Mechanical Engineering Systems Capstone
Universal Proofloader

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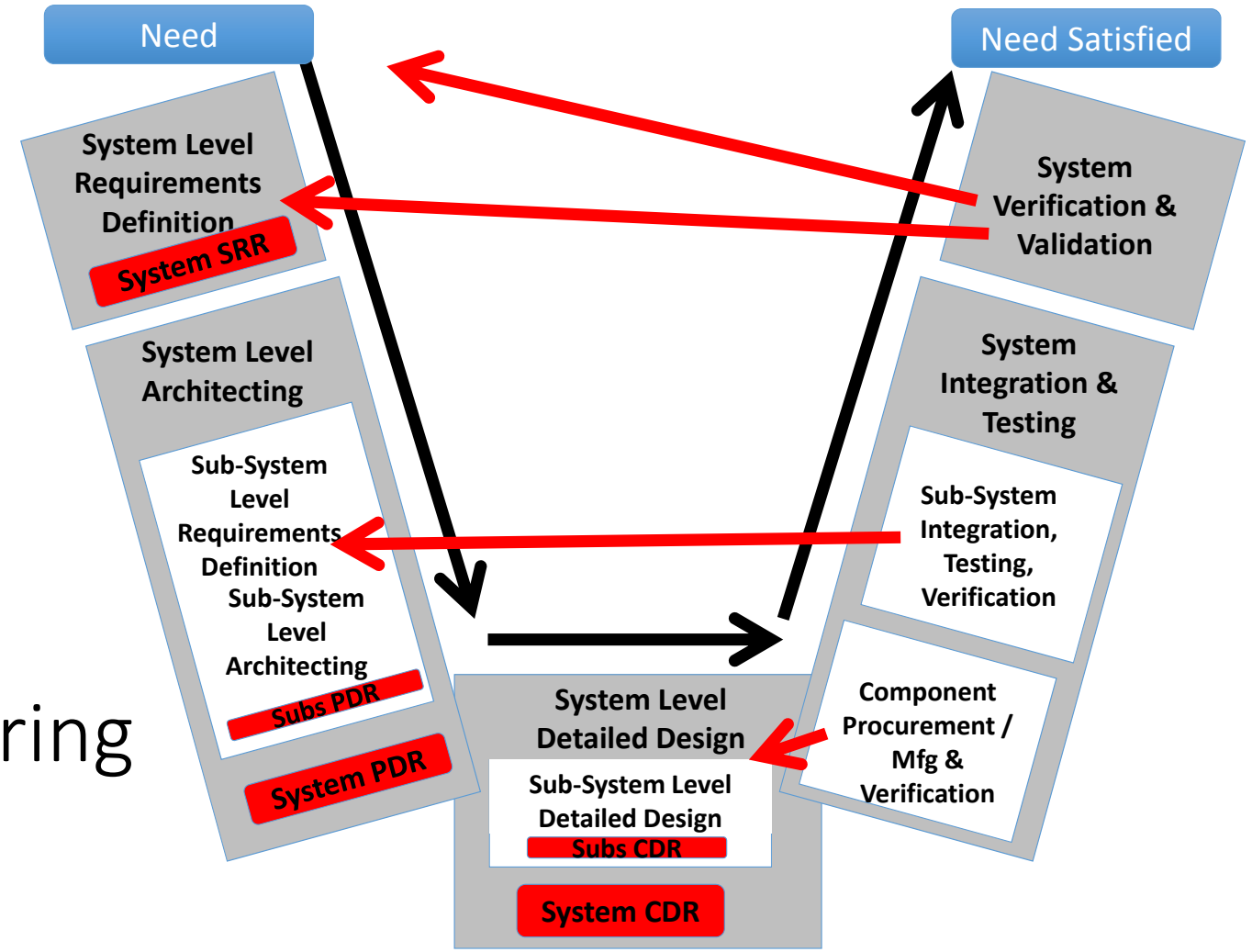
Agenda

- Systems Engineering Process
- Problem
- Solution
  - Requirements Definition
  - Conceptual Design
  - Detailed Design
- Cost/Capability

Systems Engineering Process

Systems Engineering Process



Problem Definition

Problem

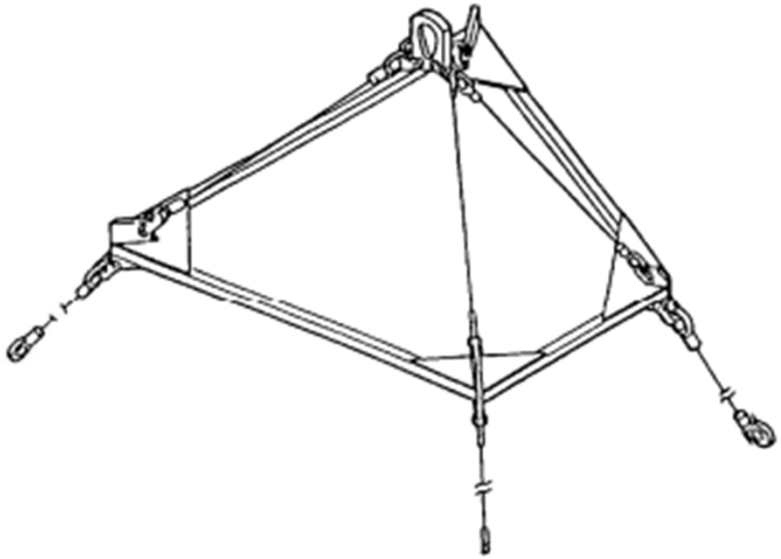
Design a Universal Proofloader that:

- Safely Load Tests Various Lifting Slings In Designed Configuration
- Eliminates The Need For Proofload Adapters and Static Weights
- Loads In 10 Pound Increments
- Is Self Contained
- Design Must Be Completed By April 25, 2016

What is a Sling?

449-240-129-101 SLING ASSEMBLY, UNIVERSAL
(WP 003 16)

70073-85000-013 Sling, Universal Lifting
WP 003 04



65720-70018-041 SLING, DOCKSIDE LOADING
WP 007 23

What is Proofloading and Why?

- Loading Slings to Test Reliability
- Must be done
  - At Manufacture
  - After Major Structural Repair

Problem

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Requirements Definition

Needs Statement

A Universal Sling Proof Loader (UPL) to apply a load to slings, in their usage configuration, up to 130,000 pounds.

Functional Block Diagram

Universal Proof Loader (UPL)

Connect to Slings:	Position Sling Connections:	Load Slings:	Safety:

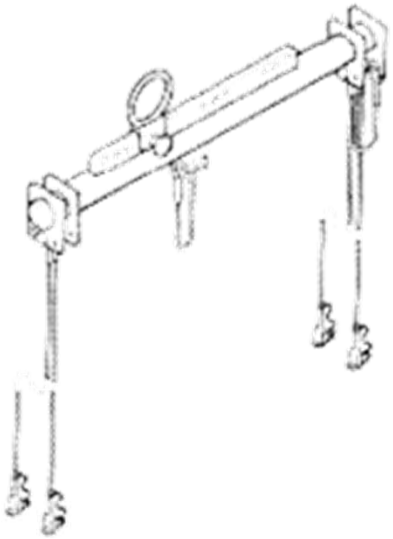
• Connect to top of sling
• Connect to bottom of sling:
  • Baskets
  • Pins
  • Bolts
  • Shackles
  • Chain loops
  • Hooks
	• Adjustable
	  • Adjustable in length and width
	  • Adjustable in Height by extension frames or chains
	• Fixed
		• Apply a load
		• Resist the load
		• Measure a load
		• Measure elapsed time
		• *Would LIKE to: Measure the load in each leg*
			• Keep operator and bystanders safe
			  • Absorb energy from sling failure

Current Proofloading Capabilities

- Calculated method for prooftesting slings with dead weights, up to 6,000 lbs.
- Straight pulls up to 120,000 lbs.

449-240-129-101 SLING ASSEMBLY, UNIVERSAL
(WP 003 16)

Database



SWE13833 SLING, ASSEMBLY
(WP 004 05)

PWC70079 SLING-LIFTING, ENGINE ASSEMBLY
(WP 004 06)

Figure 1. Sling Pictorial Index

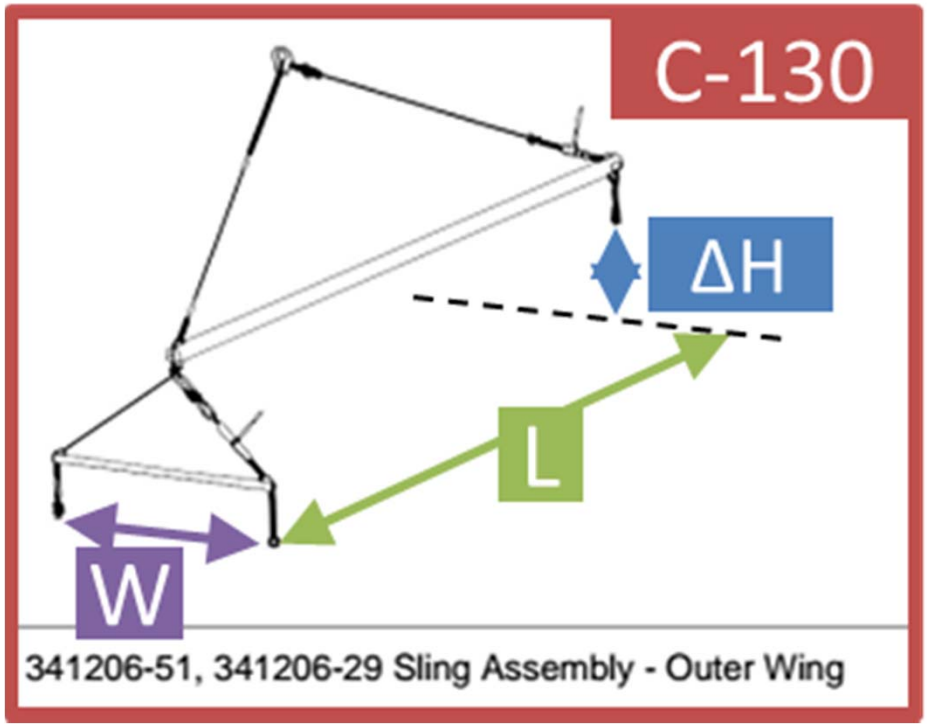
Sling Definition

Slings are defined by the following variables

- Proofload Requirement (100-130,000lbs)
- Dimensions
  - Height (from hook to lowest)
  - Length (longer horiz. dim)
  - Width (shorter horiz. dim)
  - Height Eccentricity (Δ H of connections)
- Connections
  - Quantity (1-5)
  - Type(s) (Pins, Bolts, Shackles…)
- Frame Use and Size (spreader bars etc.)

Sling Dimensions

- Height
  (from hook to lowest)
- Length
  (longer horiz. dim)
- Width
  (shorter horiz. dim)
- Height Eccentricity
  (Δ H of connections)

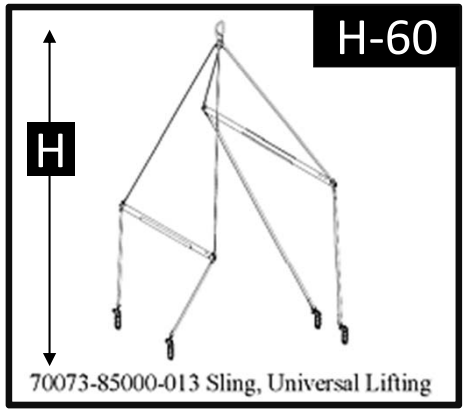


Sling Size Considerations

Slings below set the size of the Universal Proofloader (UPL)

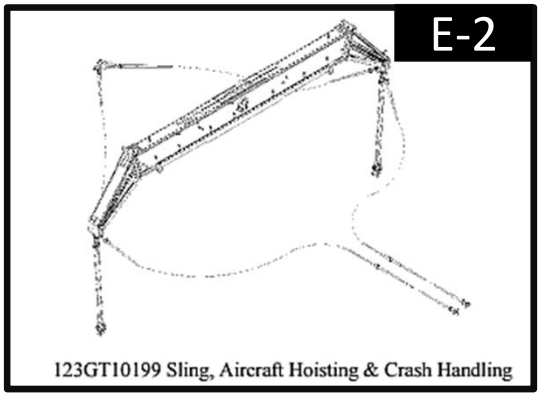
Max Height

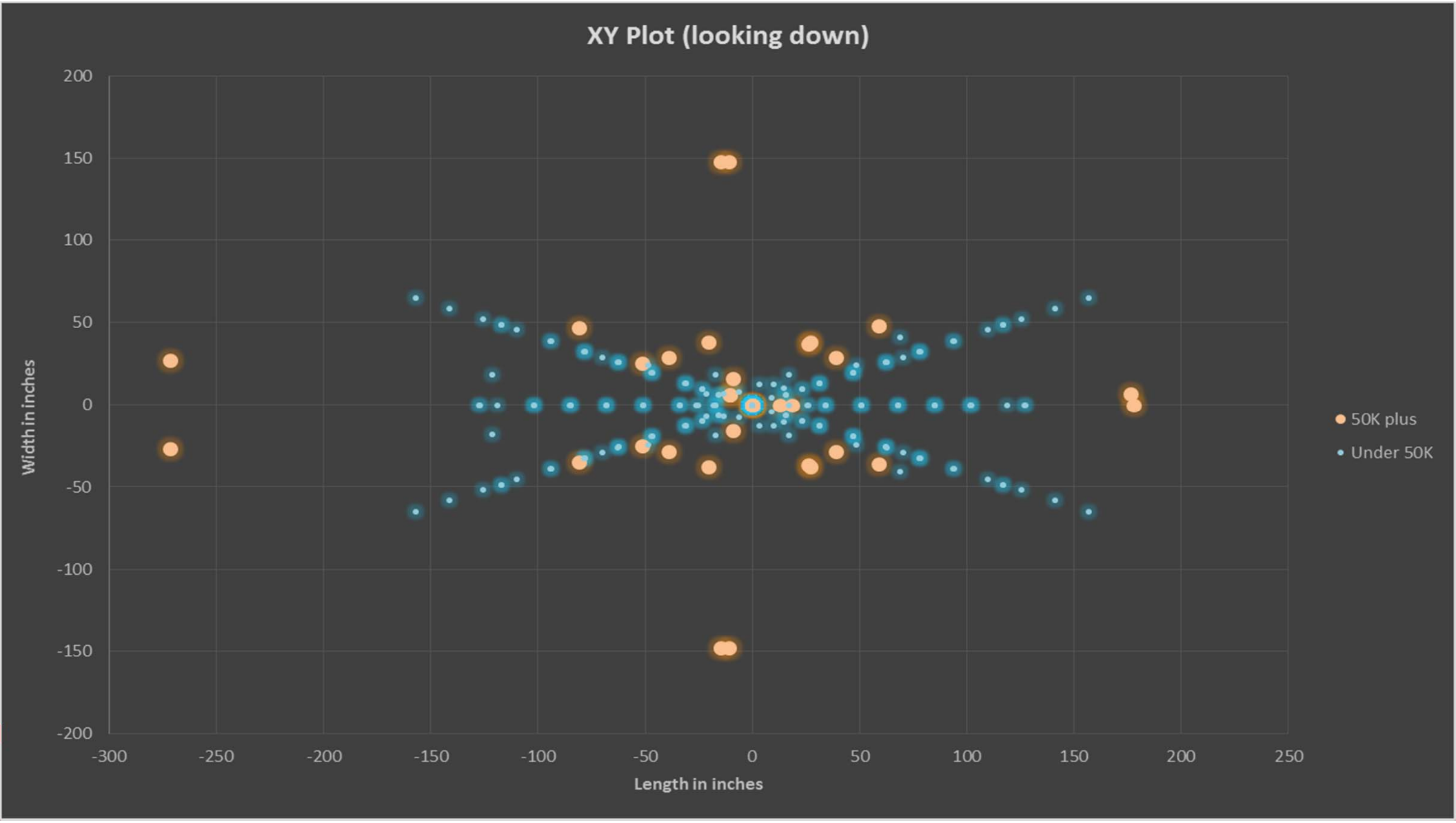
16’x7’x20’ 46,800 lbs



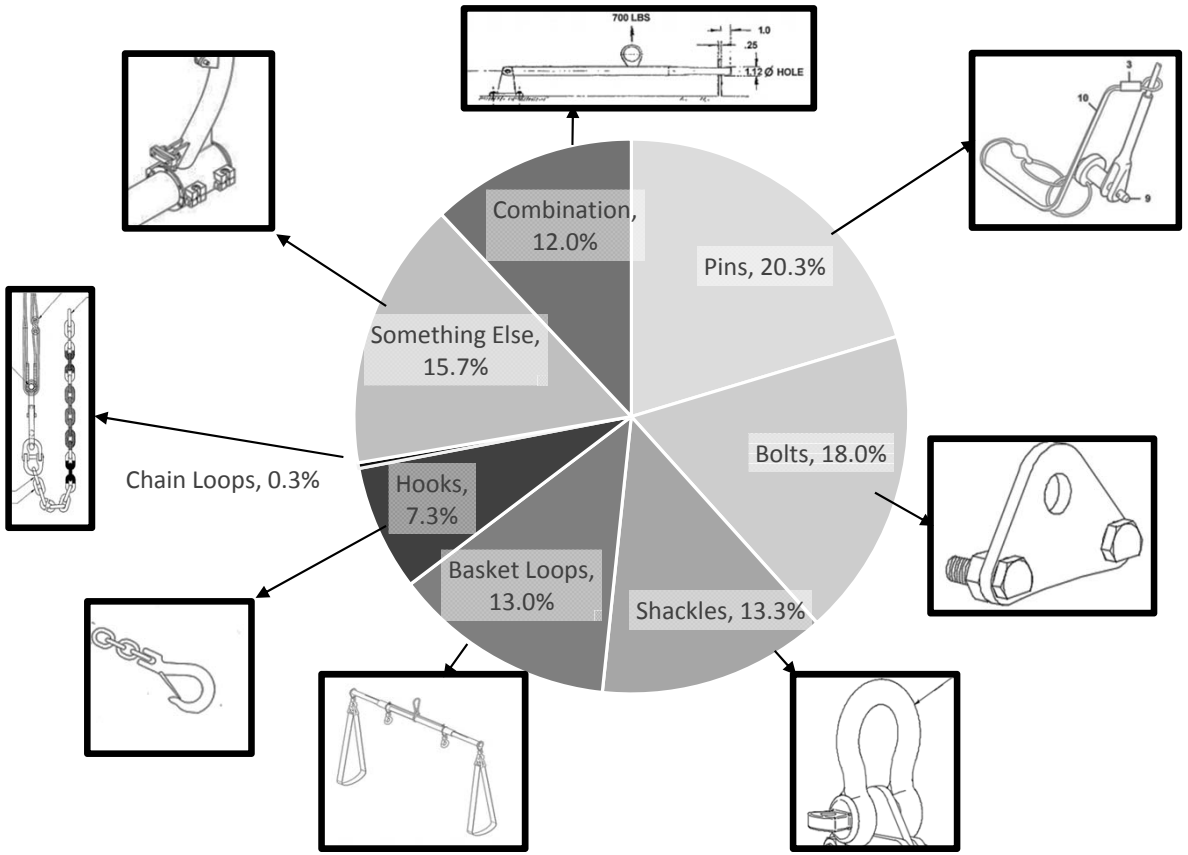
Max Length and Width

38’x25’x17’ 96,000 lbs




XY Plot (looking down)
200
150
100
50
0
-50
-100
-150
-200
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250
Width in inches
Length in inches
50K plus
Under 50K

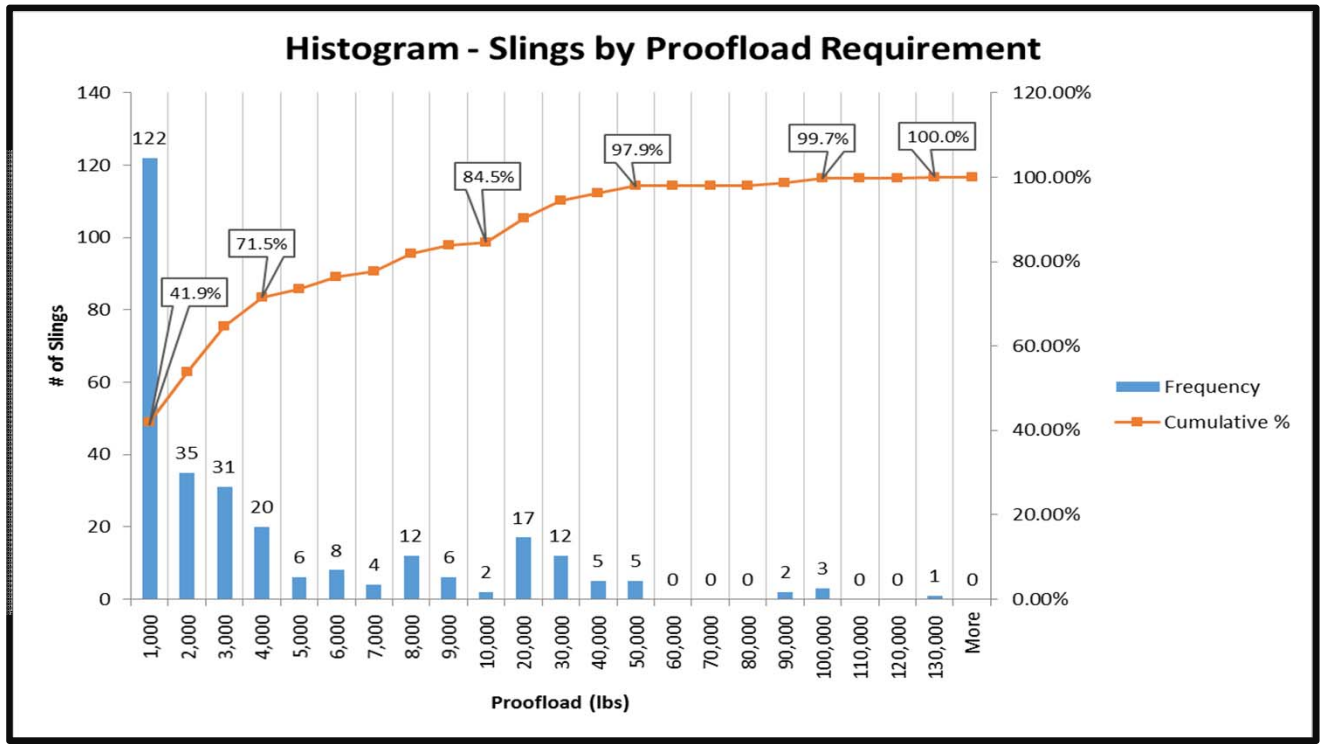
Sling Connections



Sling Proofload Requirements

0-10,000 lbs were placed in 1,000 lb bins.

10,000 lbs + were put in 10,000 lb bins.



Requirements

Need	Req #	Sub-Req #	Description
1	**0**	**0**	**1.0 The Universal Proof Loader (UPL) design shall connect to all slings listed in the interface document in the same configuration as when in normal use.**
1	1	0	The UPL design shall have a means to connect to the top of the slings as stated in the interface document.
1	2	0	The UPL design shall have a means to connect to the bottom of the slings as stated in the interface document.
1	3	0	The UPL design shall have a means to connect to slings of various sizes as stated in the interface document.
1	4	0	The UPL design shall accommodate sling frames as stated in the interface document.
1	5	0	The UPL design shall assist in connecting to the top of the sling.

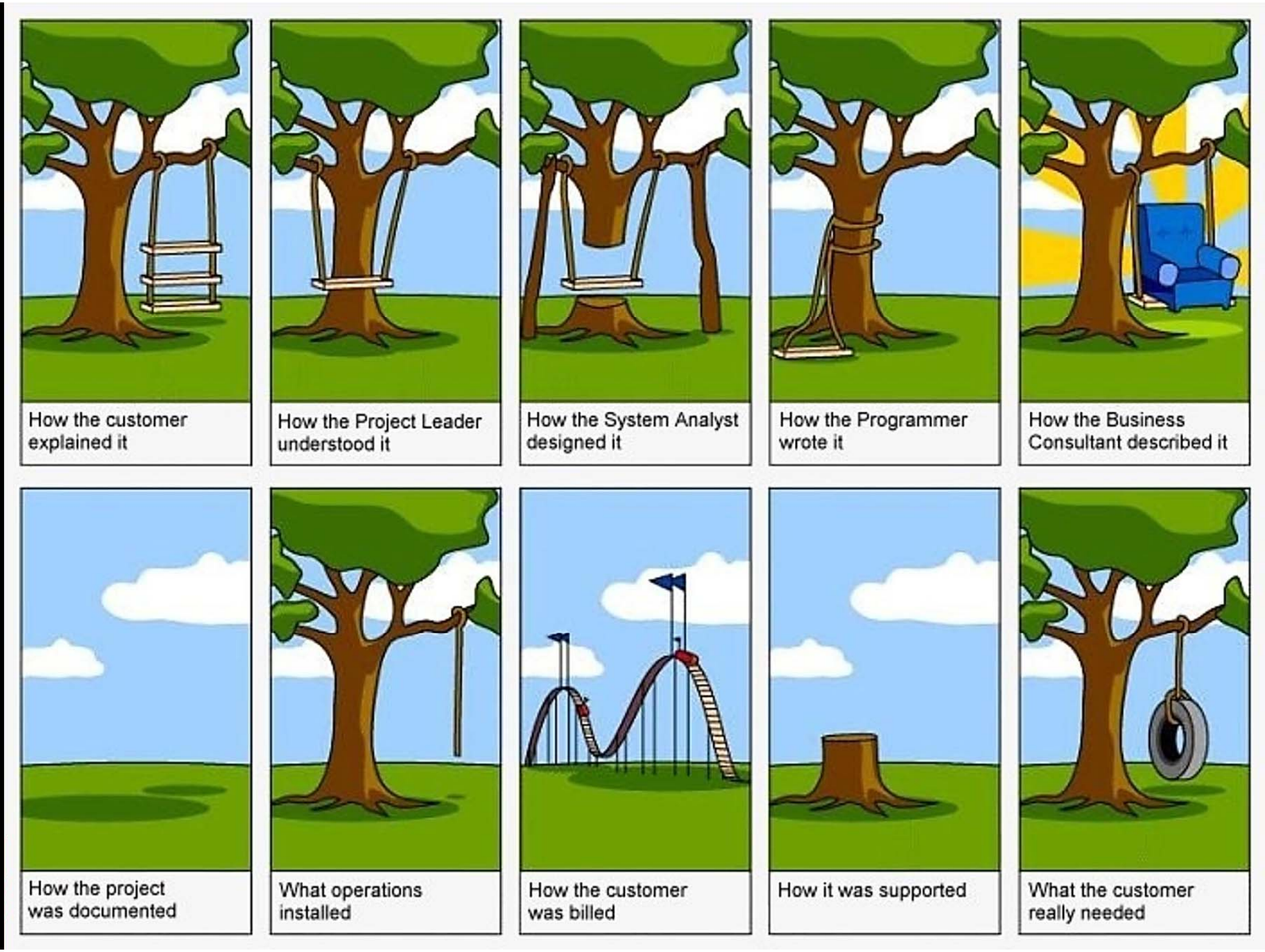
Specifications

- 130,000 lbs. on 4 legs
- 97,500 lbs. on 3 legs
- 65,000 lbs. on 2 legs
- 130,000 lbs. straight pull
- 40-90^{o} from horizontal
- 0-25^{o} from plane of leg

Measures of Effectiveness

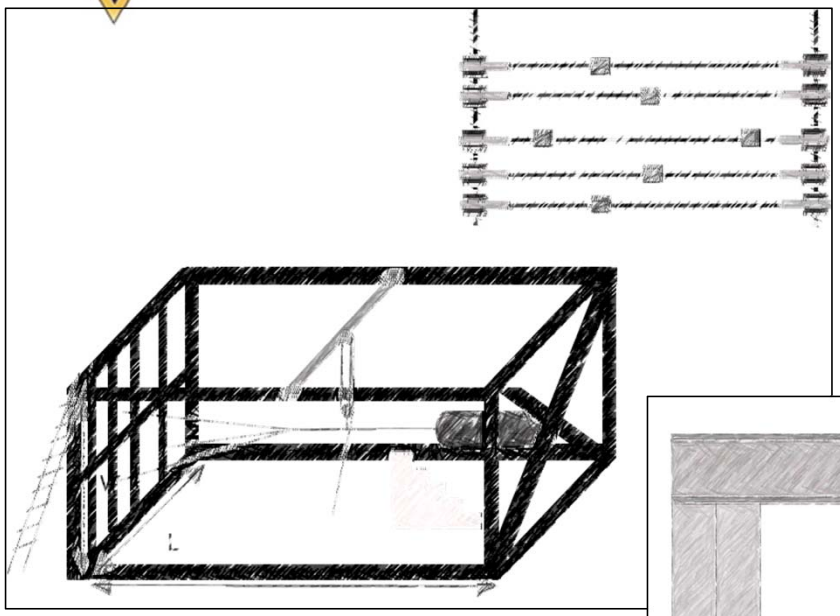
- Safety
- Reliability
- Percentage Loaded
- Connection Accuracy
- Turn Around Time
- Cost

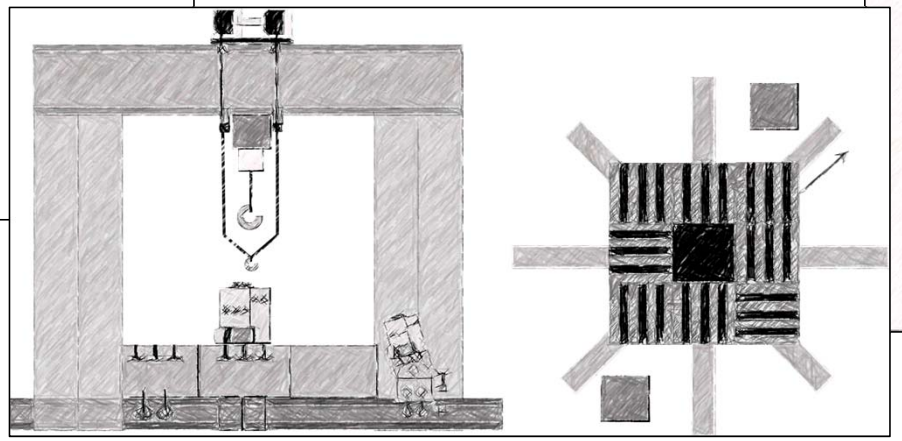
Importance of the Systems Engineering Process

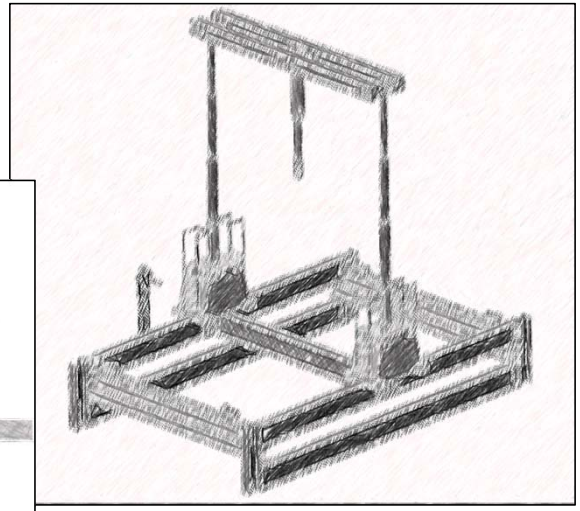


From Concept to Design

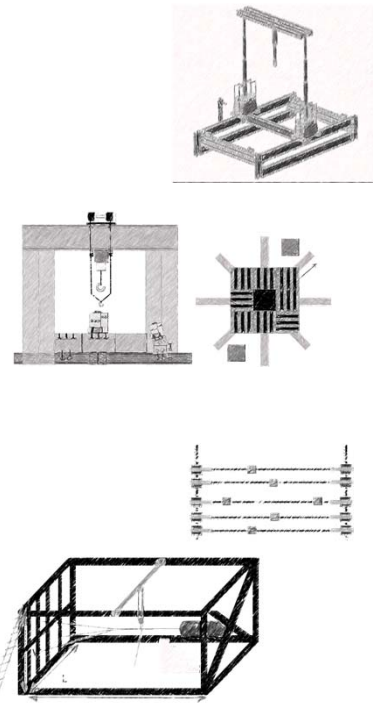
Individual Concepts







Initial Concept Developed



Inspiration

Option A

Option B

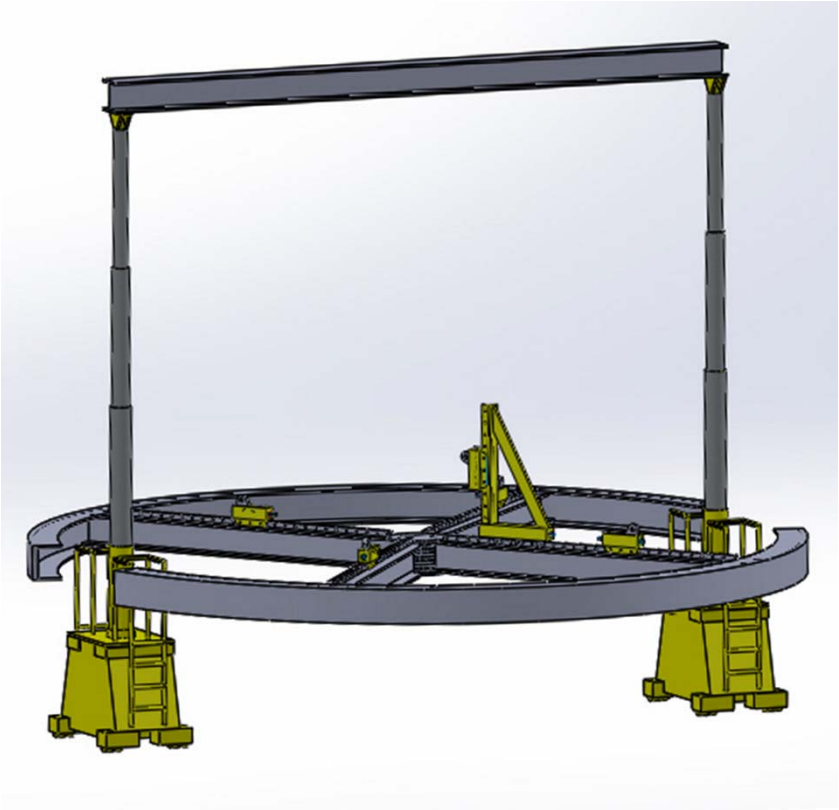
Option C

Option D

Final Concept

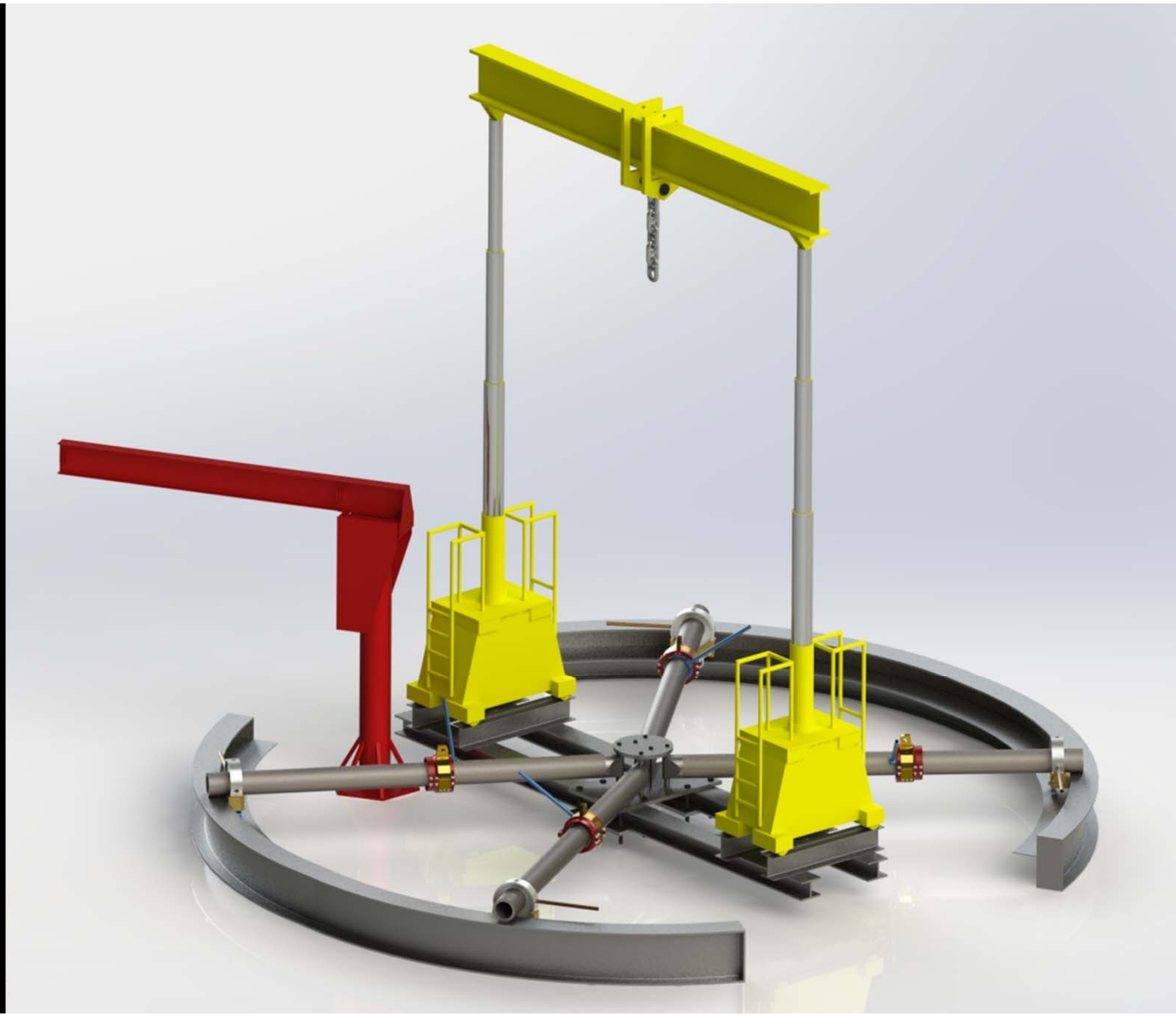
Final Concept

(but not final design)

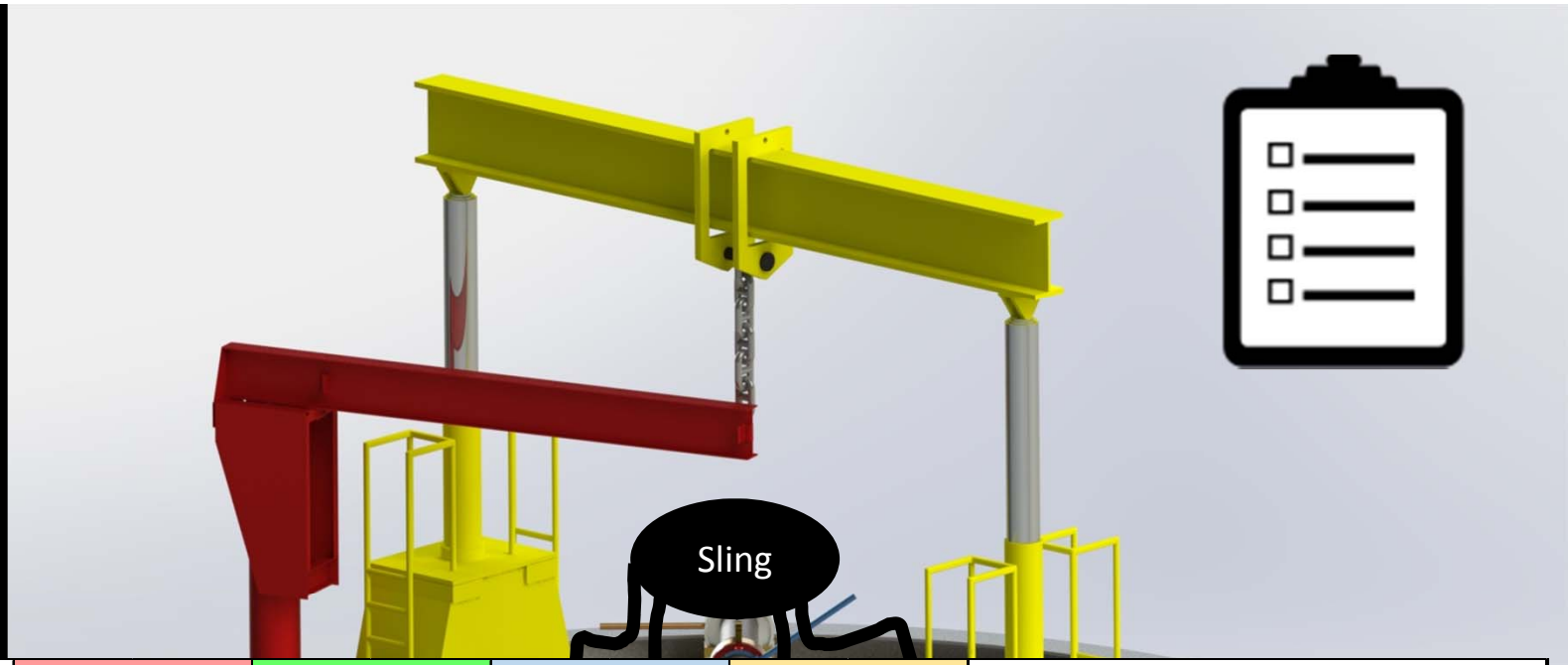


Final Design

Universal Proof Loader (UPL)

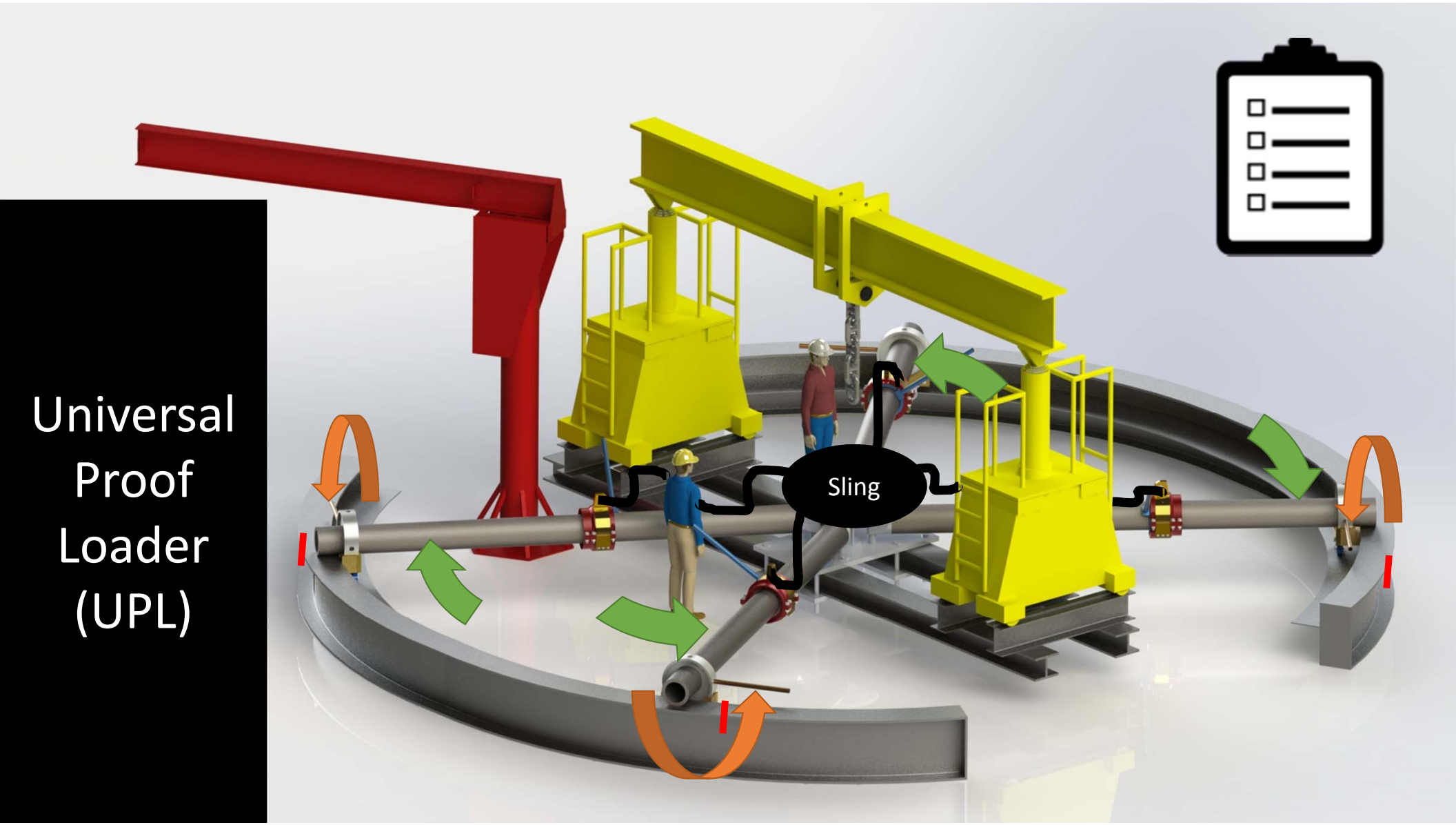


Universal Proof Loader



		Connection 1		Connection 2		Connection 3		Connection 4		Notes:
Sling Part Number	Used On	R1	θ1	R2	θ2	R3	θ3	R4	θ4	
1128SME40001-3	EA-6	36.5	56.3	36.5	56.3	36.5	56.3	36.5	56.3	
65720-70018-041	H-53	64.3	51.8	57.6	61.2	77.3	69.8	82.2	61.9	
901-220-933-103	V-22	34.9	32.2	34.9	32.2	31.9	22.3	31.9	22.3	
75D110000	AV-8	33.4	31.6	33.4	31.6	49.5	68.3	49.5	68.3	Connections 3 and 4 use adapter #1.

Universal Proof Loader (UPL)



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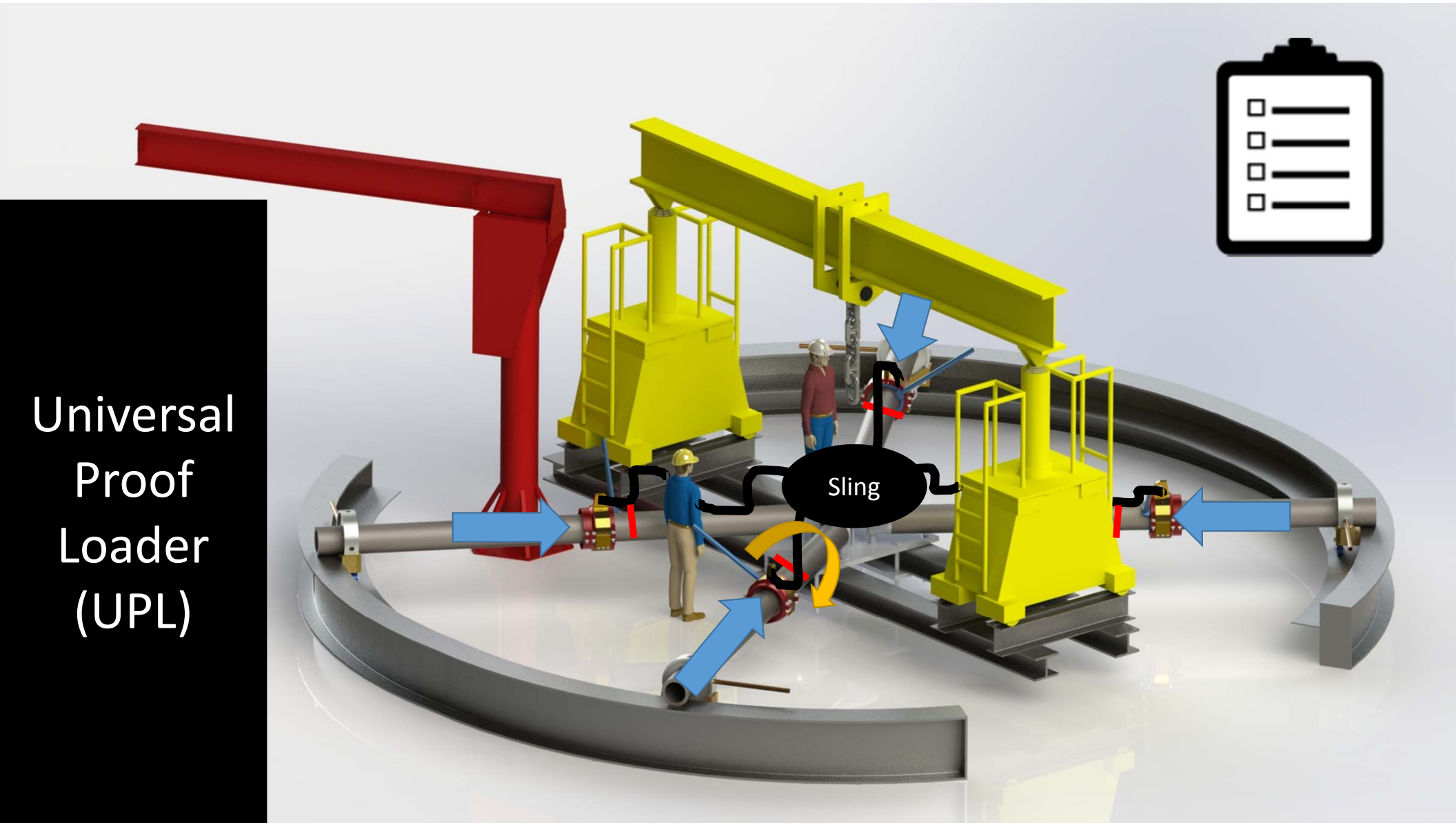

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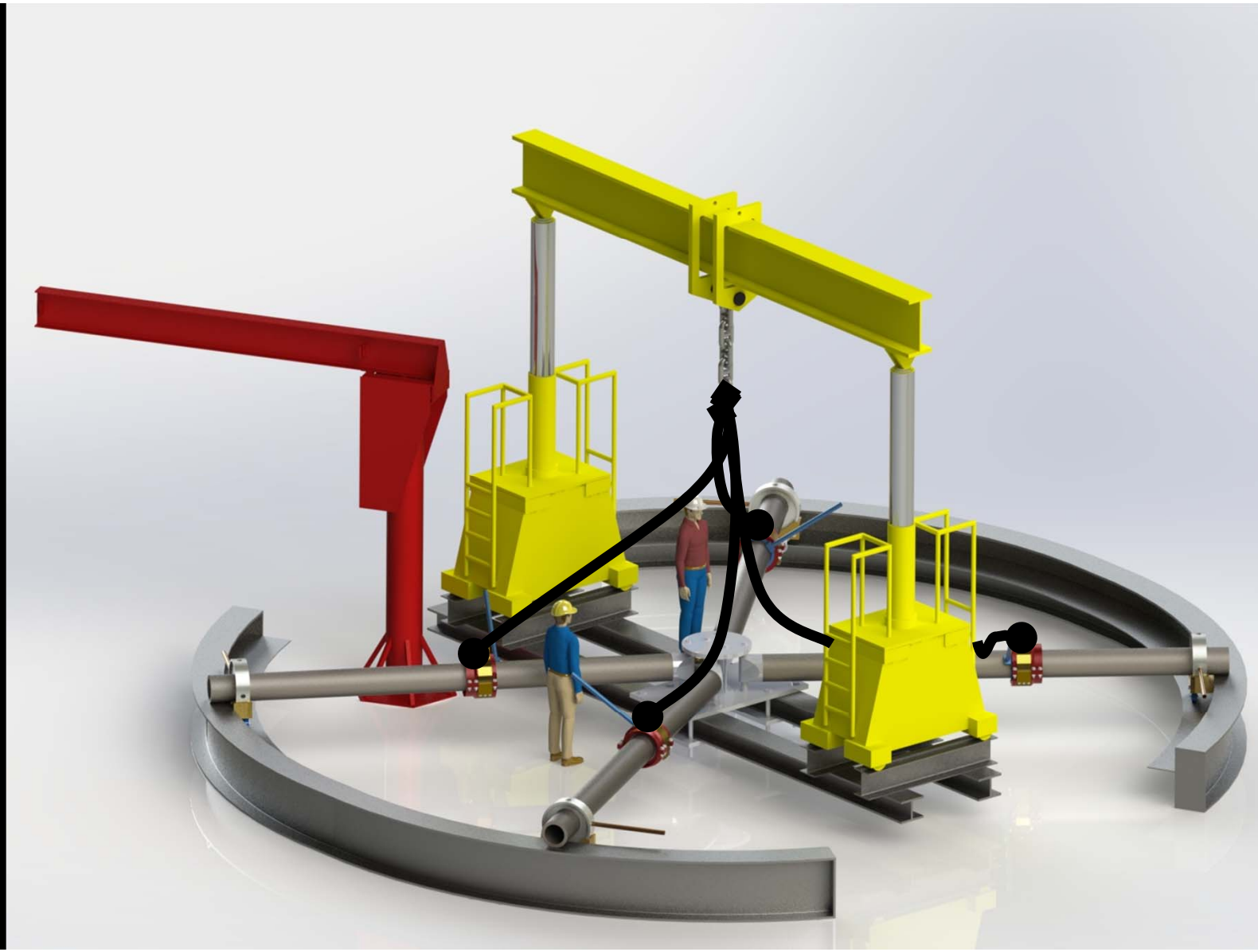

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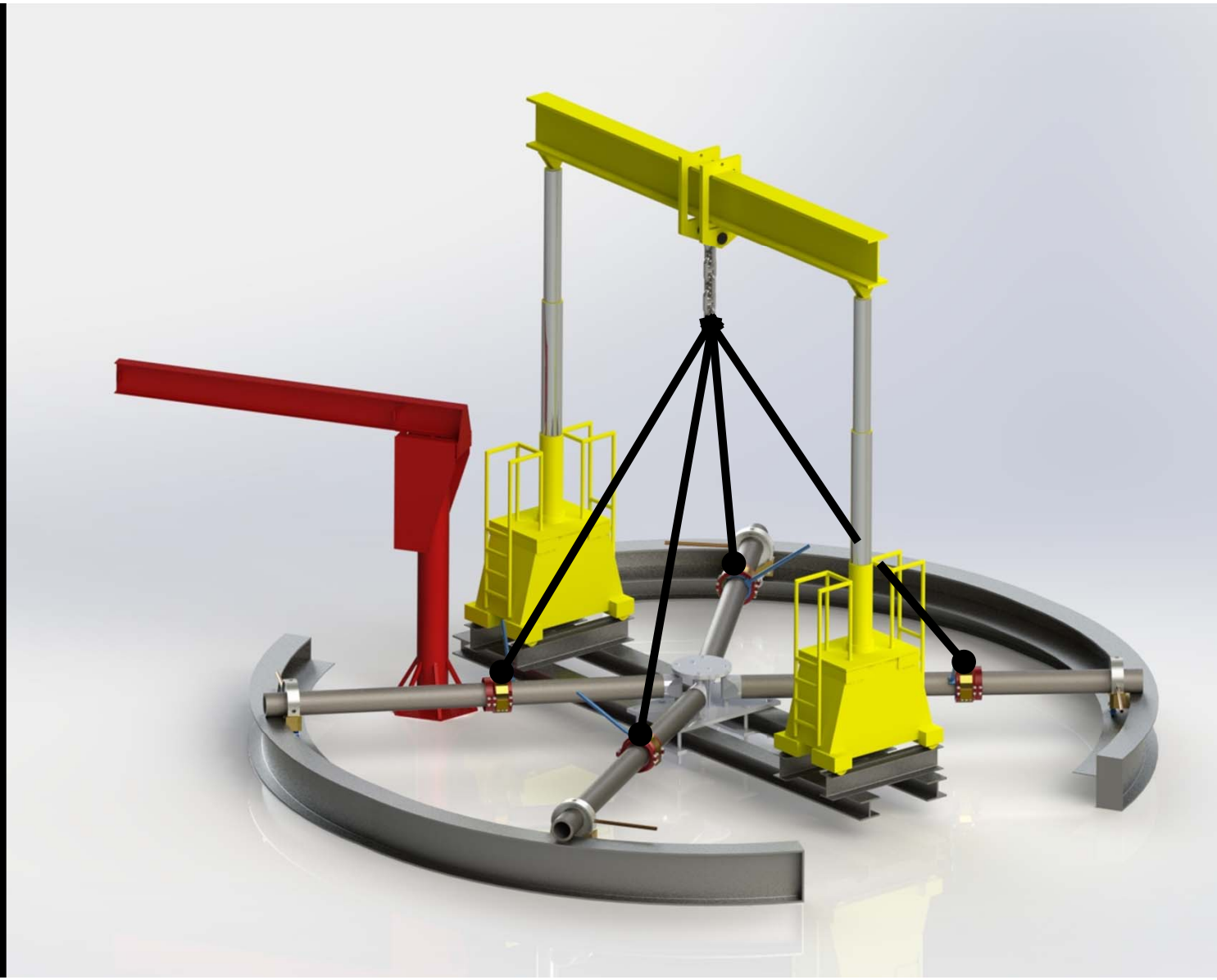
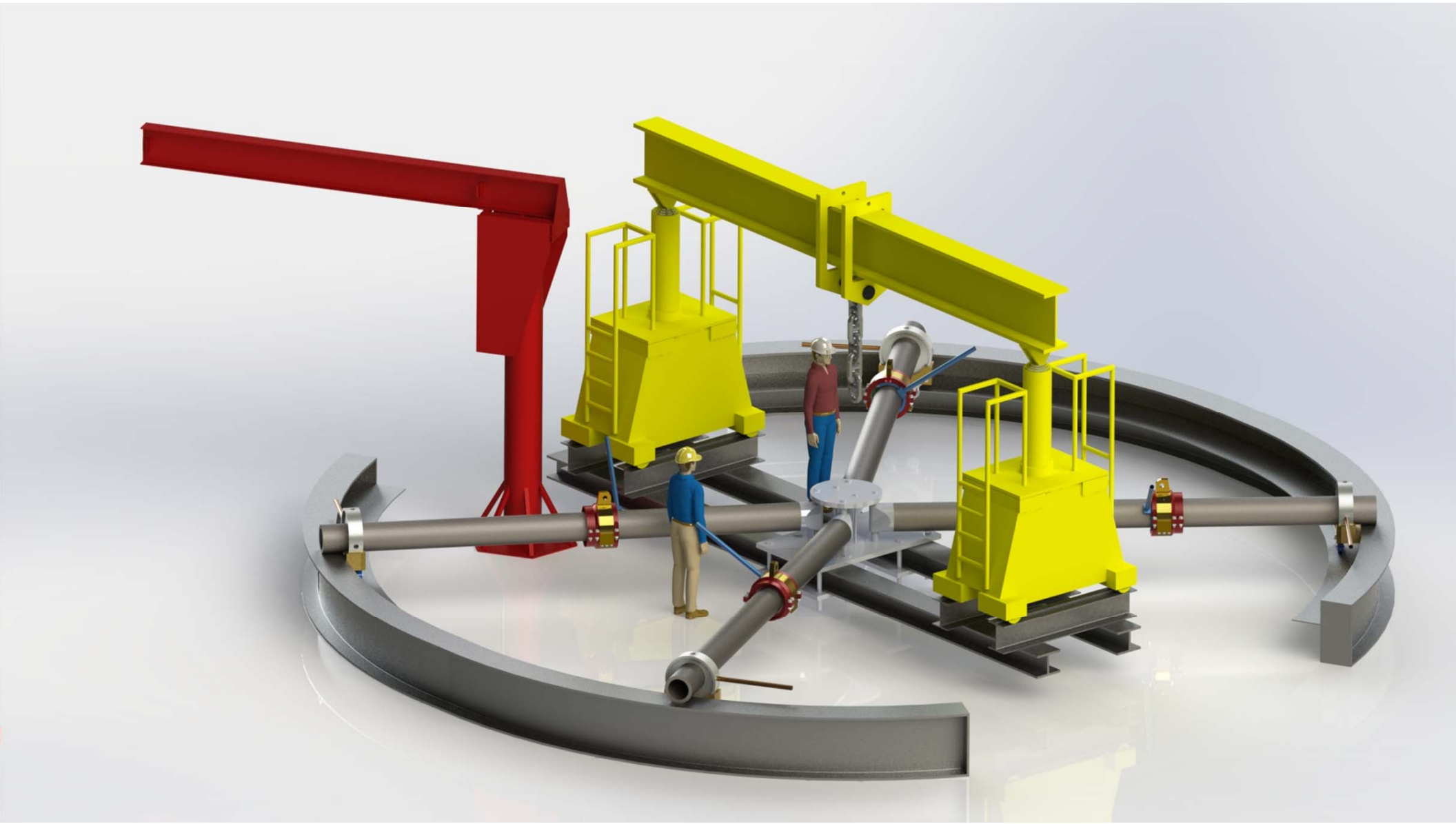
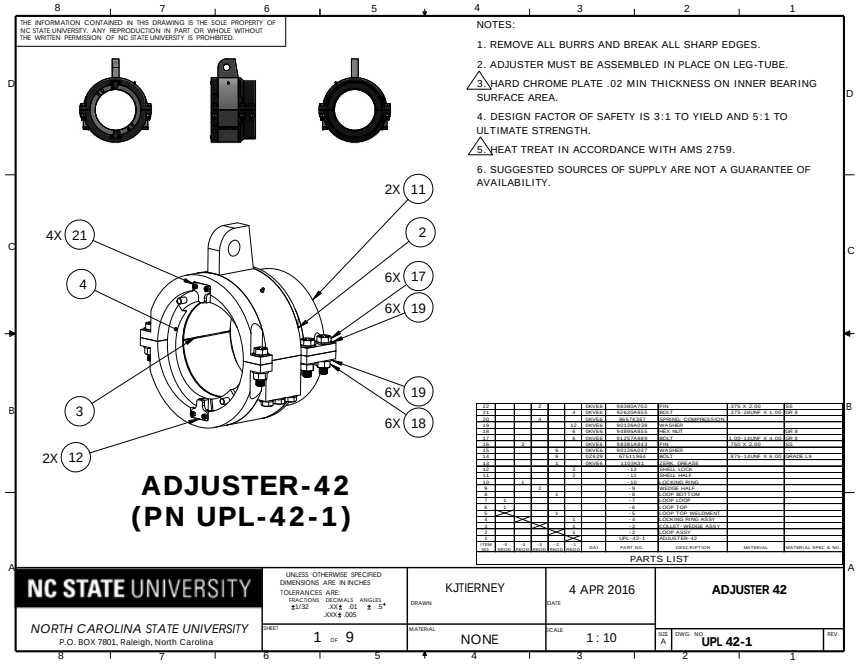


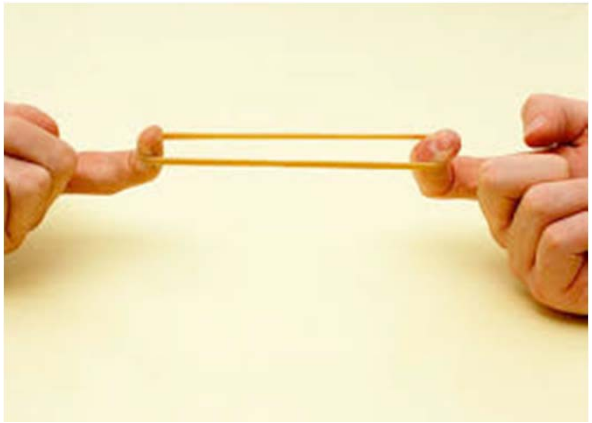


Detailed Design

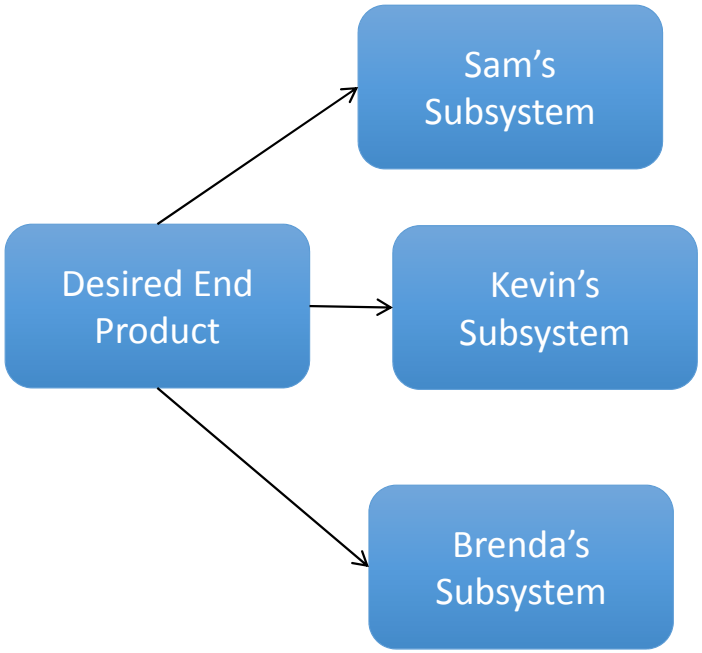
Detailed Design

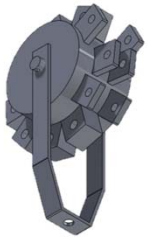
- What is detailed design?
  - Stresses
  - Safety Factor
  - Ease of use
  - Manufacturing
  - Drawings

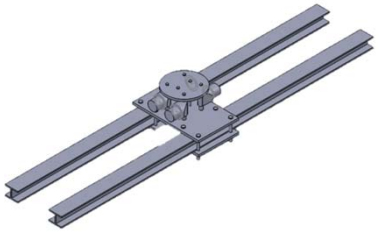


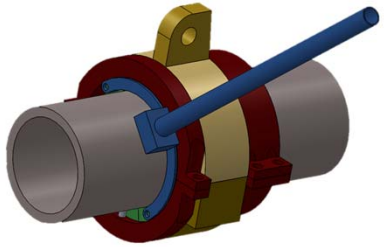


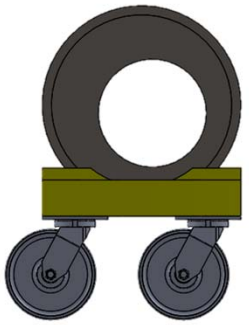
Process


Sam's Subsystem
Desired End Product
Kevin's Subsystem
Brenda's Subsystem





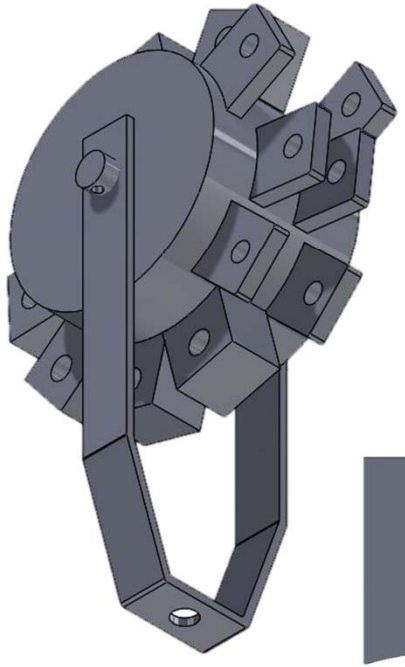


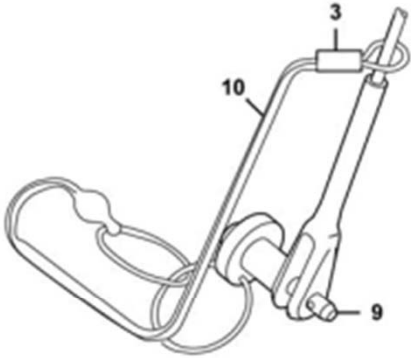


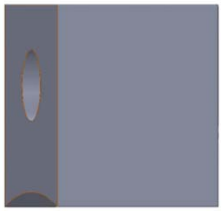
Sam's Subsystem

Pin Adapter

- Reduces total number of adapters
- Previously made out of 4130 steel

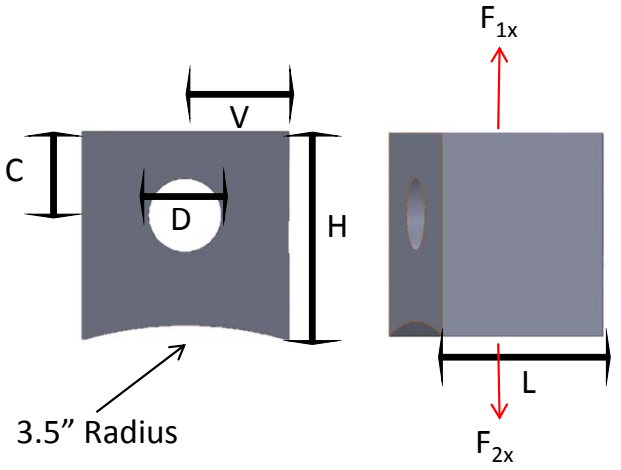






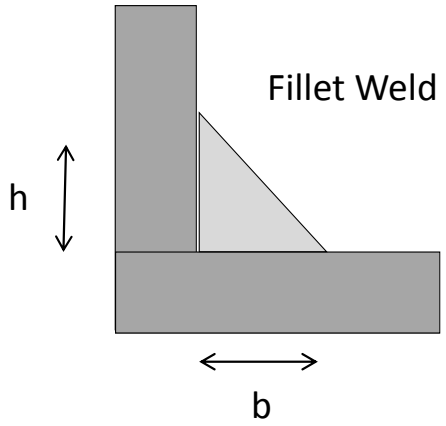
Adapters – Pins Calculations

Inner Tabs						
S/N	Pin Diameter (in) D	Length (in) L	Width (in) W	Bearing Stress (psi)	Safety Factor (Ultimate)	Tab Height (in) H
65720-700787-041	0.64	1.277	1	-779	77.03	1.9
T101897	0.625	0.760	1	-5,182	11.58	1.8
T101610	0.563	0.180	1	-5,905	10.16	1.7
65720-70005-041	0.453	0.880	1	-1,357	44.20	1.4
CPWA30804	0.437	0.625	1	-2,331	25.74	1.3
6798116	0.4	0.255	1	-6,241	9.61	1.3
70700-77408-046	0.312	2.507	1	-1,058	56.71	1.0
6797692	0.311	0.641	1	-12,781	4.69	1.0
65700-70020-041	0.261	1.647	1	-1,333	45.02	0.9



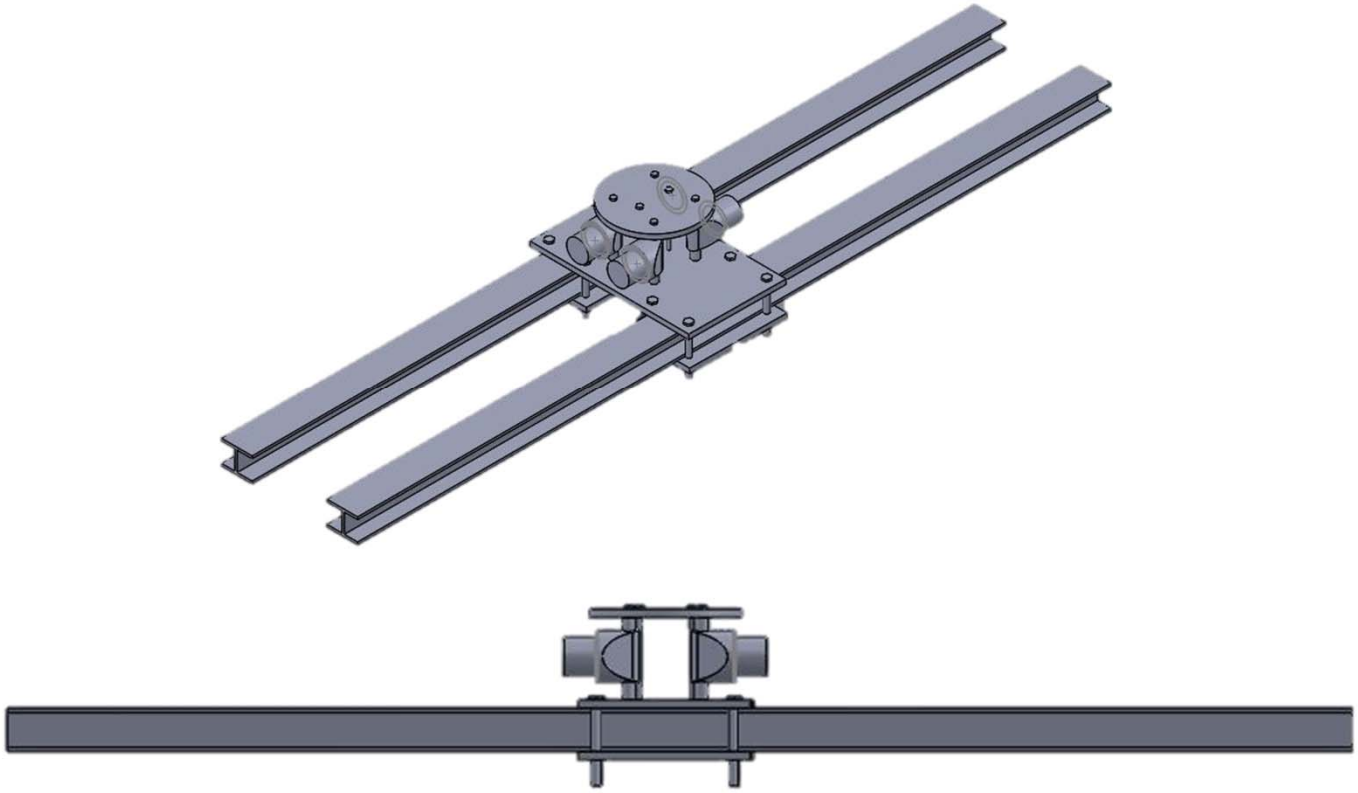
Adapters – Pins Calculations

S/N	Base Perimeter	Weld Thickness (in)	Weld Area (in^2)	PSI	Weld Material Strength (U)	Load for 5:1
65720-700787-041	4.554	1	0.5	439	586	2,928
T101897	3.52	1	0.5	2,197	2,929	14,646
T101610	2.36	1	0.5	797	1,062	5,311
65720-70005-041	3.76	1	0.5	452	603	3,014
CPWA30804	3.25	1	0.5	615	821	4,103
6798116	2.51	1	0.5	797	1,062	5,312
70700-77408-046	7.014	1	0.5	371	494	2,471
6797692	3.28125	1	0.5	2,438	3,251	16,254
65700-70020-041	5.294	1	0.5	340	453	2,267

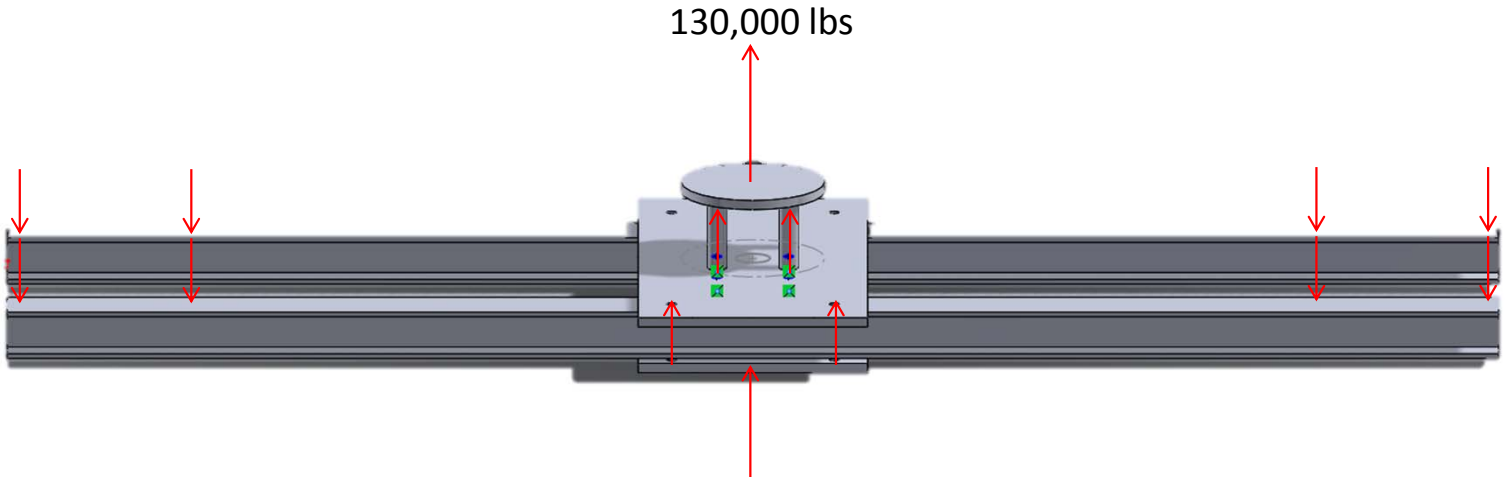


- If a one inch weld is used around the base of each tab, the minimum strength needed in the weld is 16,000 psi
- This force is well under the strength of the weld material that will be used.

Center Structure



Center Structure

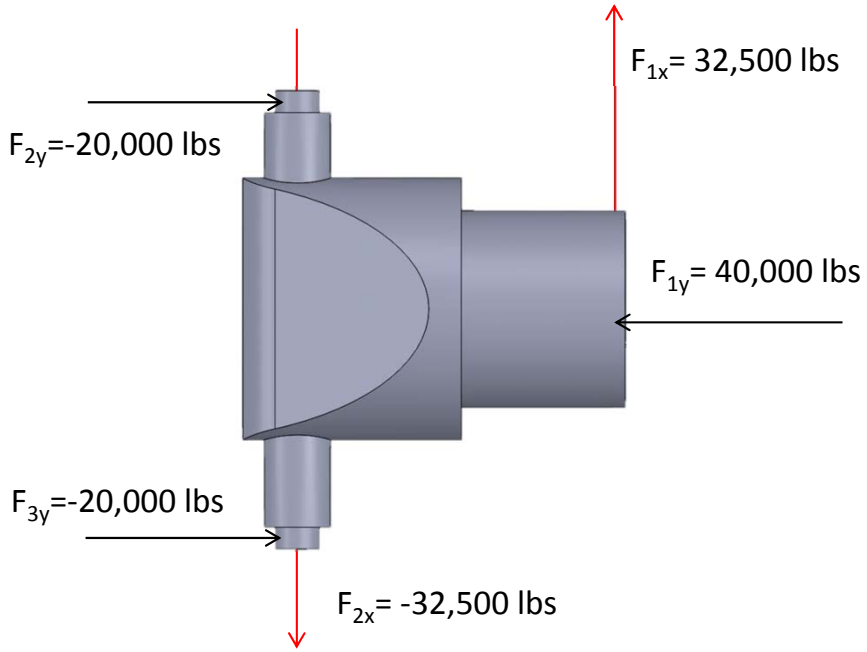


- The load is transferred down to I-Beams that push up against the feet of the gantries.
- This enables the gantry system to pull against itself, creating a self contained system.

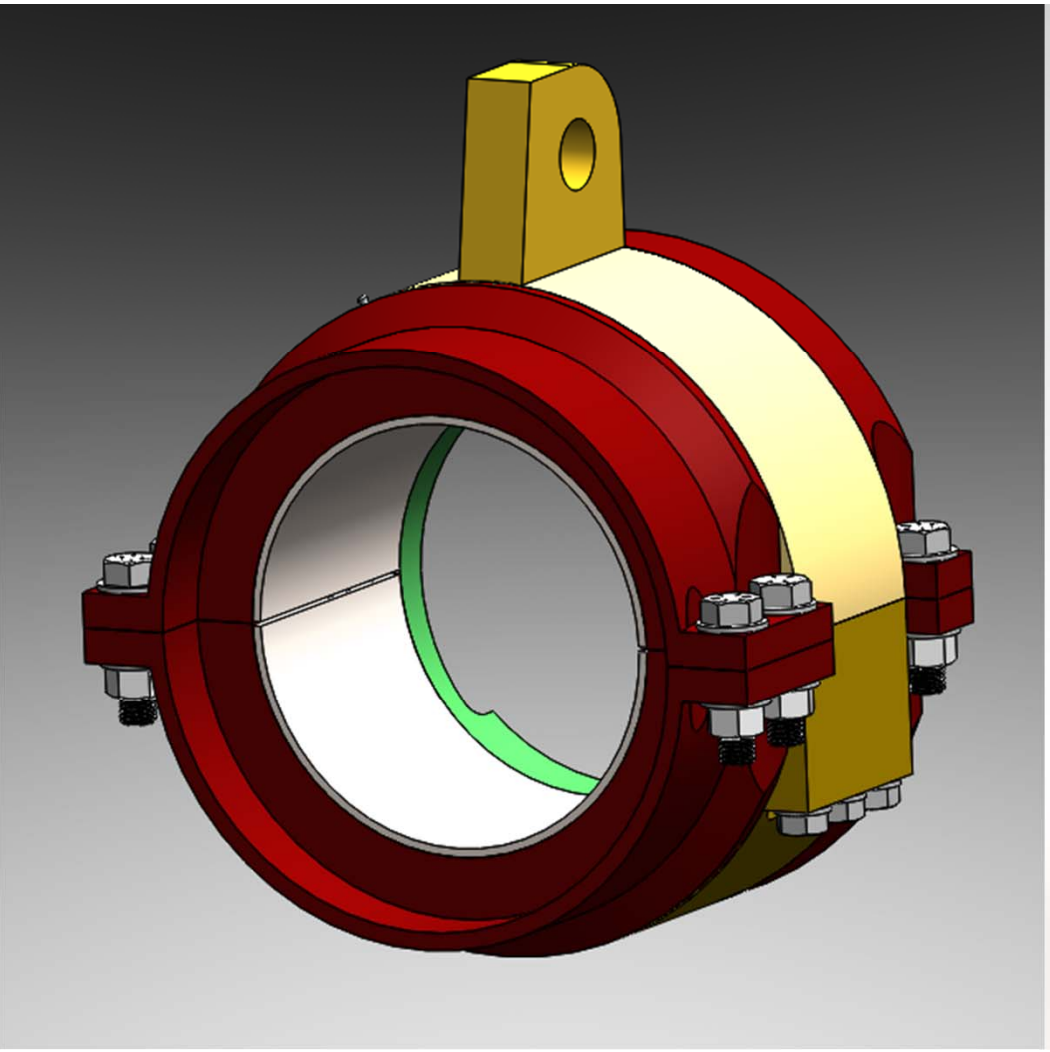
Center Structure – Tube Adapter

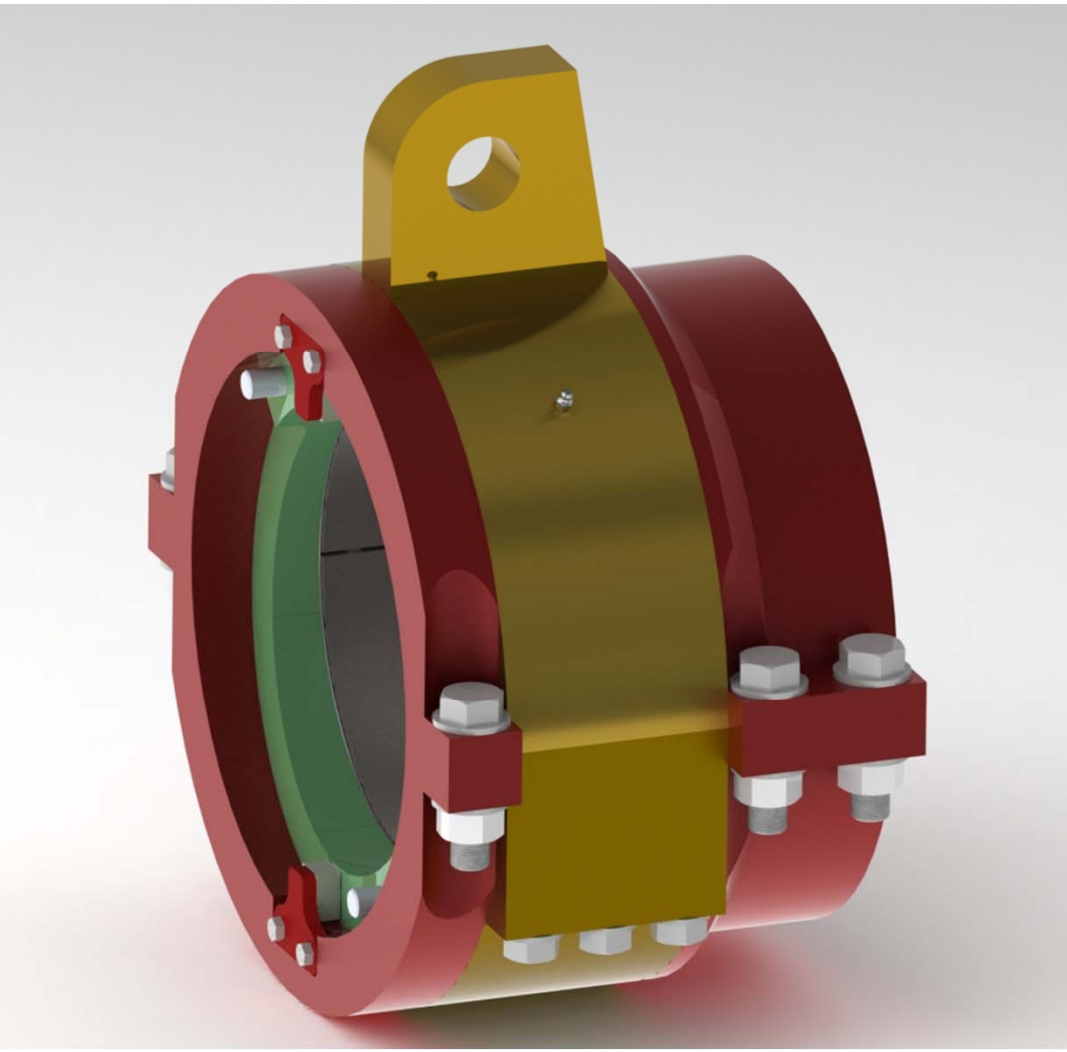
- Tube adapter is 1025 steel and is welded to tube with ER70
- Challenging

Tube Adapter		
Shear		
Allowable (U)	61,125	psi
SF	9.60	
Bearing Stress		
Allowable (U)	81,500	psi
SF	12.80	



Kevin’s Adjuster Design





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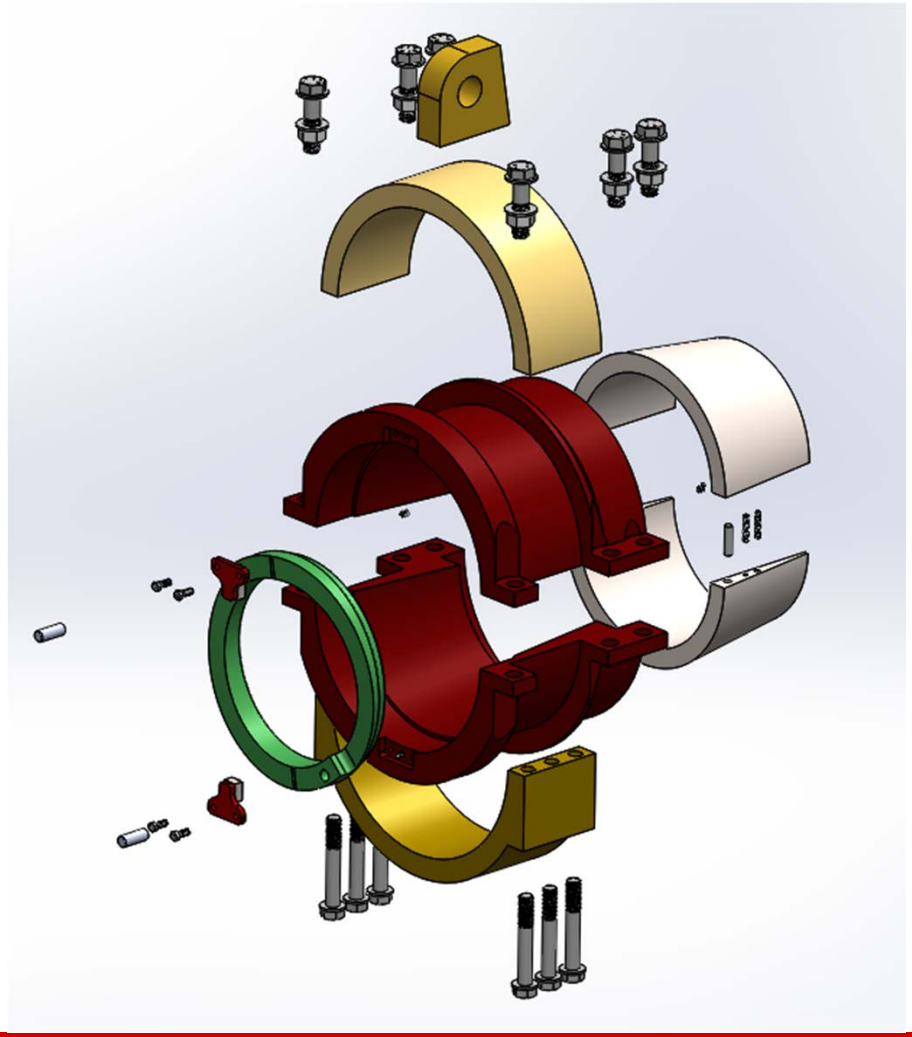
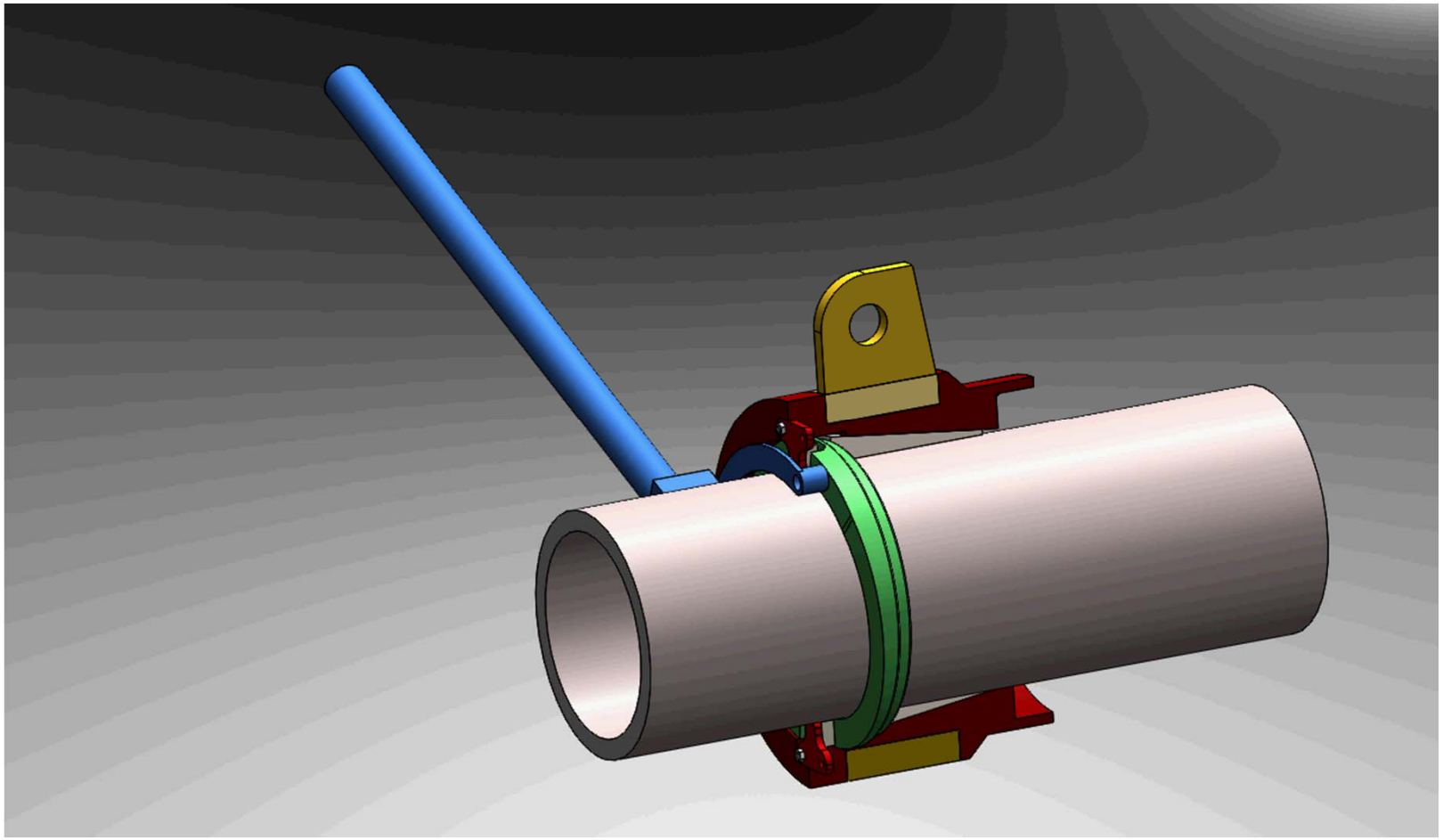
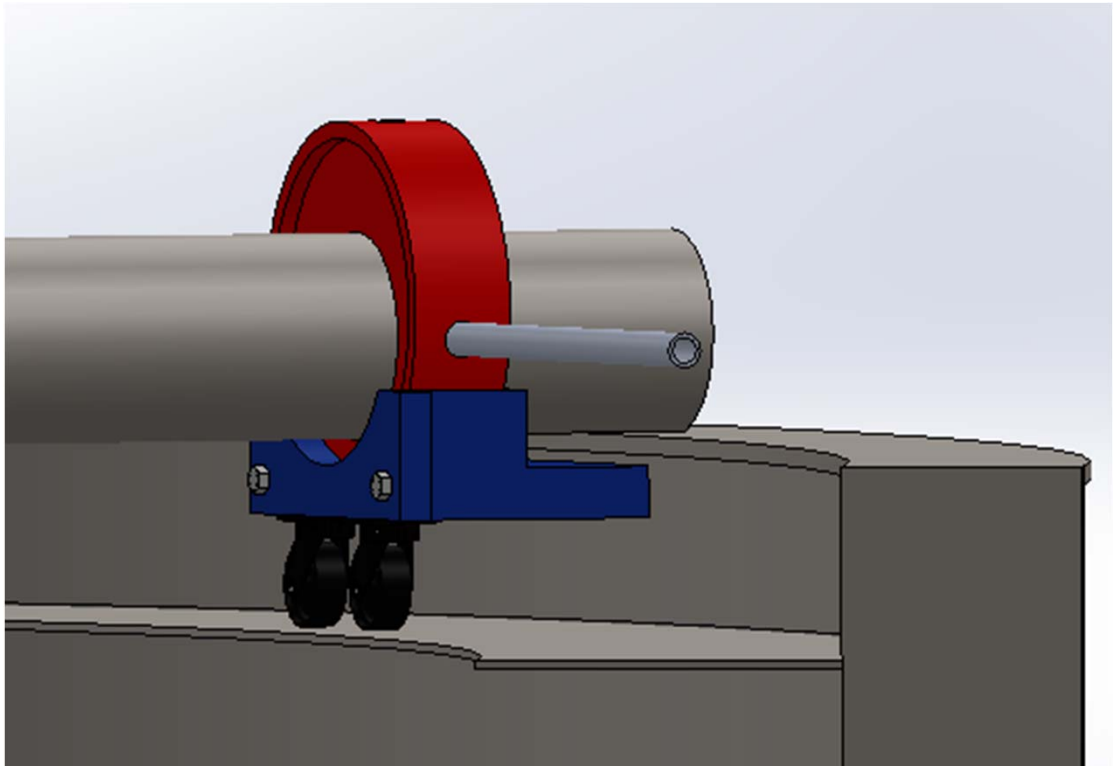
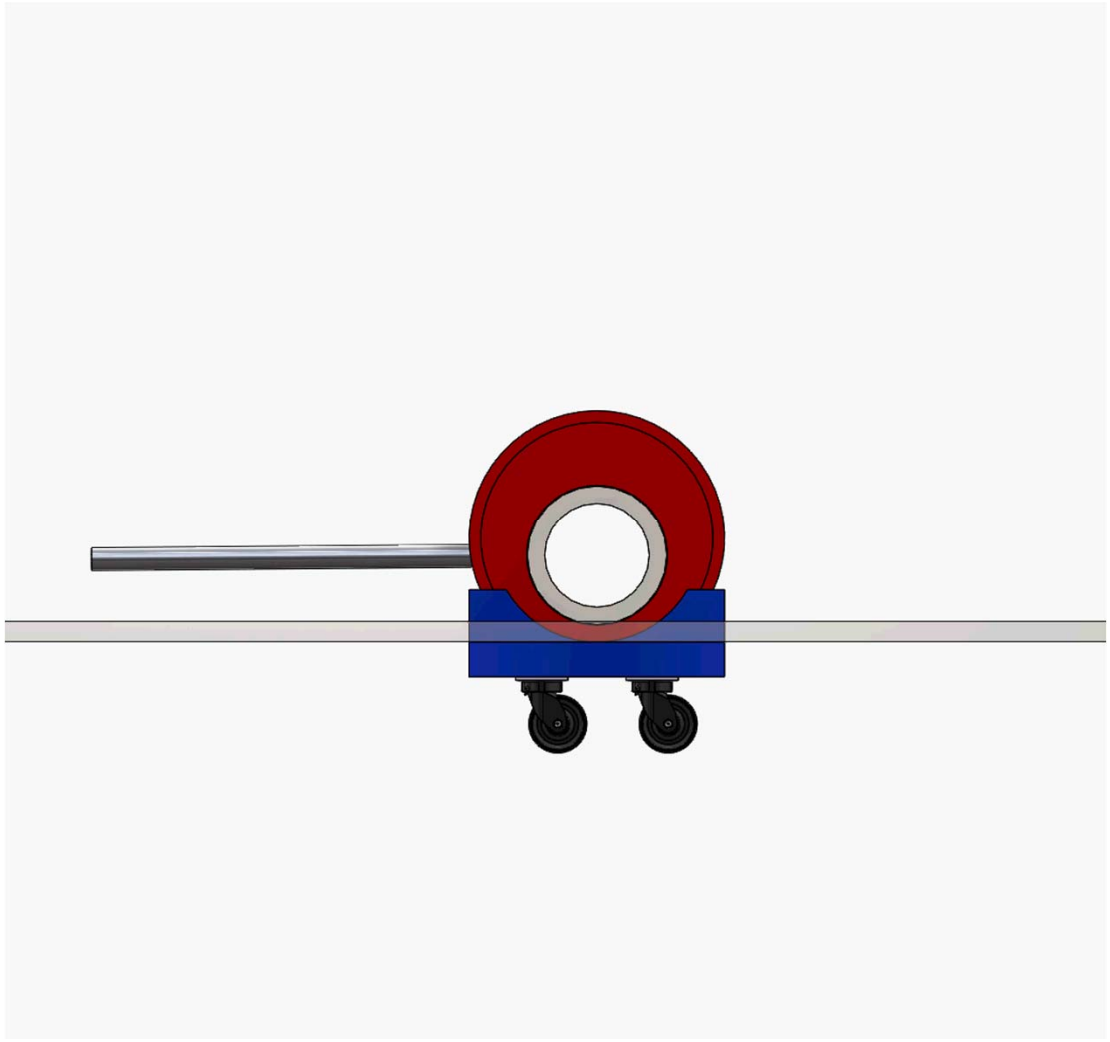


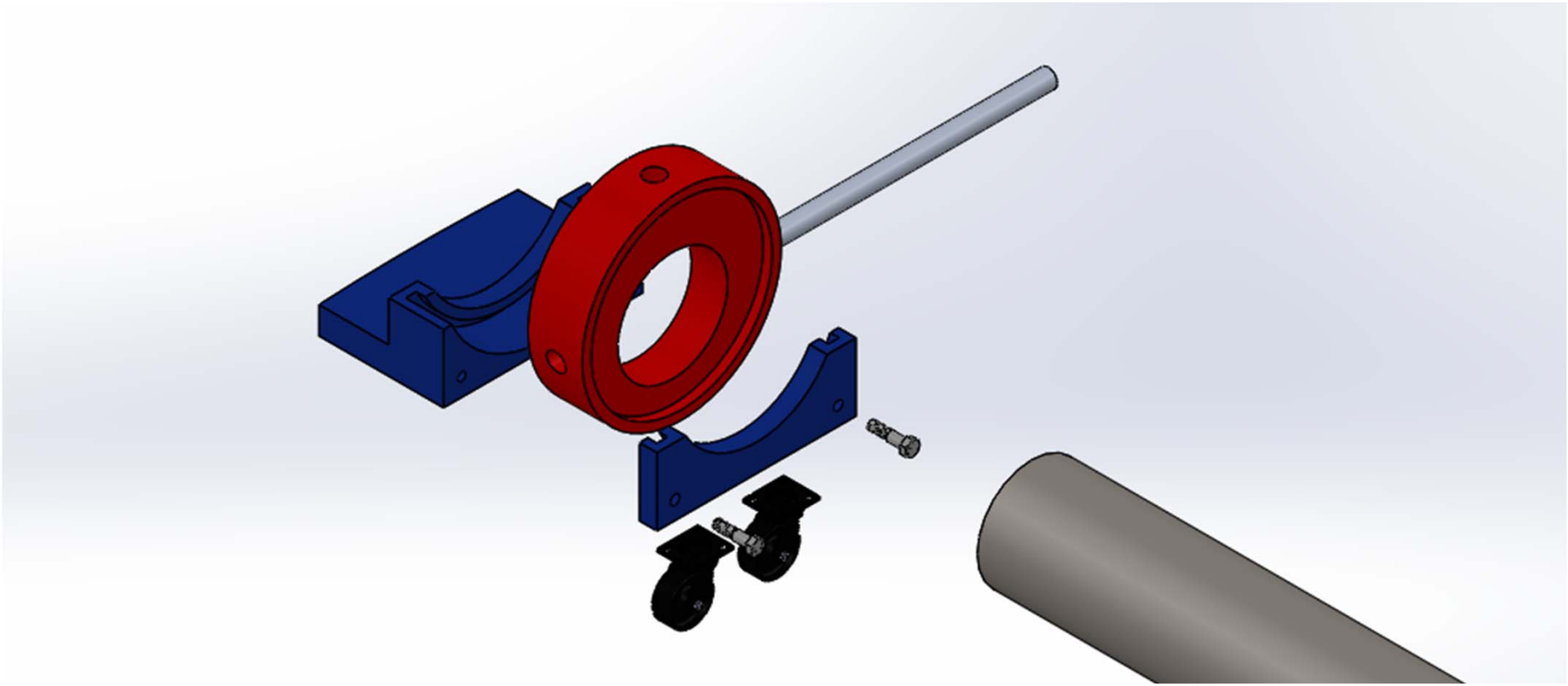


Brenda’s Sub-System





Cam Mechanism



Cost

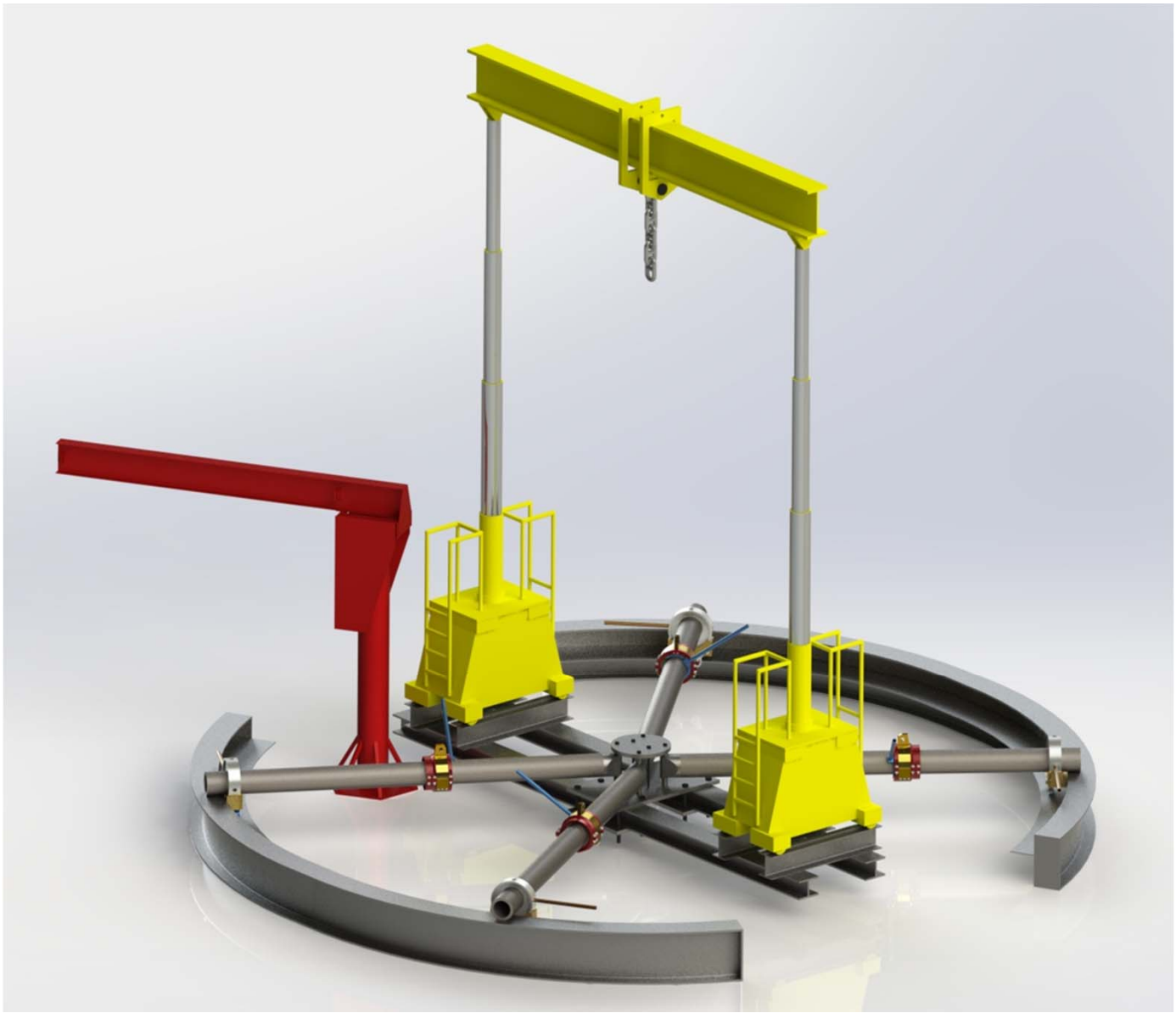
UPL Cost

COMPONENT	PART	PN	UI	QTY	Price	Part Subtotal	Component Subtotal
LIFTING SYSTEM	LIFT SYSTEMS GANTRY 22A		EA	1	$125,000.00	$125,000.00	
	CHAIN		EA	1	$2,619.00	$2,619.00	
	SUM						$127,619.00
ADJUSTER-42	SHELL RAW MATERIAL		EA	8	$450.00	$3,600.00	
	LOOP RAW MATERIAL		EA	4	$1,800.00	$7,200.00	
	LOCKING RING RM		EA	4	$300.00	$1,200.00	
	COLLET-WEDGES RM		PR	4	$1,800.00	$7,200.00	
	HARDWARE		ST	4	$206.00	$824.00	
	LABOR		HR	200	$125.00	$25,000.00	
	SUM						$45,024.00
CAM MECHANISM	CAM - MATERIAL		EA	1	$3,000.00	$3,000.00	
	LIP - MATERIAL		EA	1	$2,000.00	$2,000.00	
	LABOR		HR	100	$125.00	$12,500.00	
	CASTER		EA	8	$100.00	$800.00	
	OD 2" x 0.25" x 48" TUBE		EA	4	$60.00	$240.00	
	SUM						$18,540.00
LEGS	TUBES		4 EA	1	$7,000.00	$7,000.00	
	COATING	TRACLON	EA	1	$2,000.00	$2,000.00	
	LABOR		HR	100	$125.00	$12,500.00	
	SUM						$21,500.00

UPL Cost

COMPONENT	
LIFTING SYSTEM	$127,619.00
ADJUSTER-42	$45,024.00
CAM MECHANISM	$18,540.00
LEGS	$21,500.00
LOAD MEASUREMENT	$9,922.00
CENTER STRUCTURE	$39,600.00
PIN ADAPTER	$2,836.00
[redacted]	
TOTAL	$265,041.00

Added Capabilities

Our Universal Proofloader Will:

- Proofload <u>all</u> known slings <u>in their usage configuration.</u>
  - No more contracting out proofloading of slings.
  - No more time lost shipping slings to other FRC locations.