Yugang Ma, SINAP, RHIC Physics analysis in China

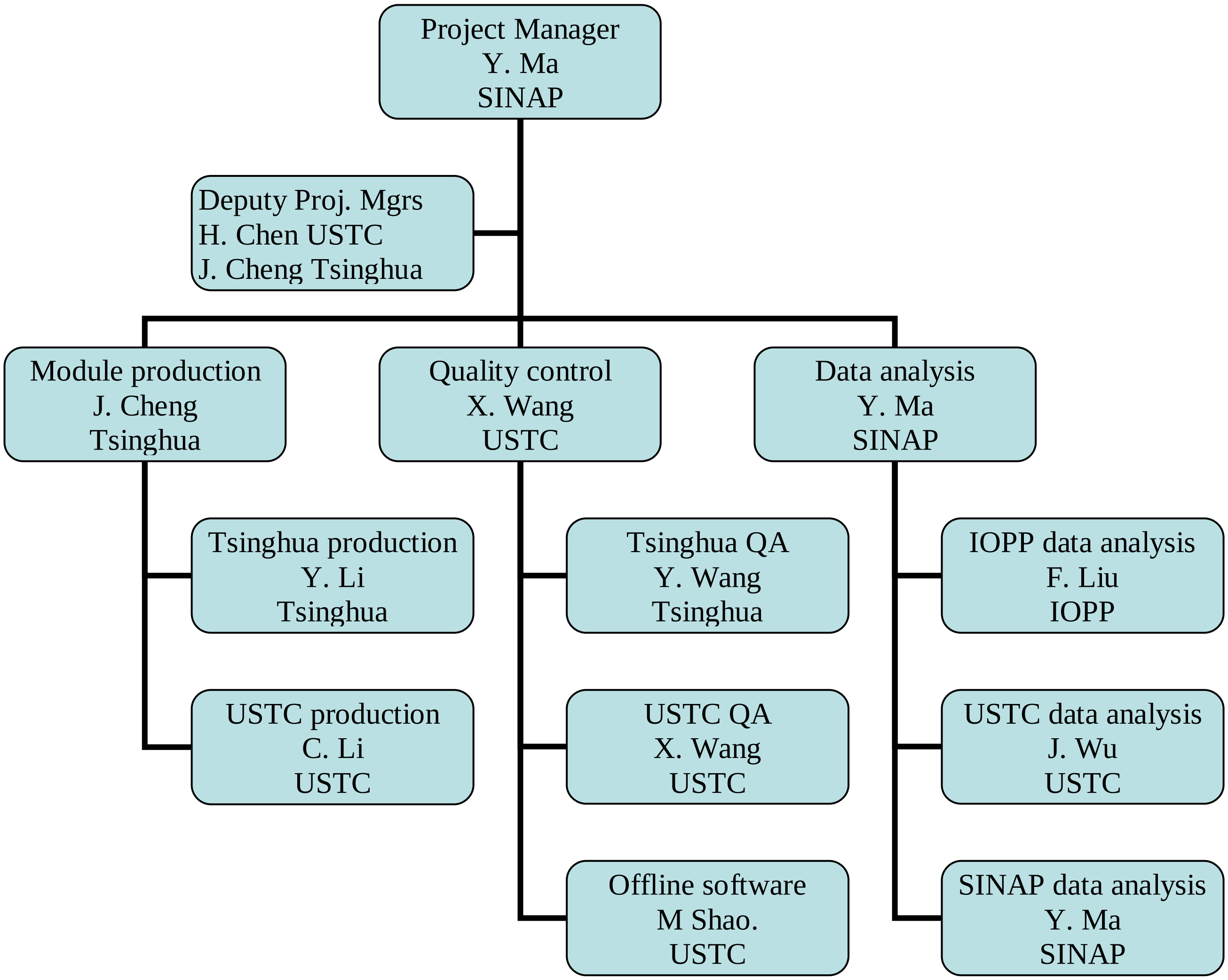
Feng Liu, IOPP, CCNU
Jian Wu, USTC group

The subsystem managers report directly to the Chinese Project Manager and will be responsible for the design, construction, installation, and testing of their subsystem, in accordance with the performance requirements, schedule, and budget.

Responsibilities

- Collaborate with the Project Manager to assemble the staff and resources needed to complete the subsystem
- Develop and follow the system design requirements
- Ensure that subsystems meet the system design requirements
- Responsible for carrying out the design and construction in accordance with the scope, schedule and budget, assuming funding and resources as described in the management plan
- Provide regular reports on the status of the subsystem to the Project Manager
- Ensure the work is performed safely and provide necessary ES&H documentation
- Develop and maintain project documentation

.



The proposed organization structure for the China STAR TOF construction project.