KGCOE MSD Detailed Design Review Agenda
P11553: ProMetal Powder Spreading System

Meeting Purpose:

1. Catch mistakes and improve design
2. Verify readiness to spend money and build prototype

Materials to be Reviewed:

1. Brief Project Overview
2. Customer Needs – Updated
3. Engineering Specifications – Updated
4. System Architecture (subsystems)
    a. Chassis
    b. Powder Platform
    c. Spreader Head Designs
    d. Motors/Controller/Electronics
    e. Binder Application
5. Feasibility Analysis (ANSIS?)
6. Bill of Materials
7. Preliminary Test Plan
8. Work Breakdown
9. Risk Assessment – Updated
10. Updated Project Plan

Meeting Date: Friday February 11th

Meeting Location: 09-3119

Meeting Time: 3:00-5:00

Meeting Timeline		
Start time	**Topic of Review**	**Required Attendees**
3:00	Brief Project Overview	Dr. Cormier, Prof. Wellin
3:05	Customer Needs – Updated	Dr. Cormier, Prof. Wellin
3:10	Engineering Specifications – Updated	Dr. Cormier, Prof. Wellin
3:20	System Architecture (subsystems)	Dr. Cormier, Prof. Wellin
4:00	Feasibility Analysis	Dr. Cormier, Prof. Wellin
4:10	Bill of Materials	Dr. Cormier, Prof. Wellin
4:20	Preliminary Test Plan	Dr. Cormier, Prof. Wellin
4:30	Risk Assessment – Updated	Dr. Cormier, Prof. Wellin
4:40	Work Breakdown	Dr. Cormier
4:45	Updated Project Plan	Dr. Cormier
4:52	Questions, Comments, Concerns	Dr. Cormier

Project Information

Project #: 11553

Project Name: ProMetal Powder Spreading System

Project Track: Printing Systems

Company: ProMetal

Start Term: 20102

Team Guide: Dennis Cormier

Project Sponsor: Denis Cormier – Brinkman Endowment

Project Background

3D Printing (3DP) is a process developed by MIT in which a thin layer of powder is spread across a platform followed by selective inkjet printing of a liquid binder. Powder is spread sequentially across each previous layer. The finished part may then be handled and placed into a furnace for sintering, if using metal powder.

Problem Statement

Variations in the density of powder occur in this 3DP process. Variations in the density of powder may lead to varying material strength, density, and dimensions following the sintering process.

Project Scope

- Create chassis with modular spreading carriage
- Create various powder spreading heads
- Test various powder spreading heads

Deliverables

- Detailed design models for system and subsystems
- Functioning powder spreading sub-system along with operating details and an interface
- Accurate and repeatable testing procedures along with results of comparisons between different spreading methods

Expected Project Benefits

The project will realize beneficial powder spreading techniques that improve powder density variation and decrease variations after the sintering process. This will improve tolerances and manufacturing costs of metal products. A test bed platform will be available for future Senior Design teams to analyze powder spreading techniques as well.

Core Team Members

- Carlos Bu – Test Plan/Documentation
- Matthew Rebisz – Binder Type & Application
- Chris Rukas – Motion Control
- Nick Shields – Spreading Platform/Carriage
- Jay Wheaton – Spreading Heads/Carriage

Customer Needs - Updated

Customer Need #	Importance	Description	Comments/Status
1.0		**Automated Spreading Head System**	
1.1	9	System Has Motion Control	
1.2	9	Has Fine Z Axis Control	
1.3	1	Capable of Printing Large Area	
1.4	3	Maintains a Level Platform	
1.5	9	Spreader Head Can Be Swapped Easily	
1.6	1	System Collects Excess Powder	
1.7	3	High Reliability	
1.8	1	Easy to Maintain	
1.9	3	System is Easy to Control	
1.10	3	Spreads Layers as Fast as ProMetal Product	
2.0		**Spreading Head Designs**	
2.1	9	Spreads with Even Density	
2.2	3	Spreads with High Density	
2.3	9	Spreads a Smooth Surface	
2.4	9	Spreads without Disturbing Lower Layer	
2.5	3	Spreads Multiple Powder Types	
3.0		**Powder Selection**	
3.1	3	System Spreads ProMetal Powder	

Customer Needs - Updated

Customer Need #	Importance	Description	Comments/Status
4.0		**Metal Binder**	
4.1	9	Printed Sample Must Withstand Light Manual Handling	
4.2	9	Binder is Applied in a Consistent Layer	
4.3	9	Binder is Applied in a Thin Layer	
5.0		**Ethical Considerations**	
5.1	9	Do Not Share Proprietary Techniques	Includes binding, spreading, sintering
5.2	3	Environmentally Safe Binder and Powder	
5.3	9	Full Disclosure of Findings	
6.0		**Documentation**	
6.1	3	CAD Drawings	
6.2	9	Test Measurements	layer height
6.3	9	Comparison of Binding and Spreading Methods	based on prototype

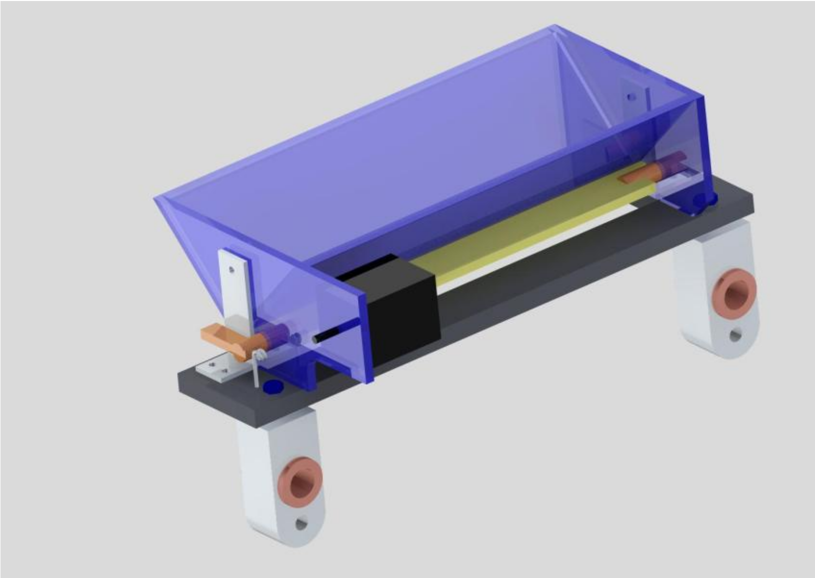
Engineering Specifications - Updated

Specification (description)	Unit of Measure	Marginal Value	Ideal Value	Comments/Status
Spreader Head				
Speed	cm/s	> 1	> 2	ProMetal is 75 seconds per Layer
Powder Density Variation - In-Plane	%	< 5	< 0.1	ProMetal Variation Unknown
Powder Density Variation - Transverse	%	< 5	< 0.1	ProMetal Variation Unknown
Powder Density %	%	> 65	> 80	Percentage of Parent Metal Density
Surface Roughness Average	µm	< 3	0.5	Use Profilometer to Measure
Platform				
Z Axis Resolution	µm	< 500	< 280	
Platform Parallelism	µm	< 78	< 10	Marginal Value Represents .01 deg. across 450 mm
Platform Size	mm	450 x 305 x 150	1500 x 750 x 700	LxWxH (18 x 12 x 6 in) Ideal value is ProMetal size
Powder				
Must Spread ProMetal Powder	Y/N	Yes	Yes	
Binder				Waiting to Hear from ProMetal
Viscosity	cP	40	20	

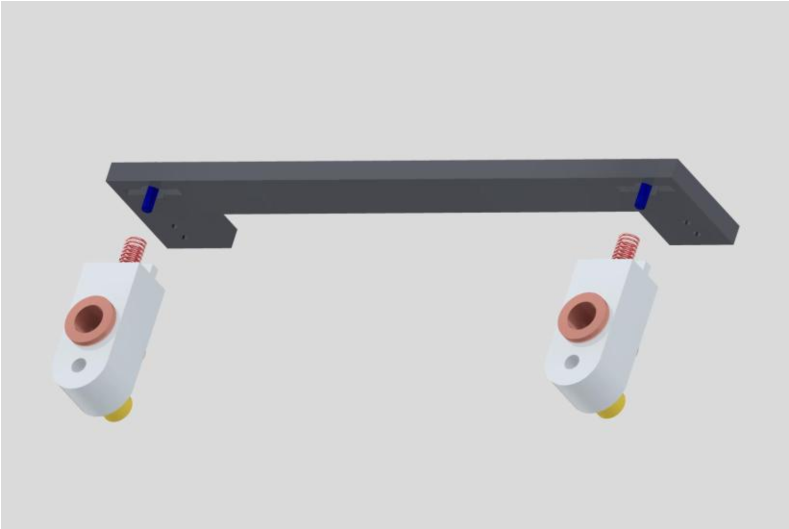
Chassis

- **System Construction Overview**
- **Key Subsystem Detail**
  - **Lifting Assembly**
  - **Spreader Carriage Rails**
- **Feasibility Analysis Results**
  - **Build Platform Deformation**
  - **Box Wall Deformation**
  - **Ball Screw Jack Loading Scenarios**
  - **Spreader Rail Jack Loading Scenarios**
- **Going Forward**
  - **Finish Machining Drawing Package**
  - **Order External Supplier Parts**
  - **Order Bulk Materials**
- **Potential Issues**
  - **Ball Screw Jack**
  - **Assembly/ Welding**

Spreader Head Designs

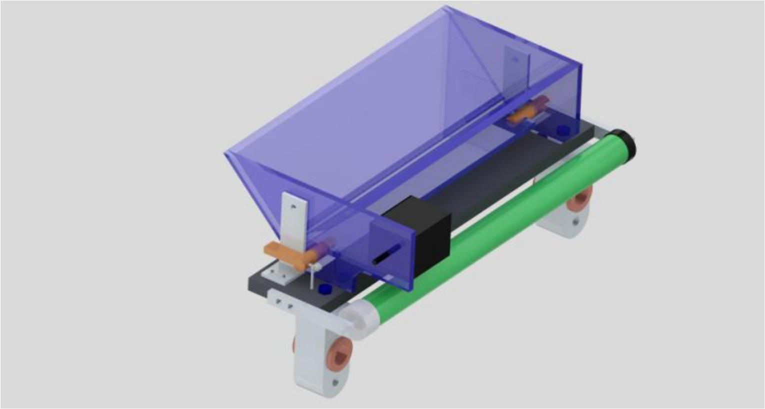


This is the spreader head without attachments

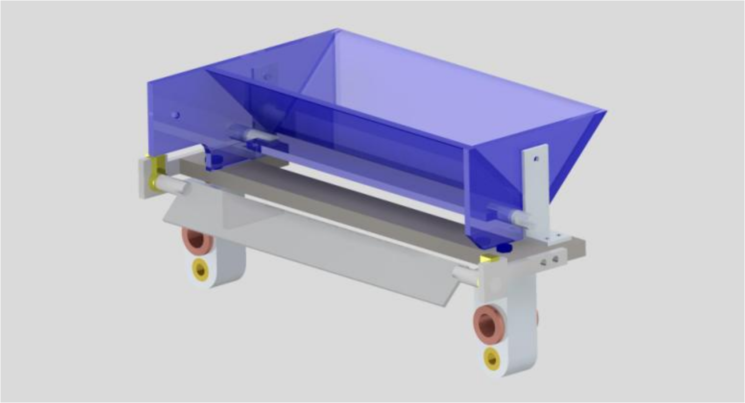


Fine adjustment is available using compression springs and bolts

Spreader Head Designs



Roller Attached



Blade Attached

Functions:

- A 1/8 inch gap at the bottom of the trough is covered by a spring loaded flapper. The flapper is held shut until a motor pushes the lever down, lowering the flapper and releasing powder.
- The roller is powered by a motor located above. The motor provides counter-rotation in respect to the moving direction when spreading powder. The roller being considered is from a used printer.
- The blade is attached using two slotted cylinders that are held by a bracket on each side. This cylinder is locked in place using a clamping device.

Total Cost: ~$175

Questions/Concerns:

- Best way to power the lever that allows powder to flow (servo, stepper, solenoid, etc.)?
  It must be left on for several seconds at a time.
- Acrylic or polycarbonate for the box?
- Connection of blade and flapper using the slotted cylinders
- Connecting the counter-rotating roller to the motor. Pulley/belt, friction wheel, gears?
- The torsion spring that holds the flapper closed. Is there a better way or better torsion spring?

Motors/Controller/Electronics

Motion Control: Arduino Mega 2560 – Provides expandability for future SD Teams

Motor Power Supply: Anaheim Automation PSAM 24V 2.7A – Suggested by Motor Selection

Z Axis Motion: Anaheim Automation 17MD302, 50 oz-in Peak (Calculations require 34 oz-in motor)

X Axis Motion: Anaheim Automation 17MD301, 31 oz-in Peak

Rotating Roller Motion: Anaheim Automation 17MD301, 31 oz-in Peak – or DC Motor?

- All above motors provide 1.8 Degree Step Angle, have integrated drivers
- Z Axis: 200 Steps per 1 Rotation, 5000 steps per inch, Resolution of about 6 microns

Trough Door Opening/Closing:

- Solenoid: $20, Problems with continuous duty?
- Servomotor: HS325HB $13
- Step Motor: Anaheim Automation 17MD301 – Expensive, $70

Rotating Roller Concern:

- Small DC Motor or Anaheim Step Motor?
  - DC Motor – Cheap
  - Step Motor – Fine Control, can roll with powder on return pass

Note: Actionjac 0.5BSJ requires 0.0105 inch*lbs to raise 1 lb, or 34 oz-in for 200 lbs

Binder Application

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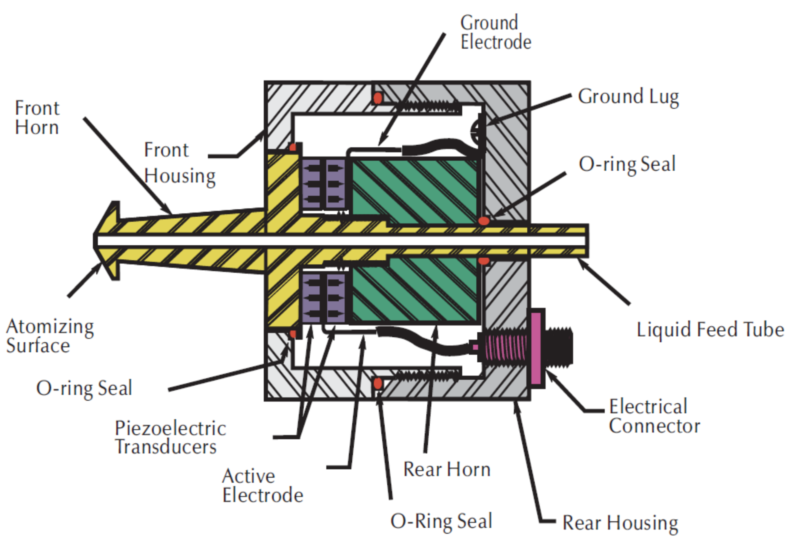
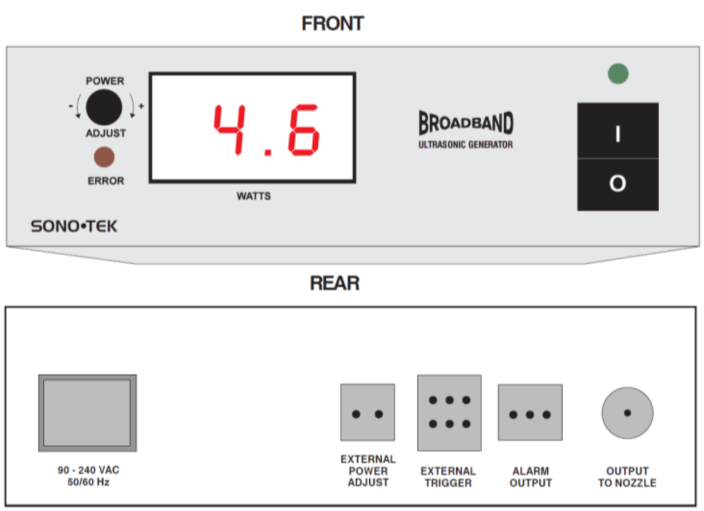




Major parts in this System and their function:

- Free-standing 100-240 VAC Broadband Ultrasonic Generator
  - Provides power to UA
  - Turned on/off by external trigger input on back that is connect to Arduino
- Ultrasonic Atomizing Nozzle
  - Atomizes binder and sprays onto metal powder
  - Turned on/off by generator
- Syringe-lead screw motor
  - Turns lead screw that is connected to plunger
  - Turned on/off by Arduino
- Syringe
  - Supplies UA with Binder
- Lead Screw
  - Controlled by motor
  - Pushes down plunger
- Syringe Plunger
  - Pushes liquid binder into UA

Binder Application

Using the Ultrasonic Atomizer to Bind 1 Layer:

1. Turn on the UA generator
2. Start x-axis movement motor
3. Turn on syringe-lead screw motor
4. When it get close to the end, turn off syringe-lead screw motor
5. Stop x-axis movement motor
6. Turn off the UA generator

Binder Choices:

1. ProMetal's Binder
    a. -Waiting to hear from company about donating some
2. Nicrobraz 320
    a. +Have a small stock on hand
    b. -Relatively expensive
    c. +Works well as a metal binder
3. Ethanol-Water Solution (16-18% ethanol by volume)
    a. +Inexpensive
    b. –Has not been tested with ProMetal powder

Factors Affecting Binding:

1. Height above spray surface (in testing, at .7 in the spray was ~2 in wide on the surface)
2. Syringe-lead screw motor speed (affects spray velocity)
3. Generator power (goes from 0-15 watts, in testing we went from 2 to 5.5 to atomize)
4. X-axis Speed (mostly based on metal powder spreading technique and trough)
5. Liquid Viscosity (higher viscosity = more watts)
6. **Binder saturation on metal powder (most important)**

Feasibility Analysis

Design Criteria

- Hand calculations
- Models in ANSYS

Component Interaction

- System model with accurate dimensions in Pro-Engineer

Calculations for motor designs

- Z-Axis using ActionJac information
- Trough Door - Pressure on door to calculate torque
- X-Axis, rolling resistance (should be a minimal torque)

Bill of Materials

System	Part	Description	Build Qty Needed	Material	Vendor	Part #	Total
Chassis							
THRUST CARRIER	Thrust Support	aluminum rod, drilled for .25 clr	4	AL		HAVE	-
THRUST CARRIER	Thrust Spacer	aluminum rod, drilled for .25 clr	4	AL		HAVE	-
THRUST CARRIER	Thrust Plate	steel support plate	2	Steel		HAVE	-
THRUST CARRIER	Thrust Bearing	for 5/8" shaft	2		McMa	5909K32	5.52
THRUST CARRIER	Thrust Washer	for bearing	4		McMa	5909K45	4
THRUST CARRIER	Shaft Collar	for 1/2" shaft	2		McMa	6436K14	6.6
THRUST CARRIER	Shoulder Bolt	0.25"x 3.25" Shoulder	4		Lowes		?
THRUST CARRIER	Washer	for .25" shoulder bolt, min thk 1/16"	4		Lowes		?
LIFT	ActionJac Ball Jack		2		Wellin		0
LIFT	Ball Nut	for ActionJac	2		Nook Industries		25
LIFT	Ball Screw Support	welded to side walls	2	Steel		BULK	0
LIFT	Radial Bearing	for leadscrew top support	2		McMa	6383K34	12.28
LIFT	Shaft Coupling	for .375" shaft, size B	4		McMa	6408K11	9.32
LIFT	Coupling Spider	size B	2		McMa	6408K84	3.04
LIFT	Driveshaft	.375" shaft	1			HAVE	-
LIFT	Motor Bracket	1/8" sheet	1	Steel		HAVE	-
LIFT	Motor Bracket Brace	1/8" sheet	2	Steel		HAVE	-
LIFT	Motor to Ball Jack Coupler	custom machine	1	AL		BULK	0
LIFT	Key	OPTIONAL PART 1/8" x 0.5" Key	6				0

Binder Application

System	Part	Description	Build Qty Needed	Material	Vendor	Part #	Total
GUIDE RAILS	T Rails		4		Wellin	HAVE	-
GUIDE RAILS	T Rail Bearing	PTFE Linear Closed Bearing, 0.75ID 1.25OD 1.635L	4		McMa	2570K13	22.76
GUIDE RAILS	External Retaining Ring	for Linear Bearings	4		McMa	9968K26	2.36
GUIDE RAILS	Bearing Housing	housing for linear bearings	4	AL		BULK	0
SPREADER RAILS	Rail Support	machined block to hold spreader rails	4	AL		HAVE	-
SPREADER RAILS	Rail	0.75" Rail from t-rails	2		Wellin	HAVE	-
SPREADER RAILS	Flanged Radial Bearing	0.25 ID for leadscrew support, 1/16 Flange Thk	4		McMa	6383K213	8.61
SPREADER RAILS	Flanged Radial Bearing	.1875 ID .04” Flange Thk	4		Fab@Home	HAVE	-
SPREADER RAILS	Wave Spring Washer	25 to a pack	4		McMa	9714K24	24.18
SPREADER RAILS	Timing Belt Gear	Reuse fab@home gears	2		Fab@Home	HAVE	-
SPREADER RAILS	Timing Belt	.200" (XL) Pitch, 153 Teeth, 3/8" Wide, Neoprene Belt	1		SDP/SI	A 6R 3153037	8.19
SPREADER RAILS	Motor Drive Gear	5.08mm(XL) Pitch, 13 Teeth, 9.5mm belt width	1		SDP/SI	A 6Z 3M13DF09505	6.79
SPREADER RAILS	Leadscrew Drive Gear	Reuse fab@home gears	1		Fab@Home	HAVE	-
SPREADER RAILS	Drive Belt	5.08 mm (XL) Pitch, 37 Teeth, 9.5 mm Wide, Neoprene Belt	1		SDP/SI	A 6R 3M037095	5.49
SPREADER RAILS	Leadscrew	3/8"-12 X 36" long	2		McMa	99030A001	28.64
SPREADER RAILS	Motor Bracket	1/8" sheet	1			HAVE	-
SPREADER RAILS	Bracket Brace	1/8" sheet	2			HAVE	-

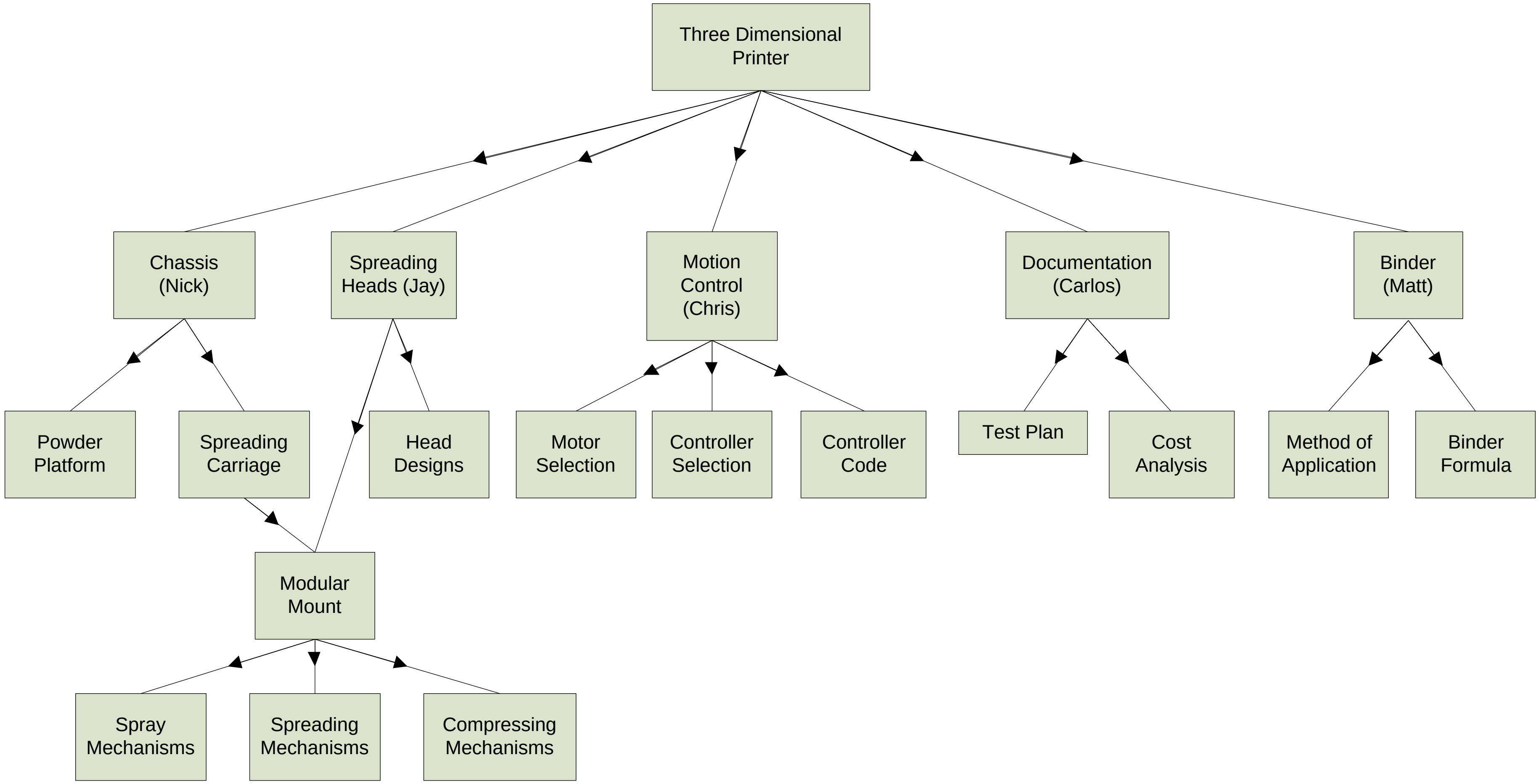
Binder Application

System	Part	Description	Build Qty Needed	Material	Vendor	Part #	Total
CARRIAGE	Leadscrew Nut	for 3/8"-12 screw	2		McMa	95365A111	39.68
CARRIAGE	Linear Bearing	PTFE Linear Closed Bearing	2		McMa	2570K13	11.38
CARRIAGE	Retaining Ring	for Linear Bearings	8		McMa	9968K26	2.36
CARRIAGE	Carriage Block	machined aluminum block	2			HAVE	-
BASEPLATE	Base	large plate, actual mat'l doesn't matter	1			BULK	0
BASEPLATE	Supports	Steel or Al ok, steel rods in shop	6			HAVE	-
BASEPLATE	Support Plates	Have scrap for steel or al construction	6			HAVE	-
BASEPLATE	Build Platform	mat'l must be weldable to ribs	1	Steel		BULK	0
BASEPLATE	Short Rib	mat'l must be weldable to build platform	2	Steel		BULK	0
BASEPLATE	Long Rib	mat'l must be weldable to build platform	1	Steel		BULK	0
BUILD BOX	End Wall		2	Steel		HAVE	-
BUILD BOX	Side Wall		2	Steel		HAVE	-
Spreader Head							
Hopper	Container, Flap	-	1	Acrylic	McMa	8560K356	32.76
Hopper	Flap Spring	2 inch lbs	1	302 Stainless	McMa	9287K141	5.5
Hopper	L-Bracket	-	2	Steel	McMa	1556A39	3.66
Hopper	Brass Bearing	-	2	Brass	?	-	5
Hopper	Clamp	Holds flapper	4	Steel	McMa	8930K222	5.92
				A			0
Roller	Toner Roller		1	Aluminum	Scrap	-	0
Roller	Bracket		2	Steel	Scrap	-	0
							0
Blade	Blade	Can use from bulk?	1	Steel	McMa	8131K351	13.14
Blade	Holder Clamps	Estimated Cost	2	-	Scrap	-	20
Blade	Bracket		2	Steel	Scrap		0
							0
Base	Connector Bar		1	4140 Steel	McMa	8892K287	57.61
Base	Compression	59.5 in/lbs	2		McMa	9657K255	9.47

Binder Application

System	Part	Description	Build Qty Needed	Material	Vendor	Part #	Total
	Spring						
							0
Misc.	Bolts	Estimated Cost	~80				~40
Motion Control							
Microcontroller	Arduino Mega 2560		1		RobotShop	RB-Ard-19	63.99
Power Supply	Power for Z Axis Motor	24 Volt 2.7Amp Power Supply	1		Anaheim Automation	PSAM24V2.7A	100
Motion	Chassis Motor (Z)	Stepper Motor with built in driver	1		Anaheim Automation	17MD202S-00	81.3
Motion	Carriage Motor (X)	Step Motor with Built In Driver	1		Anaheim Automation	17MD102S-00	70.5
Motion	Trough Door Motion	Servo Motor, Solenoid, Step Motor?	1		Al's Hobby Shop	HS325BB	12.99
Motion	Relay (If Solenoid)	Solid State Relay, Power Control for Solenoid and Sifting Screw M	2		McMasterCarr		0
Motion	Sifting Screw Motor	DC Motor?	1		Jameco	176050	22.95
Motion	Rotating Roller Motor	Step Motor or DC Motor	1		Anaheim Automation	17MD102S-00	70.5

Work Breakdown



Risk Assessment - Updated

Risk Item	ID	Effect	Cause	Likelihood	Severity	Importance	Action to Minimize Risk	Owner
Cannot get ProMetal binder	**2**	Test results cannot be directly related to ProMetal process	ProMetal wont provide binder or not given enough leadtime to provide it	2	2	4	Research alternative binders compatible with metal powders	Matt
Project goes over budget	**4**	Cannot complete project	Parts are too expensive	1	2	2	Research alternate suppliers for parts	Team
	5	Cannot complete project	Design includes too many high price items	1	2	2	Utilize alternative designs using cheaper parts	Team
Ordered parts do not arrive in time	**6**	Design cannot be assembled	Wrong part ordered	1	2	2	Maintain contact with suppliers / order parts as soon as need is recognized	Team
	7	Design cannot be assembled	Supplier send the wrong part	2	2	4	Maintain contact with suppliers / order parts as soon as need is recognized	Team
	8	Design cannot be assembled	Late ordering, unreliable supplier	2	2	4	Maintain contact with suppliers / order parts as soon as need is recognized	Team
	9	Design cannot be assembled	Delayed for weather	2	2	4	Maintain contact with suppliers / order parts as soon as need is recognized	Team
Lifting mechanism binds	**13**	Cannot create multiple layers of powder	Lifting screws not synchonized properly	2	3	6	Design lifting screws with timing belts to ensure synchronous motion	Nick & Chris
Motor is too weak to move build platform	**14**	Design is not completed, failure to satisfy customer needs	Insufficient research into available Fab@Home parts, failure to order new parts if needed	1	3	3	Determine compatibility of Fab@Home parts, order larger motor if needed	Nick & Chris

Risk Assessment - Updated

Risk Item	ID	Effect	Cause	Likelihood	Severity	Importance	Action to Minimize Risk	Owner
Build platform step is larger than marginal value	**17**	System fails to satisfy customer needs	Insufficient research into available Fab@Home parts, failure to order new parts if needed	1	3	3	Determine compatibility of Fab@Home parts, order new leadscrew if needed	Chris
Powder density is not even throughout test specimen	**19**	Failure to satisfy customer needs	System is poorly designed	2	2	4	Build early, allow room for error	Team
	20	Failure to satisfy customer needs	System is not an improvement to ProMetals'	2	2	4	Follow through with risk assessment, early testing	Team
	21	Failure to satisfy customer needs	Testing procedure is not accurate	2	2	4	Accurate testing procedure, validate results	Carlos
System cannot maintain accurate spreading depth	**24**	Cannot properly create test specimens	Deflection in spreader supports	1	2	2	Use FEA to analyze spreader supports and design to avoid large deflection	Nick
	25	Cannot properly create test specimens	Deflection in build platform and supports	1	2	2	Use FEA to analyze build platform and design to avoid large deflection	Nick
Surface is too rough for printing	**26**	System fails to satisfy customer needs	Poor choice of spreading/smoothing method	1	3	3	Test smoothing methods before choosing final concept	Jay
Binder is too weak to hold powder together	**28**	Difficult/impossible to evaluate effectiveness of design	Cannot get ProMetal binder, alternative binder sources not researched	1	3	3	Research and test alternative binders to ensure metal powder compatibility	Matt
Cannot attach Ultrasonic Atomizer to powder trough	**32**	Cannot accurately spray binder, poor testing possibilities	Poor design of trough	1	2	2	Use correct material, lot of time spent on integrating binding application with rest of system	Matt

Risk Assessment - Updated

UA moves when being used	**33**	Cannot accurately spray binder, poor testing possibilities	Not attached correctly, poor design of trough	1	2	2	Use correct material, lot of time spent on integrating binding application with rest of system	Matt
Cannot Accurately control binder spray	**34**	Poor testing possibilities, part is not built correctly	Viscosity of liquid, not wired correctly, UA not working	3	2	6	Testing and learning how to control UA	Matt
Trough door doesn't open	**35**	Powder can not be spread	Spring(s) is too stiff or motor is too weak	2	2	4	Size motor and spring as close as possible, leaving some room for adjustability	Jay
Trough door won't stay closed	**36**	Powder is wasted; trough is rendered useless	Spring(s) is too weak	2	2	4	Size spring as close as possible, leaving some room for adjustability	Jay
Spreader head is too heavy (large deflection)	**37**	Trouble controlling density variation	Poor material selection or too much powder in hopper	2	2	4	Choose lightweight materials such as acrylic vs. steel	Jay
Powder gets clogged in hopper	**38**	Uneven or no powder distribution	Compacted powder in hopper before exit	1	2	2	Don't overload the hopper	Jay
Flapper doesn't open consistently	**39**	Trough doesn't spread powder consistently	Brass bearings aren't properly aligned	1	2	2	Keep components level and aligned properly when assembling/manufacturing	Jay

Updated Project Plan

Future Project Schedule Outline	
Winter	
Week 10	Finalize designs and BOM
Week 11	Order most components
Spring	
Week 1	Procure all components and begin manufacturing parts
Week 2	Begin assembly and continue manufacturing
Week 3	Finish assembling the system
Week 4	Troubleshoot and redesign
Week 5	Troubleshoot
Week 6	Test system with binder and make improvements
Week 7	Build small specimen with binder. Verify test methods against test plan
Week 8	Build actual specimens (baseline and improved)
Week 9	Analyze specimens
Week 10	Put report together with findings
Week 11	