ProMetal Powder Spreading Improvement

SYSTEM LEVEL DESIGN REVIEW
SENIOR DESIGN I

Project #:
P11553

Project Guide:
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PROBLEM STATEMENT

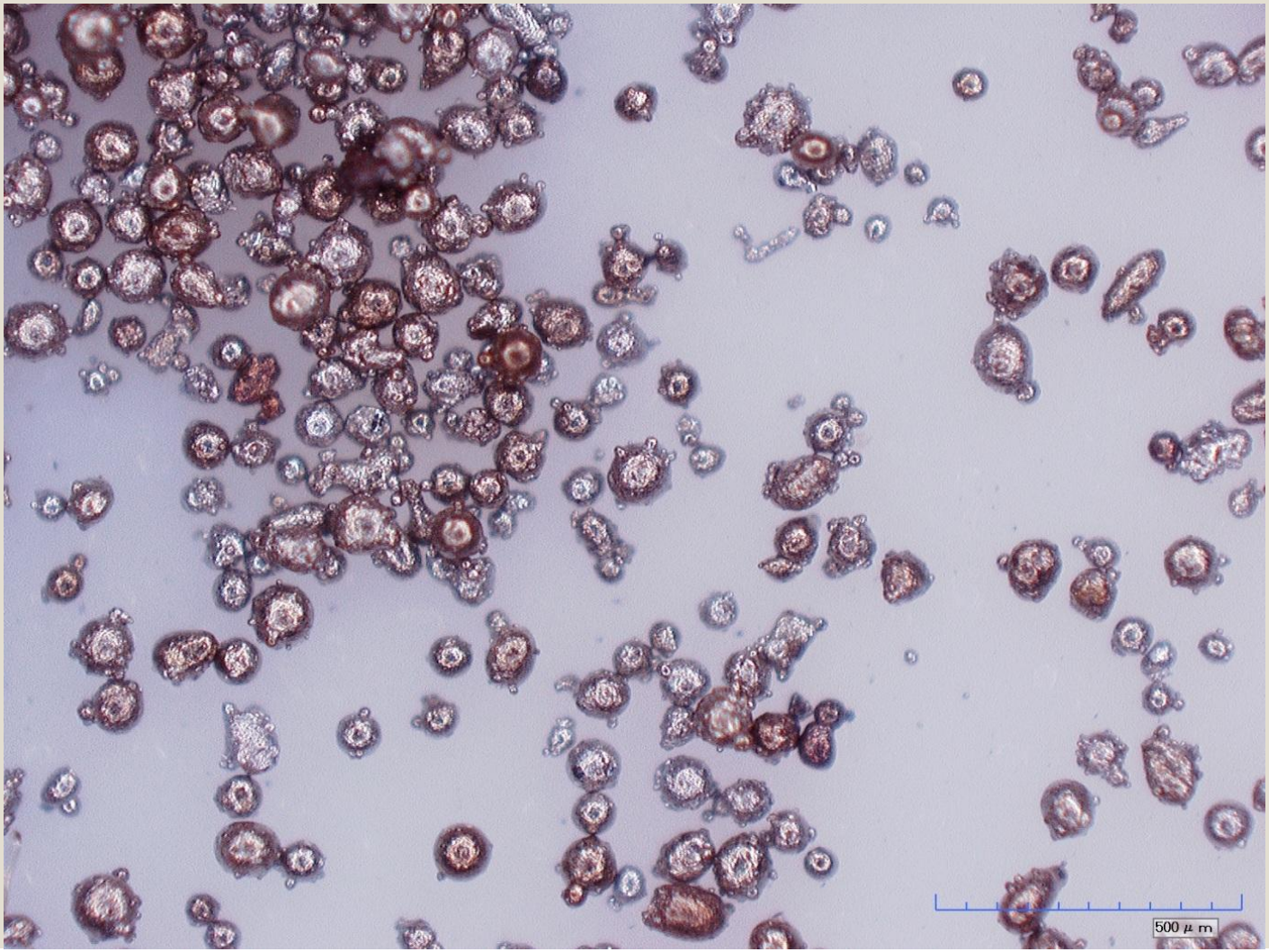
Variations in the density of powder occur in the 3DP process. This may lead to varying material strength, density, and dimensions following the sintering process.

PROJECT BACKGROUND

- ProMetal
  - Printing Process
  - Metal Powder
  - Binder
  - Licensed by MIT

http://www.exone.com/eng/technology/x1-prometal/equipment_prometal.html

METAL POWDER UNDER MICROSCOPE



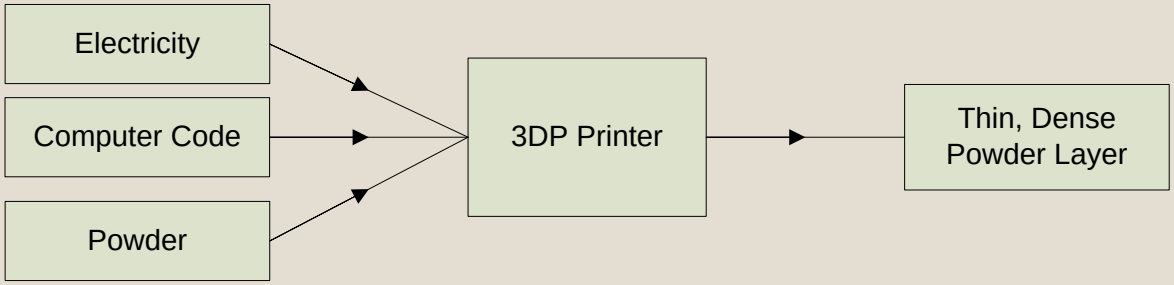
PROJECT SCOPE

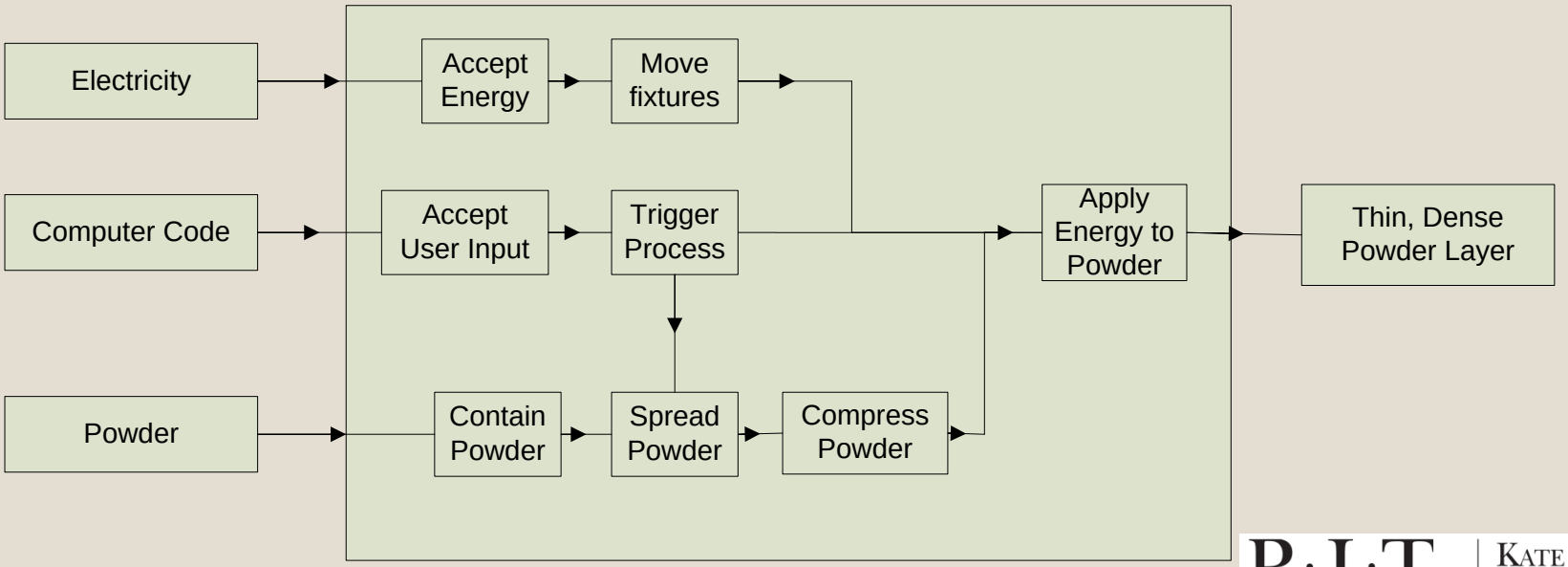
- Develop a modular chassis that moves horizontal and vertical
- Control movement via user input
- Implement a powder spreader
- Bind layers using simple techniques
- Use microscope to measure density variation

DELIVERABLES

- Modular powder spreading system
- Program interface
- Detailed design(s) drawings
- Compare different spreading methods
- Accurate and repeatable results

FUNCTIONAL BLACK BOX





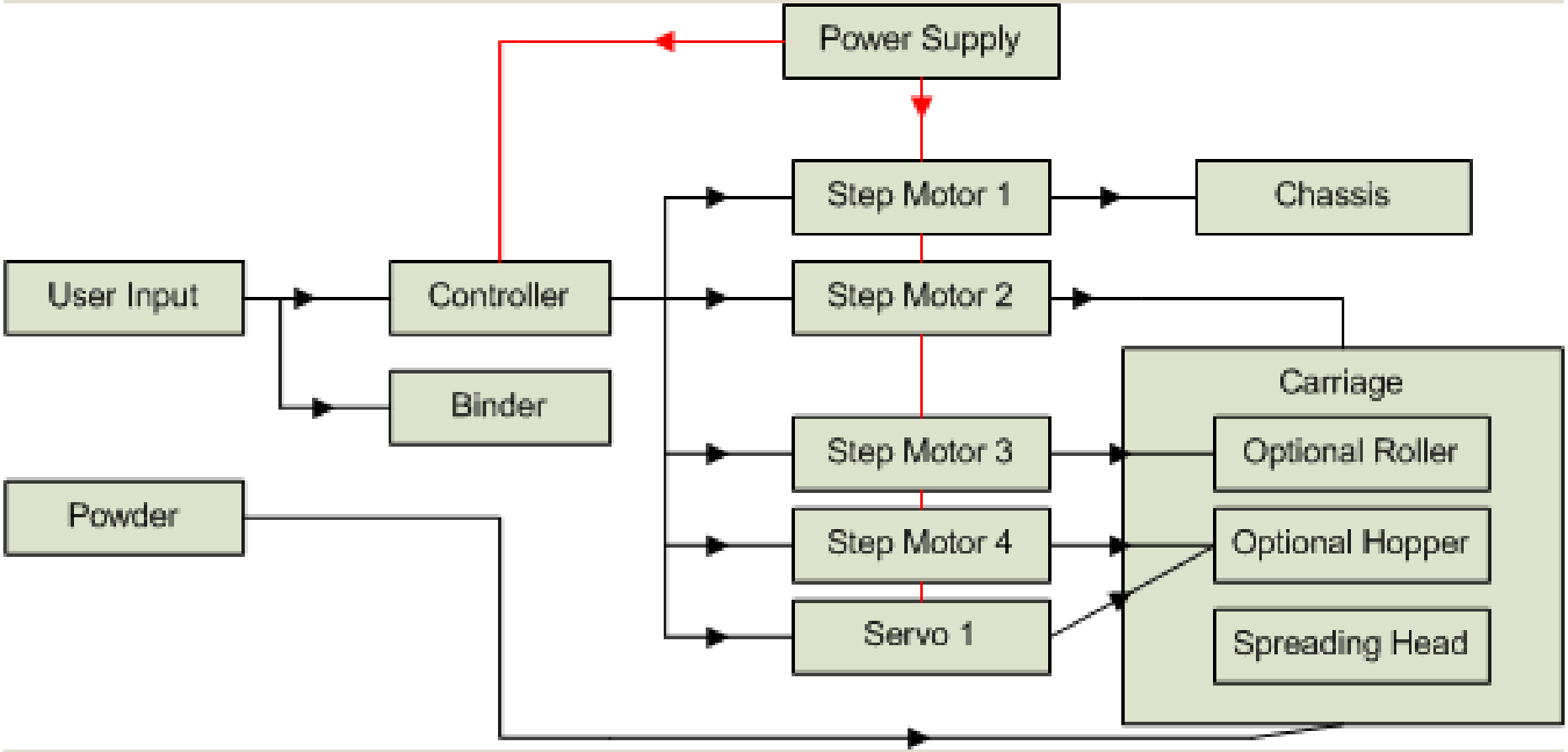
CUSTOMER NEEDS

- System Has Motion Control
- Fine Z-axis control
- Spreader head can be swapped easily
- Spreads with even density
- Spreads a smooth surface
- Comparison testing
- Cost under $1000

ENGINEERING SPECIFICATIONS

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	
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
Binder				
Viscosity	cP	40	20	

SIMPLE SYSTEM DIAGRAM



SPREADER CONCEPT BRAINSTORMING

Criteria	1	2	3	4	5	6	7	8
Distribute Powder	Dump Pile	Blade	Sift	Per Particle	Trough	w/ Lead Screw	w/Sifting Drum	Spray
Smooth Powder	Roller	Blade	Vibrate	Compressing Plate	Flapper			
Compress Powder	Roller	Pressurize	Vibrate	Compressing Plate	Reverse Blade			
Z axis Control	Worm Gear	Hydraulic	Belt	Chain	Shims			
Move Along XY Plane	Worm Gear	Hydraulic	Belt	Chain	Pivot	By Hand		
Apply Binder	Spray Bottle	Eye Dropper	Brush	Inkjet	Stamp			

CONCEPT SELECTION BASED ON CUSTOMER NEEDS CRITERIA

Criteria	Fast	Easy To Build	Cheap	Datum	Scalable	Accurate
Distribute Powder	Dump Pile	Dump Pile	Dump Pile	Blade	Trough	w/ Sifting Drum
Smooth Powder	Blade	Blade	Blade	Blade	Roller	Vibrate
Compress Powder	Roller	Reverse Blade	Reverse Blade	N/A	Roller	Compressing Plate
Z axis control	Belt	Shims	Worm Gear	Worm Gear	Chain	Worm Gear
Move along xy plane	By Hand	By hand	Worm Gear	Worm Gear	Chain	Worm Gear
Apply Binder	Spray Bottle	Spray Bottle	Spray Bottle	Inkjet	Inkjet	Inkjet

CONCEPT EVALUATION AND RANKING

Selection Criteria	Fast	Easy To Build	Cheap	Datum	Scalable	Accurate
Distribute Powder	-	-	-	DATUM	+	+
Smooth Powder	0	0	0		0	+
Compress Powder	+	+	+		+	+
Z axis control	-	-	0		-	0
Move along xy plane	-	-	0		-	0
Apply Binder	-	-	-		0	0
Sum +'s	1	1	1		2	3
Sum 0's	1	1	3		2	3
Sum -'s	4	4	2		2	0
Net Score	-3	-3	-1	0	0	3
Rank	**4**	**4**	**3**	**2**	**2**	**1**

CONCEPTS SELECTION SECOND ITERATION

Criteria	Option 1	Option 2	Option 3	Option 4
Distribute Powder	Trough	Trough w/ sifting drum	Blade	Trough
Smooth Powder	Roller	Vibrate	Blade	Tamper
Compress Powder	Roller	Roller	Roller	Tamper
Z axis control	Worm gear	Worm gear	Worm gear	Worm gear
Move along xy plane	Worm gear	Worm gear	Worm gear	Worm gear
Apply Binder	Spray bottle	Spray bottle	Spray bottle	Spray bottle

CHASSIS CONCEPT SELECTION

Criteria	1	2	3	4	5	6
Movement Method	Power Screw	Hydraulics	Pulleys	Lever	Rack & Pinion	Shims
Movement Power	Servo	Hand	DC Motor	Stepper Motor		
Control Mechanism	Microcontroller	PC	Pushbutton			
Material	Steel	Aluminum	Acrylic	Composites	Wood	
Movement Type	Spreader	Platform				
Spreader Attachment	Pins	Screws	Pressure Fit	Magnets	Latch	

CHASSIS CONCEPTS SELECTION BASED ON CRITERIA

Criteria	Speed	Cost	Accuracy	Datum
Movement Method	Lever	Lever	Power Screw	Power Screws
Movement Power	Hydraulics	DC Motor	Stepper Motors	Stepper Motors
Control Mechanism	Microcontroller	Pushbutton	PC	Microcontroller
Material	Wood	Wood	Steel	Steel
Movement Type	Platform	Platform	Spreader	Platform
Spreader Attachment	Magnets	Pins	Screws	N/A

CONCEPT EVALUATION AND RANKING

Criteria	Speed	Cost	Accuracy	Datum
Movement Method	-	-	0	0
Movement Power	+	0	0	0
Control Mechanism	0	-	0	0
Material	-	-	0	0
Movement Type	0	0	0	0
Modular Carriage for Spreader Attachment	+	+	+	0
Sum +'s	2	1	1	0
Sum 0's	2	2	5	6
Sum -'s	2	3	0	0
Net Score	0	-2	1	0
Rank	**2**	**3**	**1**	**2**

QFD RESULTS

- Largest impacts on requirements
  - Spreader Speed
  - Z-axis resolution
  - Platform Size
  - Powder Density Variation

RISK ASSESSMENT

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 won't 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 synchronized 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

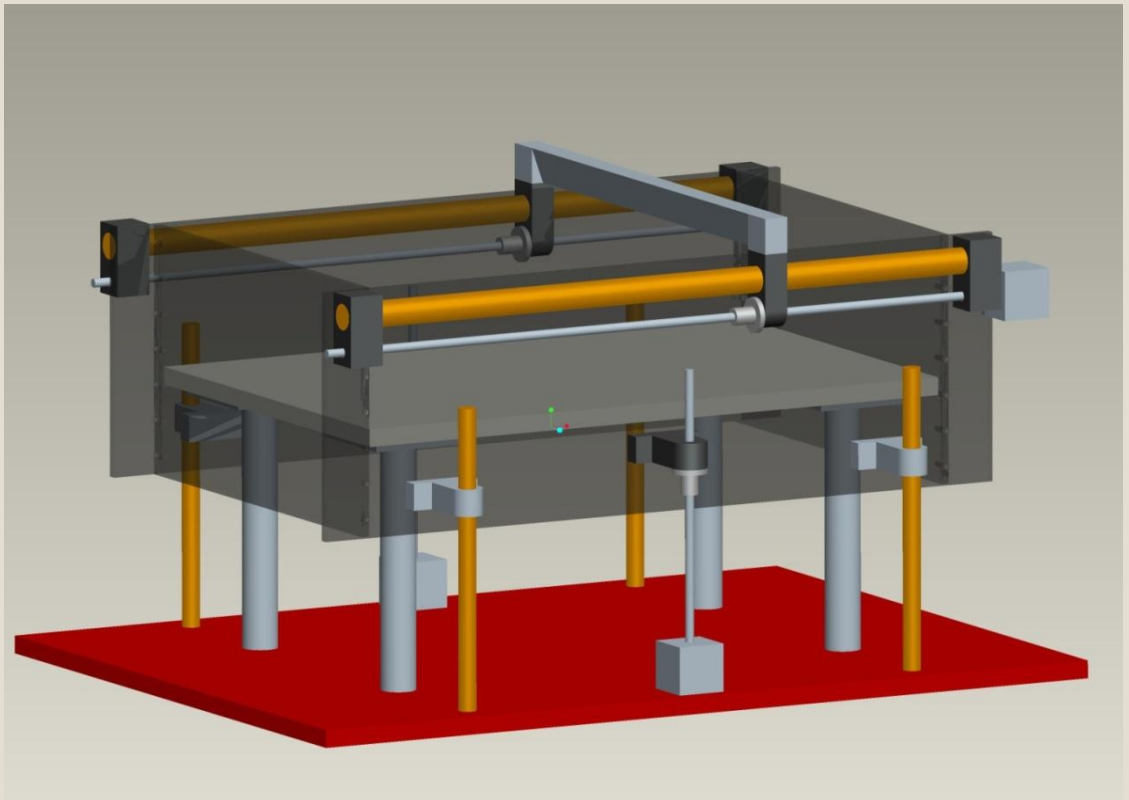
RISK ASSESSMENT (CONT.)

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

CHASSIS MOVEMENT: MOVING THE POWDER PLATFORM AND THE POWDER SPREADER ASSEMBLY

Factors to Consider:

- **Accuracy**
- **Weight**
- **Cost**



WEIGHT APPROXIMATIONS

- Assumption: It's easier/more accurate to control the step distance when there is less weight on the lead screw

- Powder Platform
  - Platform Volume (12in * 18in *1 in) = 216 in^3
  - Platform Density (steel) = .283 lb/in^3
    - Platform Weight (steel) = 61.13 lbs
  - Build Part Volume (assuming 6 inches high) = 1296 in^3
  - Build Part Density (ProMetal powder) = .21 lb/in^3
    - Build Part Weight = 271.41

Total Weight with Finished Product:
~330 lbs

- Powder Spreader Assembly
  - Frame Volume = 138.55 in^3
  - Frame Density (steel) = .283 lb/in^3
  - Guide Rails Volume = 30.2 in^3
  - Guide Rails Density (steel) = .283 lb/in^3
  - Motor Weight = Negligible
  - Spreader Head Weight w/Trough (est. max) = 100 lbs

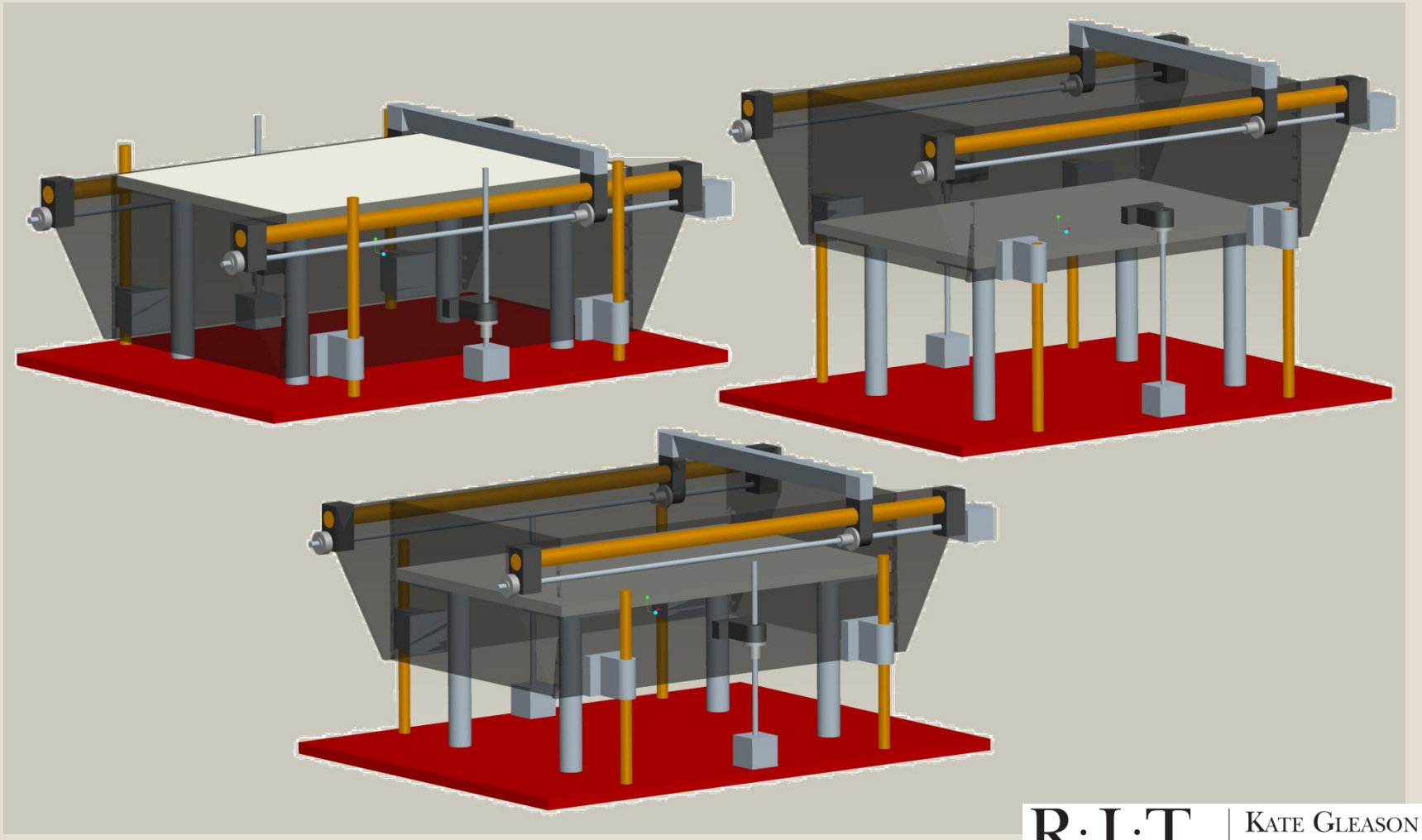
39.21 lbs

8.55 lbs

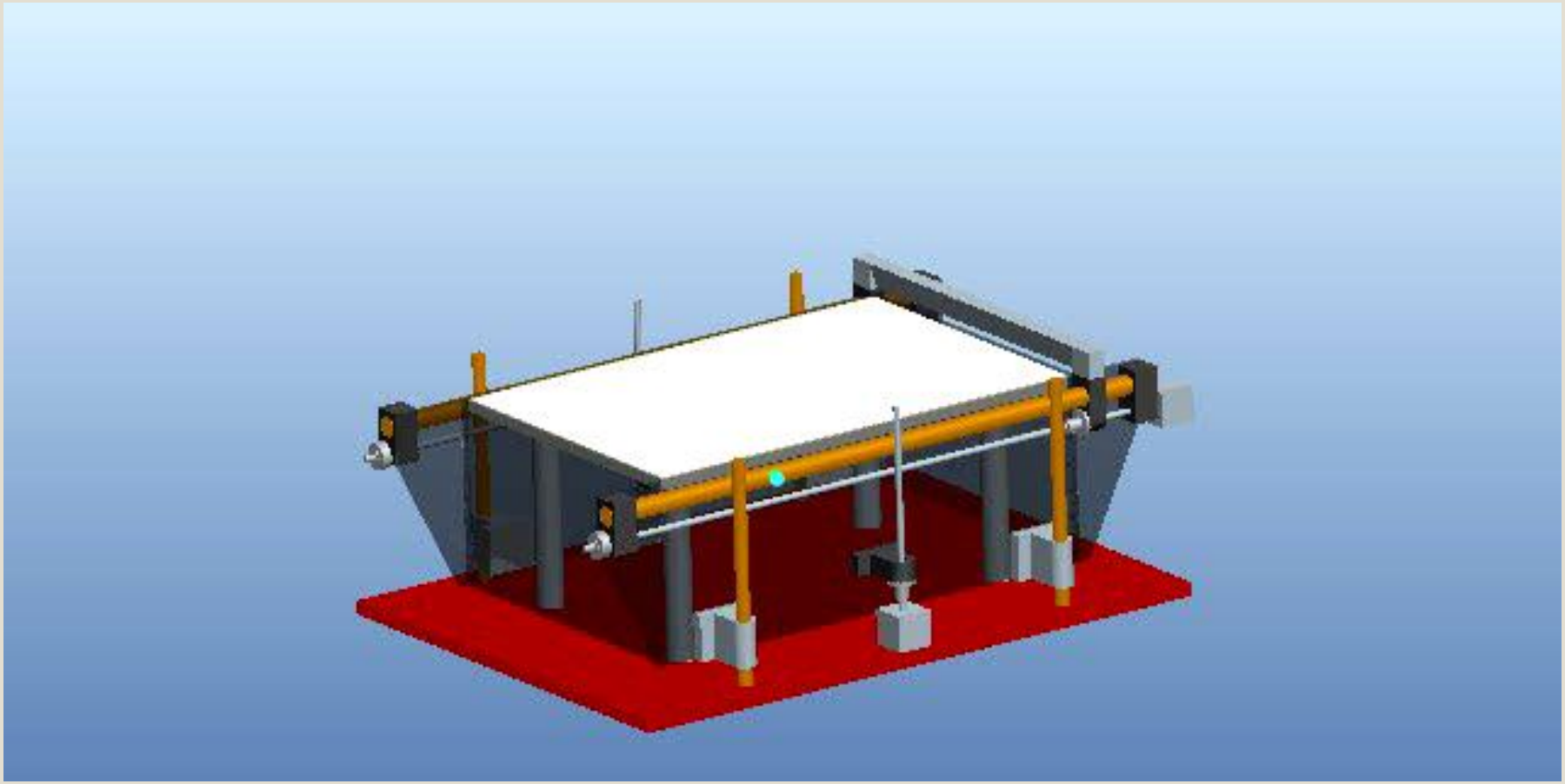
Total Weight with Finished Product:
~150 lbs

- + Powder Spreader Assembly

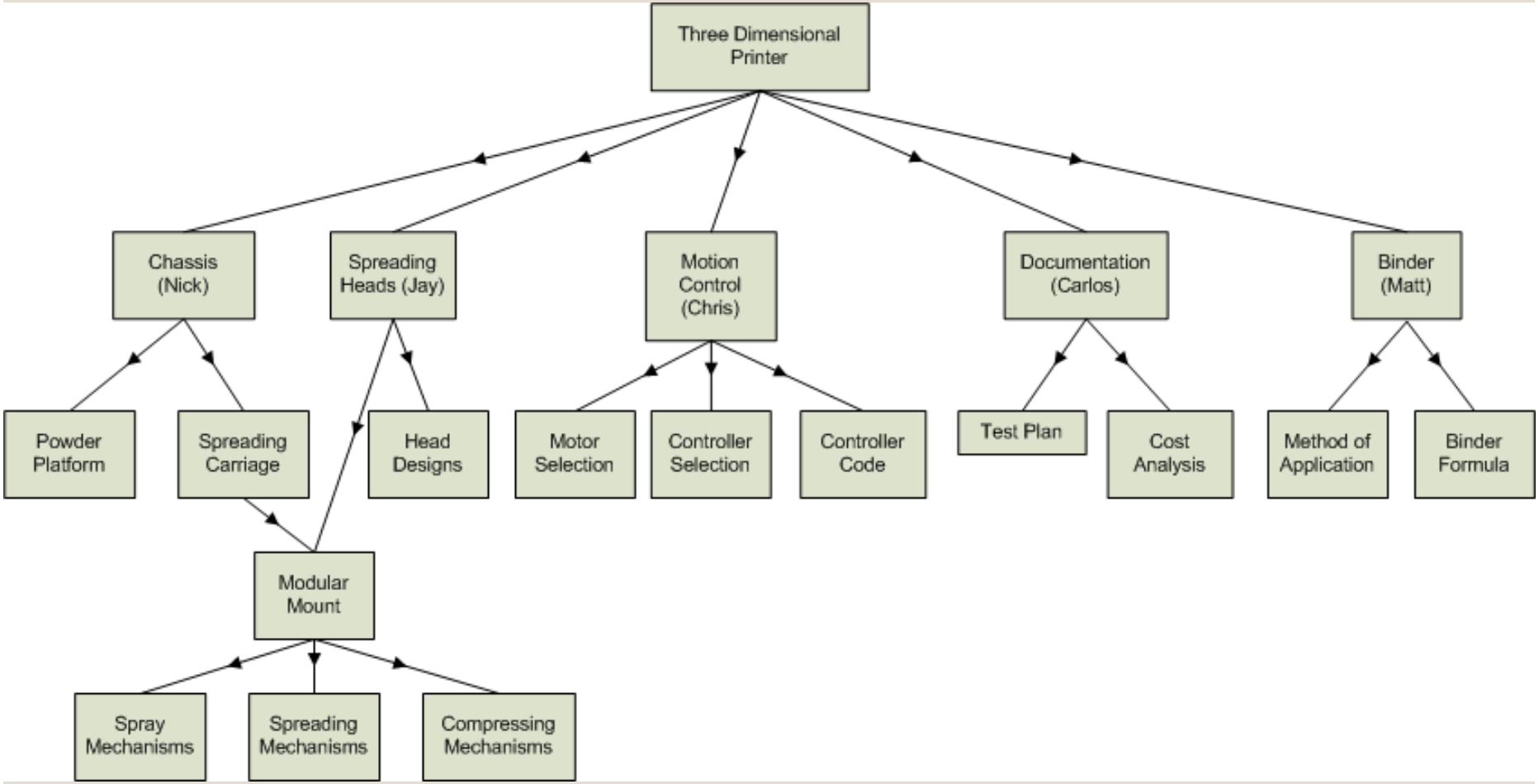
PRELIMINARY CONCEPT DESIGN



ANIMATED SPREADER



DETAILED DESIGN RESPONSIBILITIES



PROJECT COMPARISON

- Z Axis Accuracy
  - Center controlled lift
    - **+ Powder Spreader Assembly**
  - Edge controlled lift
    - **+ Powder Platform**
- Weight
  - Less energy to move lighter system
    - **+ Powder Spreader Assembly**
- Cost
  - Less energy, less expensive equipment

- ProMetal's System
  - Larger
  - Bigger Budget
  - Tested Design
  - More Experience
- Our System
  - Modular Head Attachment
  - Moving spreader assembly vs. moving platform
  - Creative Ideas