Air Force Research Laboratory Challenge

Fast Rope Insertion Device

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Agenda

- Mission Statement
- Current Issues with Fast Roping
- Requirements
- Current Designs
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  - Design 2: Gloves
  - Concept: Auto Belay System
- Test Setup
- Preliminary Tests
- Discussion of Other Rope Types
- Conclusion and Future Plan
- Questions

Mission Statement

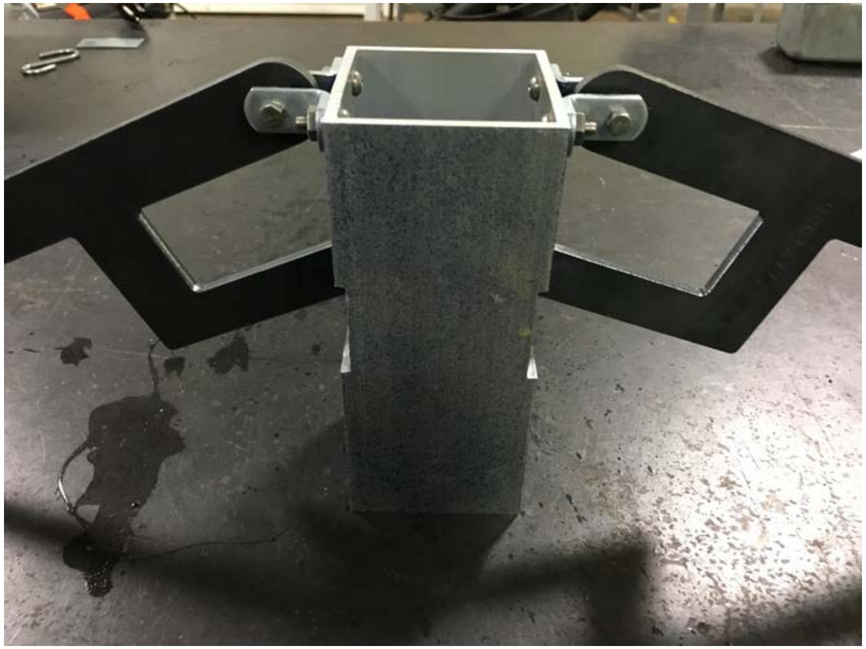
Corporation 13's objective is to design a system that can replace or can be integrated into the current descending system known as "Fast Roping." The new system will solve the problems in the current system such as friction burn, piling up, and missing the rope. The new system will be as or more efficient than the current system and will be safe, simple to use, and dependable. Corporation 13's design will be creative, engineered with excellence, and meet all of the requirements for the competition.

Requirements

- Safe
- Max load of 450 lbs
- Descent rate: 7-8 ft/s
- Quickly executable
- Quick to detach from
- Operable with gloves on
- Functional in all weather conditions
- Easy to use
- The same or better expediency as the current design
- Accepted by the BA SOF community

Design 1: The Clamp

- Concept of Operation
  - Device pre-set on rope before mission
  - User grabs handle
  - User jumps from aircraft and applies weight to handles
  - Handles use user's weight to clamp rope inducing proportional frictional force
  - Controlled descent due to clamping action from to handle geometry
  - User's hand placement and applied force can further adjust user's descent
- Governing Principles
  - Friction force proportionally counteracts weight of user's weight
  - Proportional friction force results in constant descent speed
  - Handle shields user's hands from frictional heat



Design 1: The Clamp (Cont.)

Advantages

- Simple Design
- Lightweight
- Enables multi-user descent
- Inexpensive, easy fabrication
- Can be used on any rope

Disadvantages

- High friction and stress applied to rope (increased wear and tear)

Design 1: The Clamp (Cont.)

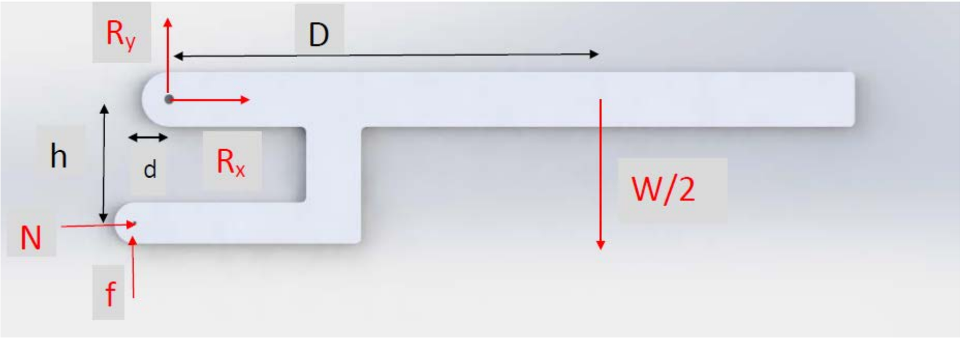
$$\sum M_p = Nh - \frac{WD}{2} - fd = 0$$

$$f = \mu N \rightarrow N = \frac{f}{\mu}$$

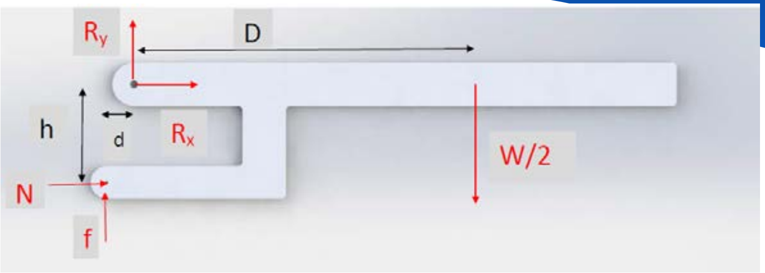
$$f\left(\frac{h}{\mu} - d\right) = \frac{WD}{2}$$

$$f = \frac{WD}{2(h/\mu - d)}$$

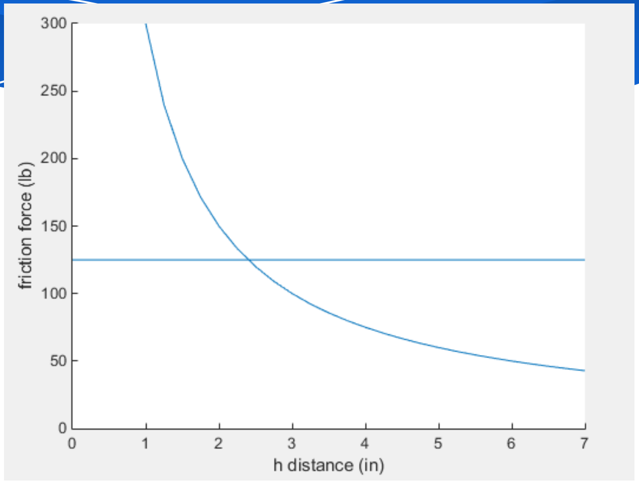
FBD:

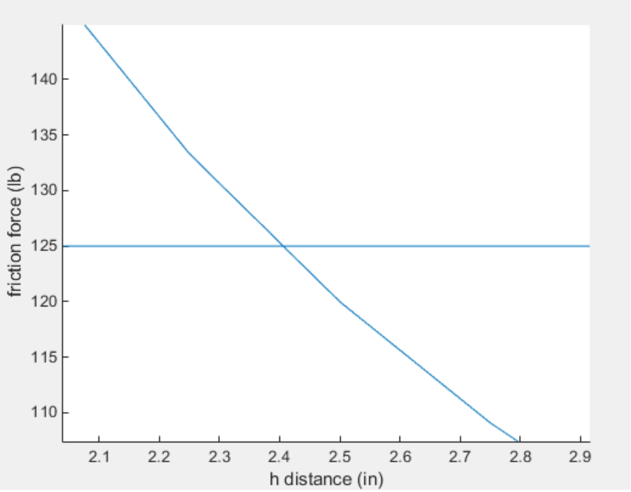


Design 1: The Clamp (Cont.)



- In the geometric construction of the clamp, calculations were performed to find a value for h (as shown to the right)
- Using an average rider weight of 250 lbs. and D value of 12 in. based upon average body positioning, the threshold for slipping occurs just below 2.5 in
- The selected value of h was 2.25 in. in order to ensure stoppage

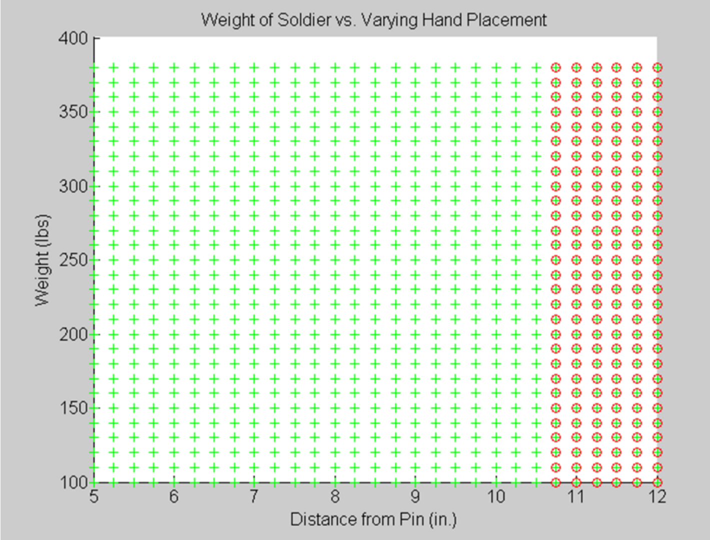




Design 1: The Clamp (Cont.)

The Clamp design will allow the user to fall at a controlled speed, since the frictional force applied to the rope is proportional to the weight of the user.

Each user will need to place their hands the same distance away from the rope on the handles (controlled by grips placed at the set distance)



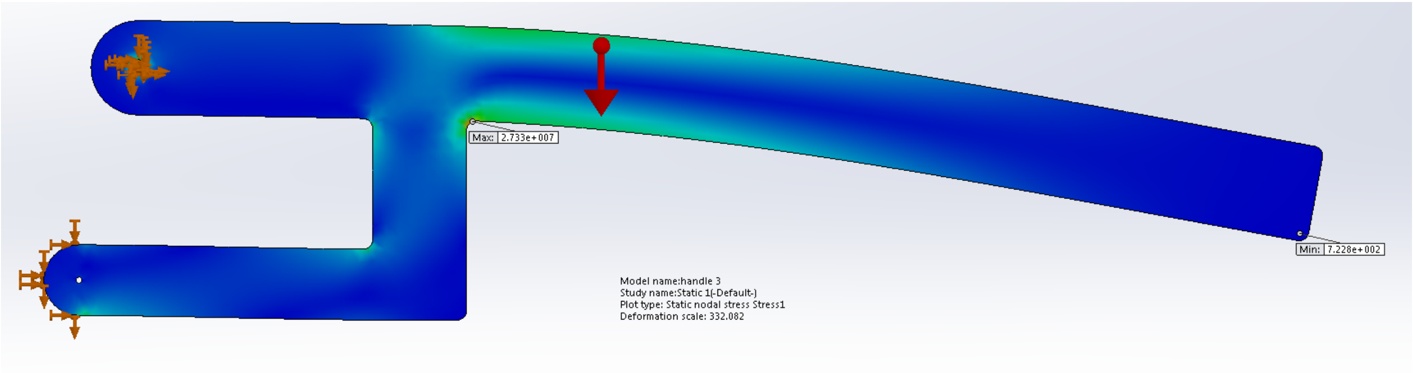
The graph to the right shows that at a distance of 10.75”, each user will fall at the same constant speed, regardless of weight. (shown by the red circles)

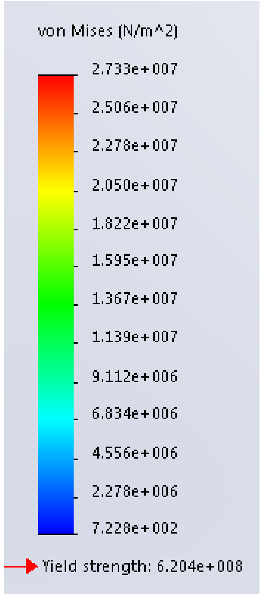
- This speed is set by the handle geometry and the braking material

Design 1: The Clamp (Cont.)

Analysis of the handles and pivot joints has been done to ensure that this design will hold up during a mission.

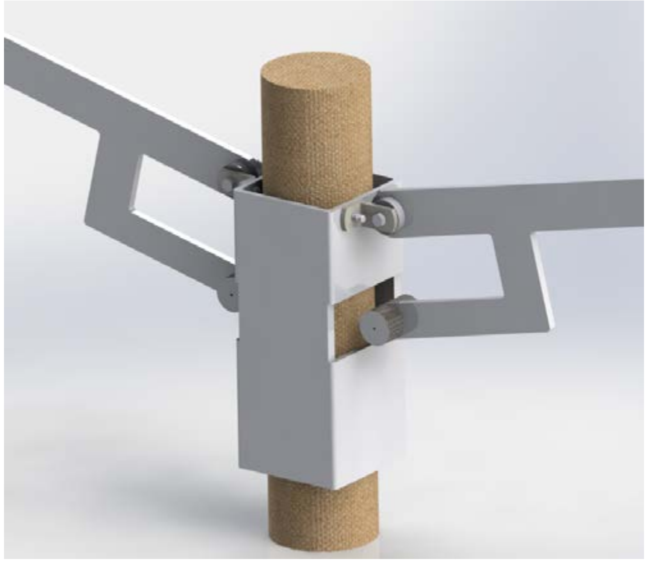
This analysis shows a Factor of Safety of 22, and was calculated using a 450 lb user.





Design 1: The Clamp (Prototype)

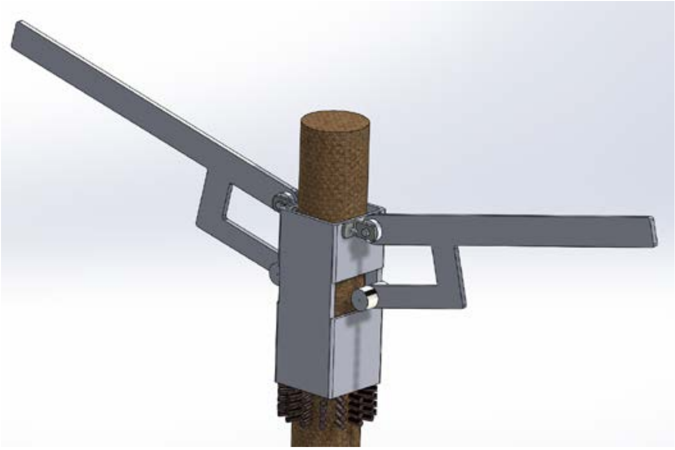
- First Prototype
  - Designed to prove clamp can apply needed frictional force
  - Machined and tested in a preliminary setting



Testing Results

- Successful proof of concept
  - Clamp locked under its own weight
  - Clamp locked and held 200 lbs.

- Moving Forward
  - Handles must be moved to a more centered position on the sleeve
  - Handles displayed excess freedom of motion (roll and yaw)
  - Preventative method to clamp falling down rope due to the flight of helicopter



Possible Improvements

Geometry

- Handle width
- Design Geometry
- Ergonomics
- Change the pivot joint
  - Decrease degrees of freedom to only rotate about the pin

Braking Method

- Test roller bearings
- Sliding friction – change material of rollers

Design 2: The Gloves

∗Re-engineered Heat Resistant Gloves

- This glove will be comprised of a base made of extremely heat resistant material, coated with a protective and heat resistant material, and will have small brake pads attached externally directly to the glove
- Ordered: Mechanix gloves, coated Kevlar gloves, silicone gloves, epoxy, silicone, ceramic brake pad material, welders gloves

Gloves

Base Material	**Inner Coating**	**Brake Pads**
Kevlar	Latex	Ceramic
Silicone	Neoprene	Carbon Ceramic
Nomex	Silicone	Non-Asbestos Organic

Design 2: The Gloves (Cont.)

- Corp 13 has developed a decision matrix for glove materials. As shown below, Kevlar, silicone, and Nomex are the best materials and will be pursued.

	Heat Resistant	High Operating Temperature	Wear Resistance	Practical	Ease of Acquisition	Total Score
Kevlar	✓	375°F	5	5	5	17
Carbon Fiber	✓	900°F	1	2	4	13
Silicone	✓	550°F	3	5	4	16
Nomex	✓	400°F	5	5	4	18
Vectran	✓	500°F	5	3	2	14
Zylon	✓	1200°F	3	1	1	11

Glove Testing Results

Glove	Outside Temp		Inside Temp	
	Before	After	Before	After
A) Green Silicone	83	100	85	86
B) Gray Hyflex	88.5	95	85	94
C) Tactical Nomex Leather	83.5	90	86	87
D) Nomex/Kevlar	82	92	84	86
E) Welders w/mechanix	75.5	93	84	84

A

B

C

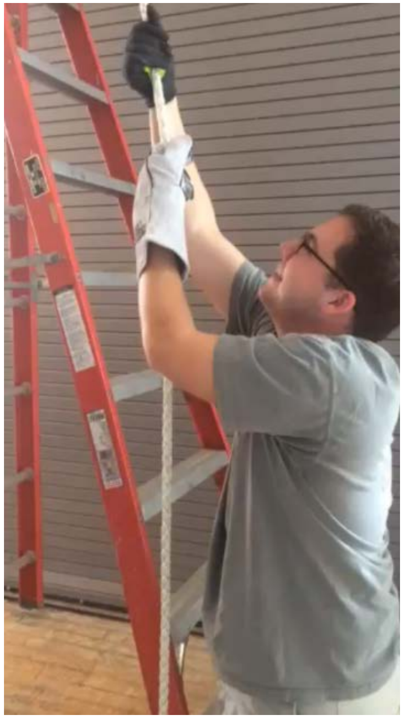
D

E

Design 2: The Gloves (Testing)

Different Prototypes

1) Kevlar base, Hyflex coating, silicone pads
   - Epoxy adhesion failed (video)
2) Kevlar base, Brake pads on tactical Nomex
   - Too bulky
   - Not ergonomic
   - Adhesion issues



Refining Design

- Improve pad attachment
  - Sewing
  - Test alternative adhesive
  - Test alternative pad materials and location

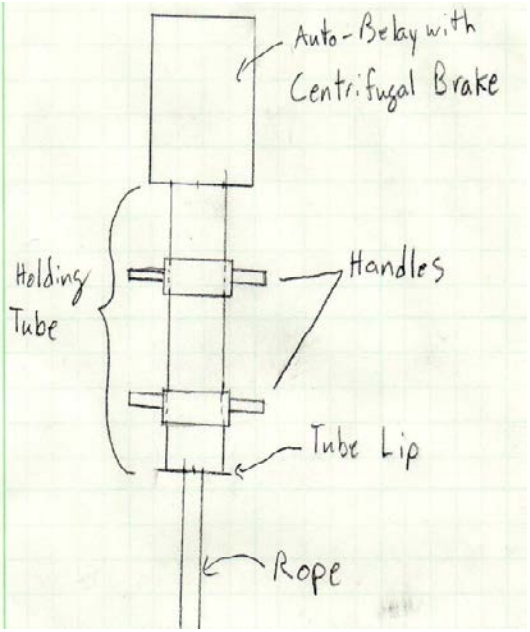
Additional Concepts

- In addition to the aforementioned designs, we will be revisiting previous concepts to discuss the possibility of testing more devices
- We believe that testing more designs will lead us to the best choice, and open up new paths to achieve our end goal
- The most promising alternative concept is the Auto-Belay device

Additional Concept: Auto-Belay

Concept of Operation:

- The rope feeds out of the centrifugal brake through the tube to the ground.
- The handles are set on the tube
- When the user jumps on the handle the cams activate and lock them onto the rope pulling out rope with their weight and deploying them to the ground.



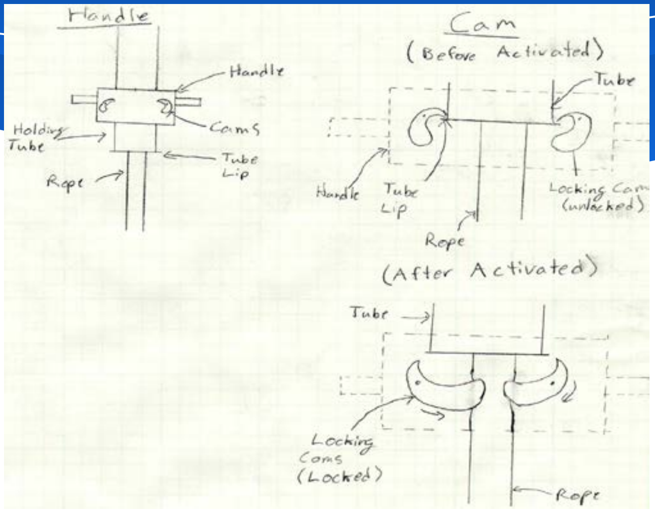
Additional Concept: Auto-Belay (Cont.)

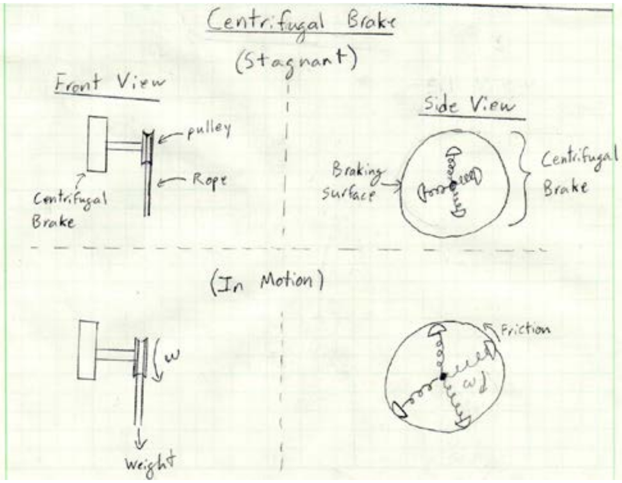
Advantages

- Easy to use
- Decrease potential for human error (piling up)
- No friction transmitted to the soldier
- Quickly executable
- As efficient as current design

Disadvantages

- Potential for mechanical failure
- Weight
- Volume
- Maintenance
- May not be accepted by BASOF community





Testing Methods

Full Scale Testing

- Location: General J.E. Livingston Obstacle Course

Small Scale Testing

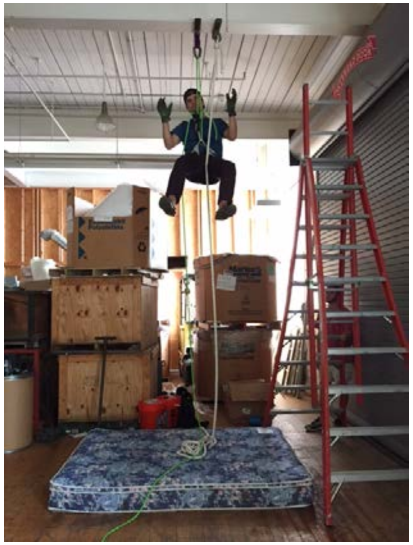
- Location: Gavin Research Laboratory

Safety

- A safety belay system will be used to ensure safety

Preliminary Testing

* Testing has taken place at the Gavin Research Laboratory
* The test setup utilizes clamps the connect our testing rope to a structural I-beam



Possible Change in Rope Type

Kevlar

- Failure due to splitting
- Low abrasion resistance

Spectra

- High stretch
- Creep
- Flexibility

Vectran

- Low stretch
- High abrasion resistance
- High heat resistance

Conclusion &Future Plan

Further Prototyping of every design
- Changing handle geometry and brake material
- Testing new epoxies and glove materials

Further Testing
- Test new prototypes
- Develop methods for measuring results
- Research and test different rope materials
- Large scale testing

Finalize Concept
- Concept Verification