Department of Computer Science and Engineering  
The University of Texas at Arlington

Ink3d

3-D Printer Fabrication System

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# General Organization

## Project Manager

Daniel Lain is the project manager and team lead for the 3-D Printer Fabrication System. Dan was selected for this role due to his many years of project management and leadership experience in manufacturing and materials. The project manager will be responsible for creating and maintaining the project plan, assigning team tasks, and monitoring progress toward completion. The project manager will also be responsible for leading team meetings and document review activities.

## Project Oversight

Project oversight will be achieved through internal and external team controls. Internally the project manager will track and ensure the team adheres to the published project plan. Task status will be reported via email or during the regularly scheduled team meetings. The team will review all deliverables for accuracy and completeness. Externally Mr. O’Dell will manage the project through the regularly scheduled gate reviews and status reports. The sponsor, Dr. Shiakolas, will oversee the overall project goals and scope through regular meetings with the team. Additionally the team will meet with the ME team regularly to ensure the projects are aligned for success.

## Roles and Responsibilities

|  |  |  |
| --- | --- | --- |
| **Role** | **Assigned To** | **Responsibility** |
| **Development Manager** | **Mr. O’Dell** | **Mentoring**  **Documentation Approval**  **Schedule Approval**  **Expense Approval** |
| **Project Sponsor** | **Dr. Shiakolas** | **Requirements Approval**  **Guidance**  **Customer Representative**  **Change Approval** |
| **Project Manager** | **Daniel Lain** | **Maintain Project Plan**  **Assign Tasks to Team**  **Turn in Deliverables**  **Risk Manager**  **Change Approval** |
| **Hardware Lead** | **Shawn Simonson** | **Plan Hardware Interfaces**  **Research Hardware**  **Hardware Development**  **ME Liaison**  **Change Approval** |
| **Software Engineering Lead** | **Jesse Bowles** | **System Architecture**  **Modular Planning**  **Scalability Planning**  **Develop UMLs**  **Change Approval** |
| **Lead Programmer** | **Tim Edmonson** | **Algorithm Development**  **Open Source Selection**  **Algorithm Research**  **Change Approval** |

**Table 1.1**

## Project Constraints

The 3-D Printer Fabrication System will have to cope with a number of constraints during the course of the project. Specific constraints below:

* Team’s limited analytical geometry experience
* Budget of $800
* Hardware is controlled by ME team
* Schedule limited to eight months

## Project Assumptions

* Project will utilize an open source system for the analytical slicing
* ME team will produce a functional printer
* Team will meet at least twice a week
* Team will work as required to fulfill the project needs

## Preliminary Schedule and Cost Estimates

|  |  |
| --- | --- |
| **Preliminary Schedule** | |
| Project Milestone | Due Date |
| SRS Draft Document | 10/9/13 |
| Project Plan First Draft | 10/16/13 |
| Project Charter First Draft | 10/16/13 |
| Requirements Gate Review | 10/30/13 |
| Architecture Design Specification Draft | 12/2/13 |
| Baseline Project Charter | 12/4/13 |
| Baseline Microsoft Project Plan | 12/4/13 |
| Final Gate Review ADS | 12/11/13 |
| Baseline Architecture Design | January 2014 |

Table 1.2

|  |  |  |  |
| --- | --- | --- | --- |
| **Preliminary Costs** | | | |
| Component | Quantity | Cost/Unit | Total Cost |
| SainSmart Mega2560 Controller | 1 | 43.17 | 43.17 |
| SainSmart RAMPS 1.4 Shield | 1 | 25.9 | 25.9 |
| SainSmart A4988 Driver | 7 | 10.97 | 76.79 |
| Raspberry Pi Model B R2.0 | 1 | 39.95 | 39.95 |
| 8GB SD Flash Card | 1 | 9.88 | 9.88 |
| Male/Male USB 2.0 Cable | 1 | 9.95 | 9.95 |
| 50ft. 20GA Solid Copper Interconnect | 1 | 15.95 | 15.95 |
| SainSmart 1602 LCD Shield | 1 | 24.95 | 24.95 |
| Passive Electronics Budget | 1 | 25 | 25 |
| Total |  |  | 271.54 |

Table 1.3

# Scope Statement

## Introduction

The goal of the 3-D Printer Fabrication System is to provide an interface and control software that operates a multiple extruder 3-axis printer to the printer operator. The interface shall allow the operator to define objects to be printed and associate materials with the objects in a simple manner. The control software shall provide the appropriate machine instructions to print the objects as specified by the machine operator.

## Product Definition

The 3-D Printer Fabrication System shall be broken down into three primary components. The host machine, the intermediate machine, and the print controller.

The host machine shall be a PC-type workstation. The host will provide the operator a graphical interface with which the operator can load an object file specified by the .STL file format. It will also store a library of materials with which the operator can associate multiple objects with different materials. The host will also generate a database of these associations and provide these to a geometry processing API such that machine instructions can be generated and passed to the intermediate machine.

The intermediate machine shall receive the generated machine instructions either via a streamed interface such as a USB or parallel interface or via an SD Card or flash memory. The software hosted on the intermediate machine shall read the machine instructions and issue them to the machine. While issuing instructions, the intermediate machine will also monitor hardware status given by the print controller. The hardware status will consist of extruder temperature, extruder flow, motor speed, and other parameters.

The print controller shall be selected by the ME (Mechanical Engineering) team. The task of the print controller is to drive and monitor the stepper motors, cams, and extruders of the 3-D printer bed itself. The print controller will also monitor the various sensors that monitor the 3-D printer’s status in real time. It will also provide this information to the intermediary device such that corrective action may be taken if necessary. The primary responsibility of programming the print controllers resides with the ME team, but the CSE team will be prepared to provide assistance where and if necessary.

## Intended Audience

The intended audience of the 3-D Printer Fabrication System will be the ME team, Dr. Panos Shiakolas, other operators authorized by the aforementioned, and experienced 3-D and CNC machine operators.

# Cost Management Plan

## Introduction

The cost management plan shall ensure the success of the team by providing a plan to remain within the allocated project budget of $800. The project manager shall be responsible for managing the costs incurred by the group as well as maintaining the time spent by team members on their given tasks. The costs and earned work shall be contained within the project’s Microsoft Project Plan and will be maintained by the project manager. The team shall work with the project sponsor to ensure that any deviations from a cost perspective are dealt with in a timely and coordinated manner.

## Cost Management

Cost will be outlined within the Microsoft Project Plan work breakdown structure. The project manager shall maintain accurate assessment and reporting of individual tasks. The material costs will be agreed upon by the team and coordinated with the hardware lead and the project sponsor.

## Labor Management

Earned value and labor times are provided by the project manager. These values are rough estimations. The individual team members shall be responsible for completing their tasks in a timely manner. However, the time taken may be more or less than the time estimation. The team members shall report time spent on each task to the project manager so that it can be entered into the Microsoft Project Plan.

## Project Cost

### Performance Cost

The performance cost of the project shall be measured using Earned Value Management. The team shall use the following metrics to measure the earned value: Budgeted Cost of Work Scheduled (BCWS), Actual Cost of Work Performed (ACWP), and Budgeted Cost of Work Performed (BCWP). These values will be logged in the team’s Microsoft Project Plan. The values are to be logged, maintained, and interpreted by the project manager.

### Material Cost

Preliminary material costs for the project are given in Table 1.3 in this document. The hardware lead shall work closely with the ME team and the project sponsor, Dr. Shiakolas, to evaluate any potential material cost deviations. Such deviations shall be agreed upon by the CSE team before being conveyed to the ME team and sponsor. If material cost deviations extend the team beyond the $800 budget, then a proposal shall be made to Mr. O’Dell for approval.

# Earned Value Management

## Introduction

Earned Value Management will be used to monitor the progress and status of the 3-D Printer Fabrication System project. Earned Value Management provides and objective measure of the actual progress versus the planned progress at any given time during the course of the project. This measure is achieved by assigning each planned project task a value (in person-hours), then tracking the actual value spent (actual person-hours spent) for each of those tasks. This data is used to derive various metrics that can be analyzed to track project progress and status in order refine the project plan accordingly.

## Core Components

Each planned project task has the following values associated with it. These components are all recorded in units of person-hours.

**Budgeted Cost of Work Scheduled (BCWS) – Planned Value**

* How much work is planned to be accomplished at a given point in time.

This value is assigned for each task during the planning phase as an estimation of the work needed in order to complete that task.

**Actual Cost of Work Performed (ACWP) – Actual Cost**

* How much work is actually spent at a given point in time.

As work is completed on a given task, the actual cost (ACWP) for that task is updated accordingly.

**Budgeted Cost of Work Performed (BCWP) – Earned Value**

* The value earned for a given task.

For this project, this value is recorded for each task as zero until that task is complete. Once the task is completed, if the actual cost value (ACWP) is greater than the planned value (BCWS) then this value is recorded as the planned value (BCWS). If the actual cost (ACWP) is lower than the planned value then this value is recorded as the actual cost (ACWP).

## Performance Tracking

The values collected for the core components above can be used to calculate indices that provide a measure for both cost and schedule performance at any given time during the project.

### Cost Performance Index

The cost performance index (CPI) is used to measure the efficiency of the work being performed. The CPI also gives an idea of how accurate the estimated time cost of the project is.

This value can be determined by dividing the earned value (BCWP) by the actual cost (ACWP).

[insert equation]

Equation 4-1: Cost Performance Index

CPI > 1.0 🡪 Exceptional performance

CPI < 1.0 🡪 Poor performance

### Schedule Performance Index

The schedule performance index (SPI) is used to measure if project deadlines are being met.

This value can be determined by dividing the earned value (BCWP) by the planned value (BCWS).

Equation 4-2: Schedule Performance Index

SPI > 1.0 🡪 Exceptional performance

SPI < 1.0 🡪 Poor performance

## Reporting Earned Value

In order for earned value management to be a valuable tool, earned values must be current and accurate. To ensure that these values are current, each team member reports their progress on their assigned tasks at the beginning of every team meeting. This information is recorded in the team’s Microsoft Project plan, which then calculates earned value, CPI, and SPI. In addition to maintaining internal records of earned value, each team member submits an individual status report containing earned value records each week.

# Scope Management Plan

This section describes the scope management framework for this project. Any communication that pertains to the project’s scope will adhere to the procedures described in this section.

## Scope Management Approach

Scope management will be the responsibility of the team lead. Team members may propose scope changes by presenting the change to the team lead. If the team lead determines the proposed change has merit, he will present it to the team. If the entire team approves of the scope change, the team lead will propose the change to the sponsor. Only when the sponsor approves the proposed change will the change be accepted. The sponsor may also propose scope change. This scope change proposal must be made to the team lead, who will then present the proposed change to the team. All team members must approve the change in order for it to be accepted. Upon acceptance of scope changes, all documents involving scope must be updated appropriately.

## Scope Definition

The scope of this project was defined through documents derived from the collection and analysis of system requirements. Initially, the team held meetings with the sponsor to understand his vision and expectations for the 3-D Printer Fabrication System. Once the sponsor’s expectations were understood, customer requirements were created and presented to the sponsor. Once the customer requirements were approved, additional requirements were created based on research into current technology in the 3D printing domain. Based on the requirements collected, a System Requirements Specification and Work Breakdown Structure were formed. Together, these two documents define the scope of the 3-D Printer Fabrication System.

## Scope Statement

This project includes the design, implementation, and testing of a software system that analyzes digital descriptions of multi-material 3D objects and sends machine instructions to a 3-D Printer capable of extruding multiple materials in a single print. The deliverables of this project include the Systems Requirements Specification, Project Charter, Architectural Design Specification, Detailed Design Document, and the prototype of the system. This project will be accepted when all acceptance criteria items defined in the System Requirements Specification have been verified by the sponsor. This project does not include the design or development of the physical 3D printing machine, nor does it include ongoing maintenance of the product. Additionally, work on this project will not exceed past the month of May 2014.

## Scope Verification

Throughout this project, the team lead will verify all project deliverables against the original scope as defined in the System Requirements Specification and the Work Breakdown Schedule. Any concerns that arise during the verification will be discussed with the project’s sponsor and team members. If a deliverable is not found to be within the defined scope, modifications will be made and then the deliverable will be subject to the verification process once again. Only when the deliverables successfully go through this verification process will they be considered acceptable.

## Scope Control

The project team will work together to ensure the control of scope of the project. Team meetings are held twice a week, in which each team member will report on their activities and their progress toward assigned deliverables. During these status reports, team members will hold each other accountable for staying within the defined scope of their respective tasks and deliverables. The Work Breakdown Structure will serve as a definition for the scope of the work that is to be performed.

# Work Breakdown Structure

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Task Number | Task Name | Planed Start | Planned Finish | BCWS |
| 1 | Senior Design 1 | Wed 9/11/13 | Wed 12/11/13 | 227 |
| 1.1 | Documents | Wed 9/11/13 | Wed 12/11/13 | 227 |
| 1.1.1 | System Requirements Specification | Wed 9/11/13 | Fri 11/8/13 | 88 |
| 1.1.1.1 | Version 1.0 | Wed 9/11/13 | Wed 10/9/13 | 57 |
| 1.1.1.2 | Version 2.0 | Wed 10/9/13 | Fri 11/8/13 | 31 |
| 1.1.2 | Team Charter | Thu 10/3/13 | Wed 12/4/13 | 74 |
| 1.1.2.1 | Version 1.0 | Thu 10/3/13 | Wed 10/16/13 | 44 |
| 1.1.2.2 | Version 2.0 | Thu 10/17/13 | Wed 12/4/13 | 30 |
| 1.1.3 | Architecture Design Specification | Fri 11/1/13 | Wed 12/11/13 | 65 |
| 1.1.3.1 | Version 1.0 | Fri 11/1/13 | Mon 12/2/13 | 35 |
| 1.1.3.2 | Version 2.0 | Tue 12/3/13 | Wed 12/11/13 | 30 |
|  |  |  |  |  |
| 2 | Senior Design 2 | Wed 1/15/14 | Fri 5/23/14 | 261 |
| 2.1 | Documents | Wed 1/15/14 | Fri 5/23/14 | 111 |
| 2.1.1 | Detailed Design Documentation | Wed 1/15/14 | Tue 2/18/14 | 71 |
| 2.1.1.1 | Version 1.0 | Wed 1/15/14 | Wed 2/12/14 | 36 |
| 2.1.1.2 | Version 2.0 | Wed 2/12/14 | Tue 2/18/14 | 35 |
| 2.1.2 | Test Plan |  |  | 40 |
| 2.2 | Prototype Implementation | Tue 2/18/14 | Thu 5/15/14 | 150 |
| 2.2.1 | Version 1.0 | Tue 2/18/14 | Tue 3/18/14 | 50 |
| 2.2.2 | Version 2.0 | Tue 3/18/14 | Fri 4/18/14 | 50 |
| 2.2.3 | Final Product | Fri 4/18/14 | Thu 5/15/14 | 50 |
|  |  |  |  |  |
| 3 | Presentations | Fri 9/13/13 | Wed 12/11/13 | 28 |
| 3.1 | SRS Gate Review | Wed 10/9/13 | Fri 11/8/13 | 7 |
| 3.2 | Charter and Plan Review | Wed 10/16/13 | Wed 12/4/13 | 7 |
| 3.3 | Architecture Design Review | Mon 12/2/13 | Wed 12/11/13 | 7 |
| 3.4 | Team Status Report SD 1 | Fri 9/13/13 | Fri 12/6/13 | 7 |
|  |  |  |  |  |
| 4 | Team Meetings | Tue 9/10/13 | Tue 12/3/13 | 52 |
| 4.1 | Team Meeting SD1 | Tue 9/10/13 | Tue 12/3/13 | 52 |
|  |  |  |  |  |
| 5 | MS Project | Sun 9/29/13 | Fri 1/10/14 | 40 |
| 5.1 | SD 1 | Sun 9/29/13 | Wed 12/4/13 | 20 |
| 5.2 | SD 2 | Fri 1/10/14 | Fri 1/10/14 | 20 |

# Quality Management Plan

## Introduction

Team Ink3D believes that quality is important in our products and documentation. The team has derived a couple of ways to verify that the product meets the stated requirements. Below are the actions the team will take to ensure good quality.

## Documentation

Good documentation will be one of the key strategies to ensure good quality in our product. Each team member is keeping up with his own personal engineering notebook. The notebook can cover any subject that the writer feels is important for his part of the assignment and to the success of the project as a whole. The team also has deliverables for Mr. O’Dell. He requires regular individual status reports, team status reports, and other documentation to ensure that there is always progress and to prevent stagnation.

## Software

Modular and scalable software is especially important to this particular project. All individuals on the team are aware of good code formatting and including notes in the source code. The software will be designed in a top-down approach by focusing on abstraction. Design patterns that the team has learned in class will be used to create code that is easy to understand, modify, and update. To control team collaboration, the team will be using a version control manager. Github was chosen as the version control manager because of its compatibility across multiple platforms which benefits the team’s diverse work space.

## Hardware

The ME Team is behind the development of the physical 3-D Printer and the multi-material nozzle. While the ME Team will have their own plan for testing the quality of the 3-D Printer, Ink3D will also write up its own testing plan to ensure that the hardware works as required.

## Testing

Test incrementally as new requirements are added. Each time a new requirement is added, all requirements should be tested individually again before testing by use cases. Software will be tested in a vacuum to ensure modularity and will be tested along with the printer for compatibility.

# Communications Plan

## Introduction

For the 3-D Printer Fabrication System project, the team will require appropriate communication within the organization as well as communication with the team’s sponsor, the professor of this course, and the Mechanical Engineering Team.

## Internal Team Communication

The team has established three primary methods of communication for the individual members. These are team meetings, the GitHub repository, and e-mail. This section will go into detail about these communication types below and describe how and why they are used.

### Team Meetings

The team schedule two regular meetings a week every Tuesday and Thursday at 7:00 p.m. There is no defined time limit for how long the meetings should last, but before each meeting, team lead Daniel Lain is responsible for finalizing the meeting agenda beforehand. The team follows the criteria listed for the team meeting. Once everything on the agenda list has been discussed, the team finishes with a session of open discussion and then decides on the next meeting’s agenda. Team meetings are primarily for reporting individual progress, addressing concerns to the team, ensuring that each person’s individual work is collaborated, and deciding on the next step of the project.

### GitHub

GitHub is the team’s primary source control for the system. The file architecture of the team’s GitHub account is structured to neatly accommodate several types of documentation, research, and deliverables. GitHub’s comment feature allows individual members to briefly update the team on the individual’s progress.

### E-mail

The team’s quickest method of communication will be by e-mail. The consensus of the team is that not every member is comfortable with receiving and sending text messages as a reliable source of communication. However, the individual members have proven so far to be very responsive to emails. Almost every e-mail has been responded to within the day, usually within hours. E-mail is used for primarily for questions, concerns, and clarification. Important information or helpful notes that were not discussed during the meeting (ie. The team forgets to talk about it) can be brought up via the E-mail.

## External Communication

The team also needs a way to communicate outside the team itself. There are two individuals and one additional team that Ink3D must stay in frequent contact with throughout this project.

### Dr. Shiakolas (Team Sponsor)

Ink3D has two primary forms of communication with the team’s sponsor, Dr. Shiakolas. First form of communication is by e-mail. The team uses e-mail as a means to ask smaller questions such as clarification on a requirement. The other form of communication is scheduled meetings. Meetings with Dr. Shiakolas are not regular, so before a meeting can be scheduled, the team must first e-mail Dr. Shiakolas and discuss an appropriate meeting time. The normal meeting time is on Wednesday at 1:00p.m. During meetings with Dr. Shiakolas, the team discusses clarification about the requirements and discusses the scope and whether it is correct as is or needs to be changed.

### Mr. O’Dell (Professor)

Another individual that the team reports to is Mr. O’Dell. He is the professor of the Senior Design course that oversees the Computer Science Teams in his class. To ensure that every team is making progress, Mr. O’Dell requires several deliverables, including individual status reports, team status report presentations, and deliverable documents. One goal of this team is to be able to deliver on time with adequate information. In the case of questions regarding deliverables or how Senior Design works, Mr. O’Dell accepts e-mails from his students.

### Mechanical Engineering Team

As per Dr. Shiakolas’s request, Ink3D has not yet met with the Mechanical Engineering Team. However, meeting with the ME Team will eventually be necessary, so a form of communication must be established between the two teams. Very likely, the same channels of communication will be used between the ME Team and Ink3D as Ink3D uses internally. Initial contact will be made by e-mail or by both teams meeting with Dr. Shiakolas.

# Change Management Plan

## Purpose of Integrated Change Management Plan

Throughout the course of this project, it is inevitable that change will be required. In order to have the highest probability of success, it is important to define a plan for identifying acceptable changes and controlling the impact of those changes.

The early stages of 3-D Printer Fabrication System project still involves many unknowns and loosely defined components that are likely to change as the project progresses. The areas most likely to change are the scope of the team’s involvement in the printer’s firmware and the interface between the printer and the host software. Early meetings with the project’s sponsor also suggest that the required printing methods may also change throughout the course of the project depending on the efficiency of the project’s progress.

This Integrated Change Management Plan is intended to define all processes, practices, tools, review bodies, and authority necessary to monitor and control the identification of changes and the impact of those changes on the project objectives.

## Roles and Responsibilities

* **Project Sponsor:** Dr. Panos Shiakolas will inform the team if any changes are needed to the project to achieve his expectations of the project. He will also have to approve any changes that the team decides are necessary.
* **Project Lead:** Dan Lain is responsible for leading team discussions about any proposed changes. He is also responsible for presenting changes proposed by the team to the sponsor and presenting any changes proposed by the sponsor to the team.
* **Project Team:** The project team is responsible for identifying needed changes throughout the project. Also, every member of the project team must approve changes before the changes can be accepted.
* **Project Advisor:** Mr. O’Dell will give advice to the team about proposed changes. He may be approached to discuss changes when there is a disagreement between the project team and the project sponsor.

## Review and Approval Process

The project sponsor or any member of the project team may propose changes. To propose a change, the sponsor or team member must first present the change to the project lead. The proposal must be made using the Change Control Form found in section 9.4. If the team lead decides the change has merit, he will present the proposed change to the entire team and open a discussion of the proposed change. The team must then consider if the change is feasible and how the change will affect the scope, cost, schedule, and budget of the project. If the change cannot be completed by the deadline for the project or the change would require funds that cannot be met by the budget of the project, the change cannot be accepted. Once the change has been discussed and assessed, the team must unanimously approve of the proposed change before the change will be accepted. If a team member proposed the change, the team must also acquire approval from the project sponsor before accepting the change.

**Review and Approval Process Flow Chart**



## Change Identification, Documentation, Implementation and Reporting

To ensure that changes are made through a formal process, a Change Control Form is defined below. The purpose of this form is to document proposed changes and enforce a strict change management procedure. The form provides documentation of the proposed change, the reasons the change was proposed, the impact the change will have, the acceptance status of the change, and the reasoning behind accepting or denying the change. By using this document, the team is able to record a history of proposed changes and the reasons why the change was accepted or denied. Keeping these records can be beneficial when dealing with proposed changes that are similar to past changes and also beneficial to future interests of the system.

Once a change has been documented with the change control form and been accepted by the project sponsor and project team, all relevant documentation must be updated. First, the Work Breakdown Schedule must be updated to account for any new work associated with the change. Next, any and all documents that pertain to the change must be updated.

**Change Request Form**

**Change Proposed By:**

**Description of Proposed Change:**

**Reasons the Change is Necessary:**

**Impact of the Change:**

**Team Signatures of Approval**

|  |  |  |
| --- | --- | --- |
| Name | Signature | Date |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

Sponsor Approval

|  |  |  |
| --- | --- | --- |
| Name | Signature | Date |
|  |  |  |

Reason the Change was Accepted or Denied:

# Risk Management Plan

## Purpose of Risk Management Plan

The risk management plan is intended to provide a structured method for the team to identify, evaluate, and deal with risks appropriately as they come up over the course of the project. Risks can be categorized by severity and probability. They can then be managed or possibly even avoided.

## Roles and Responsibilities

* Project Sponsor: Dr. Panos Shiakolas is the sponsor for the project. The sponsor will assist the team in identifying the major requirements and needs for the project. The sponsor will also assist the ME team in identifying the hardware requirements and relaying the information to the CSE team. Dr. Shiakolas has a wealth of experience with 3-D printing and the CSE team will meet with him on a weekly or bi-weekly basis to discuss any risks and possible resolutions to the risks.
* Project Manager: Dan Lain is the project manager. The project manager will meet with the team at scheduled intervals to discuss any risks encountered. The project manager will also coordinate with the project sponsor at meetings and discuss possible risk resolutions.
* Project Team: Team members shall present any identified risks to the project manager and the rest of the team. The team members will identify the risk, scope, and possible solutions so that they can be discussed with the team and project manager before scheduled meetings. Team members will also offer input about risks during team meetings.
* Project Stakeholders: Dr. Shiakolas, the ME team, and machine operators of the UTA Mechanical Engineering Department will address any potential risk as well as possible courses of actions to the CSE team.
* Risk Manager: Dan Lain will serve as the risk manager for the project as well as the project manager. The risk manager will be responsible for documenting and providing assistance in resolving risks identified by the team.

## Risk Identification

The risk manager shall document all risks agreed upon by the team. The risk manager will also prescribe and document resolutions for each unavoidable risk. The risks will be documented in detail such that a proper course of action may be taken. The risk manager will coordinate with the project manager so that earned value and the work breakdown structure can be adjusted to account for time spent in risk resolution.

## Risk Triggers

Risk triggers are events or performance characteristics that warn of a risk or impending risk. The team has identified the following risk triggers:

* Slic3r fails to perform adequately
* Overall analytic geometry skills are less than adequate
* Hardware selection is largely out of the team’s control
* The computer engineer on the team is encumbered with tasks

## Risk Analysis

This section determines the effects of the identified risks on the project in terms of probability of occurrence and the risk exposure.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Category | Risk | Probability (%) | Cost (Days) | Risk Exposure (Days) |
| Software | Slic3r fails to perform adequately | 50 | 45 | 22.5 |
| Team | Analytic geometry skills are not sufficient | 50 | 45 | 22.5 |
| Team | Hardware selection outside of team control | 50 | 60 | 30 |
| Team | Computer engineer over encumbered with tasks | 50 | 20 | 10 |
| Total |  |  |  | 85 |

## Risk Severity

This section categorizes the identified risks by priority and provides a possible resolution. This section also identifies the possible triggers.

|  |  |  |  |
| --- | --- | --- | --- |
| Risk | Priority | Resolution | Triggers |
| Slic3r fails to perform | High | Must modify Slic3r or identify another open source slicing utility | Slic3r fails to perform adequately |
| Analytic Geometry skills not sufficient. | High | Extra time must be spent on research | Unable to process geometry sufficiently to produce adequate output |
| Hardware selection beyond team control | Medium | Prove more input to ME team on hardware selection | Excessive incompatibilities and firmware modification requirements |
| Computer engineer encumbered with tasks | Low | Other team members must assist with CpE tasks | ME team is excessive |

## Risk Response Planning

Risk response planning will prepare the team to identify and resolve risks associated with the project through either mitigation or evasion. The risk manager is responsible for providing a strategy for resolving risks as they occur throughout the project. The team will work with the risk manager and with other team members during scheduled team meetings to provide the risk manager with a detailed description of the risk. Risk response planning will be broken into the following three steps:

1. Risk Management Plan: This will describe how risk management will be implemented according to the risk response planning.
2. Identify Risks and Scope: Team members shall work with the risk manager to identify risks so that they can be documented and dealt with.
3. Quantitative Analysis: The risk manager shall develop a numeric value associated with the risk based on work breakdown and/or cost.

## Risk Documentation and Reporting

Create a central repository for risk information and mitigation strategies. This is typically an automated system where risk information is available to appropriate project team members and risk owners. Typical tools include the risk register (the complete risk database) and a monthly risk status report that is part of the OMB Exhibit 300 process.

## Risk Control

The team members are individually responsible for identifying risks as they become aware of them. Team members shall have access to the risk database and documentation such that they can be modified after the risk has been adequately identified. In each team meeting, team members will present any risks that have arisen since the last team meeting. Each risk shall be discussed until an appropriate solution is reached. Critical risks shall be escalated to the project manager and project sponsor as soon as possible so that a possible solution can be reached in a timely manner.

# Procurement Management Plan

## Purpose of the Procurement Management Plan

The purpose of the procurement management plan is to organize how the team will gather additional supplies for the completion of this project. It is very unlikely that the team will have all of the proper equipment on hand to complete the 3-D Printer Fabrication System, so a system must be in place to ensure that the team can procure the correct and best products for the job in an efficient manner.

## Roles and Responsibilities

Below describes the role each person plays in the team’s procurement management plan:

* **Project Sponsor:** Dr. Shiakolas will be providing advice on what items could be beneficial to our project. In addition, Dr. Shiakolas has offered to give the team access to many tools he has that can assist the creation of the project.
* **Project Team:** Before a product can be purchased, the team must undergo a meeting about the purchase. One or more individuals of the team should perform research on the availability, cost, and usefulness of the product being considered. The individual(s) should then present his research to the team and explain if the purchase should be considered or not.
* **Project Manager:** When the team has decided on the product purchase, the Project Manager, Daniel Lain, will pass on the request to the Project Supervisor, Mr. O’ Dell, for consideration. The Project Supervisor has the final say on if the product is purchased.
* **Project Stakeholders:** This project does not have any *additional* stakeholders at this time, but in the event that more stakeholders are added, they will be notified of any purchasing decisions before they are made. Advice by stakeholders will be put into consideration, but will need sufficient cause first.

## Required Project Procurements and Timing

Items needed for this project should be procured before or at the start of the implementation phase. Because of the unique situation between Ink3D and the ME Team, it maybe be necessary to hold off on some purchases until the 3-D printer they are designing is better understood. Towards the end of the designing phase, but before implementation, both teams need to meet to design the integration of the product. Here, both teams will agree on the last items that need to be procured for integration.

## Description of Items/ Services to be acquired

At this time, the following items are the known necessities that must be acquired before or at the start of the implementation phase. Without these items, integration with the ME Team and their 3-D printer will be difficult.

* Printer Microcontroller
* Cables to connect microcontroller and computer to the 3-D printer. (The type of cable required has yet to be discovered. This is an area that can use more research, and will also depend on the outcome of the physical 3-D printer.)

# Project Closeout Report

## Purpose of Closeout Report

Upon completion of this project, a closure report will be produced. The purpose of the closure report is to insure that personnel, contract, administrative, and financial issues are resolved, that documents are archived, and lessons learned are captured.

## Administrative Closure

### Were the objectives of the project met?

The closure report will examine all objectives of the project and determine if they have been met. The final product of the project will be compared with requirements specified in the System Requirements Specification. If all requirements are met by the final project, the project will be deemed a success. If requirements are left unfulfilled, the obstacles and constraints for those requirements will be analyzed and documented.

### Archiving Project Artifacts

All project artifacts will be archived using GitHub so that they may be available for future interests in this project. The following is a list of the artifacts to be archived:

* System Requirements Specification
* Project Charter
* Microsoft Project Plan (Work Breakdown Schedule)
* Architectural Design Specification
* Detailed Design Specification
* Meeting Agendas
* Meeting Notes
* Research Documentation
* Financial Records
* Team Status Report Power Point Presentations
* Change Control Forms
* Product User Manual
* Source Code
* Source Code Documentation

The GitHub repository where these artifacts will be archived is located at https://github.com/qpHalcy0n/SRDesign.

### Lessons Learned

At the end of this project, a team meeting will be held with the intent of discussing the lessons learned throughout the project. It is important to reflect on the project and take away experiences that can contribute to success in future projects. Each team member will be present the lessons they have learned throughout the project and the team will discuss each lesson. The discussion will include the topics of how each lesson can be applied to future projects and how the project would have been affected if the lesson was learned prior to the start of the project. Each item discussed will be documented in the closeout report.

### Plans for Post Implementation Review (PIR)

A post implementation review will be conducted on the final product of this project. The final product will be compared with the System Requirements Specification to determine if the product was implemented according to specified requirements. In order to verify that the product is acceptable, the team and the project sponsor will go through each verification procedure defined in the Acceptance Criteria section of the Systems Requirements Specification. In addition to verifying that requirements were met for the project, the team will review the effort put into the project and analyze if the scope of the project was realistic given the amount of resources available. This process will be documented in the closeout report.

### Final Customer Acceptance

For this project, the customer is the project’s sponsor. The product will be considered accepted by the customer when the customer verifies the acceptance criteria defined in the System Requirements Specification. A meeting will be held where all team members of the software team, all team members of the mechanical engineering team, and the sponsor are present. During this meeting, all verification procedures defined in the System Requirements Specification will be conducted. In addition to verifying acceptance criteria, any open issues will be discussed with all parties present. All parties will have an opportunity to discuss their vision for the future of the product and make suggestions about any further steps that must be taken in order for the next team to continue development on the product.

### Financial Records

All financial records will be accounted for, documented, and archived. Physical invoiced and purchase orders will be scanned and archived on GitHub with sensitive information blacked out. A final cost report will be created that accounts for all project spending and this report will also be archived on GitHub.

### Final Project Performance Report

Once the project is completed, a final project performance report will be created. The purpose of this report is to summarize the project’s scope management, schedule performance, cost performance, quality achievements, and review the risk containment performance. Any reasoning behind cost or schedule variance will be analyzed and explained in this report.