2 Project Plan

2.1 Project Management/Tracking Procedures

Which of agile, waterfall or waterfall+agile project management style are you adopting. Justify it with respect to the project goals.

Due to the large amount of knowledge that we need to build up, we will be using a waterfall approach. Creating a viable product iteration simply isn't possible within a small portion of time such as a sprint. The requirements are also well worked out and shouldn't update as the semester progresses. Due to this being a largely physical design (in concept) of this Quantum Computer (QC), the iteration will come in further implementation of features into an overall computer design, as opposed to doing full minimum viable product (MVPs) and iterating on each one.

What will your group use to track progress throughout the course of this and the next semester. This could include Git, Github, Trello, Slack or any other tools helpful in project management.

We are using GroupMe for communication and sharing knowledge amongst student team members. We utilize a mass-email chain for communication amongst all individuals involved in the project. We also have a shared drive with an extensive directory containing our accumulated knowledge base, presentations, design documents, and eventually our designs. Finally, we have weekly 2-3 hour meetings to talk about the progress that we have made with our project. We may use Git if we get to a point where software development becomes relevant, and are generally in an ad hoc stage of development tool selection as we are become more acquainted with our needs.

2.2 Task Decomposition

In order to solve the problem at hand, it helps to decompose it into multiple tasks and subtasks and to understand interdependence among tasks. This step might be useful even if you adopt agile methodology. If you are agile, you can also provide a linear progression of completed requirements aligned with your sprints for the entire project.

1. **Knowledge Acquisition: Reading papers, projects, journal, courses, etc. on quantum mechanics and computing. Can be broken into semi-distinct areas of research:**
    a. **General Quantum Mechanics Knowledge - Mike and Ike book on Quantum**
    b. **Quantum Computer Design - Client Provided State of the Art Review, Honeywell and IonQ whitepapers, etc.**
    c. **Quantum Simulation and Design - IBM Quantum, QISKIT, Quirk, more forthcoming**

2. **Initial computer design: Decomposing this step is contingent on adequate understanding of quantum computing components. Tentatively, as follows**
    a. **Defining Ion-trap Design**
        i. **Memory vs. Computation Traps**
        ii. **Geometry Selection (tentatively: 2D linear, junctioned with trap inversion)**
        iii. **Electrode configuration (Quantum implications)**
        iv. **Laser Systems (Quantum implications):**
            1. **Cooling: Doppler, Simulated Raman, Sideband**
            2. **Operational: Gate Implementation**
            3. **Global**
    b. **Classical computer control systems**
        i. **Laser system controls (Classical implementation)**
        ii. **Electrode controls (Classical implementation)**
    c. **Stuff we don't know enough to list**
3. **Revised computer design(s)**
    a. **Client functional review and testing benchmarks**
    b. **Optimization**
        i. **MLfQ**
        ii. **Circuit optimization techniques**
        iii. **Noise reduction methods**
        iv. **Error correction implementation/revision**
4. **Simulate portions of the quantum computer.**
    a. **Simulation will be an ongoing component of the initial and revised computer design tasks, and does not subdivide well separate from the initial computer design subdivisions. We include it as a separate major on account of the fact that the initial design sections are not concretely or exclusively tied to simulation.**
5. **Rough draft of write up about design.**
    a. **Background Section**
    b. **Highlight of novel developments**
        i. **Methods, Goals, Results**
    c. **Testing and performance evaluation**
        i. **Methods, Results**
    d. **Conclusion**
        i. **Final results, fabrication discussion (if applicable), further work**
    e. **Reference/Resource Section**
6. **Final write up with design and all documentation allowing for future continuation.**
    a. **Population of missing figures/experiments**
    b. **Draft revision**

2.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

What are some key milestones in your proposed project? It may be helpful to develop these milestones for each task and subtask from 2.2. How do you measure progress on a given task? These metrics, preferably quantifiable, should be developed for each task. The milestones should be stated in terms of these metrics: Machine learning algorithm XYZ will classify with 80% accuracy; the pattern recognition logic on FPGA will recognize a pattern every 1 ms (at 1K patterns/sec throughput). ML accuracy target might go up to 90% from 80%.

In an agile development process, these milestones can be refined with successive iterations/sprints (perhaps a subset of your requirements applicable to those sprint).

Due to the highly theoretical nature of our project -the construction of a quantum computer- , quantitative or physical milestones are difficult to create:

1. **Knowledge Acquisition**
    a. **This step is purely measured by relative knowledge**
    b. **In all likelihood, knowledge acquisition will continue to be the primary step of this entire project, and will extend until the end of the project in some fashion**
    c. **A good yardstick to measure our success in this step is by our understanding of increasingly complex bodies of knowledge**
    d. **Completion of this step can be marked when we feel comfortable enough to create an initial computer design**
2. **Initial Computer Design**
    a. **Milestones for this step can be measured based on relative completion on individual components:**
        i. **ion trap (Electrode induced pseudopotential well, optical hardware system, doppler cooling system);**
        ii. **Computational, Memory, and possibly Transport Trap configuration (i..e. differentiating trap implementations/connections between traps)**
        iii. **Classical control systems for lasers and electrodes, etc.**
    b. **Performance metrics will include: error, coherence time, noise, and quantum volume. These will be more important for the revised design, as we focus more on improvement.**
    c. **This step will be complete when we have a single iteration, comprehensive QC design consisting of layout of ion traps, nodes, and clusters**
3. **Revised Computer Design**
    a. **Performance metrics will include: error, coherence time, noise, and quantum volume. <u>These are quantitative measures, but at this time describing them quantitatively would be unreasonable in the scope of this document.</u>**
    b. **This step will be complete when we have tested and gone over multiple iterations of the initial computer and component designs**
4. **Simulation**
    a. **This will be an easy step to benchmark, as simulations can be run based on current QC benchmarks**
    b. **Similar to knowledge acquisition, this step will not be complete until we say it is. As we come up with different designs for components, we can simulate each of them to any extent necessary.**
5. **Paper / Presentation Rough Draft**

   a. **This step will not have significant substeps or milestones other than completion**
   b. **Evaluation can be done by completion of individual paper sections listed in 2.2**
   c. **This step will be complete when the paper is written in its entirety**
6. **Paper / Presentation Final Draft**
   a. **This step will not have significant substeps or milestones other than completion**
      i. **We will divide successive drafts between the initial rough draft and final draft as milestones,**
   b. **Evaluation can be done by completion of sections listed in 2.2**
   c. **A good evaluation metric would be whether or not we get published in a journal. This will not be required, but completion to the extent we could reasonably submit and be reviewed for publication, as well as publication, would serve as indicators of exceptional performance. This will be subject to the descretion of our client.**

2.4 Project Timeline/Schedule

• A realistic, well-planned schedule is an essential component of every well-planned project

• Most scheduling errors occur as the result of either not properly identifying all of the necessary activities (tasks and/or subtasks) or not properly estimating the amount of effort required to correctly complete the activity

• A detailed schedule is needed as a part of the plan:

– Start with a Gantt chart showing the tasks (that you developed in 2.2) and associated subtasks versus the proposed project calendar (including both 491 and 492 semesters). The Gantt chart shall be referenced and summarized in the text.

– Annotate the Gantt chart with when each project deliverable will be delivered

• Project schedule/Gantt chart can be adapted to Agile or Waterfall development model. For agile, a sprint schedule with specific technical milestones/requirements/targets will work.

	August	September	October	November	December	January	February	March	April	May
Knowledge Acquisition										
Initial										

computer design										
Revised computer design										
Simulate										
Rough draft write up										
Final write up										

2.5 Risks And Risk Management/Mitigation

Consider for each task what risks exist (certain performance target may not be met; certain tool may not work as expected) and assign an educated guess of probability for that risk. For any risk factor with a probability exceeding 0.5, develop a risk mitigation plan. Can you eliminate that task and add another task or set of tasks that might cost more? Can you buy something off-the-shelf from the market to achieve that functionality? Can you try an alternative tool, technology, algorithm, or board?

Knowledge Acquisition: No risks present, risk factor of zero.

Initial design: Risk of software design not meeting the design specifications of the hardware. Very significant, risk factor of 0.75. We can mitigate this by peer-reviewing each of our solutions and having many stringent checking processes in place.

Revised design: Risk of implementing improper software, which could lead to a faulty fabrication. Risk factor: .1 due to lots of revisions done at each step.

Simulations: There are risks in not being able to manipulate whatever software we choose in the correct way, or getting the wrong software. The risk should be low due to our mentors knowledge therefore the risk is: .2

Rough draft write up: No risks present, risk factor of zero.

Final write up: There are severe risks with messing up the final design, which is why we mitigate the risk by having a rough draft. Risk: .1 since we take lots of care to mitigate risks to get to this step

Agile project can associate risks and risk mitigation with each sprint.

2.6 Personnel Effort Requirements

Include a detailed estimate in the form of a table accompanied by a textual reference and explanation. This estimate shall be done on a task-by-task basis and should be the projected effort in total number of person-hours required to perform the task.

	Explanation	Textual reference
Knowledge acquisition	Each individual will do 5 hours a week of knowledge acquisition and compiling the information along with a 3 hour meeting, accumulating in about 224 hours over the course of 4 months.	*Mike and Ike Quantum Book, QisKit, Honeywell Quantum Computing, IBM Quantum Computing*
Initial Design	Each individual will spend 6 weekly hours to contribute to a large design document. Creating the design from our knowledge should take about 100 hours.	*Mike and Ike Quantum Book, QisKit, Honeywell Quantum Computing, IBM Quantum Computing*
Revised Design	Each individual will spend 3 weekly hours to review and revive aspects of our design. Revising should take about 75 hours.	*Mike and Ike Quantum Book, QisKit, Honeywell Quantum Computing, IBM Quantum Computing*
Simulation	Each individual will spend 4 weekly hours to assist in the construction of a simulation of our design. Simulation will take longer due to a new learning curve, making it take around 150 hours.	*Mike and Ike Quantum Book, QisKit, Honeywell Quantum Computing, IBM Quantum Computing*
Rough Draft	Each individual will spend 6 weekly hours to contribute to a rough draft of our paper. The rough draft should be able to take from things we have already done, though taking a good amount of work amounting to 100 hours.	*Mike and Ike Quantum Book*

Final write Up	Each individual will spend 6 weekly hours to revise the rough draft to produce a final draft. The final write up will have to be carefully produced, taking 90 hours.	*Mike and Ike Quantum Book*

2.7 Other Resource Requirements

Identify the other resources aside from financial (such as parts and materials) required to complete the project.

- **Knowledge base entries: textbooks, journal articles, whitepapers, etc.**
- **Simulation softwares (possibly local computational power for running simulations)**
- **High-end fabrication facilities/tools ⇒ Connections with Sandia established**
- **Physical System model (i.e. implementing controls for optical hardware, trap electrodes, etc. will require a system model for these components… buy or build indeterminate)**