Conduct of Operations for Hall B
Proton Radius Experiment (PRAD)
April 25, 2016

Contents

1 Preface

As part of its mission, JLab provides the resources necessary for international collaborations of scientists to carry out basic research in nuclear physics and related disciplines. This research must be conducted in a manner that ensures that environmental, health and safety (EH&S) concerns receive the highest consideration. At the same time the programmatic goals of the laboratory require that it produce the highest quality physics results efficiently.

Guidance on how to balance thoughtful, measured EH&S concerns with efficient operation has been taken from the Director's Safety Council, the JLab EH&S Manual, and the JLab Director's Office. A graded approach is followed in which the measures taken are matched to the scale, cost, complexity, and hazards of the operation.

This document outlines how approved experiment collaboration will conduct operations in a safe and effective manner during the time period that Proton Radius Experiment (PRAD) is on the floor. Installation periods are not covered by this document. Furthermore, this document is directed to physics users and physics staff rather than the Hall B technical staff. It must be read, understood, and followed by all members of the collaboration.

2 Documentation

This experiment uses the standard Hall B beamline equipment and the PRAD setup. All of the procedures to be used during the course of the experiment are contained in the following documents[1]:

- The Conduct of Operations for Hall B Proton Radius Experiment (COO), the document you are now reading.
- Experiment Safety Assessment Document (ESAD) for Proton Radius Experiment (referring to the base equipment as well as any experiment-specific changes)
- Radiation Safety Assessment Document (RSAD)
- JLab Emergency Response Guidelines (ERG)
- Hall B Standard Beamline Equipment Manual
- PRAD Standard Equipment Manual

Reference copies of these documents will be available in the Counting House for the duration of the experiment. The present document shall hereafter be referred to as the COO. The Experiment Safety Assessment Document shall hereafter be referred to as the ESAD, and the Radiation Safety Assessment

[1] The process is documented at `http://www.jlab.org/user_resources/PFX`

Document shall be referred to as the RSAD. The ESAD and COO are also available at an experiment-specific web site. **The COO, the ESAD and the RSAD are required reading for shift personnel.**

A full description of the physics motivation for the experiments, collaboration lists, and general plans for carrying out an experiment can be found in the proposal(s) to the JLab Program Advisory Committee (PAC).

3 Shift Personnel Training

All personnel on shift are required to have successfully completed and be current in the following JLab safety training:

- EH&S Orientation (SAF 100)
- Radiation Worker Training (SAF 801)
- Oxygen Deficiency Hazard Training (SAF 103)
- Hall B Safety Awareness Walk-Through (SAF111)

All experiment personnel are required to have radiation badges in their possession during their shifts. The Safety Awareness Walk-Through will emphasize hazards that are typical of normal Hall operations. Hazards peculiar to the current experimental setup are addressed in the appendices of this document. In addition, all shift personnel will be trained in the safety procedures to be followed for access to the Hall. This training will include a brief discussion of the purpose and operation of the Personnel Safety System (PSS) for the Hall. Individuals within the collaboration may be required to have other equipment or procedure-specific training. The need for such training shall be determined by the experiment spokesperson in consultation with the Hall Leader and Physics Division Safety Officer.

In addition, experiment personnel must familiarize themselves with the sections of the JLab EH&S Manual relevant for their work in the Hall. A reference copy of this document is available in the main hallway of the Counting House. It is also available via `http://www.jlab.org/ehs/ehsmanual/index.html`.

Finally, JLab Lock and Tag[2] training is required for all staff/users who will be performing maintenance on electrical and mechanical equipment which cannot be physically and verifiably isolated from an energy source. This training, SAF104, can be found at:
`http://www.jlab.org/div_dept/train/webbasedtraining.html`.

[2]The EH&S Manual provides Lockout/Tagout information in Chapter 6110 at `http://www.jlab.org/ehs/ehsmanual/manual6110.html`.

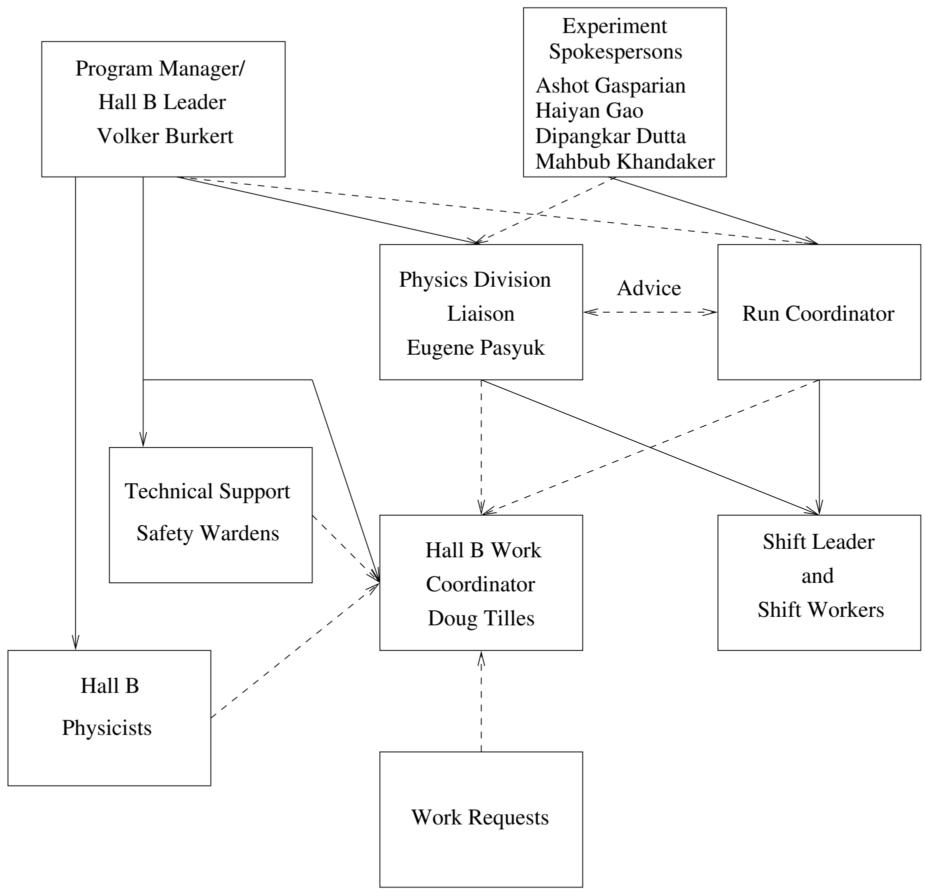


Figure 1: Functional Organization of the Hall B Team. Dashed lines indicate information flow, solid lines indicate responsibility.

4 Organization and Administration

The operation of the experiment is directed by the Spokespersons and the Hall Leader, Volker Burkert. An organization chart for the experiment is found in Fig. 1.

4.1 Run Coordinator

The Run Coordinator is the immediate on-site manager of the experiment and is responsible for ensuring that the physics goals of the experiment are met. This individual is designated by the experiment spokespersons and approved by the Hall Leader. The Run Coordinator shall ensure that the Hall Group Leader, Physics Division Liaison, and at least one Spokesperson are aware of all pertinent issues. The Run Coordinator shall promote an environment in which

the highest safety standards are maintained. **All Run Coordinators must ensure that all of the JLab training necessary to perform their duties is up to date before their shift as Run Coordinator commences.** The functions of the Run Coordinator are:
I. To manage daily operation of the experiment:

- to ensure that the run plan is clear to the shift workers.
- to define the data quality appropriate for the goals of each shift.
- to track the progress of the experiment.
- to coordinate and schedule activities (e.g., Hall accesses) in order to optimize productivity.
- to ensure that an experiment checklist is completed every 24 hrs during standby shifts.
- together with the Physics Division Liaison, to ensure that the counting house is manned appropriately: i.e., sufficient personnel are present to safely carry out the experimental program or monitor the apparatus as needed.

II. To coordinate interactions between JLab and the experiment. This entails:

- to ensure that the Hall B Group Leader and Experiment Spokespeople are aware of all necessary issues.
- informing the Program Deputy of the experiment's status and plans at a 7:45 AM program deputy/halls meeting in the MCC during the working week, and at an agreed upon time on weekends or holidays.
- representing the collaboration at the 8:00 AM daily summary meeting in the MCC during the work week.
- attending the 1:30 PM Wednesday scheduling meeting in the MCC conference room to represent the collaboration and to present a report on the preceding week.
- remaining in the local area and being available by cell-phone/pager at all times. (If temporarily unavailable the Run Coordinator must designate another qualified collaborator as a replacement.)
- interact with the Accelerator Program Deputy to plan and conduct unscheduled activities.
- in conjunction with the Hall Work Coordinator, scheduling work by groups outside the collaboration. This work will normally coincide with the scheduled machine maintenance days. This coordination requires a weekly meeting of these two individuals. The product of this meeting will include any necessary updates to the "Access Authorization List".

- to be responsible for safe transition of the Hall to Restricted Access in coordination with the Hall work coordinator.
- to provide an oral report at the weekly Hall B meeting[3] updating the experimental progress to the collaboration.

III. To submit a written report to the Hall Leader which includes run time statistics and a description of any significant problems with the Hall instrumentation.

4.2 Physics Division Liaison

Broadly speaking, the Physics Division Liaison to the experiment is a Hall B staff member selected by Volker Burkert to oversee the hall's interests with respect to personnel and equipment protection.[4] This is true for all three halls. However, the role of the Physics Division Liaison may include other responsibilities depending upon the experiment and other factors. His/her responsibilities include:

- Oversee that proper rules of safety are carefully followed in the conduct of the experiment.
- Approve a Hall status change to Restricted Access in coordination with the Hall Work Coordinator.
- Training verification of shift workers via JList software.
- Together with the Run Coordinator, ensure that the counting house is manned appropriately: i.e., sufficient personnel are present to safely carry out the experimental program or monitor the apparatus as needed.

4.3 Hall Work Coordinator

The Hall Work Coordinator's responsibilities are:

- to act as the **single point of contact for all work in the hall.**
- to determine if the scheduled activities in the hall can be done safely. These activities shall be coordinated with the Physics Division Liaison and the Run Coordinator. Tasks should also be inputted into the work task lists `http://www.jlab.org/listsites/`.
- to ensure that workers are properly trained, are familiar with all significant hazards, and are aware of all applicable work control documents associated with the project.

[3]typically held at 9:00 AM on Monday.

[4]The responsibilities described here correspond to those of the Physics Division Liaison during the operating phase of the experiment as outlined in the EH&S Manual Chapter 3120/Glossary.

- in coordination with the Physics Division Liaison, ensure that the hall apparatus is made safe before giving permission to make a transition to Restricted Access (e.g., turn off unused magnets, install protective shields as needed, fulfill specific requirements in the ESAD, etc.).

4.4 Shift Leader

Each shift is led by a Shift Leader. The selection of shift leaders is the responsibility of the Run Coordinator and Physics Division Liaison. The Shift Leader has the following responsibilities:

- to carry out the scientific program planned for the shift in a safe and efficient manner.
- to ensure that the logbook contains a complete and accurate description of the events and actions which occurred during the shift.
- to serve as primary contact between the machine control center (MCC) and experiment personnel.
- to oversee that hall equipment is operated properly.
- to ensure the shift checklist is performed every eight hours on operating shifts.
- to ensure that equipment malfunctions are properly labeled and locked-out if necessary and to communicate this to shift personnel and subsystem experts.
- to note in the logbook when workers from outside groups (such as survey and alignment) stop by the counting house before entering the hall when in Controlled Access. Furthermore, to confirm that these workers have communicated with the Run Coordinator and the Hall Work Coordinator.
- to coordinate the response of the shift crew to any emergency situation, including the notification of appropriate individuals as outlined in the Hall B Emergency Response Guidelines (ERG).
- to ensure that in any emergency situation the experiment Physics Division Liaison, Run Coordinator, and Hall Leader are notified immediately.
- to notify the Run Coordinator and the Hall Leader, if the hall is down due to equipment failure for more than four hours.

The Shift Leader has the following authority:

- to assign tasks to the shift members as needed.
- to request that the state of the hall be changed (Request for a change to Restricted Access must be approved by the Physics Division Liaison.)

- to limit the number of people in the Counting House or hall if required to effectively and safely carry out the experiment.
- to limit access to hall on-line computers if required to effectively and safely carry out the experiment.
- to authorize qualified personnel to make modifications in the experiment configuration within the allowed parameters, as specified in the standard equipment manual.
- to authorize time accounting for the shift.

4.5 Shift Member

The responsibilities of each shift member are to:

- carry out the scientific goals of the shift in a safe and efficient manner under direction of the shift leader.
- read the logbook to be aware of changes in goals, operating parameters, and new documentation.
- monitor the equipment for problems.
- maintain adequate records of the progress of the shift.
- be present before the start of each shift and coordinate current operating conditions with the previous shift.
- keep all training up-to-date.

4.6 Accelerator Operations Hall Liaison

Each physics hall has an Accelerator Operator or Crew Chief assigned as a Hall Liaison. The Hall Liaison helps to facilitate information exchange between the experimenters and the MCC Operations Group, both in advance of and during actual experiments. The Hall Liaison, among other things, is responsible for making sure that experiment-specific information, procedures and requirements are available to all other operators and Crew Chiefs so that beam delivery can proceed efficiently.

4.7 Accelerator Physicist Liaison

The Accelerator Physicist Experiment Liaison serves as the primary contact on hall beam physics issues for the Physics, Accelerator and Engineering Divisions. This liaison owns the process of establishing physics quality beam to the experiment including developing beam optics configurations capable of meeting the experiments requirements, identifying tools needed to diagnose, monitor and verify beam performance during the experiment as well as developing beam startup, setup and commissioning plans. The Hall B liaison is Michael Tiefenback .

4.8 Engineering Liaison

Each experiment conducted at JLab will be evaluated to determine if its complexity requires facilitation with the Engineering Division to help ensure a successful outcome. Experiments that require facilitation will be assigned an individual from the Engineering Division to act as liaison between the Division and the associated Experimental and Physics Division staff. The liaison acts as a single point contact in order to facilitate information exchange between the experimenters and those in the Engineering Division responsible for, but not limited to, the systems requirements, design, scheduling, fabrication, installation, testing, documentation, and budgeting. Ideally, the liaison is aware of all work conducted by Engineering for the experiment and ensures the appropriate resources are defined and allocated. Any issues and/or concerns are identified, documented, and tracked.

For the current run period, the review found that no such liaison was required.

5 Operating Procedures

5.1 Shift Routines

There are two types of shifts for active hall experiments: Operating and Standby. Operating shifts are the normal status when beam is available for the experiment. Standby shifts are periods designated by the Run Coordinator when beam is not available or not in use in the hall and none of the equipment, except for the target, requires continuous monitoring. Standby status may result from normal operational planning or from abnormal conditions such as a major down time due to equipment failure.

5.1.1 Operating Shifts

During operating shifts, 24 hour occupation of the counting house area will be maintained by crews of at least two persons [5] in 8 hour shifts. One person per shift is designated as the Shift Leader.

The number of persons assigned to a shift will depend on the tasks assigned during the shift. A shift schedule will be posted in the Counting House listing the times and names of personnel on shift and identifying the Shift Leader and Run Coordinator, cell 876-1787. The shift schedule may be available at an experiment-specific website. The Run Coordinator may also designate and supervise other teams for duties such as offline analysis.

[5] The readiness review committee may require more personnel depending on the complexity of the experiment. Two people are the minimum required for safe operations.

5.1.2 Standby Shifts

During Standby shifts, shift personnel are not required to be on site at JLab but must be available through telephone contact to come in if they are needed. Monitoring the target system can require the presence of a Target Operator during a standby shift. The Target Operator then also acts as Shift Leader. The Run Coordinator will ensure that the shift checklist is executed at least once every 24 hours.

5.1.3 Operations Turnover

The electronic log book, accessible from the web, is a very effective means of remotely obtaining information about experimental operations. This allows experimenters to log in remotely and view all log book entries prior to commencing their shift. Information which can only be recorded in the paper log book, should be noted accordingly, point to in the electronic logbook, and communicated between incoming and outgoing shift personnel directly.

Efficient and effective shift changeovers during experiment operation are enhanced by overlapping shifts. Therefore, whenever possible, shift leaders and workers are scheduled in shifts that are staggered by at least one hour. If this is not the case, shift members must show up ten minutes prior to shift start (and plan to stay ten minutes after) for the purpose of information exchange to those taking over the same tasks. In all cases incoming shift leaders must discuss the experiment and Hall status with the outgoing shift leaders.

5.1.4 Timely Orders to Operators

The initial run plan is the responsibility of the Run Coordinator and shall be clearly recorded in the log book. This plan specifies the tasks to be performed in the next 48 - 72 hours, including any special conditions or data runs, updated documentation and its location and/or alternate plans. Any changes to the run plan shall be recorded in the log book and the white board in the counting house.

5.1.5 Operator Aid Postings

The day-to-day schedule, contact instructions for key personnel, and any other information relevant to current activities are located on the white board in the Counting House. Shift personnel should consult the white board, especially at the beginning of their shift, to be aware of any updates to current running conditions.

Information pertaining to daily activities in Hall B must be posted on the bulletin board or written on the white board at the entrance to the hall.

5.2 Hall Access

Work in designated radiation areas will be carried out in accordance with the JLab RadCon Manual. In particular, no material may be removed from the hall after beam delivery without proper approval from the RadCon Group. During operations, no one is allowed in the hall without either being accompanied, or informing shift personnel and checking in on a regular basis.

During a running experiment the hall will normally be in Beam Permit. When temporary access to the hall is needed the Shift Leader can ask the MCC to bring the hall to Controlled Access. If long term access to the hall is required, the Shift Leader may request the hall be brought to Restricted Access. Such a request requires prior approval from the Physics Division Liaison, while the actual transition will be supervised by the Hall Work Coordinator.

Restricted Access is a state where delivery of beam and/or RF power is not permitted, and entry to and exit from the hall is not controlled by the Personnel Safety System. This is the normal state of the hall when the accelerator is off and no experiments are running. Access is "restricted" only in the sense that the hall is not open to the general public. Well-defined check-list procedures are to be followed whenever the hall is brought to and from Restricted Access.

Restricted Access is the period when all major work must be completed in the hall. Consequently, all activities require advanced planning and must be scheduled for resources and safe operation. In order to streamline the activities in the hall and ensure everyone has ready access to the current status and requirements for work, there are two important resources:

- Single point of contact, which is the "Hall Work Coordinator"
- Information board at the entrance to the hall

All work must be scheduled through the Hall Work Coordinator. The content on the information board is the responsibility of the hall safety wardens and the Hall Work Coordinator. The information board will contain all critical information required for safe entry into the hall. This information will include a succinct, one page safety summary covering the hall's current safety hazards and mitigating measures (to be read by all persons working in the hall), active Operational Safety Procedures (OSPs) and Temporary Operational Safety Procedures (TOSPs), required temporary work permits (e.g., Radiation Work Permits), current activities in the hall, points of contact, and required training and safety equipment.

5.3 Collaboration Request for Laboratory Resources

The collaboration may request additional services from Accelerator Division through the Accelerator Division Liaison, Hari Areti. Alternatively, the collaboration may also request additional services from hall personnel through the Physics Division Liaison, Eugene Pasyuk. These requests should be noted in the logbook. Some requests may require that an OSP, or TOSP be developed.

Major, abnormal, or unanticipated configuration modifications such as stacking or movement of significant shielding, unanticipated vacuum work, unanticipated beam line modifications, the replacement of a wire chamber, etc., require approval of the Hall B Leader, Volker Burkert [6], and the use of appropriate personnel. The Hall Leader may require that a OSP, or TOSP be prepared.

5.4 Scheduling of Work by Outside Groups

Work in the hall that is to be performed by groups outside the collaboration such as survey and alignment, plant services, air conditioning , etc., must be scheduled so that it does not endanger personnel or equipment or interfere with the experiment. Non-emergency activities by these groups should be scheduled to coincide with the planned accelerator maintenance periods. To maximize efficiency, the Run Coordinator (representing the collaboration) and the Hall Work Coordinator (representing Hall B) will concur on work scheduling. The Hall Work Coordinator's job is to coordinate activities in the hall so that work can take place smoothly and safely and to insure that multiple activities do not interfere.

The Work Coordinator and the Run Coordinator will meet as needed to plan the work scheduled for the upcoming maintenance period. The product of this meeting will be a list of work in the hall, the required access state of the hall (Controlled or Restricted), appropriate work control documents, and educational or other safety measures (such as escorts) that are needed.

The ATLis should be used for coordinating the cross divisional work activities `http://www.jlab.org/listsites/`.

5.5 Control of Equipment and System Status

The operation of the standard experimental equipment is documented in the Hall B Standard Equipment Manual. This document includes information on the normal response to alarms and equipment malfunctions.

The ESAD and Hall B Standard Equipment Manual lists the authorized subsystem experts. This list may be amended as necessary to reflect personnel and training changes with the authorization of the subsystem expert. A copy of these amendments will be attached to the main document and kept in the Counting House.

All general equipment installation, maintenance, and testing activities are to be carried out in accordance with the JLab EH&S Manual.

5.6 Equipment Labeling

The experiment and hall equipment shall be properly labeled so it can be quickly identified by both shift and maintenance personnel. Proper labeling helps pre-

[6] Configuration changes as outlined above can affect site boundary dose and the production of airborne radioactivity. They require consulting with RadCon or EH&S personnel, as appropriate.

vent incorrect operation or modification of equipment by non-experts and facilitates proper and efficient operation by qualified personnel. Labeling also increases the likelihood that proper procedures will be followed in case of emergency.

Improper labels should be corrected immediately if possible. Otherwise, the Shift Leader should be notified so that correct labeling can be requested from the qualified expert.

5.7 Independent Verification

The Run Coordinator will provide the shift crew with a set of measures for checking the quality of the experimental data. The up-to-date Hall B shift checklist (and instructions) shall be made available to shift personnel at hall-specific sites on the data acquisition computers. The checklist will be completed at least once per shift during operating shifts and once per day during standby shifts. Additional items may be added to the list by the Run Coordinator or subsystem experts.

The Hall B work coordinator provides more general check lists for closing the experimental Hall and conditions when the Hall is used as an accelerator dump.

5.8 Logkeeping

Shift personnel will update the electronic logbook, which serves as the record of the experiment. The quality of the information recorded in the logbook determines the utility of the data. All data recorded electronically will be referenced in the computer logbook with the appropriate run number and run information. All relevant activities are to be recorded, including all changes of experiment conditions and equipment failures.

Checklists performed using Hall B-specific forms should also be scanned into the computer logbook when completed. The completed paper forms should be stored in a binder in the counting house. All deviations from normal operating parameters shall be recorded in the logbook.

The computer logbook will also serve as the primary reference for the determination of the operational efficiency of the experimental apparatus in the Hall. As such it is essential that it provide an accurate record of the capability of the equipment to carry out the intended research program. Finally, the computer logbook is the place of record for all safety issues and introductions of new or updated documentation and procedures.

A Special Procedures for Hall B

There are no special operating procedures for Hall B.

B Special Procedures for PRAD

Each shift requires a shift leader and a worker. A third person on shift is extremely useful, in particular for the PRAD target running, but not required. The shift leader has the standard duties of shift leader to ensure proper data taking, log all activity, and to fill out the Beam Accounting form. The shift leader runs the DAQ and the worker takes care of online monitoring. This run period uses the "standard" Hall B equipment whose use and safety procedures are documented in the Hall B OSP (Operation Safety Procedures) available from the Hall B web page and wiki.

While much of the instrumentation used in the PRAD run will be standard Hall B instrumentation, the use of the HYCAL hybrid calorimeter in Hall B requires some special considerations. In particular, (1) the calorimeter will entail nearly 2000 new high voltage channels and (2) the HYCAL will be remotely movable.

B.1 Overview

The PRAD Collaboration will perform a high precision *ep* elastic cross sections measurement at very low four-momentum transfer squared, Q^2, from 10^{-4} to 10^{-2} $(\mathrm{GeV}/c)^2$ range using a high resolution calorimeter and a novel windowless cryo-cooled hydrogen gas flow target of thickness $t \sim 1 \times 10^{18}$ hydrogen atoms/cm^2 in Hall B of Jefferson Laboratory. The energies of the electron beam will be 1.1 GeV and 2.2 GeV at a beam current of about 10 nA for production running. The high precision differential cross sections, measured for the first time in this low Q^2 range, will allow a sub-percent and essentially model independent extraction of the proton charge radius.

A multichannel calorimeter, the HYCAL, will be located approximately 5.7 m (run configuration) or 7.0 m (calibration configuration) downstream of the target center. It consists of 1700 lead glass and lead tungstate detector modules, each with photomultiplier tubes. Each module is supplied with high voltage (1100V to 1500V, drawing up to 0.3 mA) and is equipped with readout of dynode and anode signals. Normal operation of the HYCAL will require the doors be interlocked with the high voltage supply system. In addition, an LED based light monitoring system is used to deliver a pulse of light to each module via a fiber optic cable. HYCAL is contained in an enclosure which will seal it both thermally and optically from the surrounding environment. The enclosure has been constructed with access doors on the rear. The HYCAL will sit in two positions along the beamline. In the "run" configuration HYCAL will sit on a stationary cart, and in the "calibration" configuration it will be mounted on a transporter which will enable motion in the horizontal and vertical directions. The detector has overall dimensions of 1.5 m$\times$1.5 m and will be centered on the beamline during production data taking. A 2×2 $PbWO_4$ modules removed at the center of the detector will allow the passage of the primary electron beam to the beam dump.

Hazards:

The major new safety considerations for this experiment involve the remotely operated motion of the HYCAL and the large number of new high voltage channels.

Although there are no large, exposed terminals inside of HYCAL carrying high voltage, there are solder points which one could come in contact with if sufficient care is not taken. The solder points are on the back of the vertically mounted printed circuit boards (VPCB) accessed from the back of HYCAL.

The PMT high voltage supplies providing power to the internal HYCAL detectors are CAEN 1932A high voltage distributor cards. These cards can supply a maximum current of 0.5 mA per channel. This is only slightly less than the 0.6 mA required for a "slight sensation" as described in section 6210 of the JLab EH&S manual. The largest risk of injury is likely from an instinctual reaction should someone feel such a sensation. Work on HYCAL detectors will require the worker to stand on a stool or platform 1 to 2 feet off of the ground. A sudden reaction could cause loss of balance.

The HYCAL PMTs use voltage dividers which require external, additional power supplies (APS). There are 6 APSs that provide between 300 V and 500 V DC. These voltages are distributed to the PMTs via a common bus which runs along each of the VPCBs. The traces which form the bus are coated so there is no risk of contacting the high voltage via casual contact with the trace itself, only the solder points present such a hazard as described above. The APS supplies present the largest risk to personal since they can supply at least 300 mA of current.

A small risk of equipment damage also exists for the PMTs should a large voltage be applied while a bright light source is shining on the detectors.

Hazard Mitigation:

Administrative measures will be taken to mitigate the risk of injury due to high voltage from the APS. These include:

A rope barrier will be maintained across the back of HYCAL with posted signs warning of the high voltage hazard. The barrier will remain in place whenever the high voltage is on, or has the potential of being turned on. A beacon light will be used in or very near the work area in the back of HYCAL. Most likely, this will be kept on top of HYCAL, but may need to be repositioned if it blocks access to connectors on the top of HYCAL. Persons will not be permitted to work on the HYCAL detectors while the high voltage crates are on unless there is another person in the area who is aware of the potential hazard.

To minimize the risk of injury from falling off a foot stool or work platform while working on HYCAL, the area directly behind HYCAL (3 foot perimeter) should be kept clear of any items which could potentially cause injury. This includes things like broom handles, or similar large hard objects which a worker could land on should they fall unexpectedly. In addition, the floor must be kept clear of all items, such as screws and tools that could cause a person to lose their balance were they to step on them.

HYCAL Transporter:

The HYCAL transporter system is composed of two stepper motors that move the detector on the X and Y axes. Each axis has hardware switches that limit its path of motion. In addition to end limit switches at the edges of axis travel, there are home switches in mid travel that will facilitate easy positioning during the experiment. To determine the exact location of the transporter, digital and analog encoders are used to transmit its position. The transporter is controlled by our standard EPICS software interface, and there are hardware interlocks installed to prevent unwanted movement.

The transporter operates in two modes: normal mode and storage mode. The normal mode is used during the experiment when the transporter is positioned within its normal operation limits. The storage mode is used when the transporter must traverse higher in the Y axis than normal. This is used to clear the area for other experiments or work that may need to be done in the hall.

During normal operation, the system must stay within set boundaries in the beam-line area. This area will be kept clear during an experiment, minimizing the damage risk to personnel and equipment. During transporter storage, operator alertness is essential. The transporter will traverse the height of the space-frame and an operator must ensure that the path is clear at all times.

Under any operational condition the transporter must be checked for mechanical problems that may arise. Drive-train problems, movement of the transporter outside of preset limits, and unbalanced loading are all examples of events that may cause damage to personnel and equipment. Interlocks have been designed into the system to stop all transporter movement in the event of a problem. With these precautions and operator alertness, the transport will operator efficiently and safely.

The following hardware interlocks are used during normal mode: (1) pitch and roll tilt sensors, (2) emergency stop buttons, (3) analog Y-axis encoder. In storage mode, we have the following hardware locks: (1) pitch and roll tilt sensors, (2) emergency stop buttons, (3) dead-man switch , (4) X center limit switch. During normal operation, all transporter movement will stop in the event of a tilt sensor alarm, an emergency stop button is depressed, or the analog encoder goes above a predetermined Y-axis range. During storage operation, all transporter movement will stop in the event of a tilt sensor alarm or emergency stop button is depressed. The transporter must have the dead-man switch depressed and the X-axis centered for any movement in the Y-axis.

Hazard Mitigation for Transporter:

Administrative measures will be taken to mitigate the risk of injury involving the transporter.

A rope barrier will be maintained around the HYCAL. The barrier will remain in place whenever the detector is in motion, or has the potential of being moved. A camera, viewable from the Hall B Counting Room, will be focused on the HYCAL to enable the observation of the detector while it is in motion. Persons will not be permitted in the vicinity of HYCAL while it is in motion.

B.2 The HYCAL High Voltage System

The executable “pradHV” which is used to control the HYCAL high voltage is under password protection. There are separate passwords to log in as an Administrator with full read/write access, User with limited read/write, and as a guest with only read privileges. We will use the Admin configuration during commissioning to calibrate the gains on each of the 1700 HV channels. We will then switch to a specially configured “user” mode for the physics run.

As it is extremely important that the voltages not be inadvertently changed, the Admin password will be restricted to only a few people qualified to change HYCAL HV settings. These people are the expert shift takers.

There is a built in crate definable High Voltage limit that can be set across a whole board. In principle, this can prevent too high of a voltage being placed on a PMT and thus damaging it. However, we are unable to use this feature due to the mixing of lead glass and lead tungstate detectors on the same board. The maximum voltage for a lead tungstate is simply too low for the lead glass PMTs to function. Therefore, a software limit has been implemented. This safeguard is based on our naming convention for our detectors. All channels with a “W” as the first letter of their name have a maximum writable voltage of 1300 V. Lead glass is similarly protected. The light monitoring system voltages will also be protected in this manner. As long as this naming convention is respected and any changes registered with the maintainers of the code, this protection should be adequate.

The CAEN SY1527 universal multichannel power supply system is interlocked to the door, moisture, and chiller interlocks. If an interlocked door is opened, moisture detected, or if the chiller is disabled, the HV is shut down. This prevents damage to the PMTs (w.r.t. the first two interlocks) and prevents rapid heating of the interior of HYCAL (w.r.t. the last interlock), which are vital to the health of the lead tungstate.

HV_status_mon: A (separate from “pradHV”) status monitoring program will query all channels every 30 seconds regarding trip, over/under voltage conditions, disconnections, disabled, overcurrent and power on/off status. Errors will be written to a file local to the Linux machine running “pradHV” and to either or both the CVS repository or to the PRAD website for archival and online purposes.

A hardware TTL signal from the SY1527 to the Counting House will also be implemented. This signal will be an OR of all possible status errors that will affect crate and board operation. All of these status errors will generate a message in “HV_status_mon”.

B.3 HYCAL Motion Control

B.3.1 Overview

The purpose of this section is to describe the theory and operation of the Hall B HYCAL transporter control system. Although the system will be controlled via EPICS software, this document will only cover the electronic hardware used to control and interlock the system. There is a distinction made between software (EPICS) and hardware (electronic) control of the transporter. All hardware interlocks will supersede any software limits that may be implemented. A basic overview of all components involved, theory of operation, and a detailed breakdown of each item that a technician may use to repair or modify the system is provided in this document.

B.3.2 Theory of Operation

The system is composed of two stepper motors that move a large transporter in the X and Y axis (see Fig. 2). Each axis has hardware switches that limit its path of motion. In addition to end limit switches at the edges of axis travel, there are home switches in mid travel that will facilitate easy positioning during an experiment. To determine the exact location of the transporter, digital and analog encoders are used to transmit its position. The transporter is controlled by our standard EPICS software interface, and there are hardware interlocks installed to prevent unwanted movement of the transporter.

The transporter operates in two modes: normal mode and storage mode. The normal mode is used during an experiment when the transporter is positioned within its normal operation limits. The storage mode is used when the transporter must traverse higher in the Y axis than normal. This is used to clear the area for other experiments or work that may need to be done in the hall.

B.3.3 System Requirements

During normal operation, the system must stay within set boundaries in the beam-line area. This area will be kept clear during an experiment, minimizing the damage risk to personnel and equipment.

During transporter storage, operator alertness is essential. The transporter will traverse the height of the space-frame and an operator must ensure that the path is clear at all times.

Under any operational condition the transporter must be checked for mechanical problems that may arise. Drive-train problems, movement of the transporter outside of preset limits, and unbalanced loading are all examples of events that may cause damage to personnel and equipment. Interlocks have been designed into the system to stop all transporter movement in the event of a problem. With these precautions and operator alertness, the transport will operator efficiently and safely.

B.3.4 Hardware Interlocks

There are two modes of operation, normal mode and storage mode. The main difference between the two modes is the height of the transporter in the Y axis. Above a certain height, an operator must be more alert to the movement of the transporter. A different set of hardware interlocks is used in each of the two modes.

The following hardware interlocks are used during normal mode:

1. Pitch and roll tilt sensors
2. Emergency stop buttons
3. Analog Y-axis encoder

The following hardware interlocks are used during storage mode:

1. Pitch and roll tilt sensors
2. Emergency stop buttons
3. Dead-man switch
4. X center limit switch

During normal operation, all transporter movement will stop in the event of a tilt sensor alarm, an emergency stop button is depressed, or the analog encoder goes above a predetermined Y-axis range.

During storage operation, all transporter movement will stop in the event of a tilt sensor alarm or emergency stop button is depressed. The transporter must have the dead-man switch depressed and the X-axis centered for any movement in the Y-axis.

See Fig. 4 for a logic diagram.

B.3.5 Hardware Layout

The main transporter system is located on the space-frame. Its normal operating range during an experiment is limited to travel around the beam-line area, and when stored it is positioned much higher in Y and limited to a centered position on the X axis.

The control system is located on level 2, North-East side of the space-frame. A rack contains the VME crate and the Motor Driver chassis. All hardware interlocks are housed in the Motor Driver chassis. When an interlock has been generated, power to the axis X and/or Y motor is removed via an All Windings Off (AWO) selection at the driver. This prevents motor movement at the end of the control chain. Hardware interlocks supersede any other control logic used. Please see Fig. 2 for the hardware layout.

Listed below are the major hardware components of the system:

- Stepper for motors X and Y motion.
- Dual upper and lower limit switches per axis.
- Home limit switches, X and Y axis.
- Emergency stop buttons.
- Dead-man switch.

- X center limit switch.
- Tilt sensor box.
- Analog encoder for position monitoring and interlocking of the Y axis.
- Two digital encoder for positioning on Y axis and one on the X axis.
- Motor Driver Chassis.
- VME crate with IOC.
- VME Motor Driver control board.
- VME Motor Driver ADC board.

B.3.6 System Components

A schematic diagram of the connections among the following system components is shown in Fig. 3.

VME Crate
The VME crate is located on level 2 of the space frame NE side. It contains the Input Output Controller, Motor Driver Board, and the Analog Input Module.

MVME 2306 IOC Board
The IOC controls the entire crate and serves variable to EPICS so that a software interface may be used to control the transporter.

OMS VS-040 Motor Driver Board
This board receives command from the IOC and transmits motor movements to the Motor Driver Chassis. As well, it receives inputs from the digital encoders via the Motor Driver Chassis for use by EPICS.

XVME-560 Analog Input Module
The XVME-560 board is used to convert signals from the analog encoder and the tilt switches into a format usable to EPICS. This is for EPICS use only. In addition, both the analog encoder and the tilt switches are hardwired to the interlock system.

Motor Driver Chassis
The Motor Driver Chassis houses two motor driver modules for the X and Y axes, a VME break-out board, and a hardware interlock board. All system hardware interlocking is implemented through this chassis. All hardware interlocks override any software interlocks that may be in place. A triggered interlock will remove power from its associated motor by using the All Windings OFF (AWO) selection at the driver module. Please see Figs. 3, 4, 5, and 6.

Interlock Board The Interlock Board in the Motor Driver chassis is the heart of the interlock system. This board controls two relays that supply power to the X and Y axis motor driver modules. If the interlocks are not made, no power will be available to drive a motor in any direction. The board has bypass switches and indicating lights so that it may be easily modified by a technician to meet non-standard system interlock requirements. Please see Fig. 6.

Stop Buttons

Four stop buttons are provided that will prevent movement of the transporter in the X and Y axis. The switches must be pulled back out to reset the interlock. There is one switch per level of the space-frame and one in the Hall B Counting House. The stop switches enable a constant high voltage level to the Interlock Board. If it is removed, power to the X and Y drives will be disabled. If the cabling for the stop switches is unplugged, the interlock will automatically disable the drives.

Dead-Man Switch

The dead-man switch is used to insure an operators physical presence when moving the transporter in the storage mode. It is a momentary on push button that must be depressed to meet the interlock requirements of the Motor Driver Chassis.

Tilt Switches

The Tilt Switches sense pitch and role of the transporter. There is a sensor box on the transporter and a control module in the control rack on the second level of the space frame. The control module provides input to EPICS and interlock inputs to the Motor Driver chassis that must be made to meet interlock requirements for system operation. It is wired in a similar fashion as the Stop Switches in that an unplugged cable will prevent motor driver operation.

B.3.7 Summary

While the operators of the transporter must be trained in its use, there are important measures designed into the system to prevent damage to personnel and the system. The hardware interlocks supersede any software interlocks that may be put into place, and will ensure the system is in a safe state in the event of an error or malfunction.

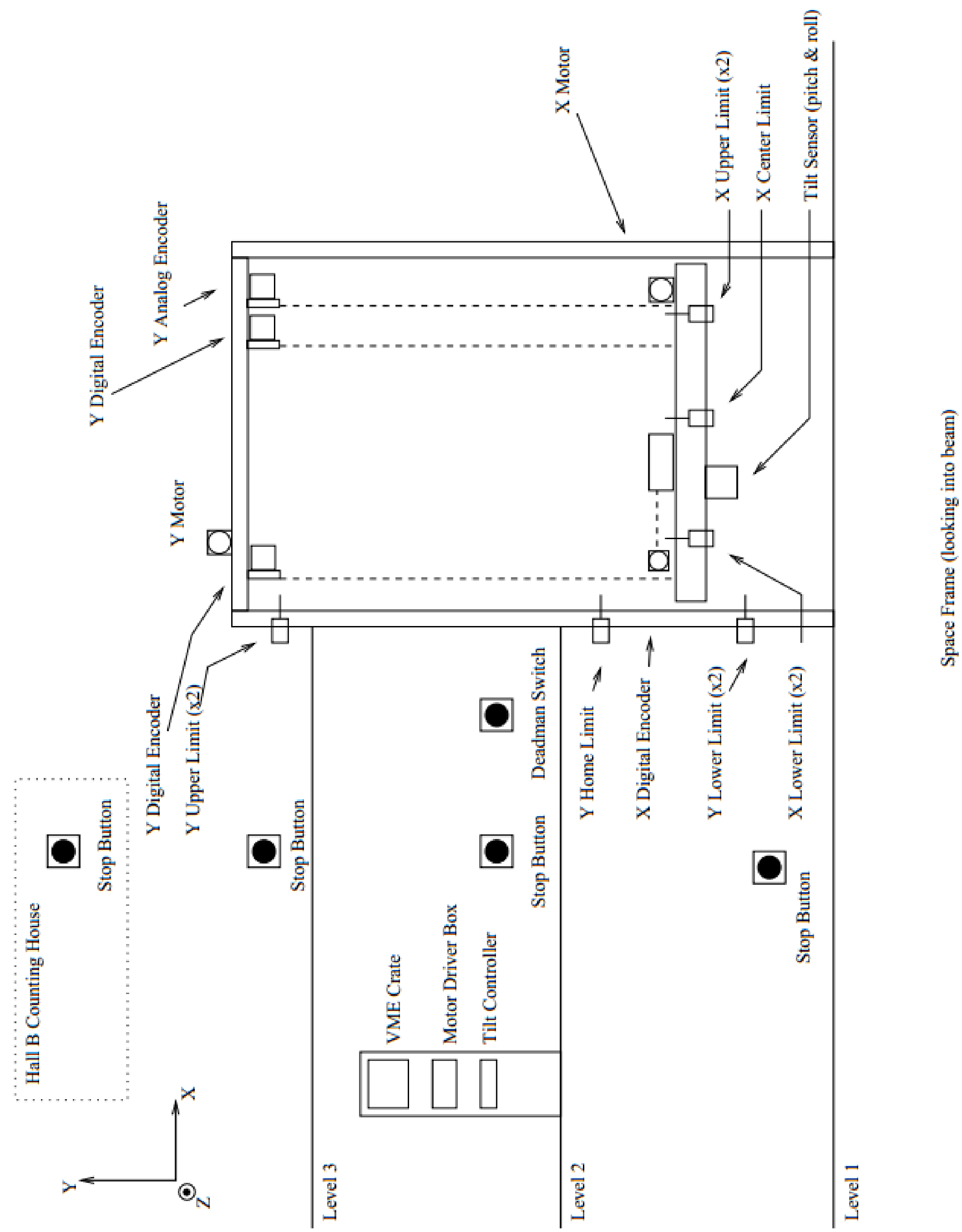


Figure 2: Hardware Overview

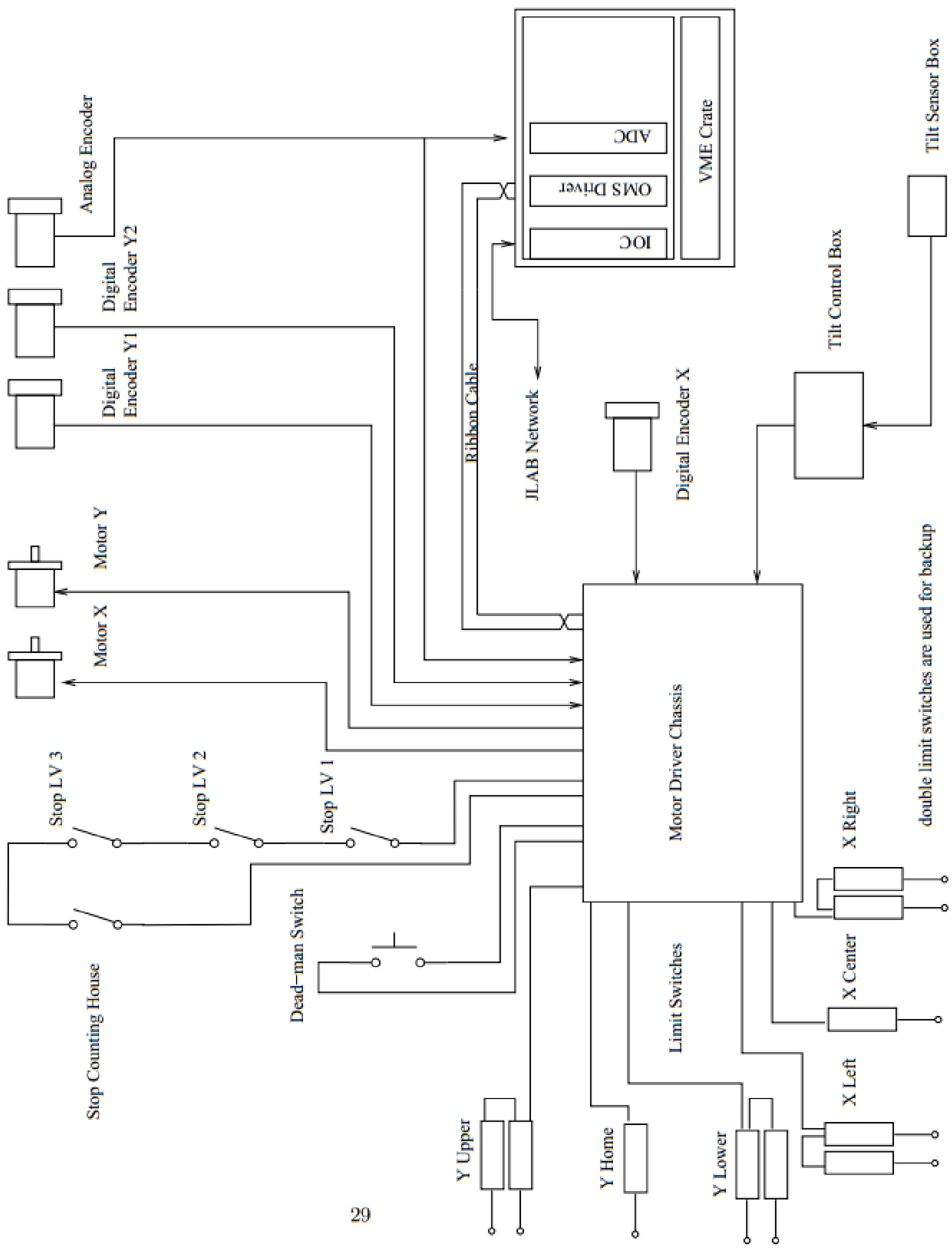
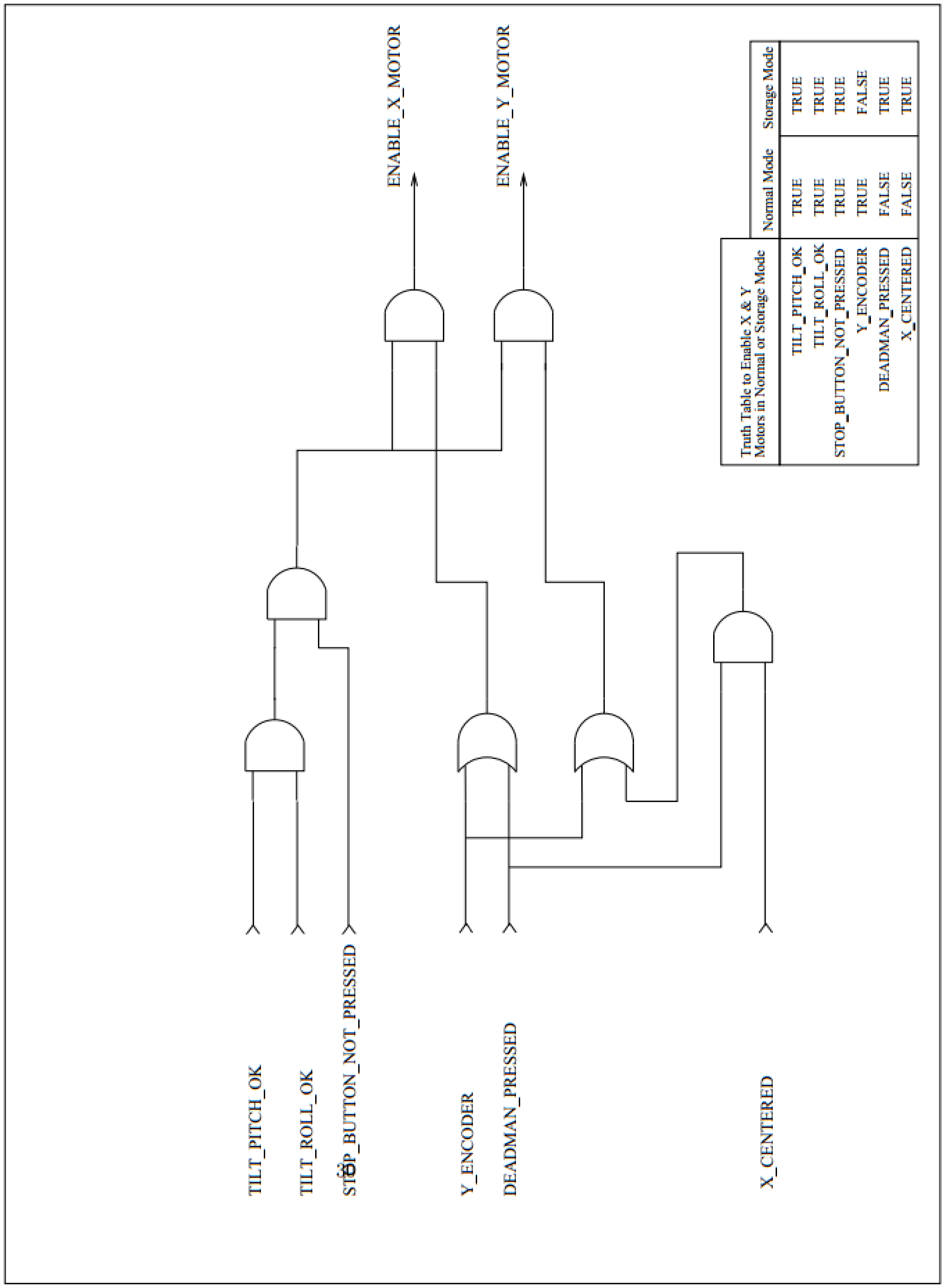


Figure 3: Motor Driver Chassis Connections



Truth Table to Enable X & Y Motors in Normal or Storage Mode	Normal Mode	Storage Mode
TILT_PITCH_OK	TRUE	TRUE
TILT_ROLL_OK	TRUE	TRUE
STOP_BUTTON_NOT_PRESSED	TRUE	TRUE
Y_ENCODER	TRUE	FALSE
DEADMAN_PRESSED	FALSE	TRUE
X_CENTERED	FALSE	TRUE

Figure 4: Interlock Logic

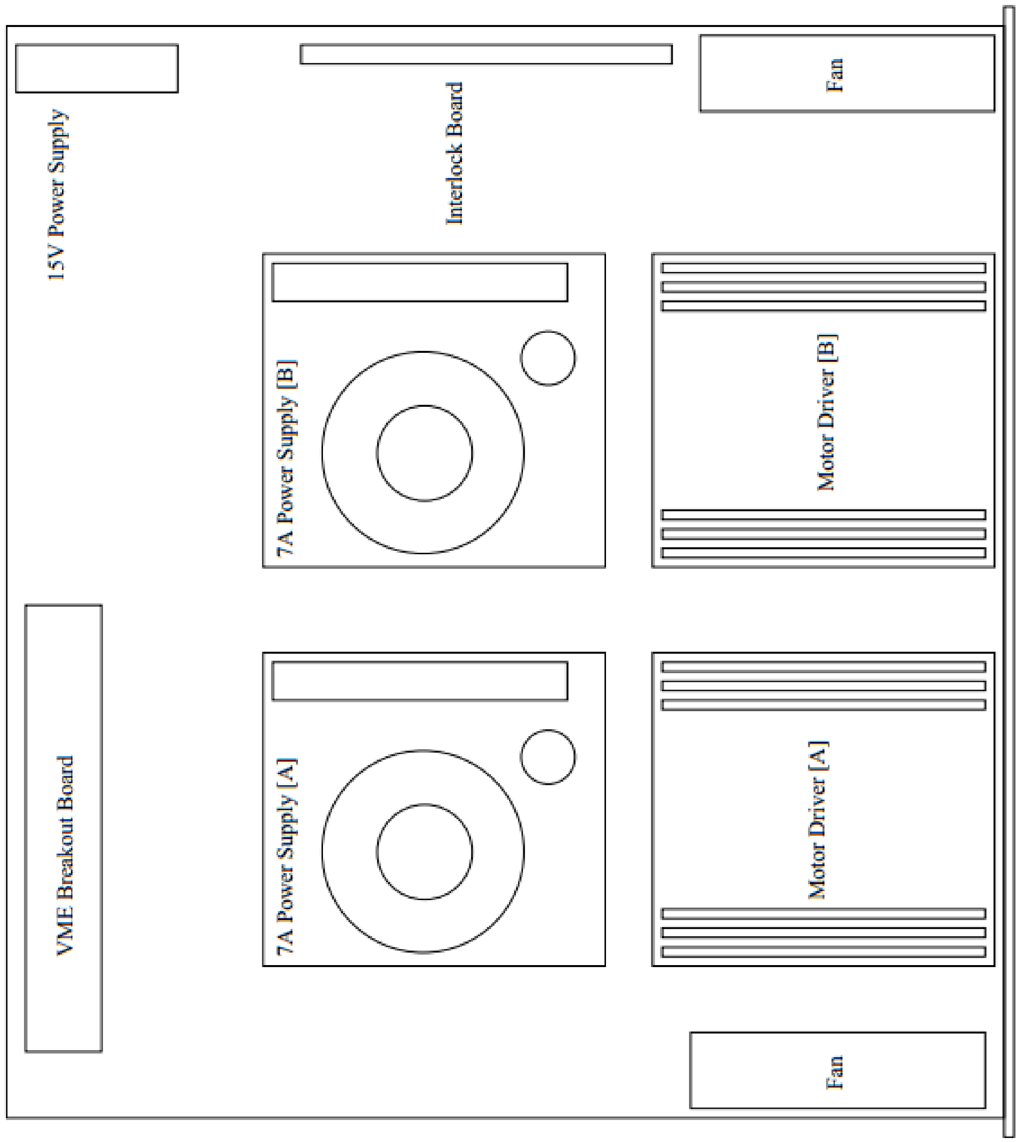


Figure 5: Motor Driver Chassis

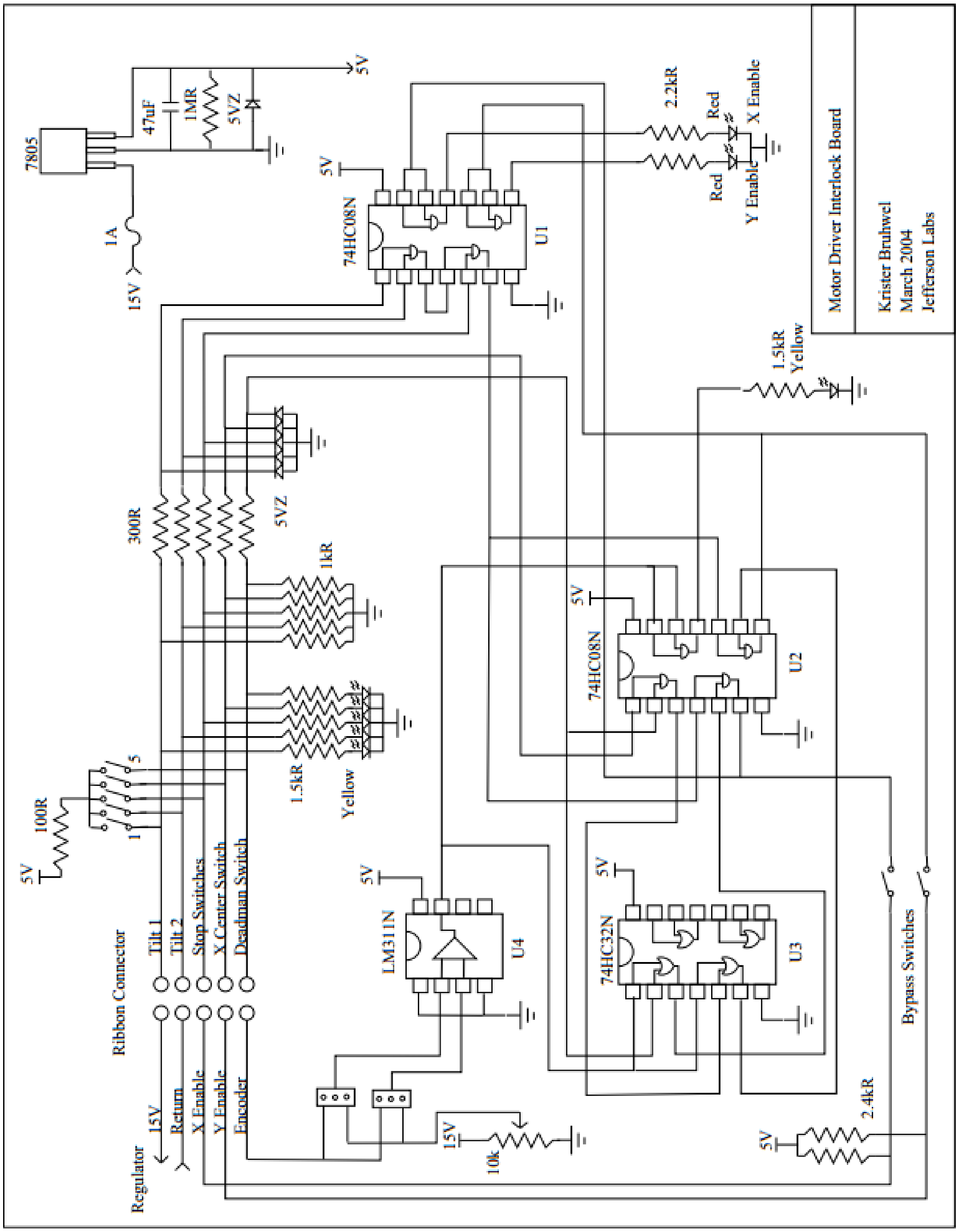


Figure 6: Motor Driver Interlock Board

C Signature Sheets

After reading this document, as well as the ESAD, RSAD, and ERG, workers need to sign the signature sheet located in the "yellow binder" of the experiment specific documents. This binder can be found in the Hall B counting house and in the MCC.