68K Blade Process Handling

Final Presentation

TECT Power

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Overview

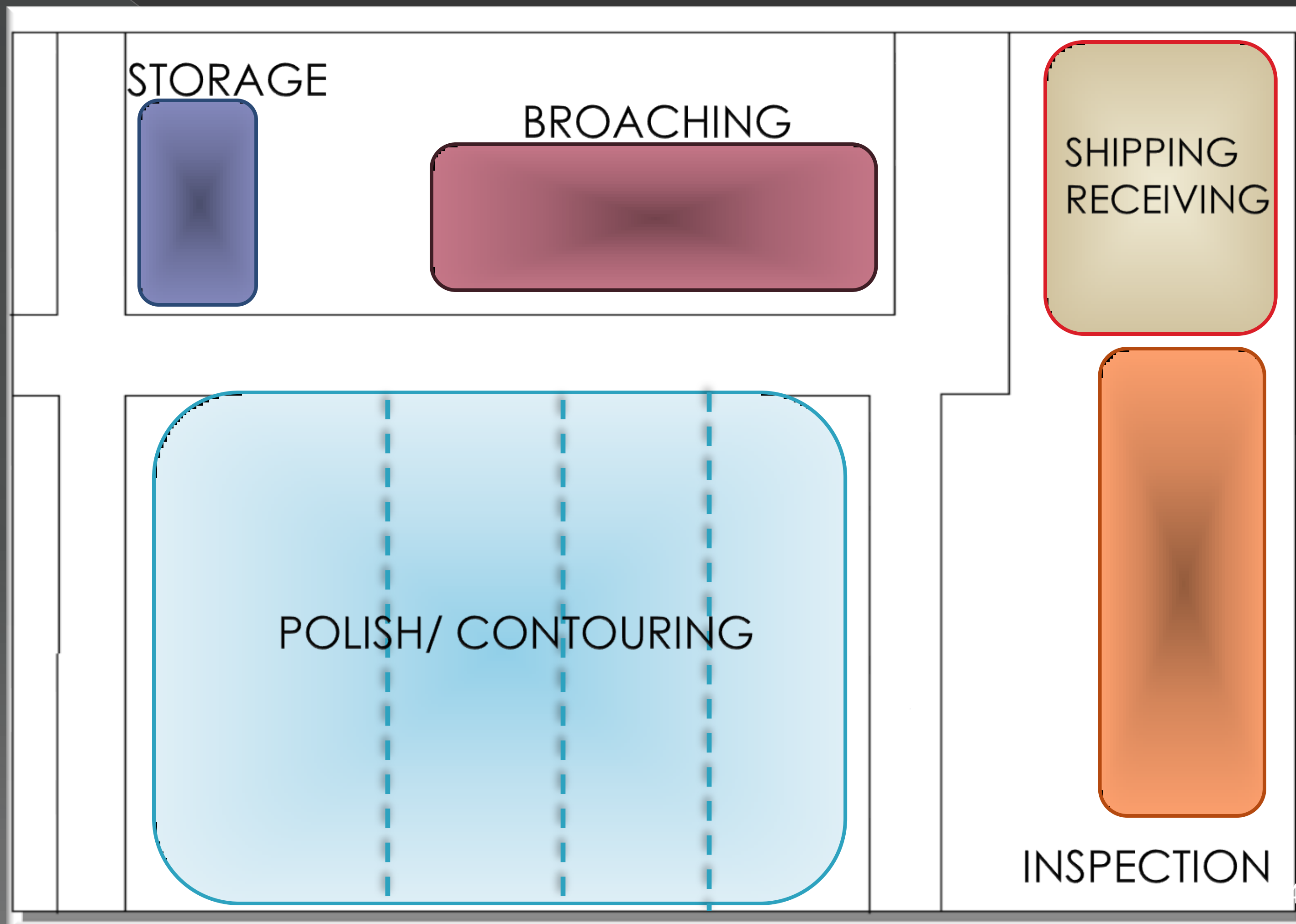
- Introduction
  - TECT Power
- Problem Assessment
- Design
- Analysis
- Results
- Optimization
- OSHA standards
  - Lifting
- Conclusion

Background

- TECT Power
  - Thomasville, Georgia
  - Sponsor: Ashok Patel
    - IE Environmental Health & Safety Manager, CSP,CHMM
- 68k turbine blades
  - 2000 68k per year, 7-8 per day
  - Weigh 45 lbs

Courtesy of TECT Power

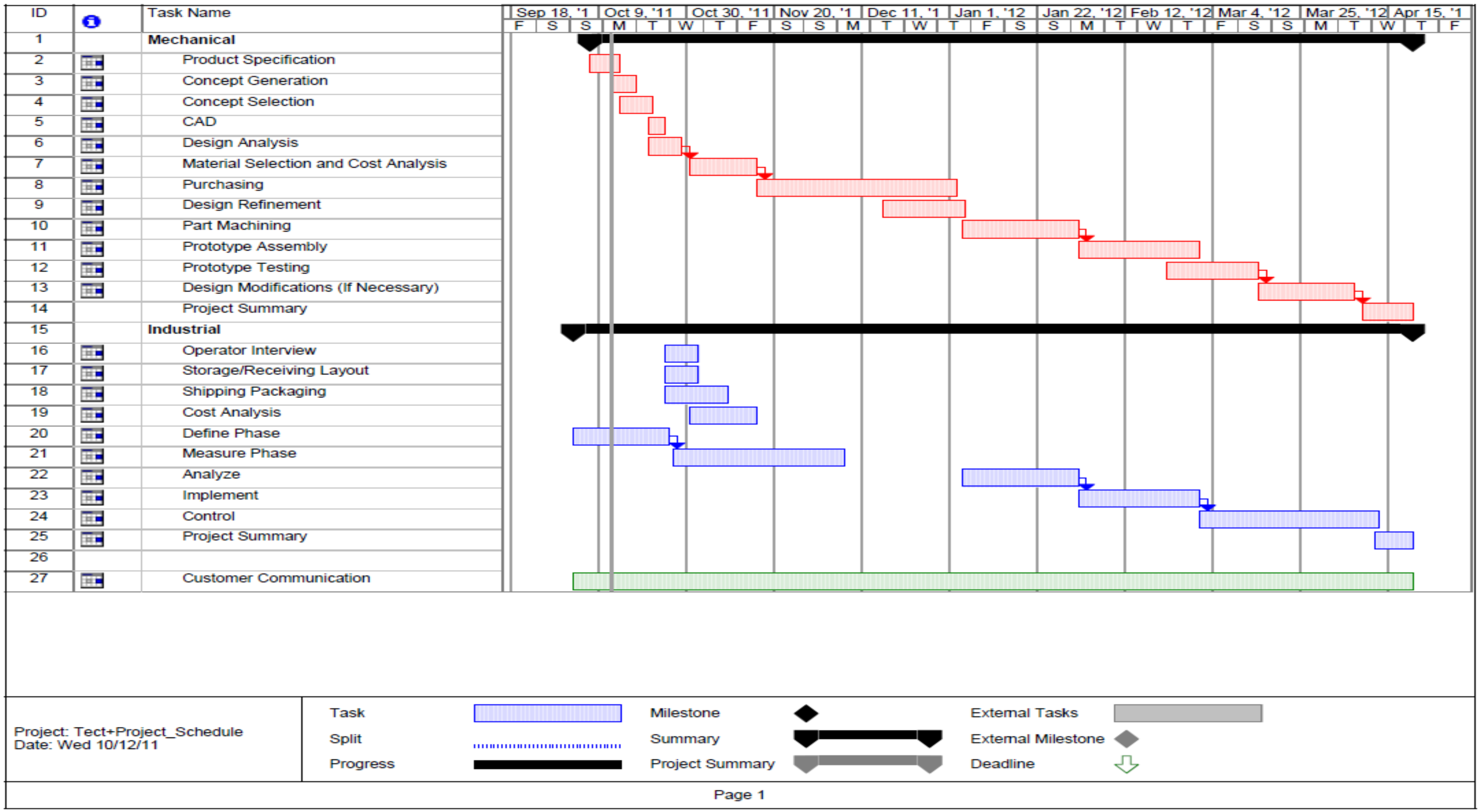
Plant Layout



Problem Statement

- Blade Handling Methods
  - Frequent lifting
  - Machine loaded by hand
  - Exclusive to specific population
- Storage Container Design
  - Stationed at ground level
  - Disorganized
- 1st Milling Fixture
  - 8 inch oil bed
  - Horizontal mount
- Safety
  - Injury performance rate: 4.3 recordable injuries per 100 employees annually at Thomasville site

Project Schedule



Needs Assessment

- Customer requests lifting be removed from process
  - Reduce potential for injury
- Mechanism to perform lift/carrying tasks
  - Replace lifting and carrying performed by operator
- Constraints
  - No stationary industrial lifts/cranes
  - Budget: $4,000

Voice of the Customer

- Redesign the receiving container
  - Redesign storage area layout
- Design and fabricate a blade handling mechanism
  - Easy maneuverability
  - Stability

Product Specification

- The Mechanical Design Must:
  - Carry a minimum of 45lb
  - Be able to extend the blade between 2-5 feet
  - The device cannot exceed allowable path dimensions
- The Process Redesign Must:
  - Maintain or improve efficiency
  - Not be operator exclusive
  - Reduce time spent between machining

Concept Generation

- Concept Generation
  - Barrel design
  - Conveyor system
  - Cart-in-Cart
  - L-Cart
  - Vehicle mounted lift
- Storage Area
  - Variously oriented containers
  - Elevated roller table

Decision matrix - Factors

Mechanism	Cost	Width	RULA
Barrel	$ 1200	44	3
L-Cart	$ 1860	60	3
Conveyor	$ 11000	N/A	7
Vehicle	$ 13899	45	3
~~Cart in Cart~~		~~44~~	~~7~~

Decision Matrix

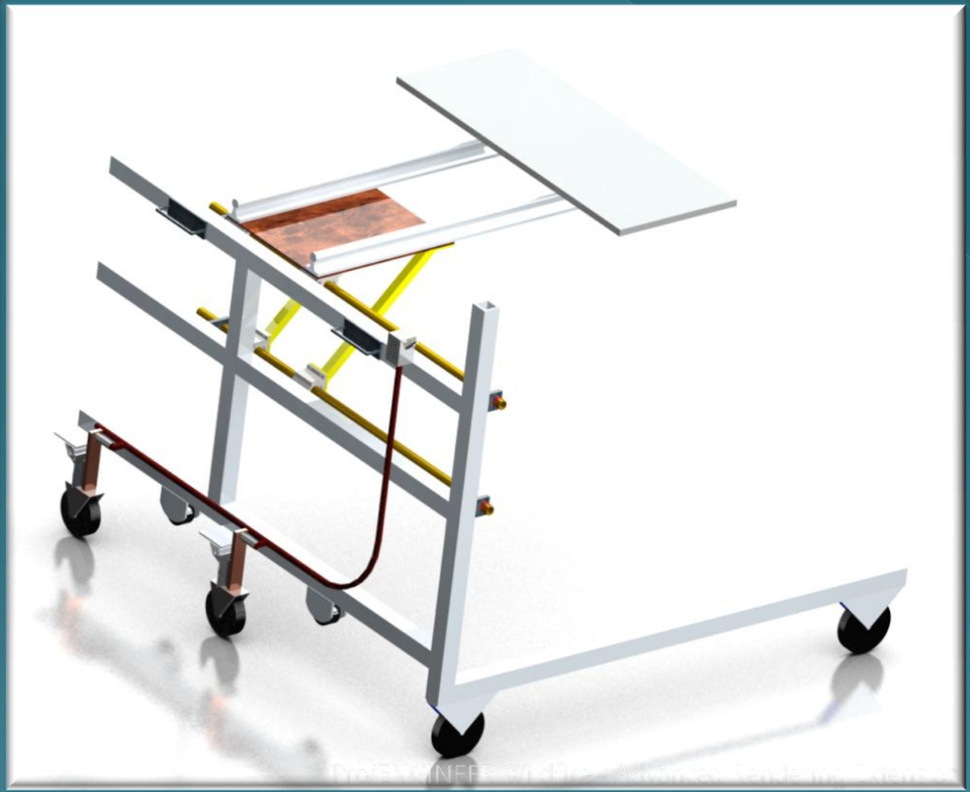
Factors	Weight	Cart-in Cart	Conveyor	Vehicle	Barrel	L-Cart
RULA	0.45	2.5	7.8	9.6	8.9	8.2
Cost	0.25	8.6	1.6	2	7.76	7
Maneuverability	0.15	8.6	9	1	7.8	6.4
Durability/Maintenance	0.15	7.8	4	8	8.2	7.9
TOTAL (max 10)	1	5.74	5.86	6.17	8.34	7.58

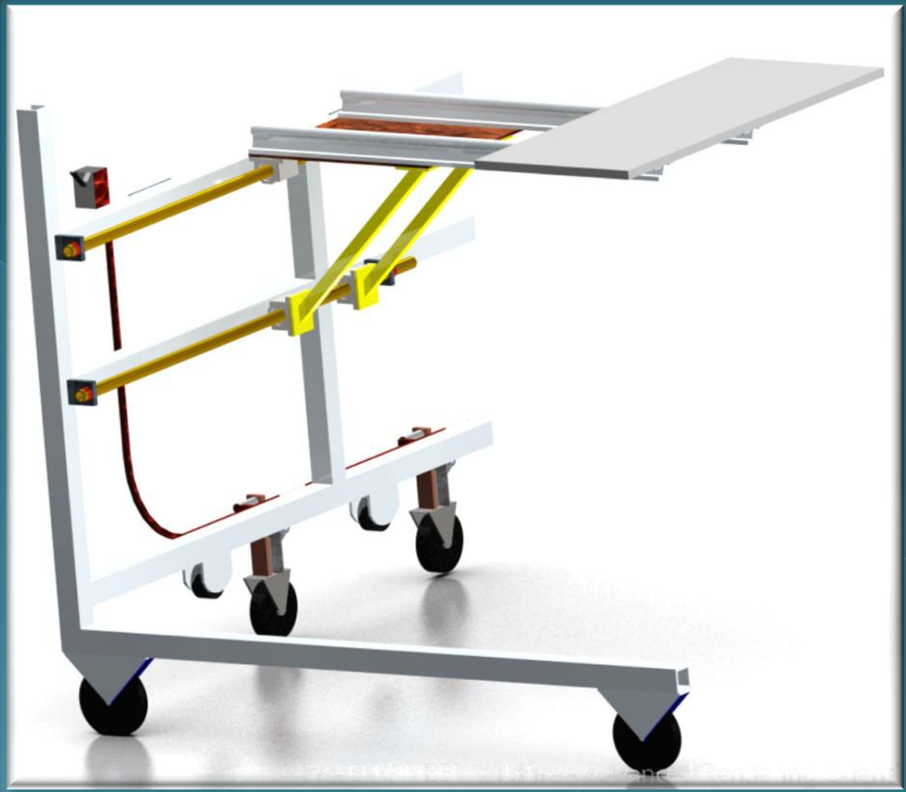
Concept Selection

- Most feasible
  - L-Cart
  - Barrel
  - Elevated storage table
- Compatibility
  - Storage table, container & Barrel
  - Barrel & L-Cart

- Rejected designs
  - Cart-in-Cart
    - Did not meet ergonomic requirements
  - Conveyor
    - Exceeds budget
  - Vehicle mounted lift
    - Exceeds budget
    - Adversely effect mobility

Design - L-Cart

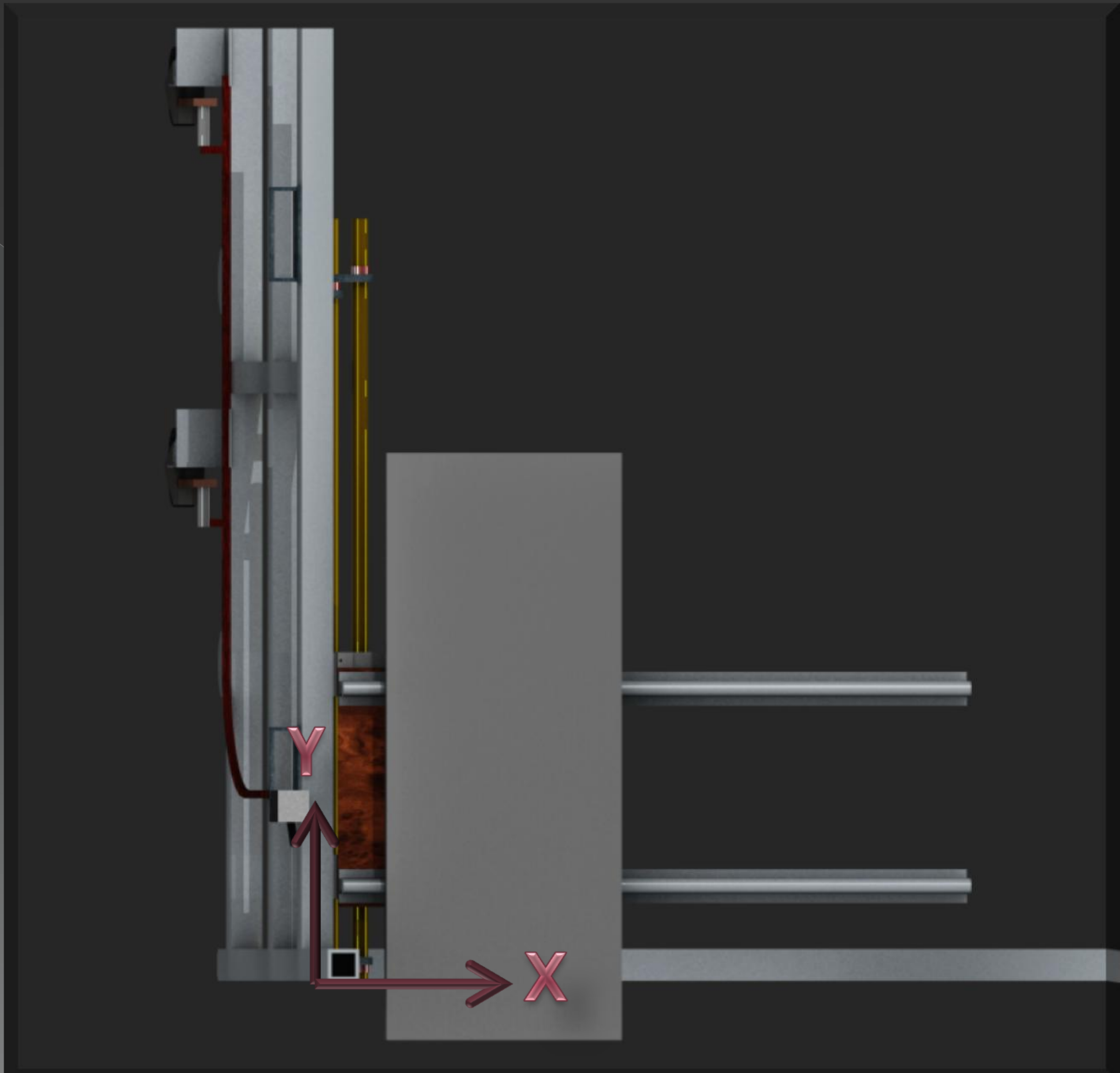




Overview Design Analysis Materials Selection Conclusion

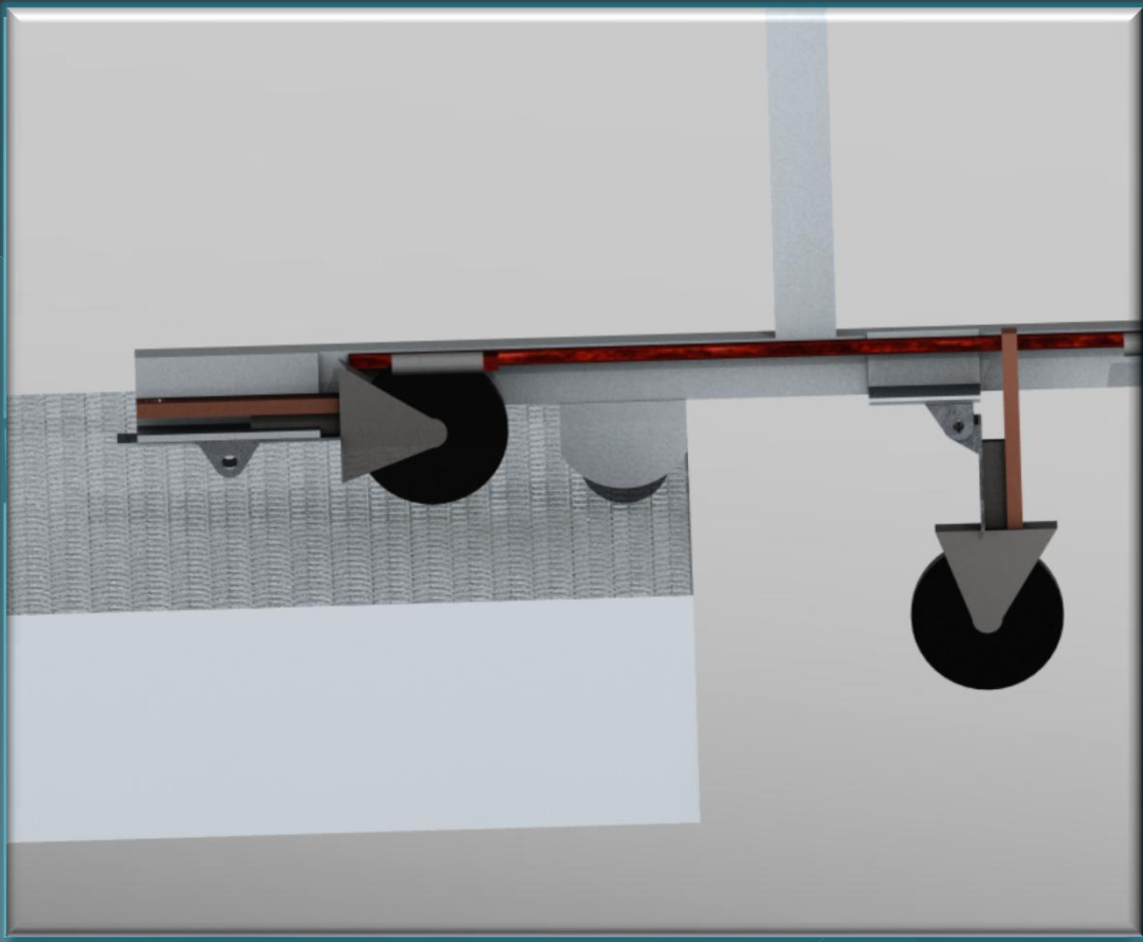
Design - L-Cart Slide

- Dual Axis Control
  - Three sets of sealed linear bearings
  - Lower set supports platform
  - Upper Set Holds blade

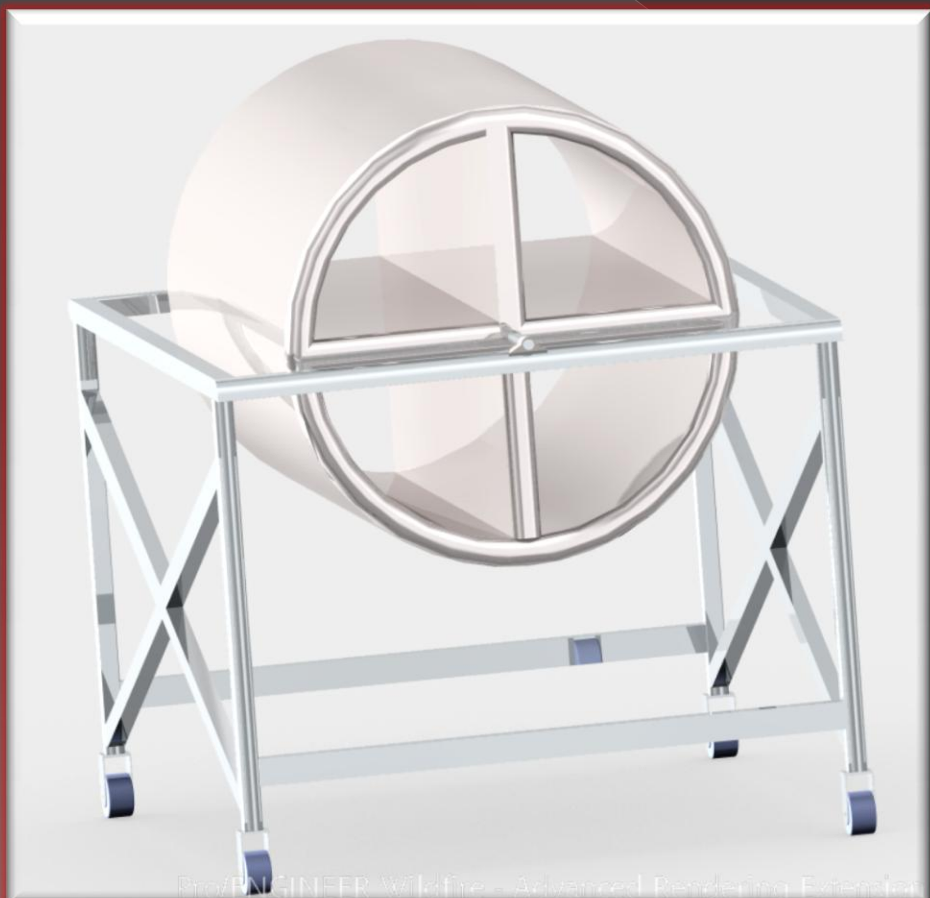


Design – L-Cart Folding Wheels

- Hinged wheels
  - Cable release mechanism
- Fixed Casters
  - Support when on an oil bed

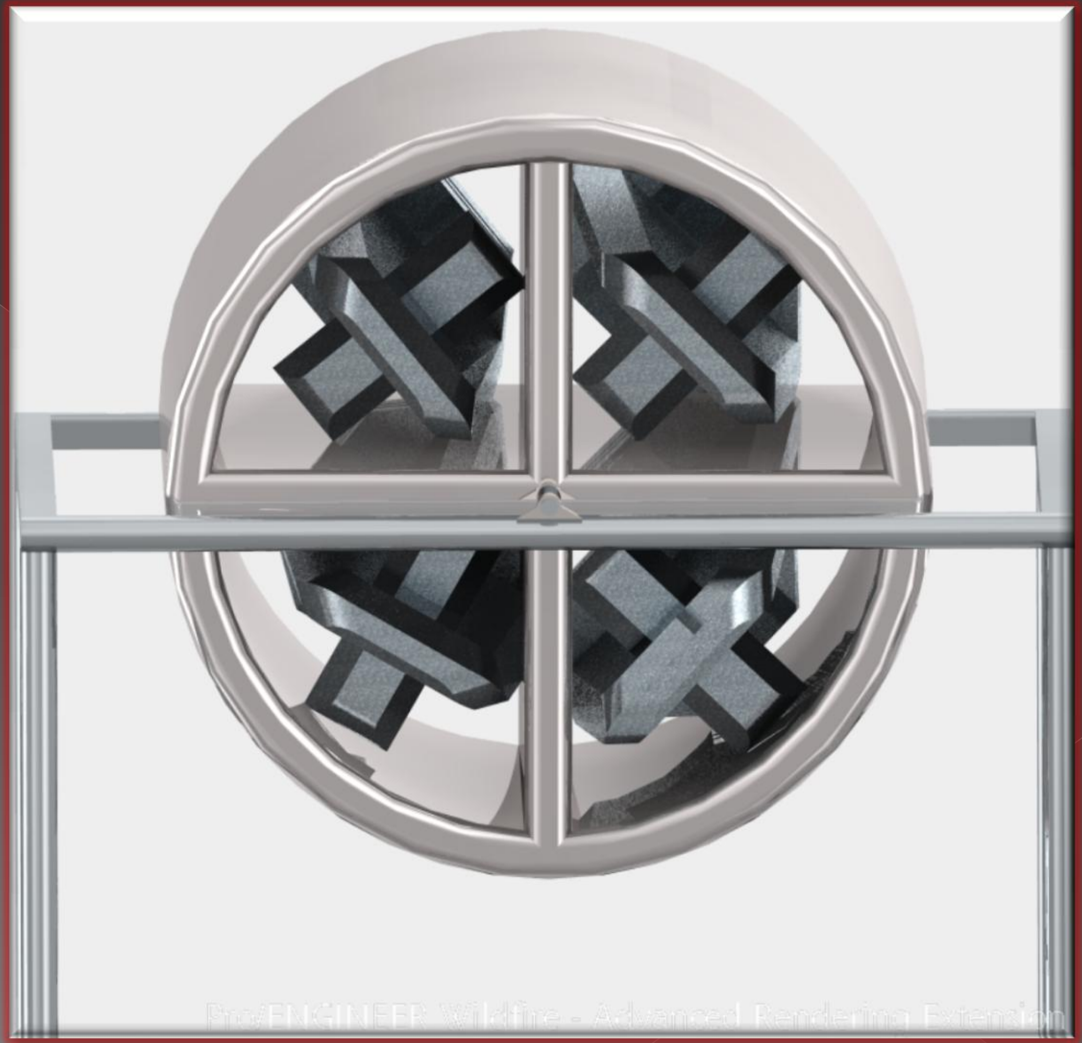


Design – Barrel Cart

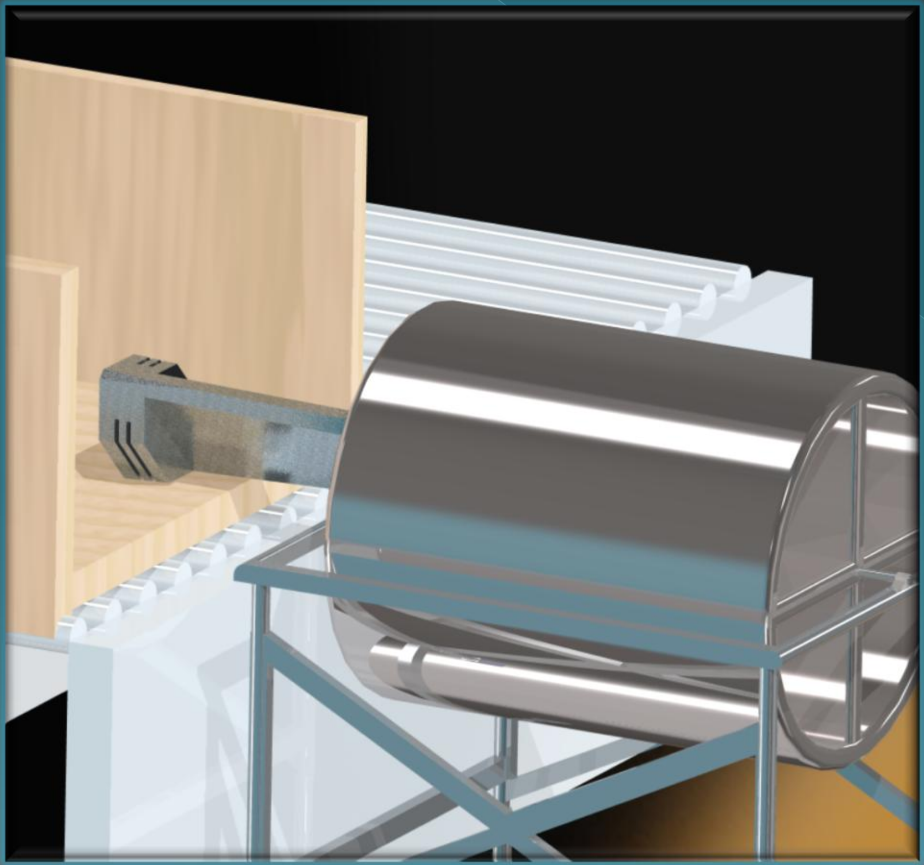


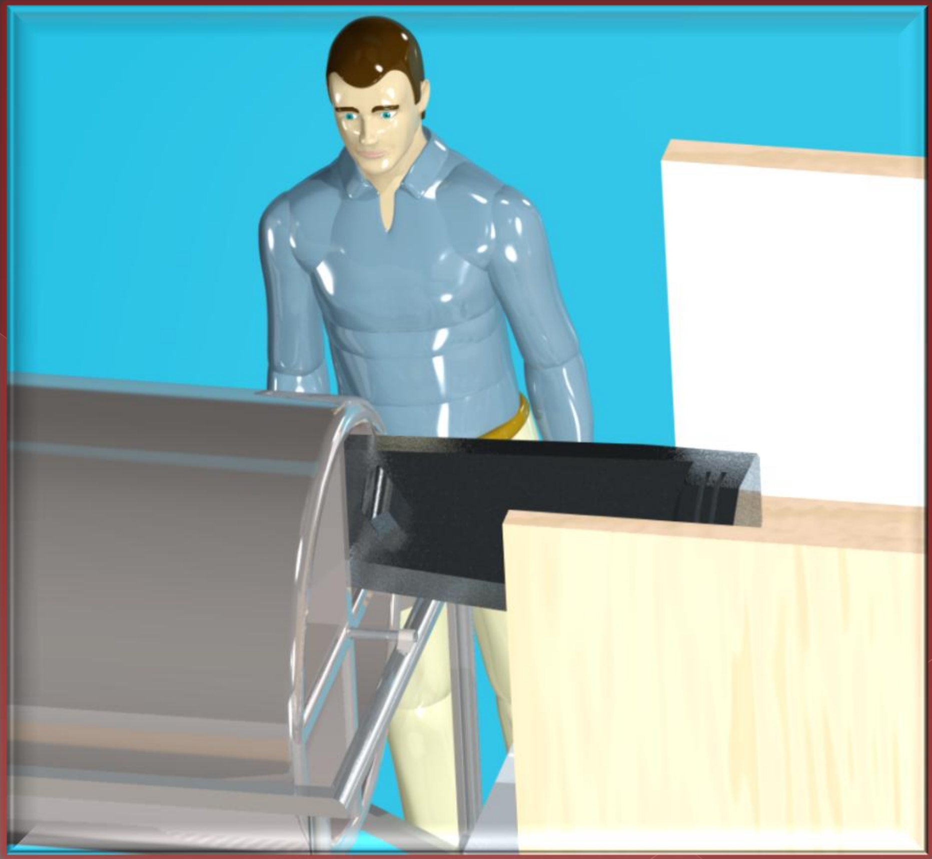
Design – Barrel Containment

- Rotating Container
- Multiple Blades Stored
- Used for transport
- Spring Loaded Locking Pin



Design – Barrel Loading



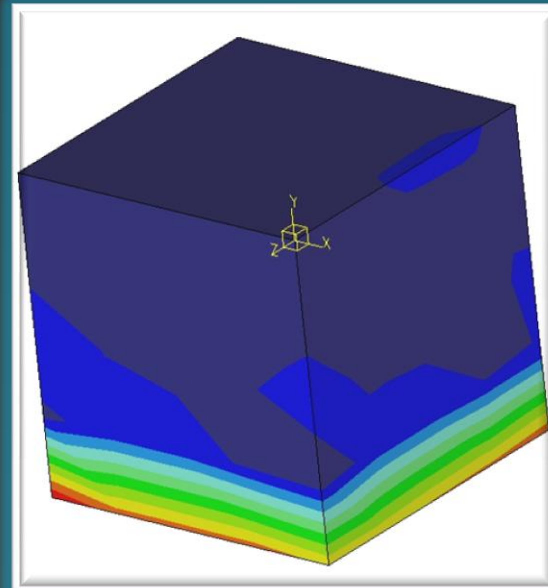


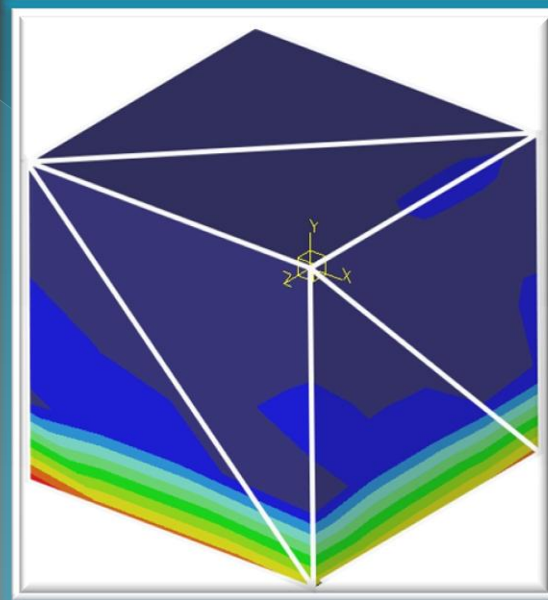
Design – Cart Connections

- Designed For Easy Loading
- Locks Prevent Platform Motion
- Brakes on Cart Wheels Prevent Separation

Analysis –FEA Methodologies

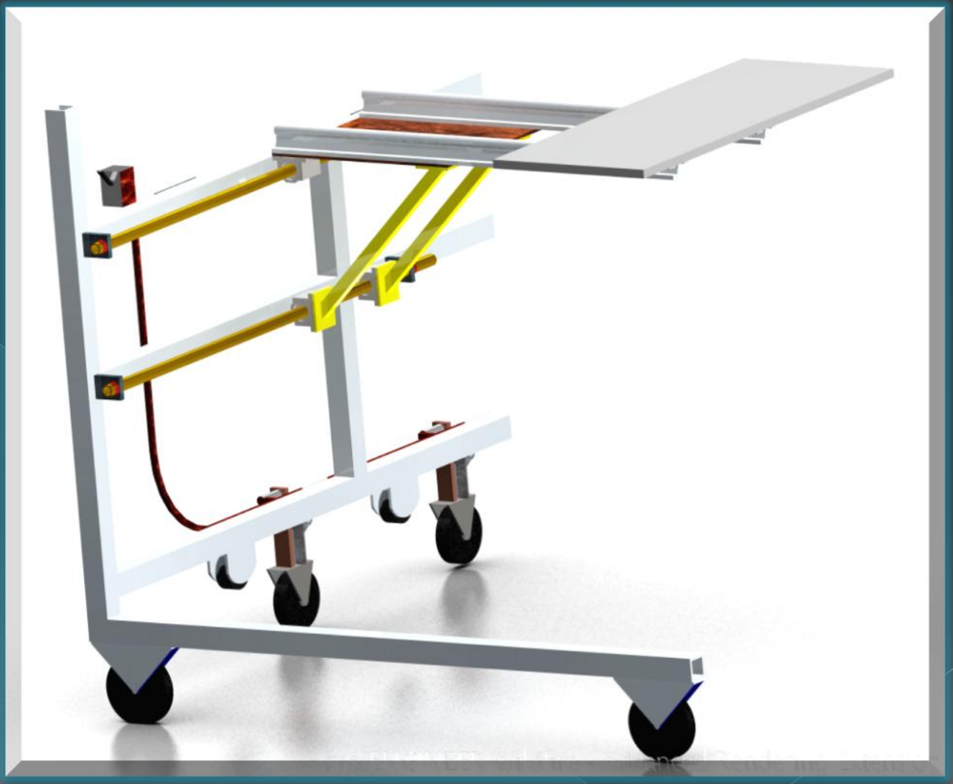
- Pro E Mechanica
  - Separates the parts into a mesh of elements
  - Geometric Elements
  - Higher order polynomial equations (P Element) to solve
  - Adaptive Passes to converge within error





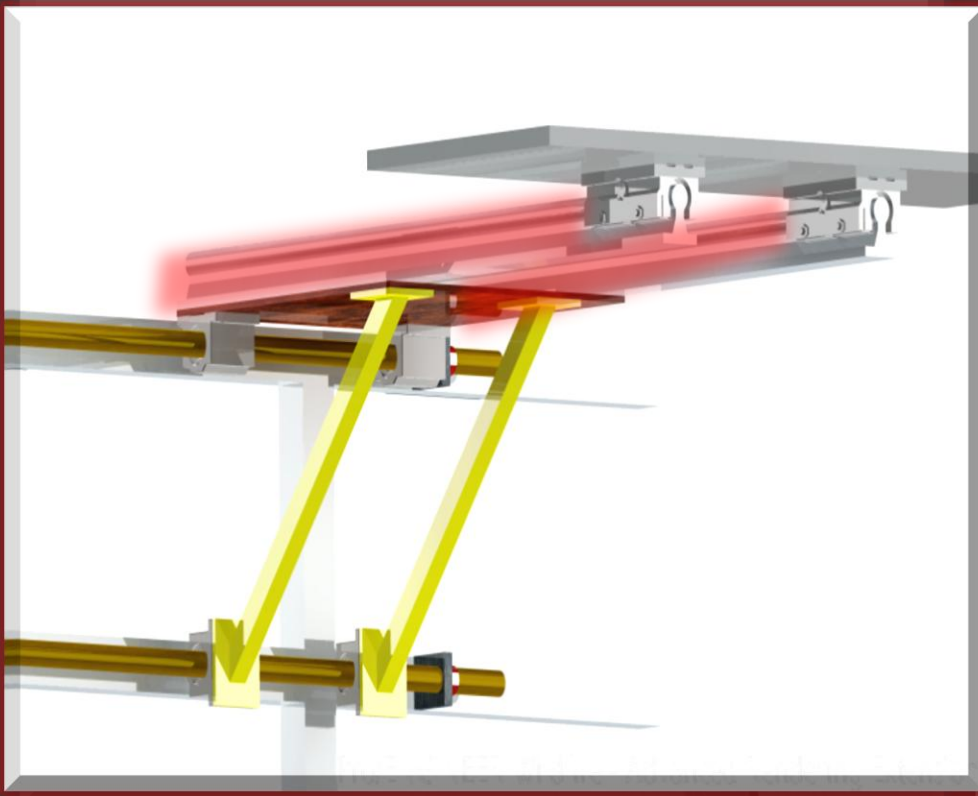
Analysis – L-Cart

- Assumptions
  - Load Used: 150lbf
  - Location: Worst case scenario
    - Maximum moment generation
  - Wheels can be left out of analysis based on dynamic load specifications



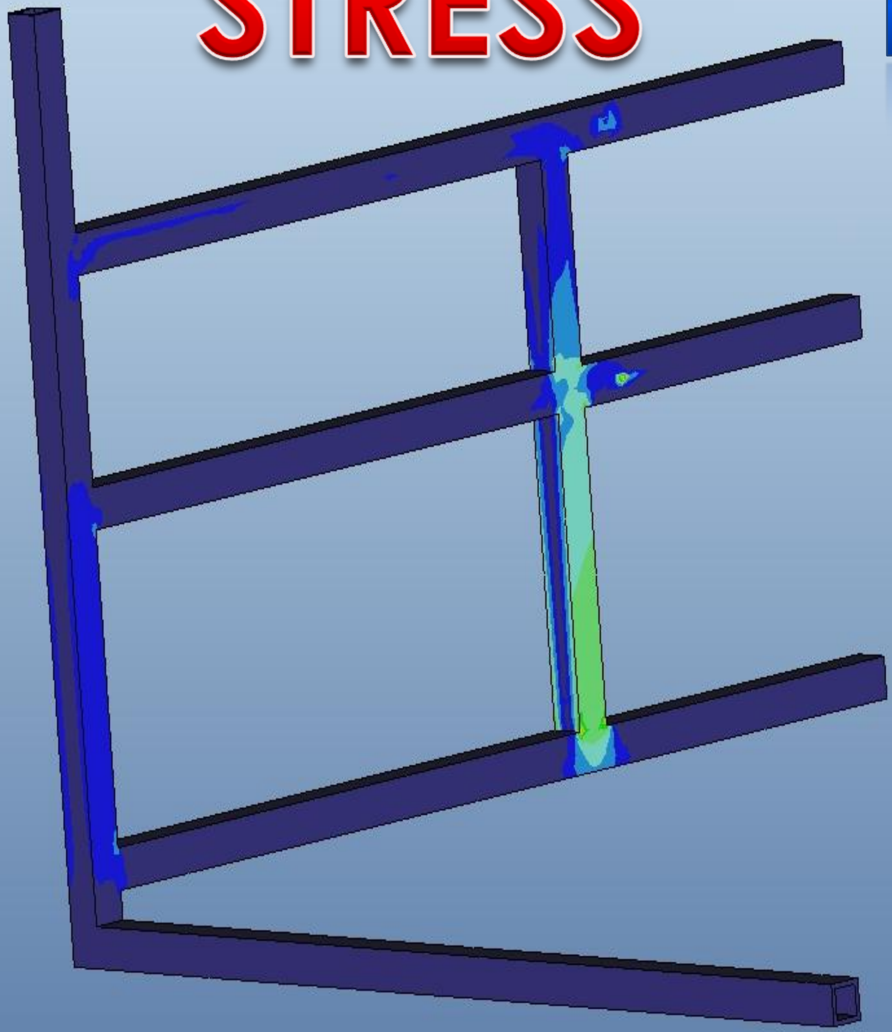
Analysis – L-Cart

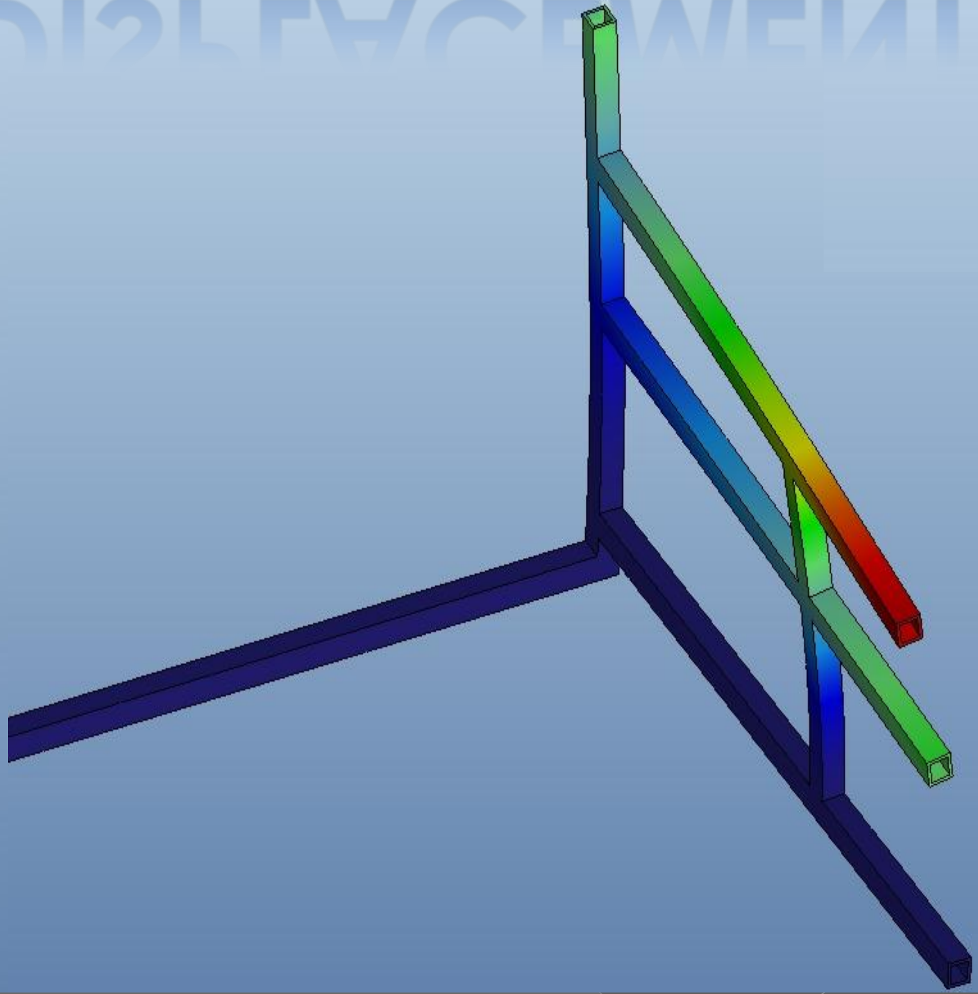
- Primary Analysis Locations
  - Base Frame
    - Load applied at rod mounts
  - Steel Bearing Rods
    - Point contact
  - Lower Platform Supports
    - Distributed load
  - Lateral Bearing Guide
    - Load applied at end



STRESS

DISPLACEMENT





3 ksi

$4*10^{-4}$ IN

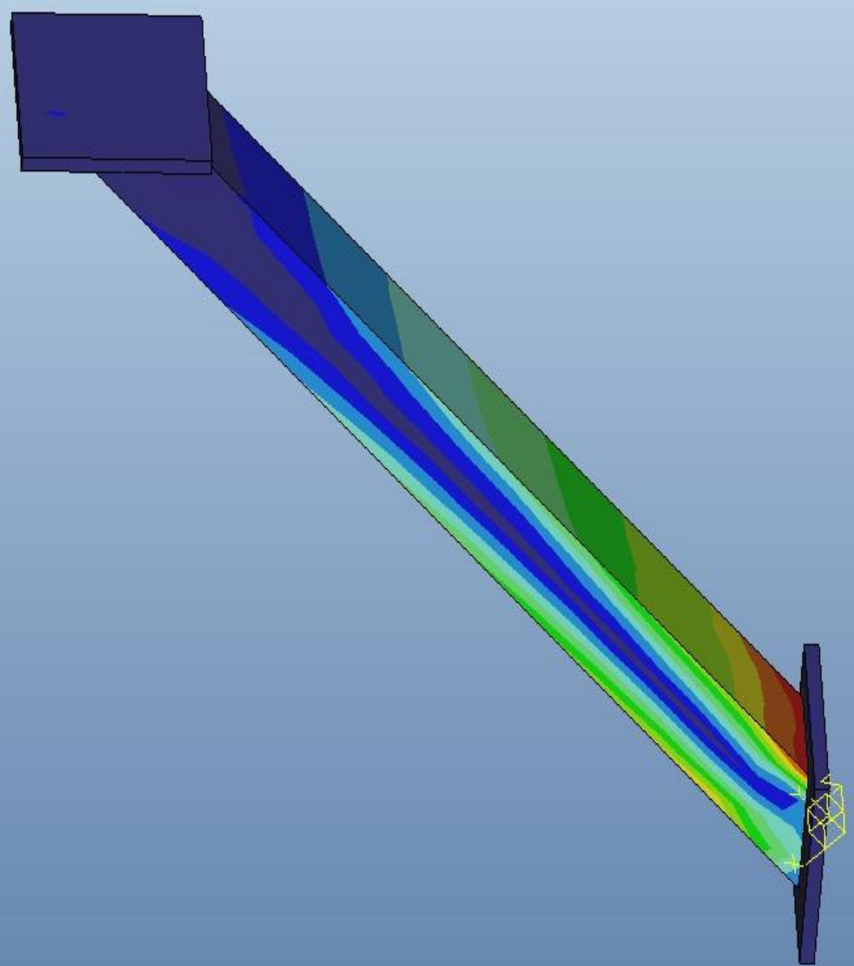
STRESS

DISPLACEMENT

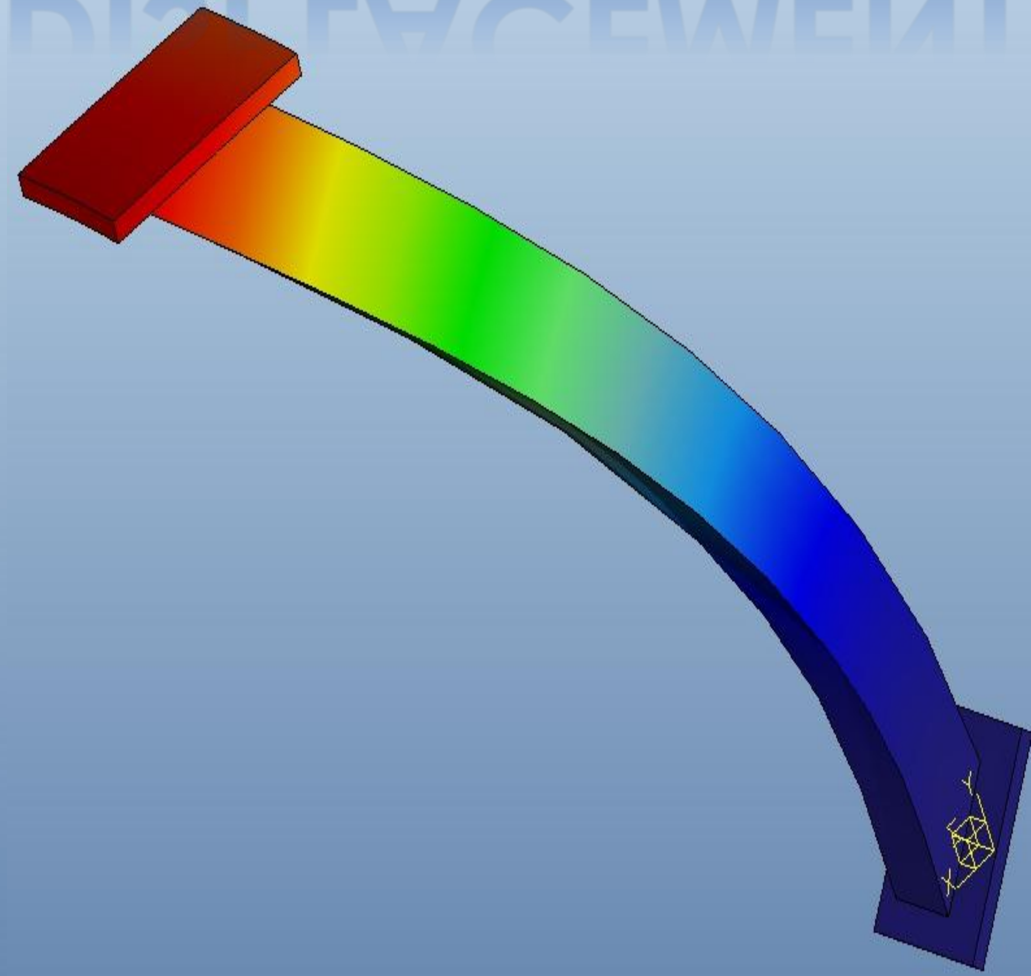
17.2 ksi

$9.5*10^{-2}$ IN

STRESS



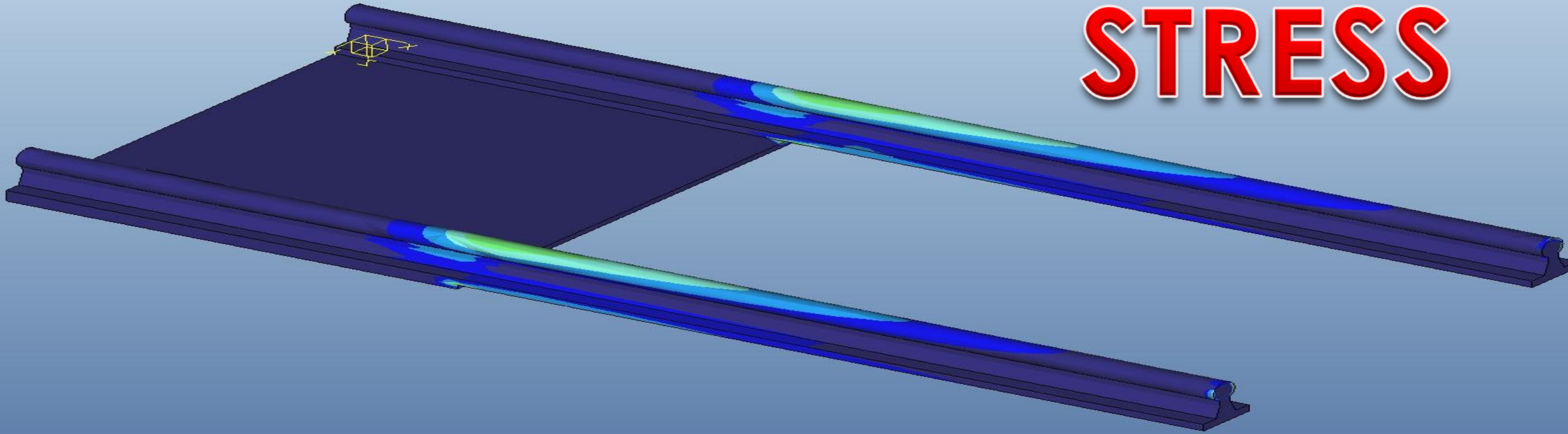
DISPLACEMENT



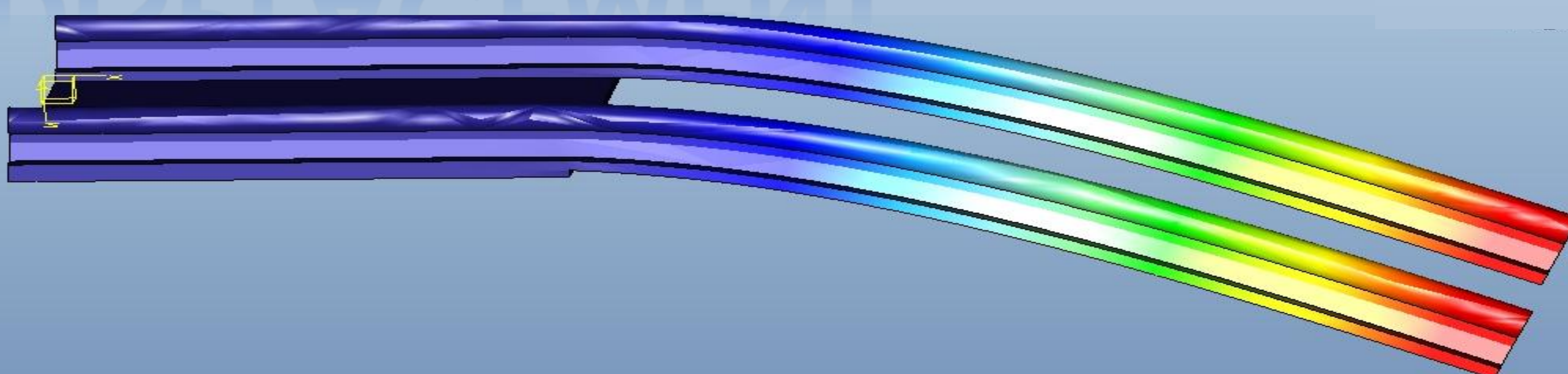
2 ksi

2.75×10^{-2} IN

STRESS



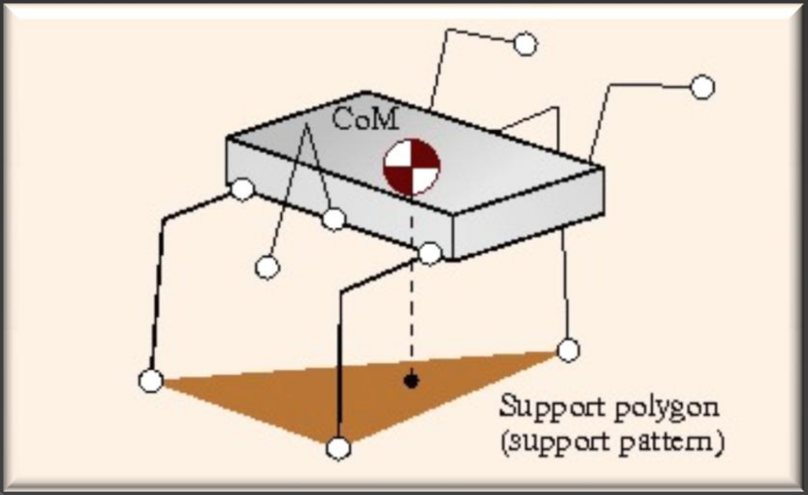
DISPLACEMENT



0.978 ksi

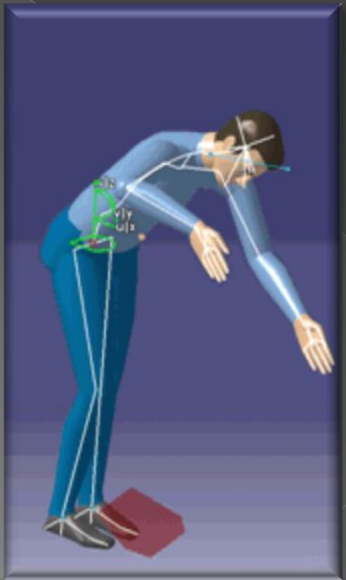
$2.14*10^{-2}$ IN

Stability Analysis Methodology



- Polygon of Support
  - Contact points create stable region
  - Center of mass must remain within the region

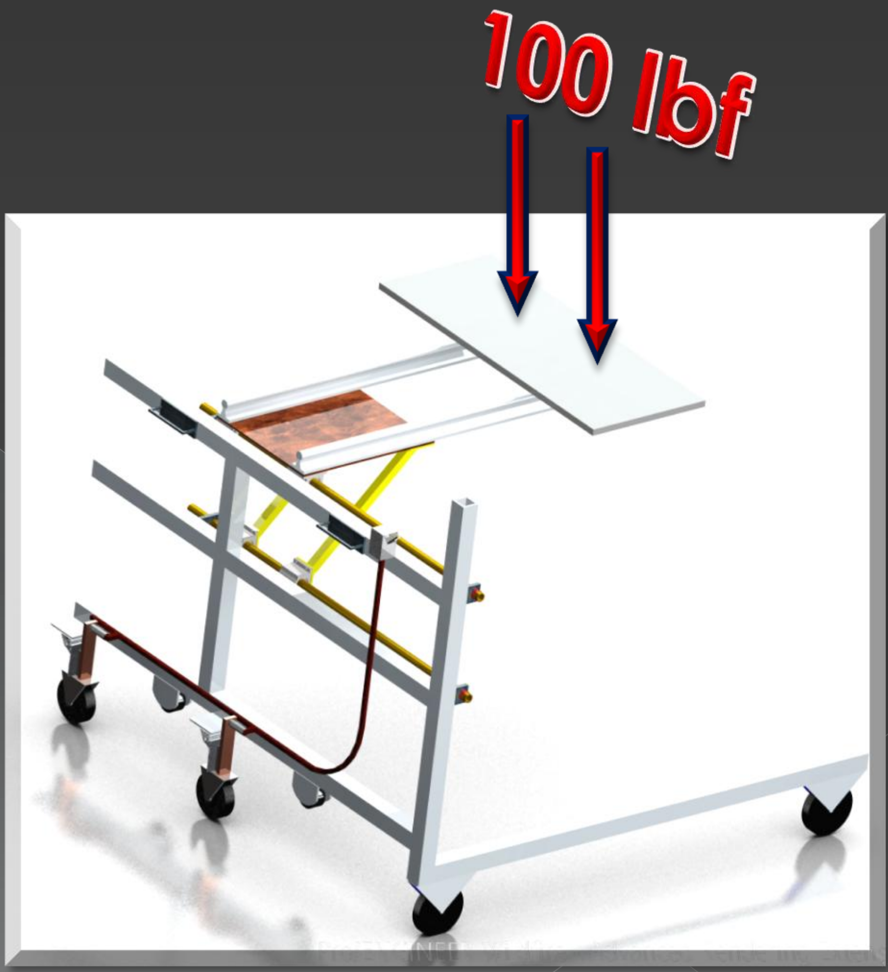
Stable



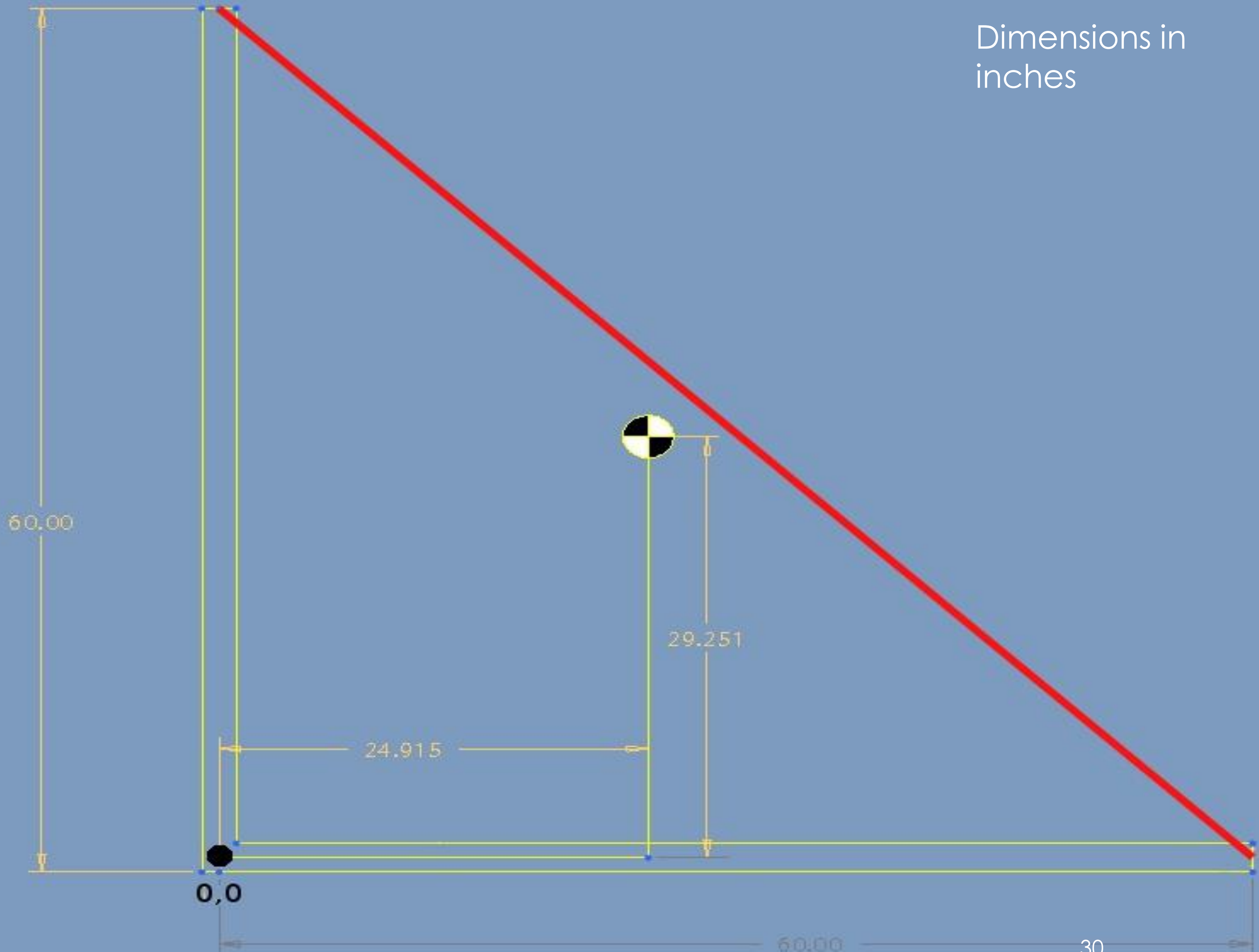
Unstable

Stability Analysis – L-Cart

- Load placed in farthest point
- Originally Unstable
  - Determined an additional 7 inches could be added to each leg
  - Addition 12 inches added to both legs



Dimensions in inches

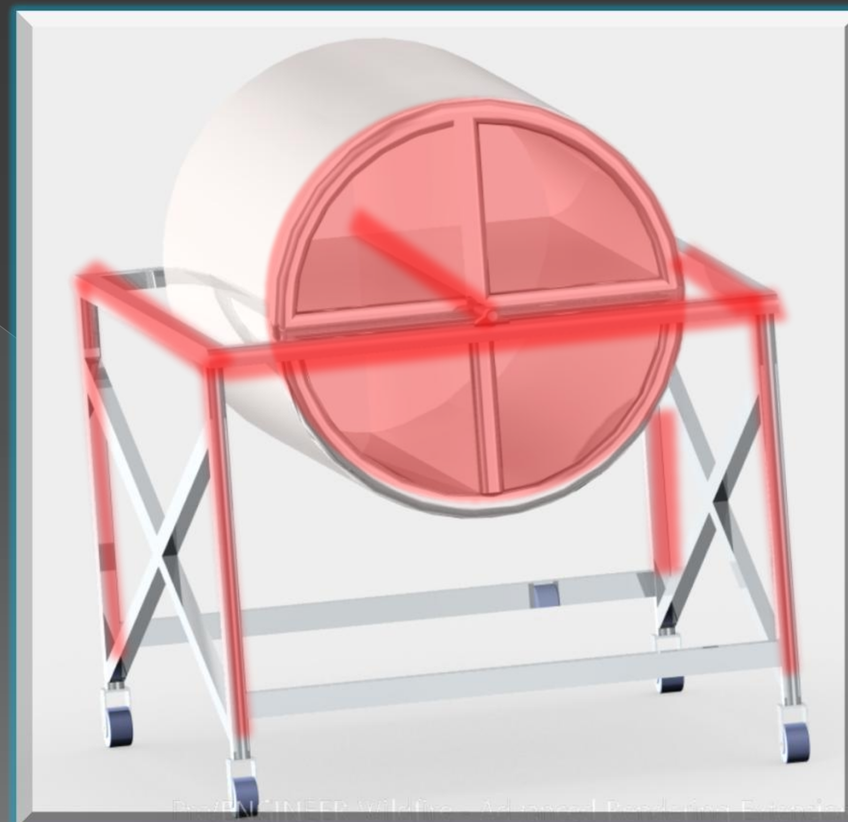


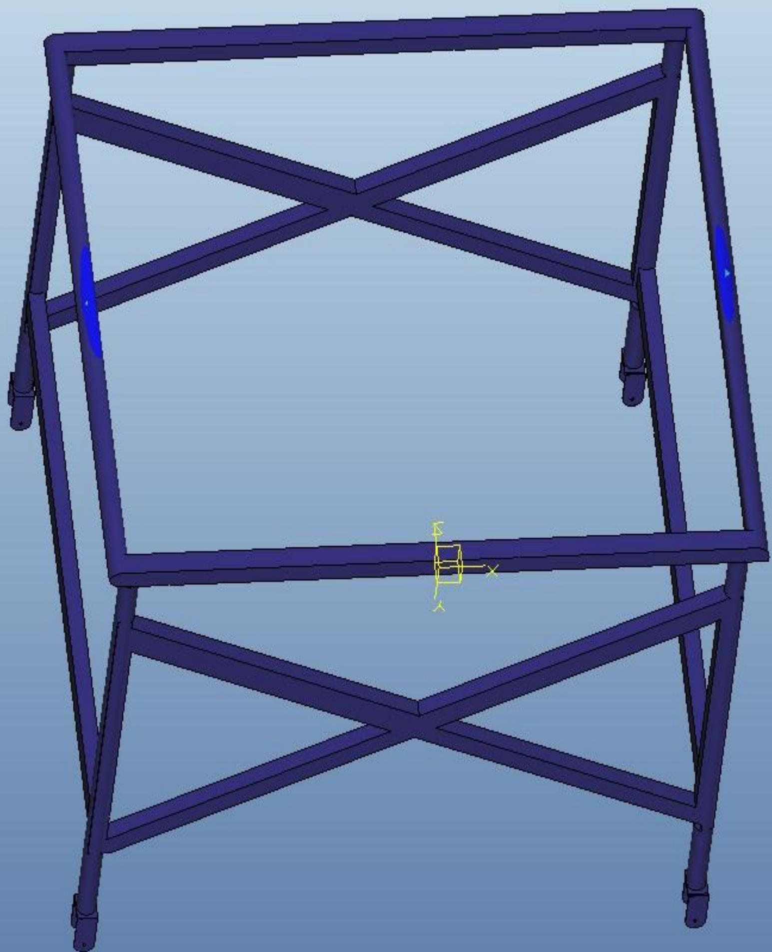
Analysis - Barrel

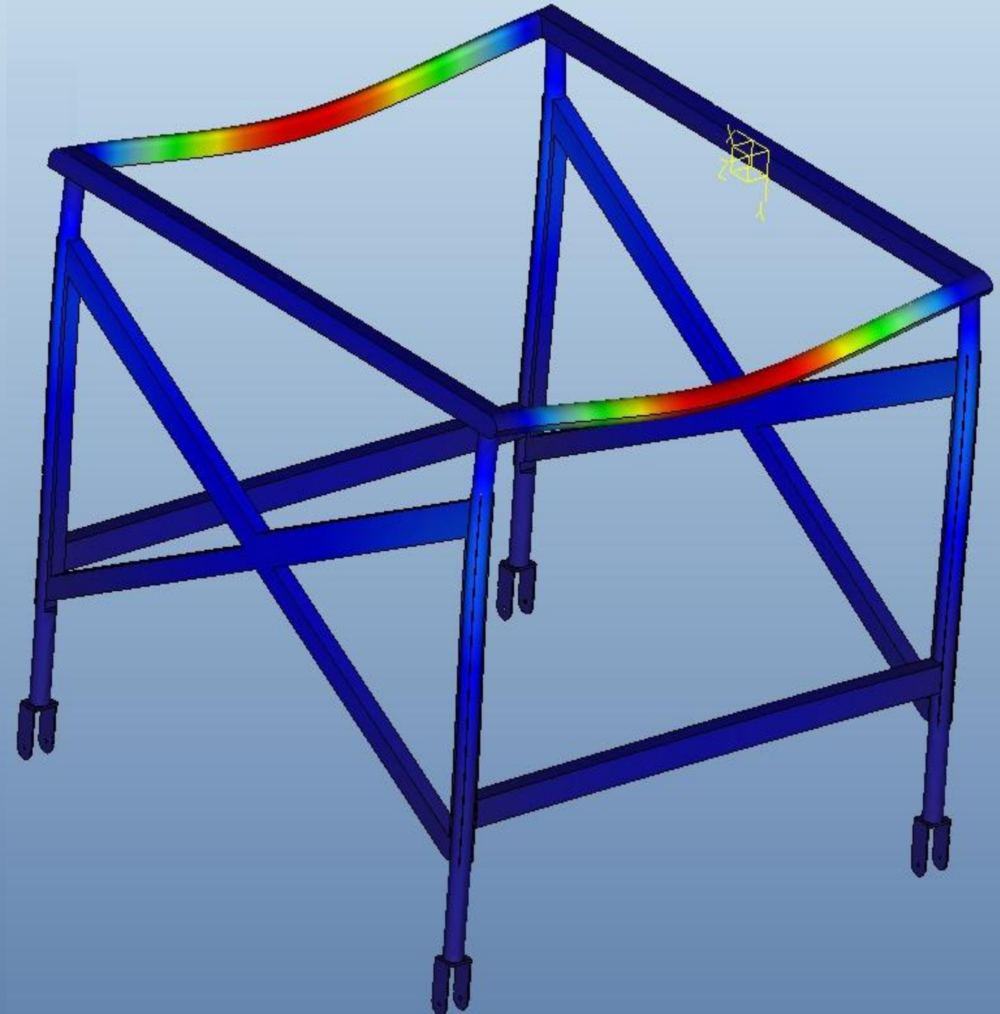
- Assumptions
  - Total Load being rotated: 500lbf
  - Wheels can be left out of analysis based off of dynamic load specifications

Analysis - Barrel

- Analysis Location
  - Overall Frame
    - Full load placed at bearing locations
  - Bearing Rod
    - Full load centered on rod
    - Full load distributed over rod
  - Barrel Surfaces
    - 100lbf loaded on areas supporting blades



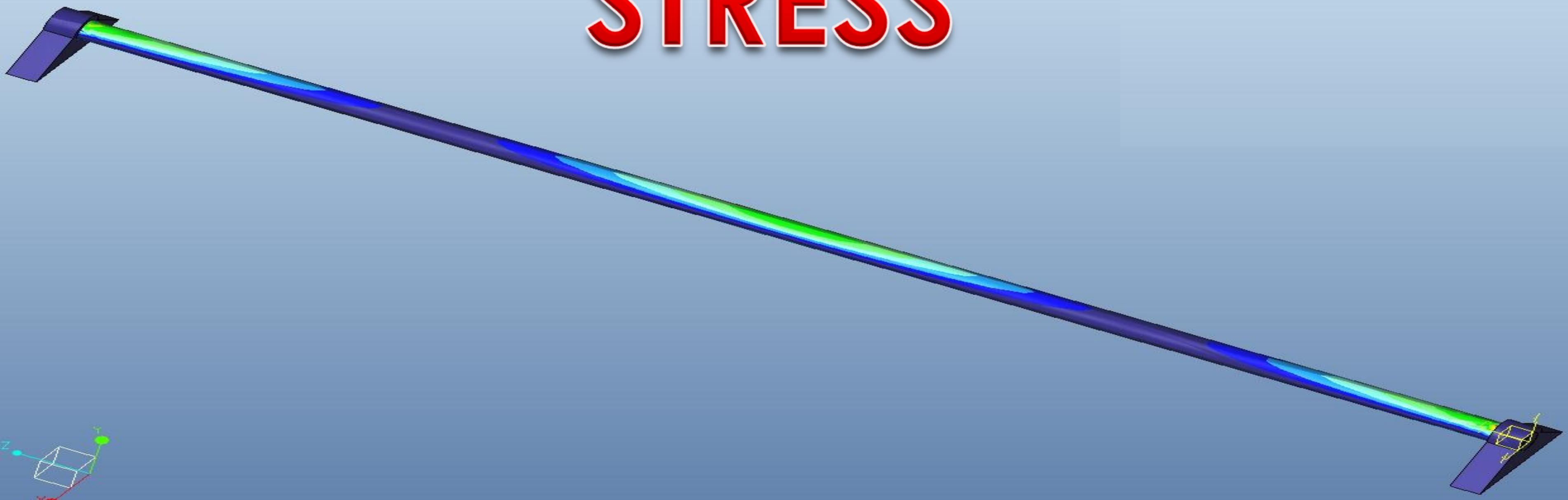




STRESS
4.58 ksi

DISPLACEMENT
$3.12*10^{-2}$ IN

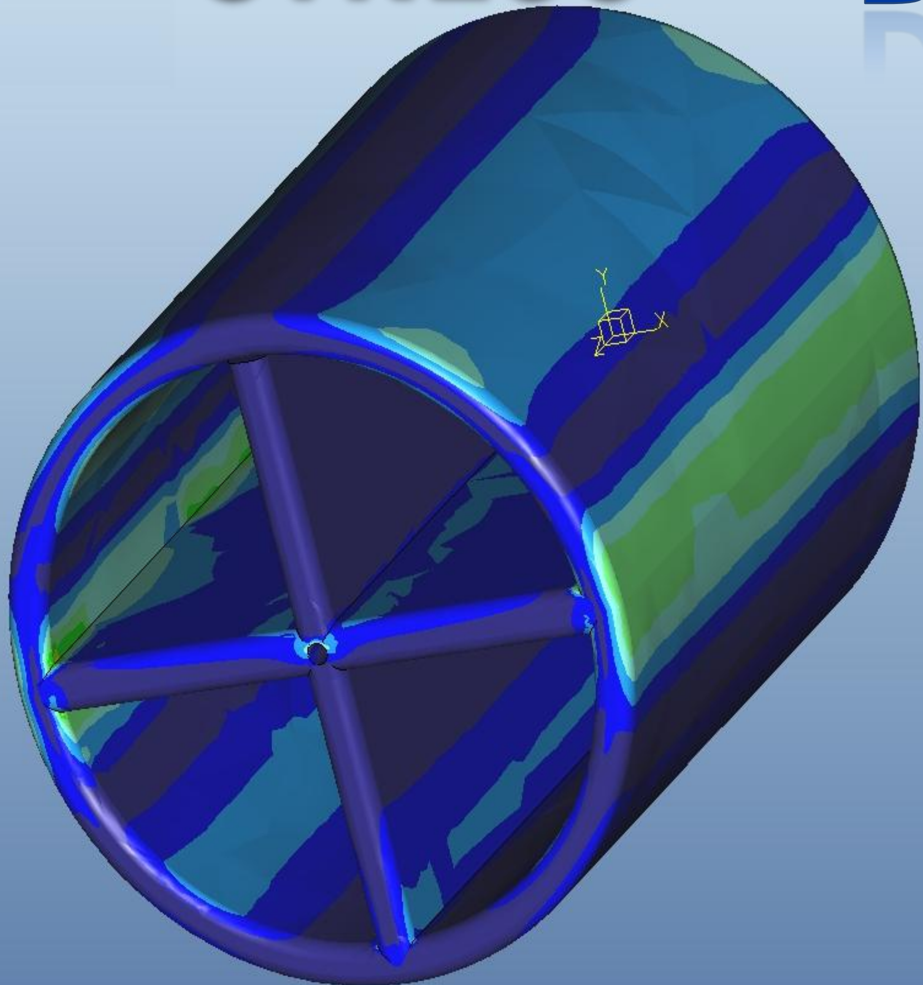
STRESS



DISPLACEMENT

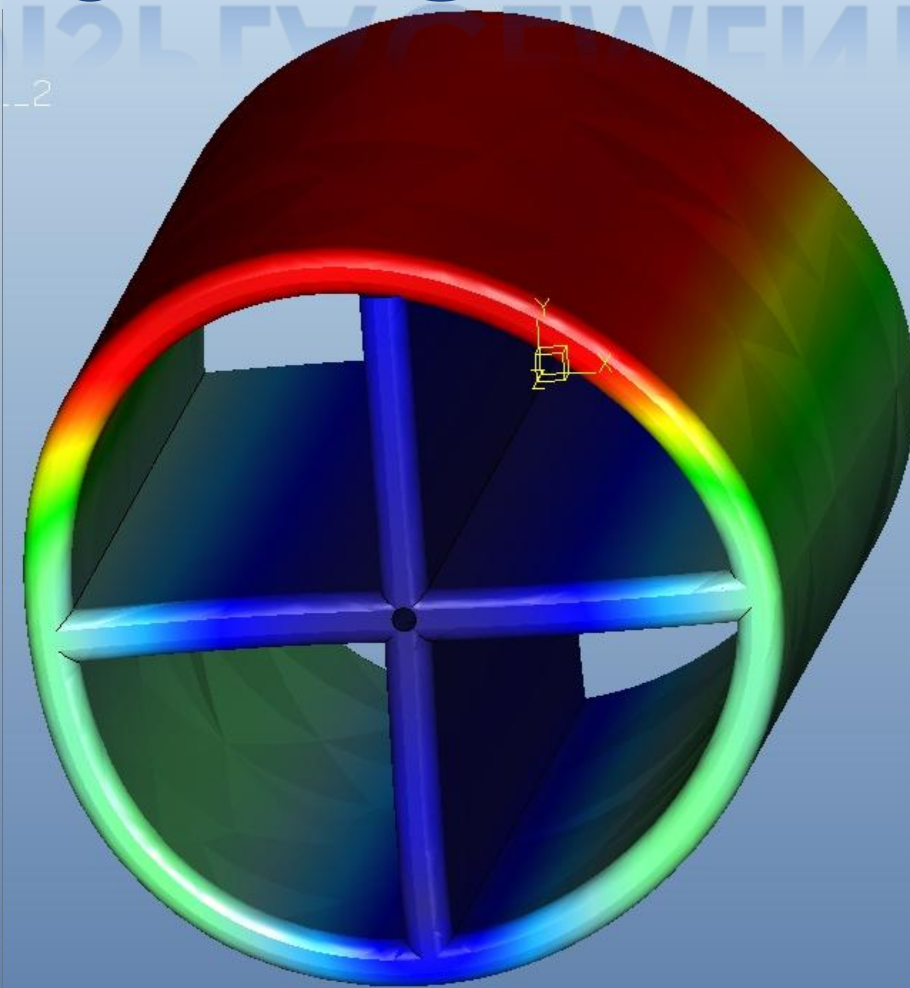
19.27 ksi **0.150 IN**

STRESS



$1.4*10^{-2}$ ksi

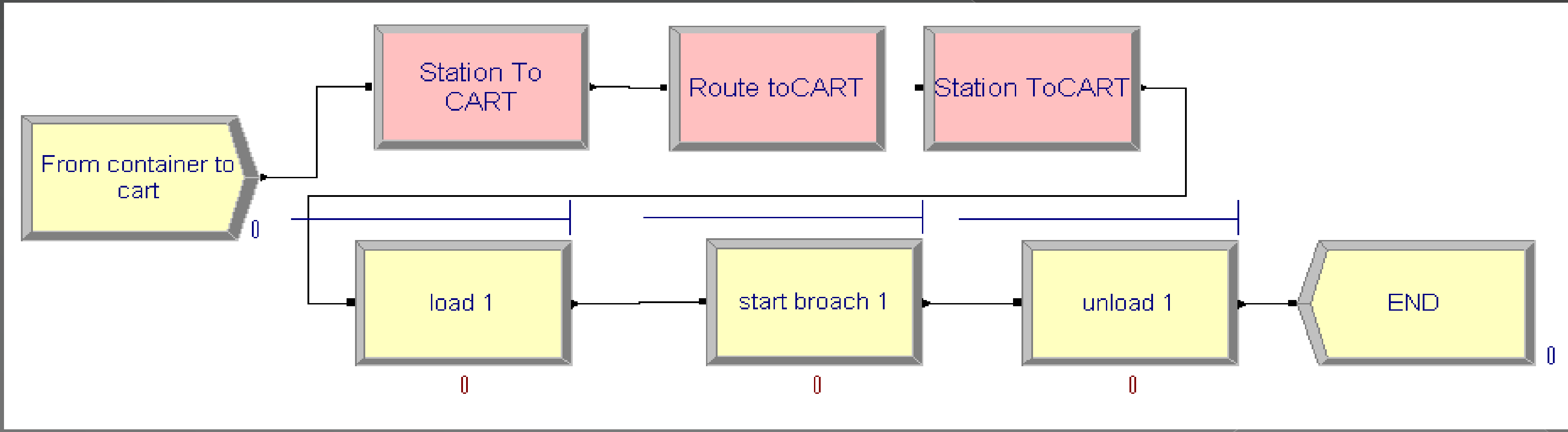
DISPLACEMENT



$7.5*10^{-5}$ IN

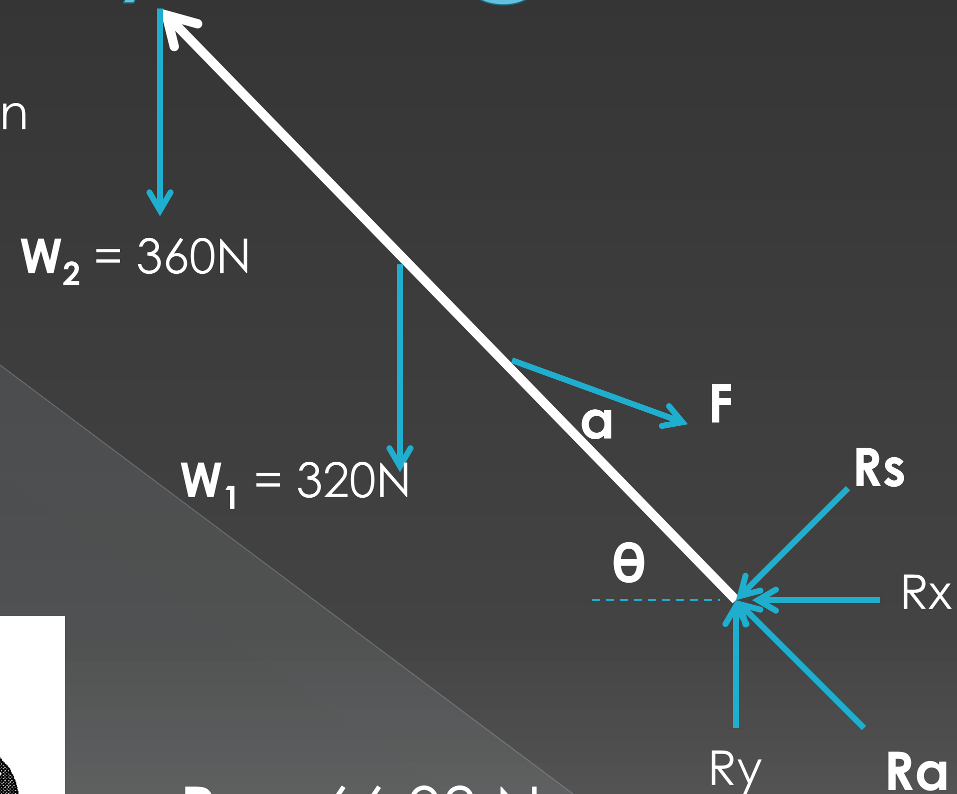
Arena

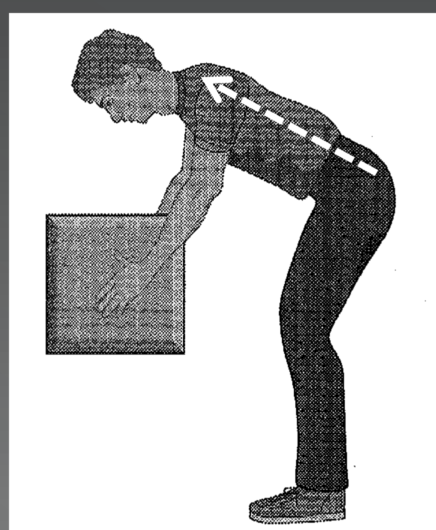
- Focus on cart loading time
  - Cannot affect machining times
- Accurate baseline
  - Results mimic real-world situation
  - Based off time studies



Free-Body Diagram

W_1 = weight of thorax & abdomen
W_2 = weight of head, neck, arms and the blade
a = 13^0 , angle of the erector spinae
θ = 45^0 , angle of bend at the waist
F = Force stabilizing the spine





Rs = 66.08 N
Ra = 2849.77 N

*Note: The axial reaction forces (**Ra**) show the strain placed on the lower back. **Ra** = 2849.77 N

NIOSH – Composite Lifting Index

- Current method
  - Results: 5.927
  - Extremely high, must be corrected
- Theoretical model
  - Expected results: 3.432
  - Nearly decrease by a factor of 2

Material Class Comparison

Material	Strength σ_f (MPa)	Density ρ (Mg/m^3).	Cost C_m (\$/kg)
Al Alloys	30 – 500	2.5 – 2.9	1.5 – 1.7
Low Carbon Steels	400 – 1100	7.8 – 7.9	0.81 – 0.89
Zinc Alloys	80 – 450	4.95 – 7	1.2 – 1.3
High Carbon Steel	400 - 1155	7.8 – 7.9	0.72 -0.80

Material Comparison

Materials	Steel(Multi-Purpose 4140)	Aluminum 6061 T6
Tensile Yield strength	417.1 MPa	276 MPa
Modulus of Elasticity	190-210 GPa	70-80 GPa
Pros	very high strength	light weight, cheap
Cons	heavy & expensive	medium strength & weldability

Aluminum Class Comparison

Materials	Aluminum 6061 T6*	Aluminum 6061 O
Ultimate Tensile Strength (UTS)	42,000 psi (300 MPa)	18,000 psi (125 MPa)
Yield Strength (σ_y)	35,000 psi (241 MPa)	8,000 psi (55 MPa)
Notes:	*Welding induced strength loss *Loss of strength of around 50 - 80%	

Cost Comparison –Raw Material

Materials	Steel (Multi-Purpose 4041)	Aluminum 6061	Combination
Total Material Cost	$ 3276.86	$ 1420.91	$ 1860

- Same material models
- Combination gives best material properties within financial constraints

Material Selection – Raw Materials

L - CART

Component	Material
Frame	6061 Aluminum
Bearing Rod Mounts	4140 Steel
Bearing Rods	4130 Steel
Angled Supports	6061 Aluminum
Support Platform	6061 Aluminum
Linear Bearing Guide	6061 Aluminum
Blade Platform	6061 Aluminum

Barrel CART

Component	Material
Cart Frame	6061 Aluminum
Pivot Rod	1566 Steel
Barrel Sheeting	6061 Aluminum
Barrel Frame	6061 Aluminum

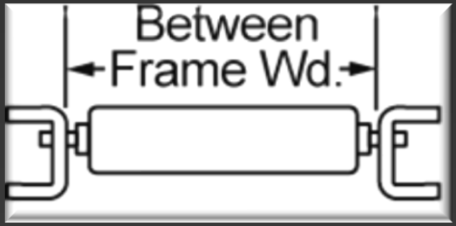
Parts Ordering

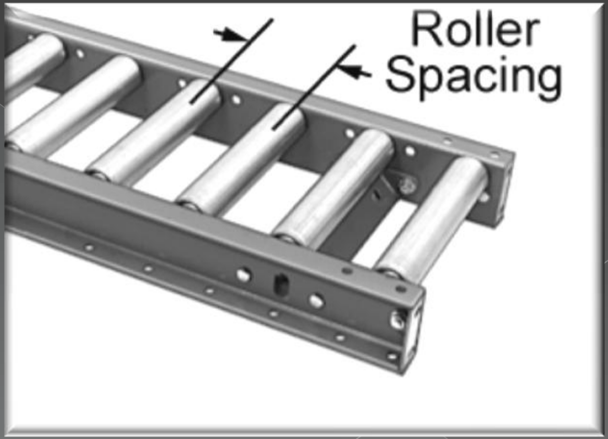
- Mcmaster-Carr
  - Short Lead time

Part	Part Number	Price	Quantity	Cost
Al square tube	6546K271	89.54	6	537.4
Steel Tube	89955K89	52.11	2	104.22
Bearings(closed)	9338T4	72.53	4	290.12
Bearing(open)	9338T17	89.93	2	179.86
Stock Steel	6554K311	213.85	1	28.25
Linear Guide	59585K85	28.25	2	427.70
Lower Platform Al	89015K33	107.34	1	107.34
Angled support	6546K11	25.04	1	25.04
Flat platform	89015K32	58.60	1	58.60
Bearings	6359K37	50.57	2	101.14
TOTAL COST:				1859.51

Optimization

- Elevated table
- Weight capacity
- Limited storage space
- Decision
  - 49 inch frame width to allow for guard rail
  - 23 – 33 inch height to place blades ideally

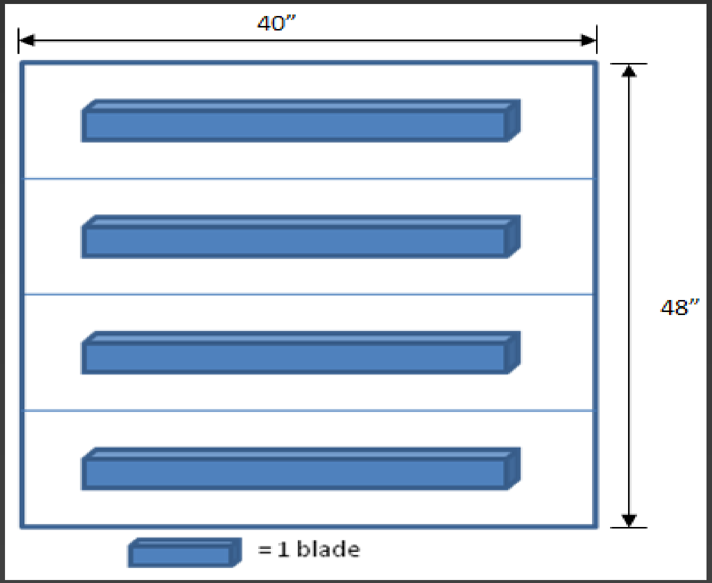




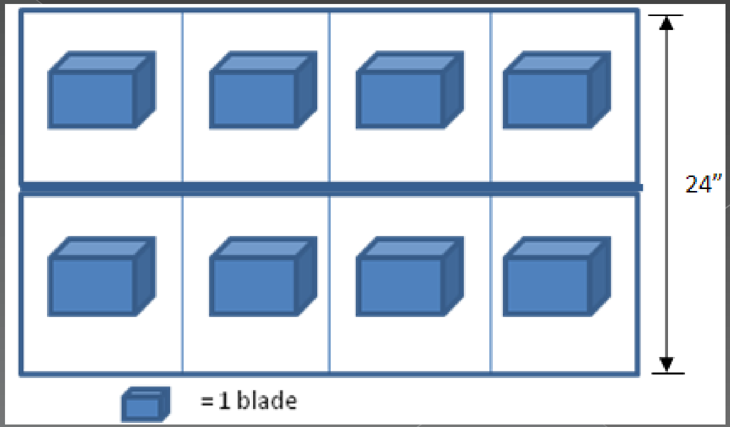
Courtesy of McMaster-Carr

Optimization

- Horizontal Orientation
- Loading height level with Barrel design
- 8 blades held per container



Top View



Side View

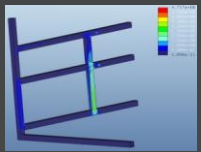
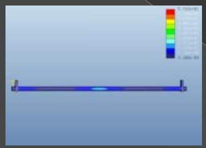
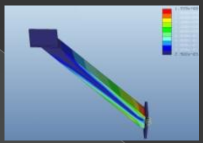
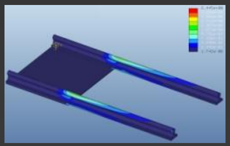
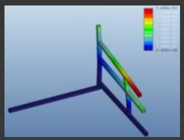
Environmental Health & Safety

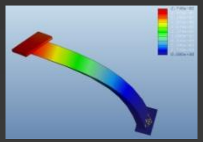
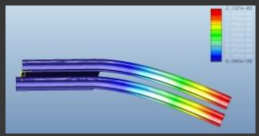
- Little to no environmental effects
- OSHA Standards
  - 29CFR 1910.176a
    - Mechanical equipment
  - 29CFR 1910.176b
    - Storage

Summary: Design

- Barrel Cart
  - Transporting of blades
- L-Cart
  - Loading of blades

Summary: L-Cart Results

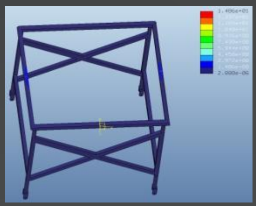
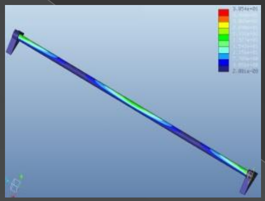
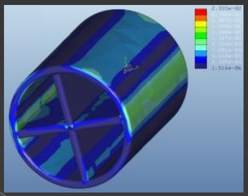
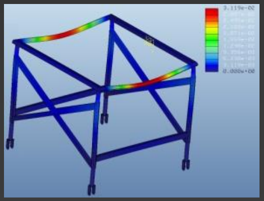
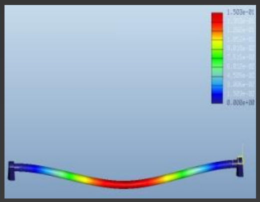
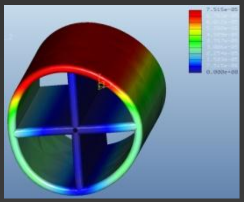






- Stress
  - Frame
    - Max Stress= 3 ksi
  - Steel Rods
    - Max Stress= 17.2 ksi
  - Lower Platform
    - Max Stress = 2 ksi
  - Linear Guides
    - Max Stress = 0.978 ksi

- Displacement
  - Frame
    - Deflection= $4.00*10^{-4}$ in
  - Steel Rods
    - Deflection= $9.50*10^{-2}$ in
  - Lower Platform
    - Deflection= $2.75*10^{-2}$ in
  - Linear Guides
    - Max Stress = $2.14*10^{-2}$ in

Summary: Barrel Results

- Stress
  - Frame
    - Max Stress = 4.58 ksi
  - Rod
    - Max Stress = 19.27 ksi
  - Barrel Surface
    - Max Stress = $1.4*10^{-2}$ ksi

- Stress
  - Frame
    - Deflection= $3.12*10^{-2}$ in
  - Rod
    - Deflection= 0.150 in
  - Barrel Surface
    - Deflection= $7.5*10^{-5}$ in

Summary – Material Decisions

- Majority of frame built from 6061 Aluminum
- High Stress areas built with 1566/4140 steel
- Components will be purchased from Mcmaster-Carr

Summary: Analysis

- IE Analysis
  - Arena
  - NIOSH
  - Ergonomics
    - Free Body Diagram
    - Work Design
- Cost Analysis
  - Maximum material properties within financial constraints

Next Phase

- Double Check Bill of Materials
- Place Part Orders
- Construct Prototype
- Modification*
- Implementation

Courtesy of TECT Power

*Steps taken only if necessary

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- TECT POWER
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  - Dr. Srinivas Kosaraju
  - Dr. Okenwa Okoli
- Advisors
  - Dr. Chiang Shih
  - Garrett Sullivan

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- www.mcmaster.com

QUESTIONS?