68K Blade Process Handling

Interim Design

TECT Power

Team 9

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Outline

- Problem Overview
- Preliminary Design
- Analysis
- Conclusion

Background

- 68k turbine blades
  - Weigh 45 lbs
  - Total Recordable Injuries: 4.3 per 100 employees
  - Scrap due to dropping: < 0.5%
- Customer requirements
  - Redesign the receiving container
    - Redesign storage area layout
  - Design and fabricate a blade handling mechanism
    - Easy maneuverability
    - Stability

Problem Statement

- Current Methods
  - Manual lifting onto rudimentary carts
  - Storage containers
    - Ground level
    - Unorganized
  - Machine loaded by hand
- Constraints
  - No industrial lifts/cranes
  - Budget: $4,000

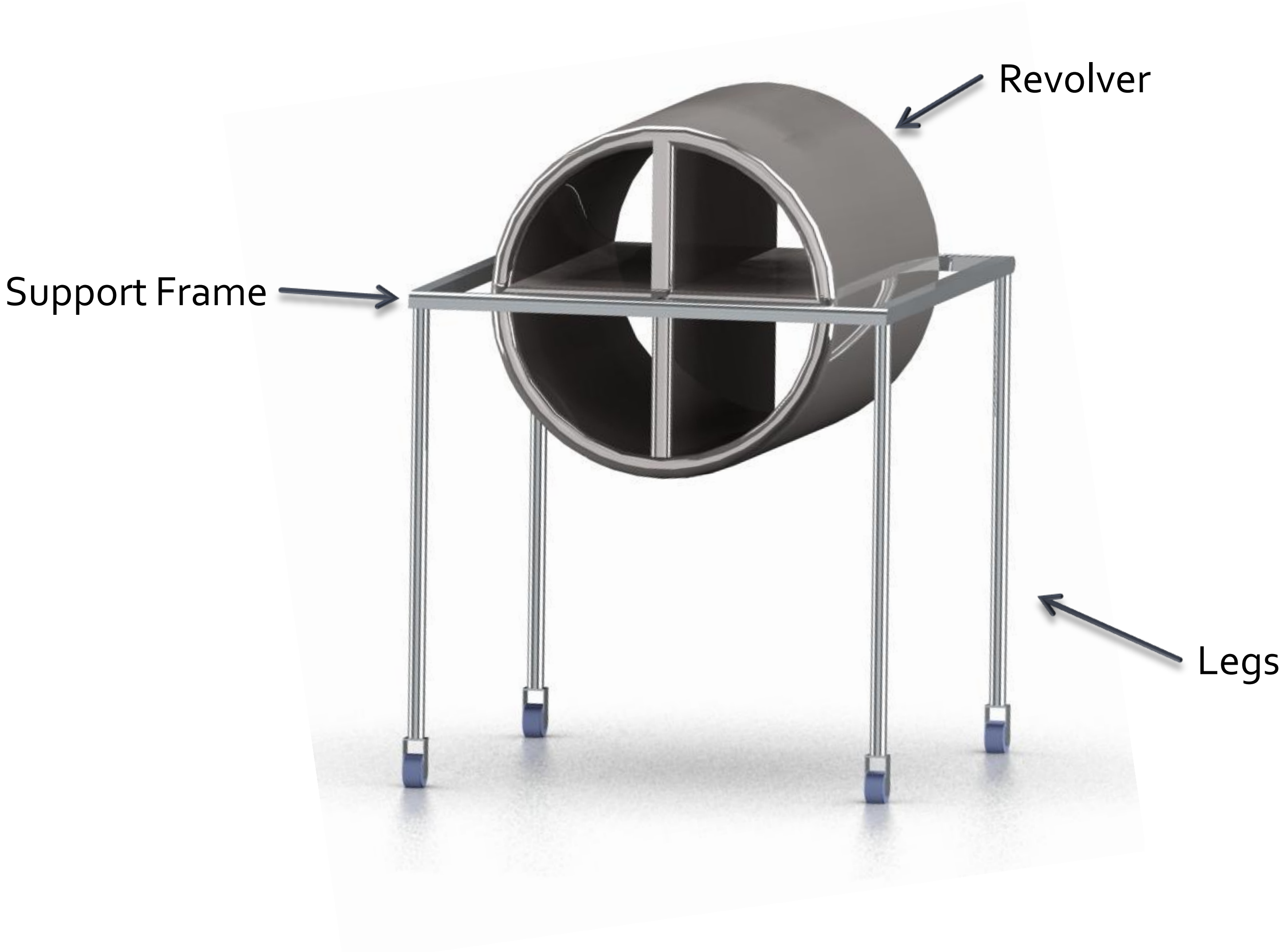
Concept Design

- Concept Generation
  - Barrel design
  - Cart-in-Cart
  - New design
    - L-Cart
- Storage Container Design
  - Multiple orientation containers
  - On elevated table

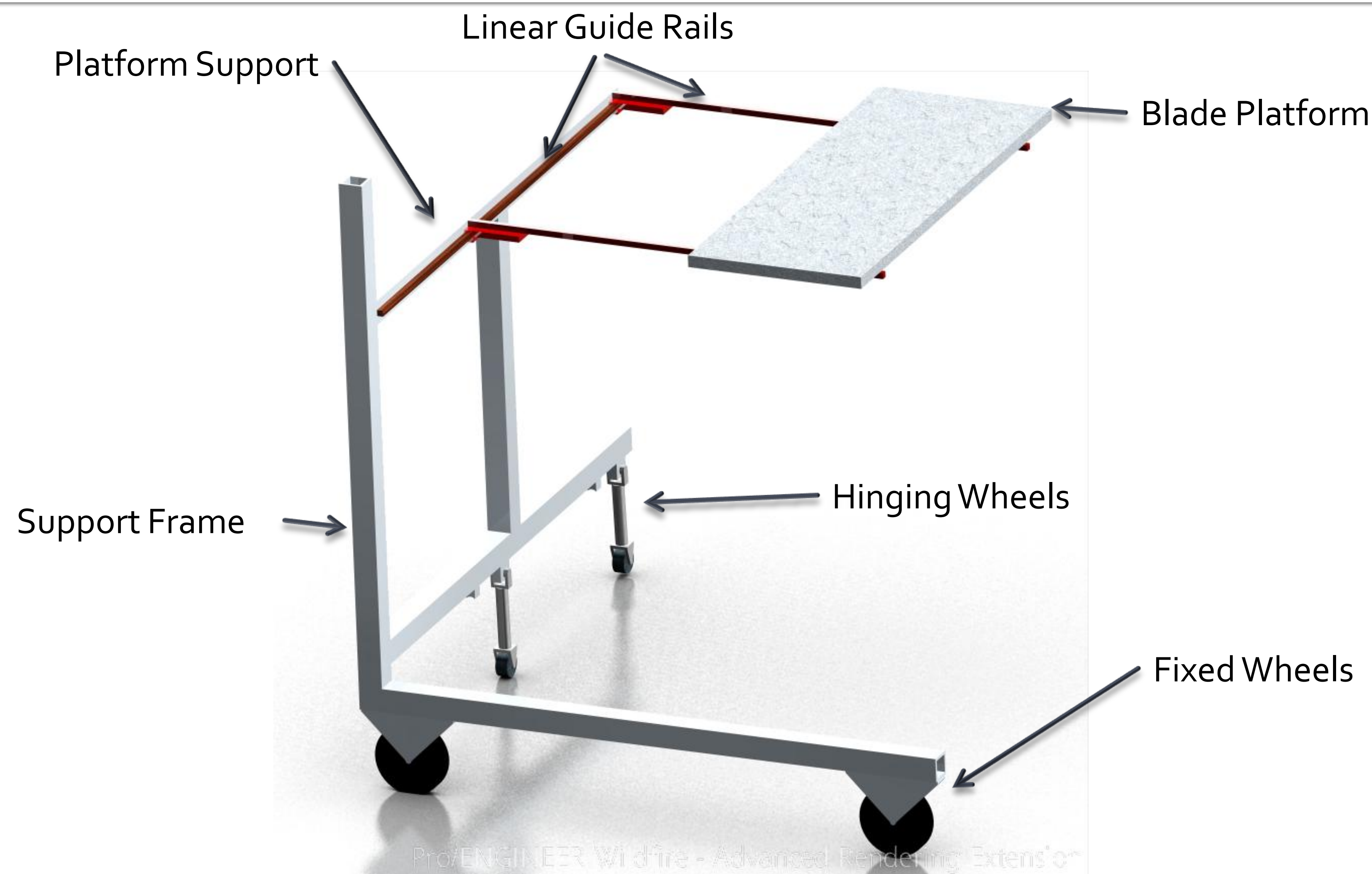
Design Decisions

- Roller Table in Storage
  - Decreases need for height variation
  - Increased blade accessibility
- Cart-in-Cart
  - Removed due to ergonomic feasibility
- Barrel design for blade storage
- New cart design for machine loading
  - L-Cart

Initial Design: Barrel

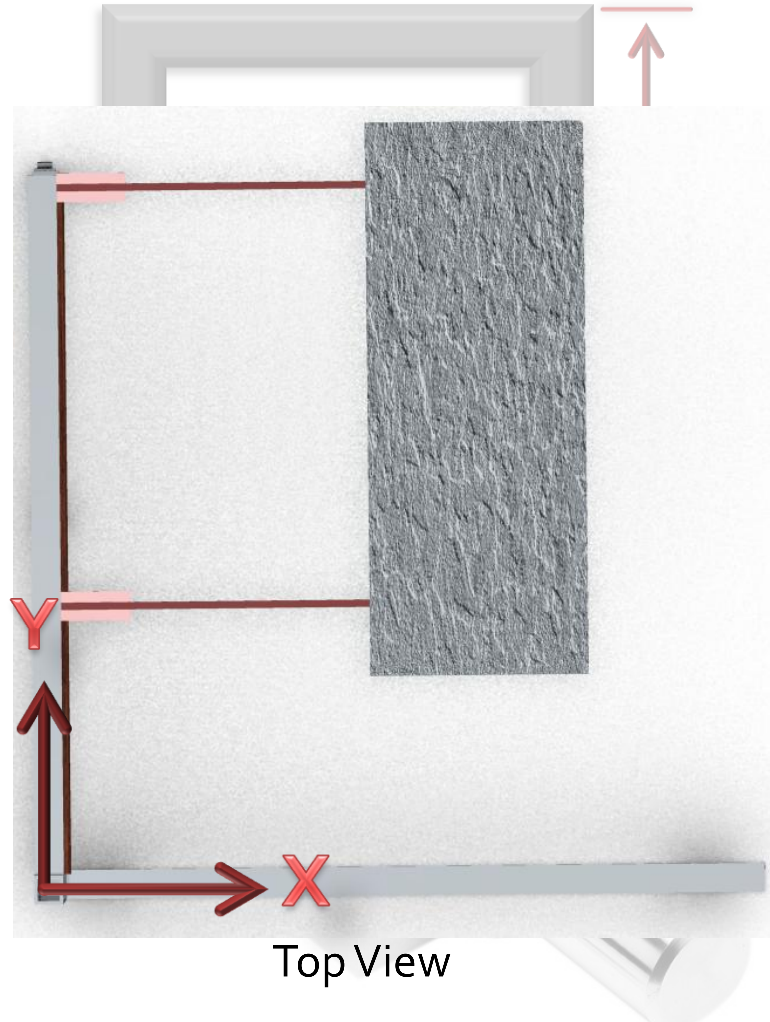


Initial Design: L-Cart



Initial Design: L-Cart

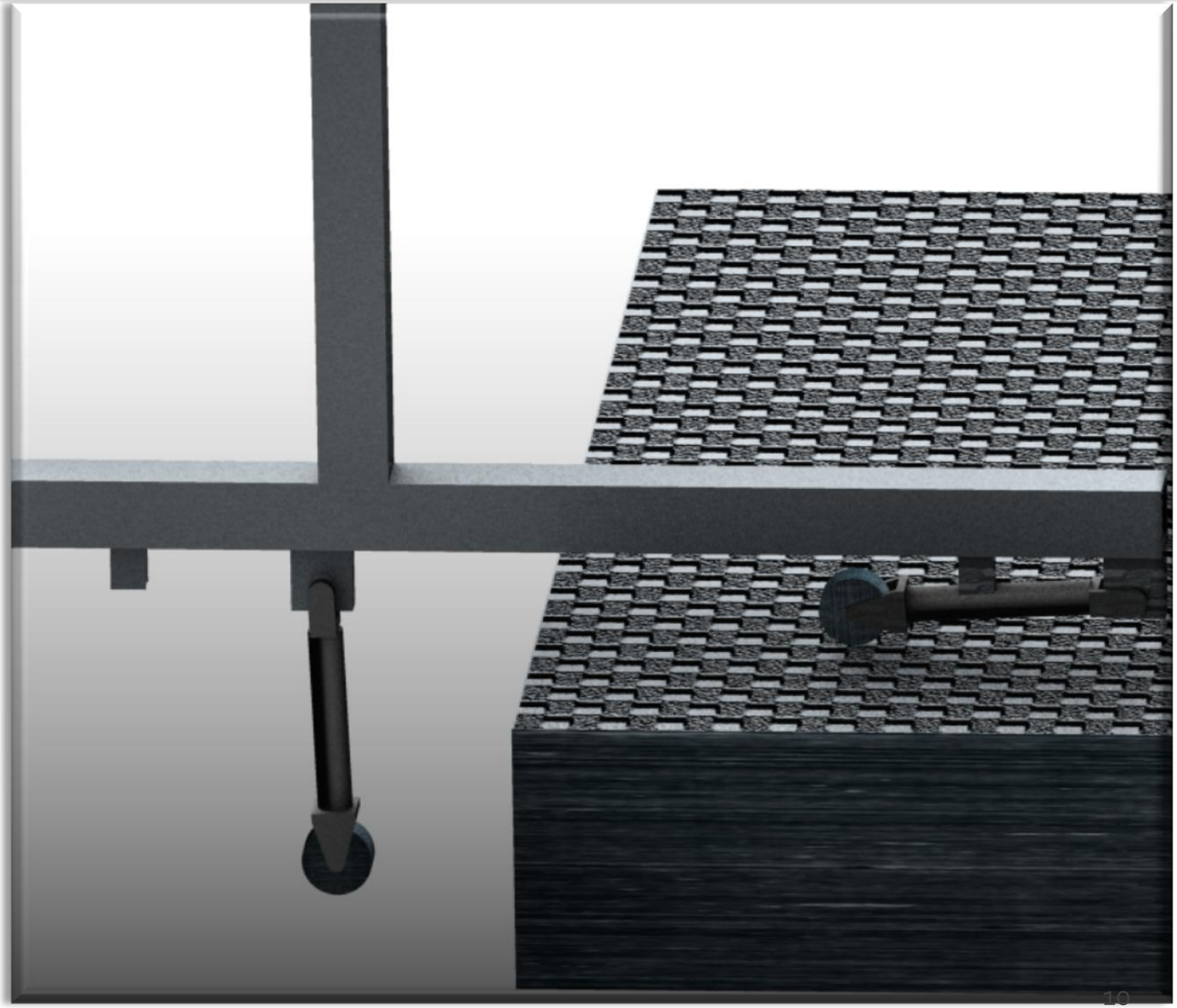
- Support Beams
  - Hollow cross section
- Linear Motion Guide
  - Fixed height for milling bed
  - Sealed from contaminants
  - Dual axis control



Top View

Initial Design: L-Cart

- Spring Loaded Wheels
  - Raise above oil bed
  - Adds support when loading
  - Locking mechanism when moving



Industrial Analysis

- Previously calculated
  - RULA for current method
  - Time Study
    - Baseline observation
    - ARENA simulation
  - Free Body Diagram
    - Shear force = 66.08 N; Axial force = 2849.77 N
  - NIOSH lifting equation

Industrial Analysis

- Future Calculations
  - Time study with new design
  - RULA with new design
  - Facility layout
    - STORAGE
    - BRAOCHING AREA
  - Cost Analysis

Time Study Worksheet

☐ Snap Back
☐ Continuous

Operation Description				
Part Number	Operation Number	Drawing Number	Machine Name	Machine Number
Operator Name	Months on Job	Department	Tool Number	Feeds and Speeds Machine Cycle Time

☐ Quality OK?
☐ Safety Checked?
☐ Setup Proper?
Notes:

Part Description: Material Specifications:

Element #	Element Description		Reading 1	2	3	4	5	6	7	8	9	10	Total Cycles	Avg. Time	% R	Normal Time	Frequency	Unit Normal Time	Range	R / $\bar{X}$	Highest
		R																			
		E																			
		R																			
		E																			
		R																			
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		E																			

Foreign Elements:

Engineer:

Approved By:

Notes:

R / $\bar{X}$	# Cycles
.1	2
.2	7
.3	15
.4	27
.5	42
.6	61
.7	83
.8	108
.9	138
1.0	169

Total Normal Min. ________
Allowance + (________)% ________
Standard Minutes ________
Hours Per Unit ________
Units Per Hour ________

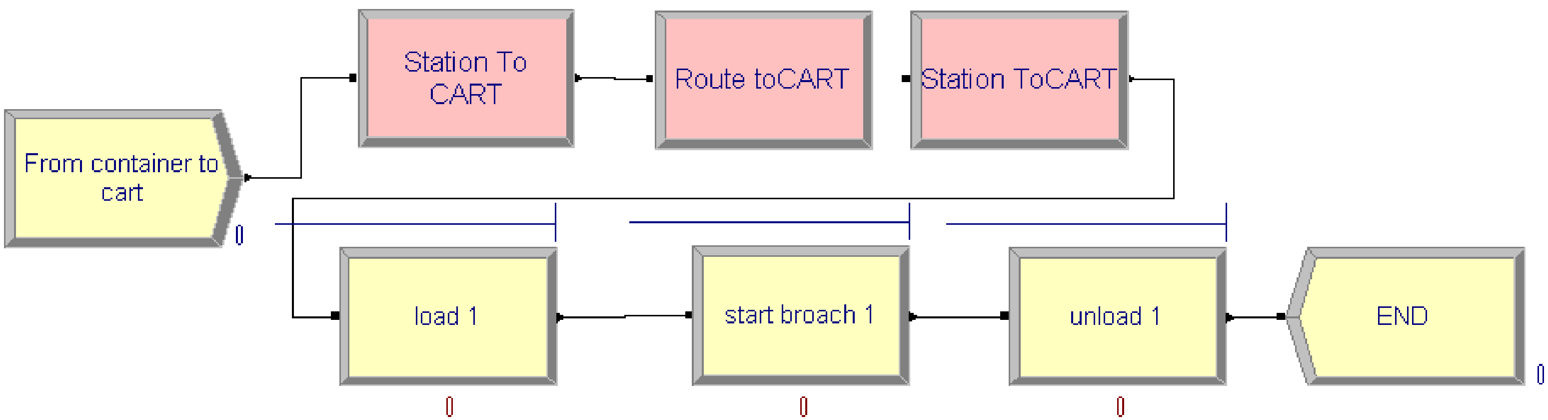
On Back: 1) Work Station Layout 2) Product Sketch

Industrial Analysis: Element Run Times

Element #	Element Description		1	2	3	4
1	Unload from 1st machine	R	.11	.9	4.32	12.69
		E	.11	.26	.10	.09
2	Put aside on cart	R	.28	1.14	.46	.82
		E	.17	.24	.14	.11
3	Get another blade from cart	R	.36	.36	.74	.93
		E	.08	.22	.28	.07
4	Load onto machine	R	.64	.73	5.16	13.0
		E	.28	.37	.42	.39

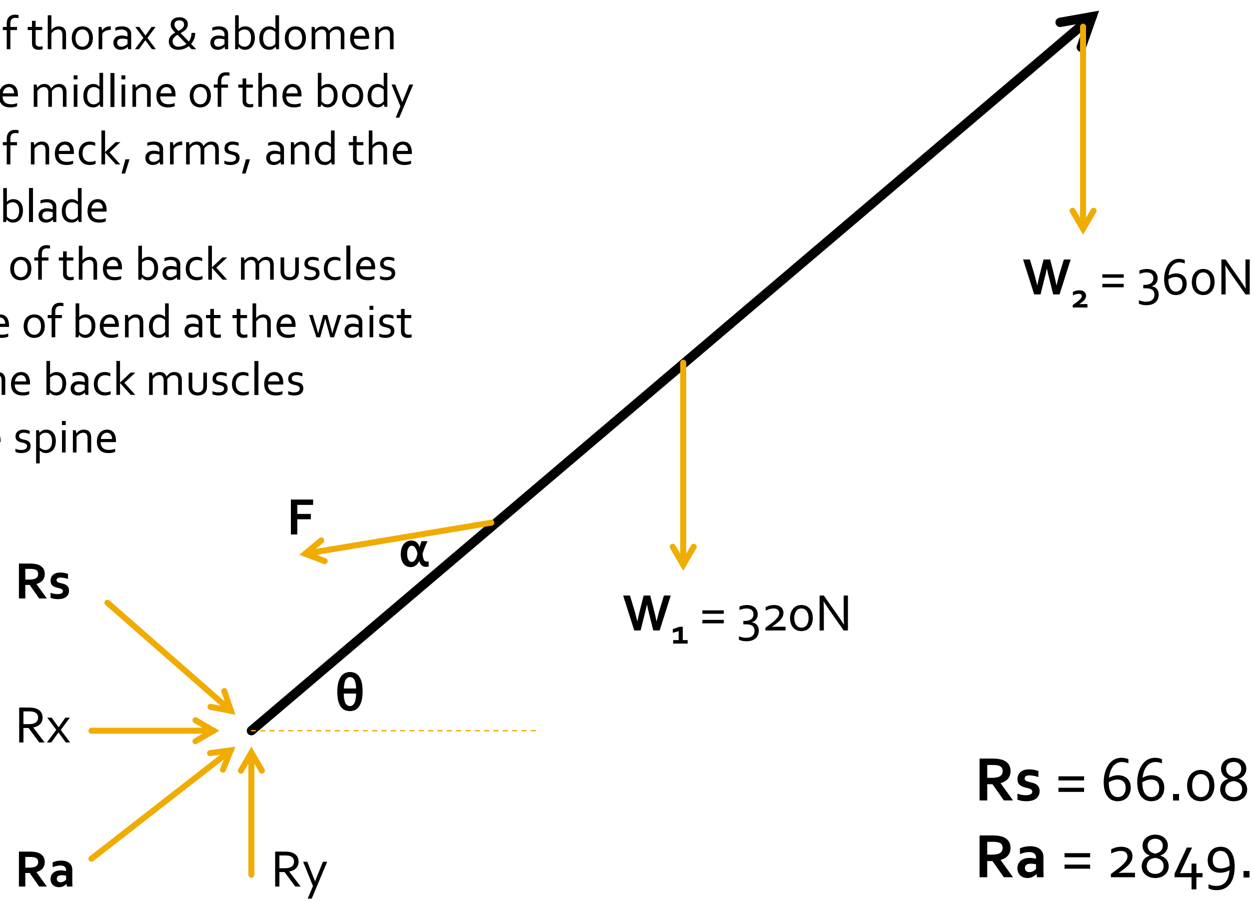
Industrial Analysis: Arena

- Bottleneck at broaching machine
- Change handling time
  - Load/unload
  - Travel



Industrial Analysis: Free-Body Diagram

W_1 = weight of thorax & abdomen taken from the midline of the body
W_2 = weight of neck, arms, and the weight of the blade
α = 13°, angle of the back muscles
θ = 45°, angle of bend at the waist
F = Force of the back muscles 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

Industrial Analysis: NIOSH Lifting Eq.

Measure and Record Task Variables

Object Wt. (lbs)		Hand Location (in.)				Vertical Distance (in.)	Asymmetry Angle (deg.)		Frequency Ratio	Duration	Coupling
		Origin		Destination			Origin	Destination	lifts/min	hrs	
L (avg.)	L(max.)	H	V	H	V	D	A	A	F		C
45	45	20	26	14	53	27	30	30	1	8	0.9

Determine the multipliers and compute the RWL's

RWL = LC x HM x VM x DM x AM x FM x CM

		LC		HM		VM		DM		AM		FM		CM		
Origin	RWL =	51	x	0.5	x	0.97	x	0.89	x	0.90	x	0.75	x	0.9	=	13.38 lbs
Destination	RWL =	51	x	0.71	x	0.83	x	0.89	x	0.90	x	0.75	x	0.9	=	16.31 lbs

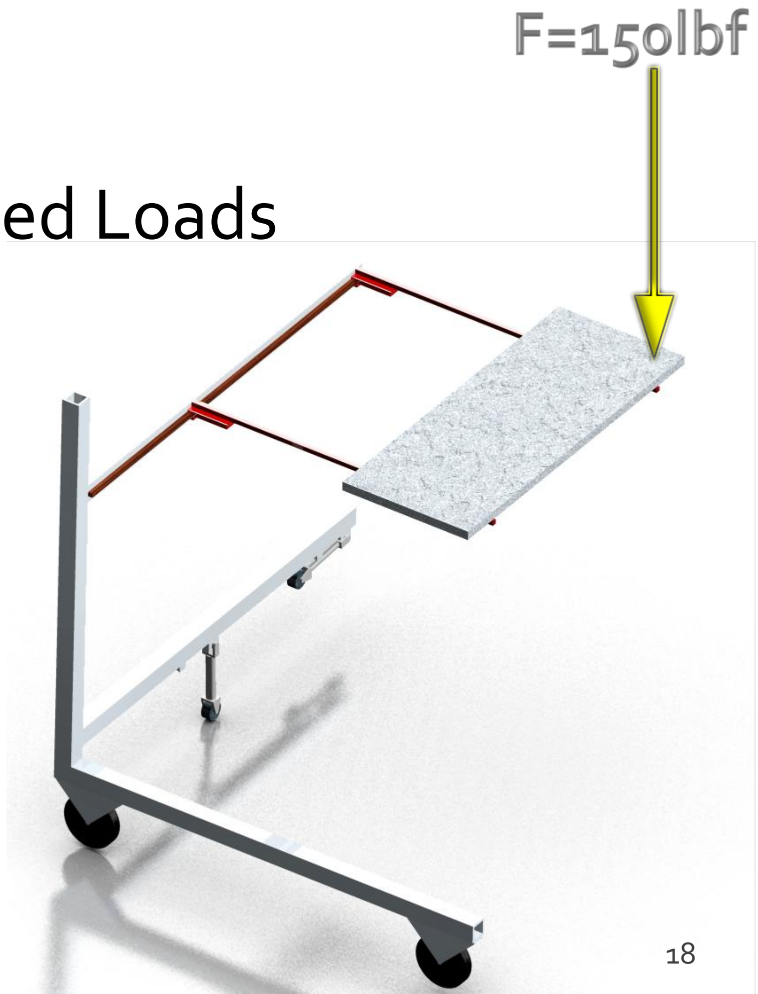
Compute the Lifting Index

Origin: Lifting Index = $\frac{\text{Object Wt. (lbs)}}{\text{RWL}} = \frac{45 \text{ lbs}}{13.38 \text{ lbs}} = 3.36$

Destination: Lifting Index = $\frac{\text{Object Wt. (lbs)}}{\text{RWL}} = \frac{45 \text{ lbs}}{16.31 \text{ lbs}} = 2.76$

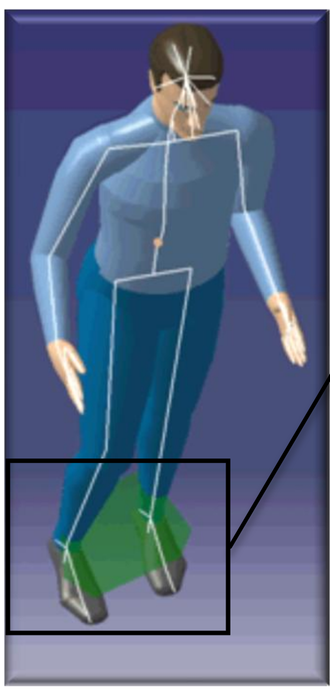
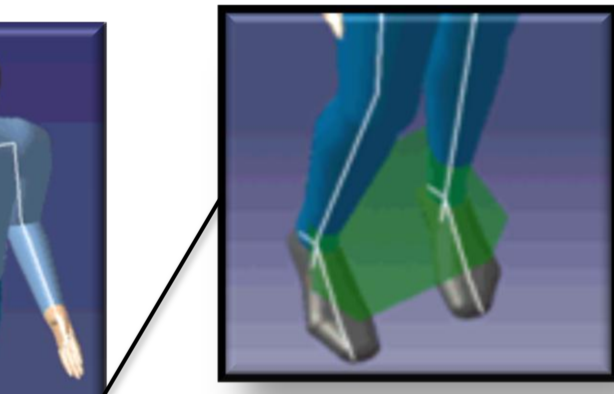
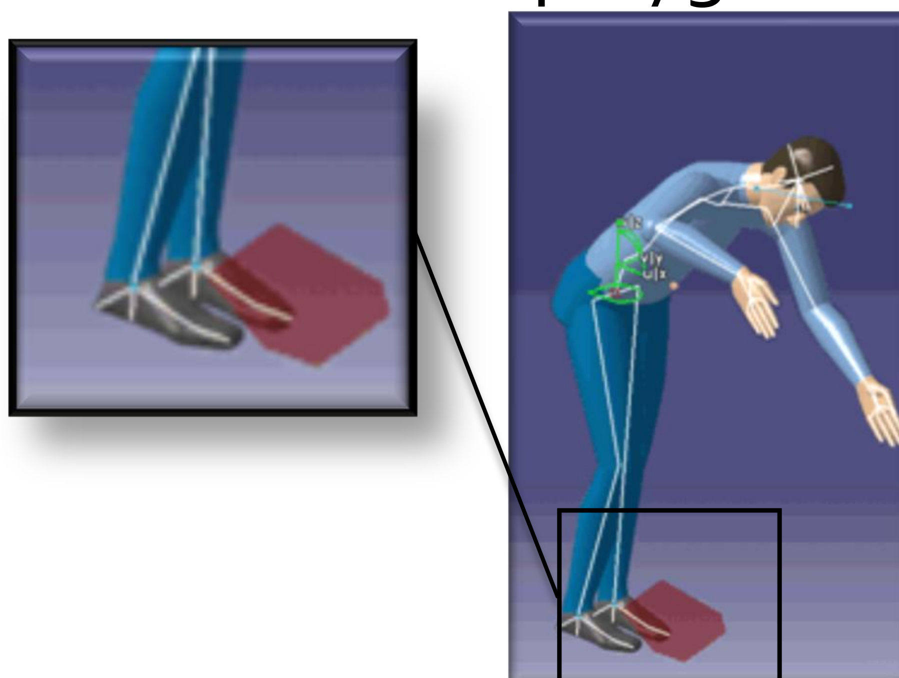
Mechanical Analysis: L-Cart

- Analysis Method: Pro Engineer Mechanica
- Design Criteria:
  - Factor of Safety of 3
  - Concentrated Point & Distributed Loads
  - "Worst Case" Load Placement
- Assumptions:
  - Max load of 50lbf per blade
  - No Deflection occurs at Slide
  - Loads are static



Mechanical Analysis: L-Cart Stability

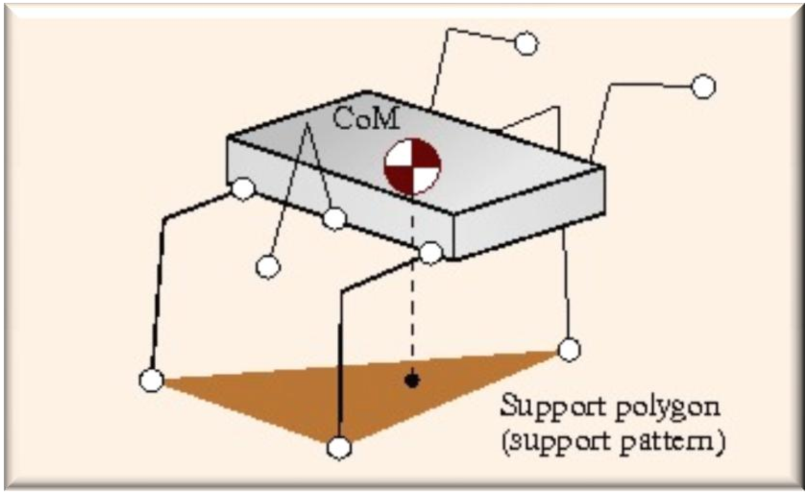
- Support Polygon
- Geometry defines polygon through ground contact points
- Unstable when center of mass leaves polygon

Images Courtesy of Catiadoc

Mechanical Analysis: L-Cart Stability

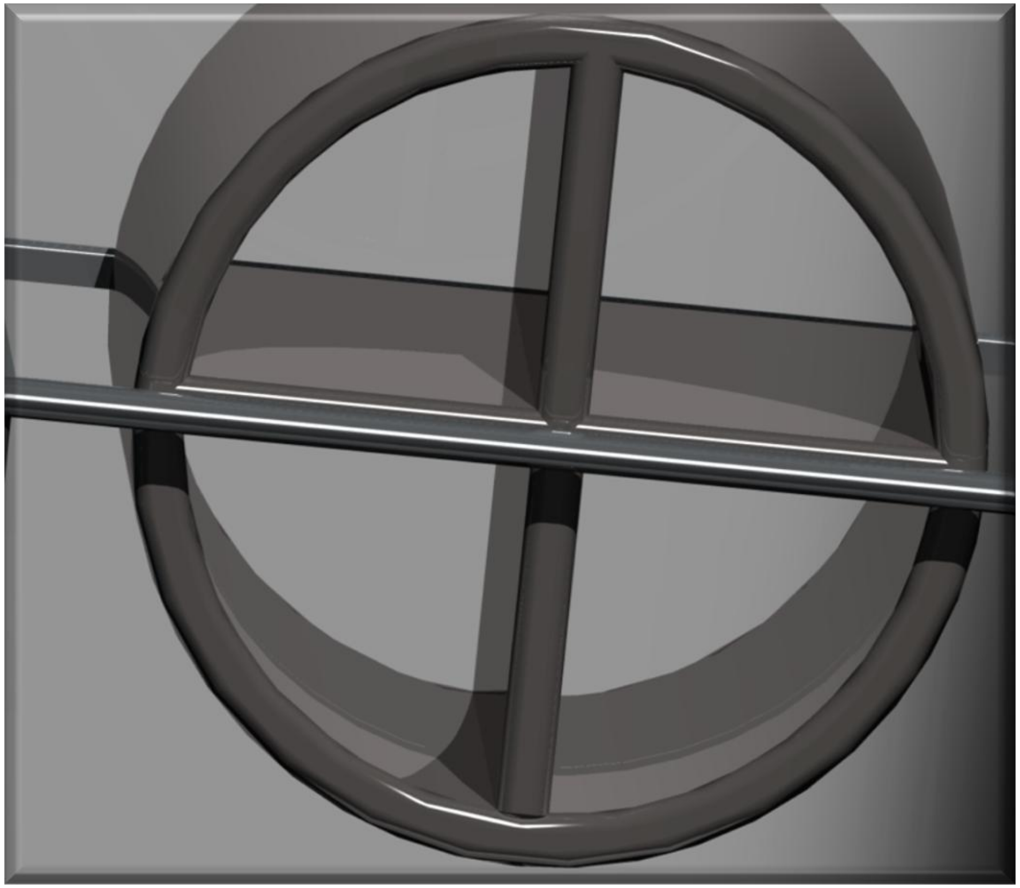
- Analysis Method: Polygon of Support
- Design Criteria:
  - Balanced through all possible blade locations
- Assumptions
  - Instability region only at outer locations



Courtesy of Springer Images

Mechanical Analysis: Barrel

- Design Criteria:
  - Factor of safety of 3
- Assumptions:
  - Frictionless bearings
  - Weight of two blades act at barrel outer diameter
  - When moving mass is centered



Mechanical Analysis: Force on Barrel

- Force analysis
  - Force required initiate movement
    - F= 298lbf
  - Force required to maintain motion
    - F=7lbf
  - Force required for barrel Rotation
    - F=100lbf

Mechanical Analysis: Electric Drive

- Electric drive estimate
  - Speed: 10rpm
  - Torque: 275 ft•lbf
  - Power: 1.05 W
- Power source estimates
  - Voltage: 12V
  - Minimum Amp Hours : 2.1

Calculated Value	Equation
Power	$P = T\omega$
Amp Hours	$AH = \frac{T\omega}{V} t$

Mechanical Analysis: Structural

- Primary Calculations:
  - Stress Concentrations
  - Displacement
  - L-Cart
    - Bending Stress: 805 PSI
    - Linear Deflection: 0.25 in

Calculated Value	Equation
Bending Stress	$\sigma_{bend} = \frac{Mz}{I}$
Normal Compressive Stress	$\sigma_{NC} = \frac{F}{A_{cross}}$
Torsional Stress	$\tau = \frac{Tc}{J}$
Shear Stress on Bolts	$\tau_{bolt} = \frac{4F}{\pi d^2}$
Linear Deflection	$\delta_{max} = \frac{FL^3}{3EI}$
Angular Deflection	$\theta = \frac{TL}{GJ}$

Summary: Design

- Barrel Design
  - Storing blades during broaching
- L-Cart Design
  - Placing blades into broaching machine
- Container Design
  - Horizontally held blades

Summary: Industrial Analysis

- Metrics
  - Rapid Upper Limb Assessment
  - Force diagrams
  - Time study
- Facility Layout
  - Storage sector
  - Broaching

Summary: Mechanical Analysis

- Force Analysis
  - Required forces for general handling
- Electric Drive
  - If necessary, an electric drive will be added
- Structural Analysis
  - Pro Engineer Mechanica
  - Barrel and L-Cart

Summary: Mechanical Analysis

- Finalize Design
- Complete Analysis
- Material Selection
- Vendor Selection
- Parts ordering

Sources

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QUESTIONS?