ASEN 2001 OMEP 1: Ralphie's Ski Free Resort

Design Team Analysis Section 307

Team Engineers:

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2) Ella Mumolo
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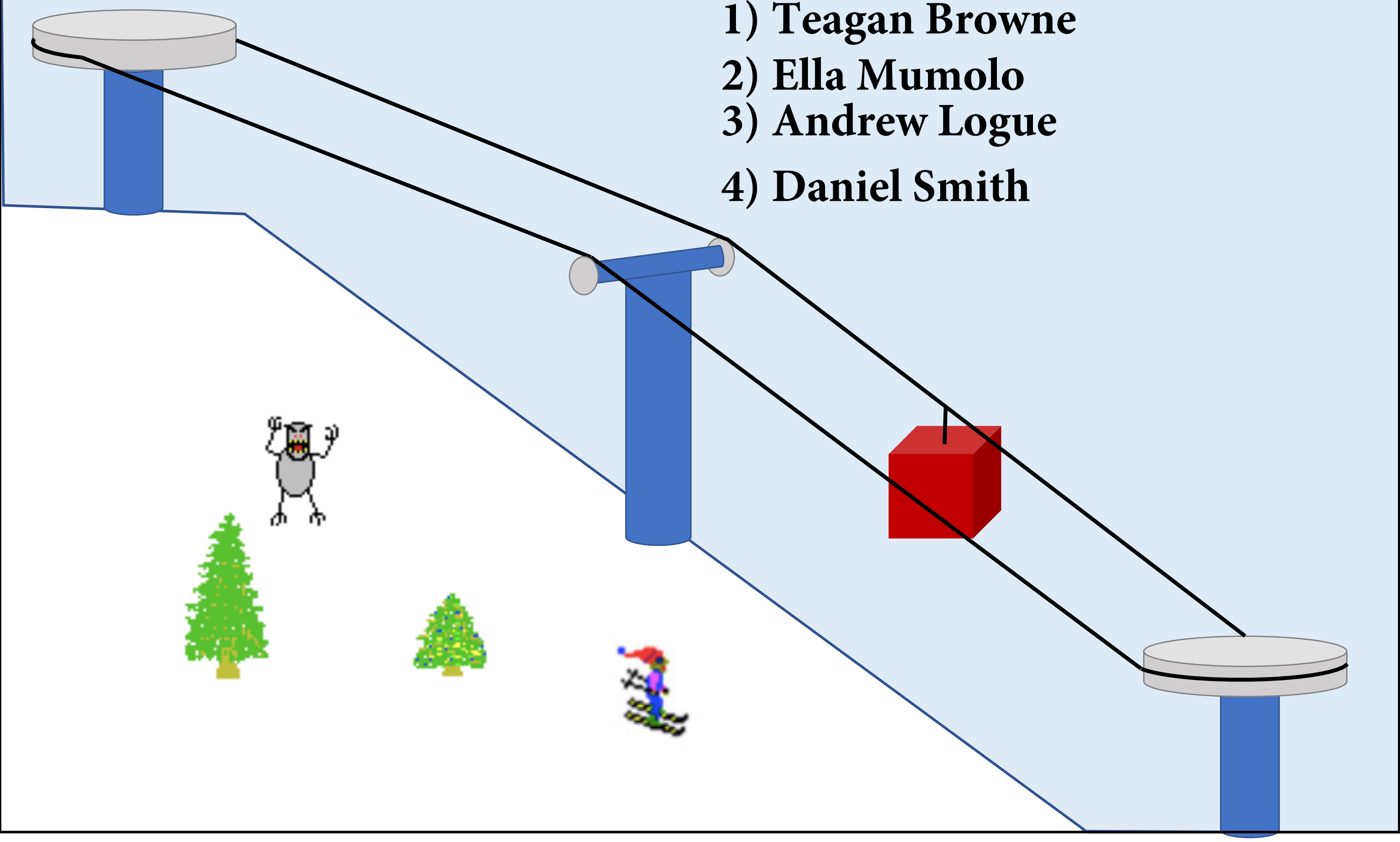

A wealthy CU Boulder alum has decided to build her own ski resort at her private mountain retreat. She has named it Ralphie's Ski Free Resort, and contacted the AES department for static analysis of the initial design concepts.

OMEP Learning Objectives:

1) Observe how real life systems are modeled as free body diagrams
2) Determine reasonable minimum and maximum external forces based off of the design environment (design requirement development)
3) Determine if FBDs are actually static situations (do static assumptions apply?)
4) Set up equilibrium equations for open ended free body diagrams
5) Apply distributed loads and point loads to open ended free body diagrams
6) Examine how supports are selected when modeling real life designs as free body diagrams
7) Perform constructive design/analysis reviews with student colleagues

Problem 1: Determine load requirements.
Review at the free body diagrams for problems 2 through 4. In this section, you will develop the requirements for the weight of gondolas at Ralphie's Ski Free Resort. This weight should be translated to a load in lbf. As these problems are 2D in the X-Y plane, you can disregard any loads due to wind pushing in or out of the page. Be sure to take in account the different operating conditions of the gondola.
Note: A 6 passenger Leitner Poma gondola has an empty weight of 1200 lb.

1) What is the range of the maximum weight of the gondola you and your teammates determined? (the maximum weight load in lbf)

   The maximum weight range was from 2,268lbf - 3,000lbf.

2) What were 2-3 assumptions regarding weight that ALL teammates made?

   Three assumptions all teammates made were there were 6 adult males, on the gondola, all passengers were an average healthy weight, and we accounted for ski equipment.

3) What were three assumptions regarding weight that were different amongst teammates?

   Some differences amongst our assumptions were:
   - Some snow on the gondola
   - The gondola wouldn't run in severe weather
   - Slight differences of the average weight of an adult male.

4) What is the final weight of the gondola (in lbf) you will use for your team calculations? Give two to three reasons why your team should design to this weight.

   The final weight our team is using for our gondola is 2575lbf and we decided to use this weight by averaging all of our individual weights as they were within an acceptable range. By averaging all of our individual weights we take into account the weight of snow and equipment as not all of our group members accounted for these factors.

Problem 2: Analysis: Gondola on a flat stretch of cable.
An engineer always analyses a design in multiple operating situations. Here you are estimating the loads in the cables assuming that the gondola is on a flat stretch of cable, and the weight of the gondola pulls the cables down at a 15 degree angle. The cables ARE NOT MOVING- assume someone has fallen and the lift operators have turned off the motor. The gondola is attached to the cable by a hook, and assume a frictionless surface between the hook and the cable. The gondola is in the exact middle between the two pulleys. Assume frictionless pulleys and a weightless cable.

Fig. 1: Real Life Design Flat

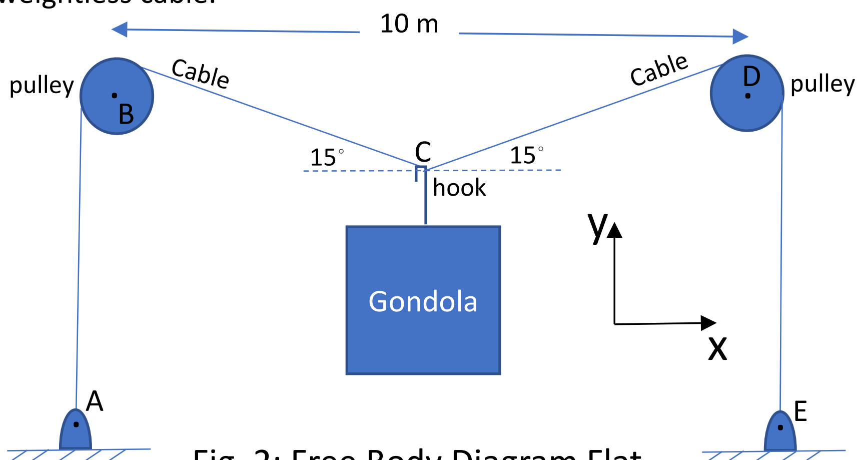

Fig. 2: Free Body Diagram Flat

As a team, compare your global free body diagrams for problem 2.

1) What were some of the SAME assumptions you and your teammates made in your individual global FBDs?
Some assumptions we made about the gondola were:
- There is a weight force on the gondola
- We used the maximum weight
- We assumed the system was static
- There are reaction forces at anchors a and e.

2) What were some DIFFERENT assumptions you and your teammates made in your individual global FBDs?
Some of our teammates accounted for friction and tension while others did not, but as we talked together we realized there was no friction present in this example.

3) What were some of the differences in the global free body diagrams that you and your teammates drew?

In addition, some of our teammates included a reactionary force from the pulleys and others did not.

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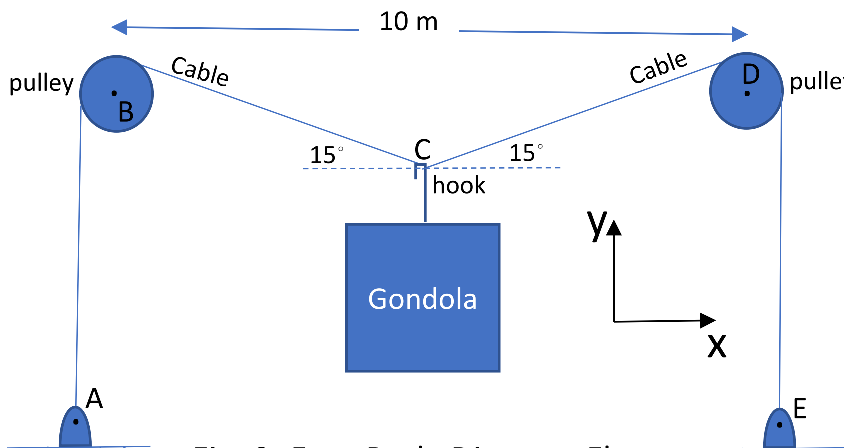
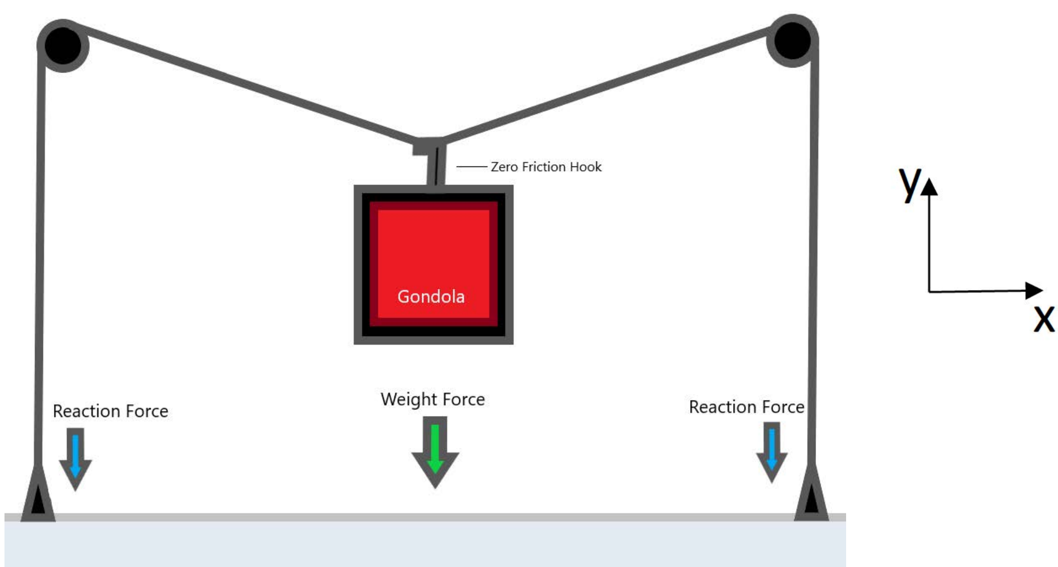


Fig. 2: Free Body Diagram Flat

4) As a team, draw a global free body diagram of the system above in Figure 2.

Global Free Body Diagram #1



5) Think about the equilibrium equations and statics principles we have learned so far.
What gives your team confidence that the free body diagram makes sense?

In both the x and y direction our net force is zero meaning it's a static system. We feel confident our free body diagram makes sense as all other forces are internal forces.

Problem 3: Analysis: Gondola with hook on a inclined stretch of cable.

Here you are estimating the loads in the cables assuming that the gondola is on a 30 degree stretch of cable. Again, the cables ARE NOT MOVING. The gondola is attached to the cable by a hook, and you can assume a frictionless surface between the hook and the cable. Assume frictionless pulleys and a weightless cable.

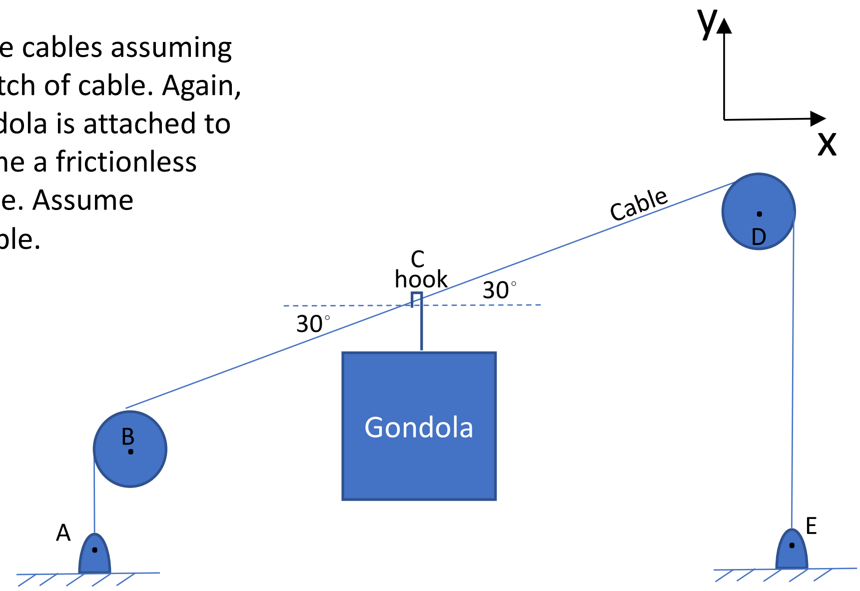
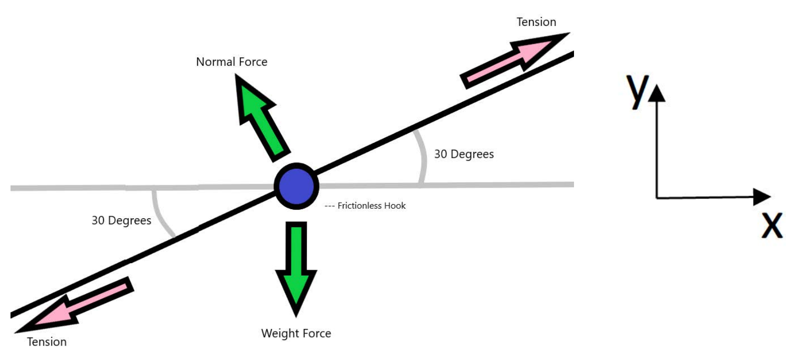


Fig. 3: Real Life Design Inclined Cable, Hook

Fig. 4: Free Body Diagram of Inclined Cable, Hook

1) As a team, draw a **local** free body diagram of point C.

Free Body Diagram #2



2) As a team, in this system, is the static assumption a valid one? Prove it with equations. What do you think is happening in the system?

The static assumption is not valid for this system because there is nothing counteracting the x component of the normal force. We think the gondola will accelerate down along the wire. We acknowledge while the rope has tension it doesn't act on point C. The tension present in the rope creates the normal force.

$$\Sigma F_x = F_n \sin(60) \neq 0$$
$$\Sigma F_x = F_n \cos(60) - weight_{gondola} = 0$$

Problem 4: Gondola with clamp on a inclined stretch of cable.

Here you are estimating the loads in the cables assuming that the gondola is on stretch of cable. Again, the cables ARE NOT MOVING. The gondola is NOW ATTACHED TO THE CABLE BY A CLAMP, and you can assume infinite friction between the clamp and the cable. To model the dip in the cable caused by the gondola's weight, there is a 40 degree angle to the right and a 30 degree angle to the left. Assume frictionless pulleys and a weightless cable.

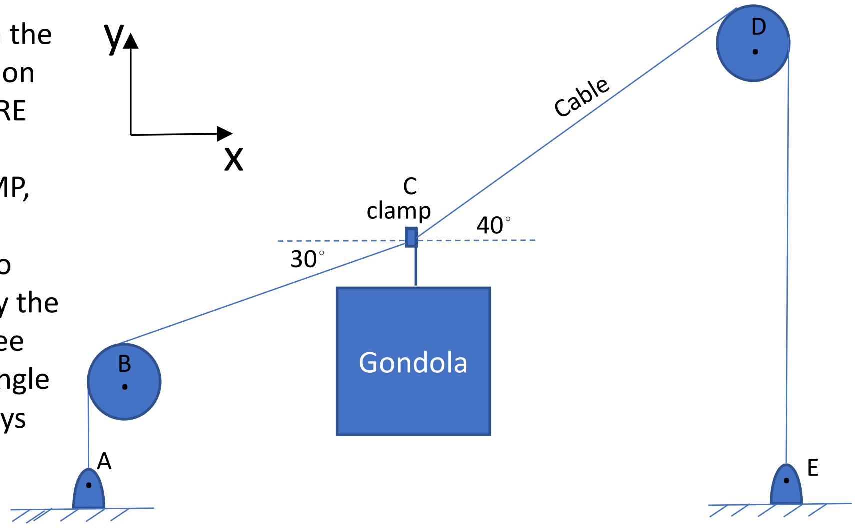


Fig. 5: Real Life Design Inclined Cable, Clamp

Fig. 6: Free Body Diagram of Inclined Cable, Clamp

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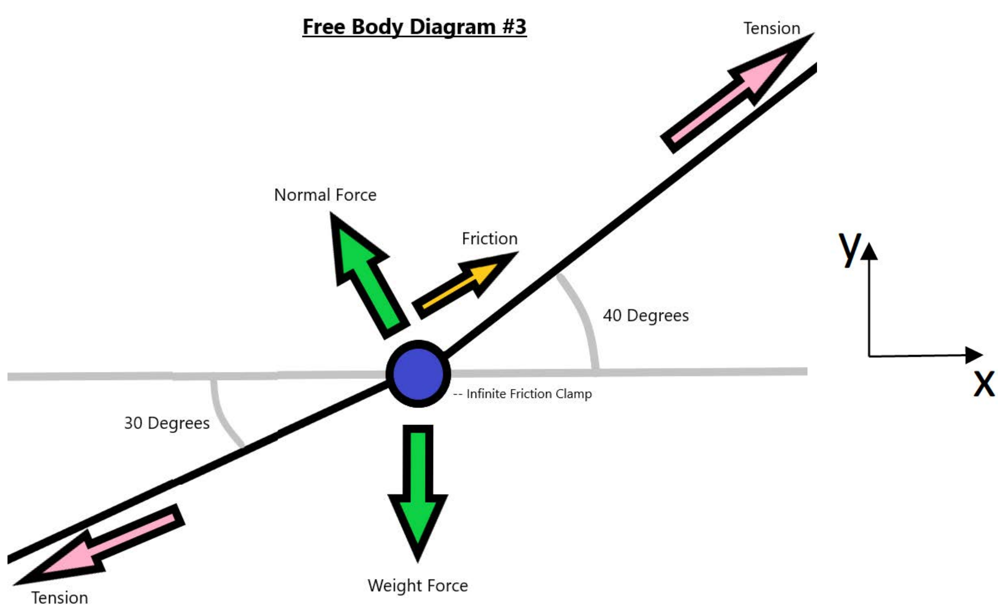

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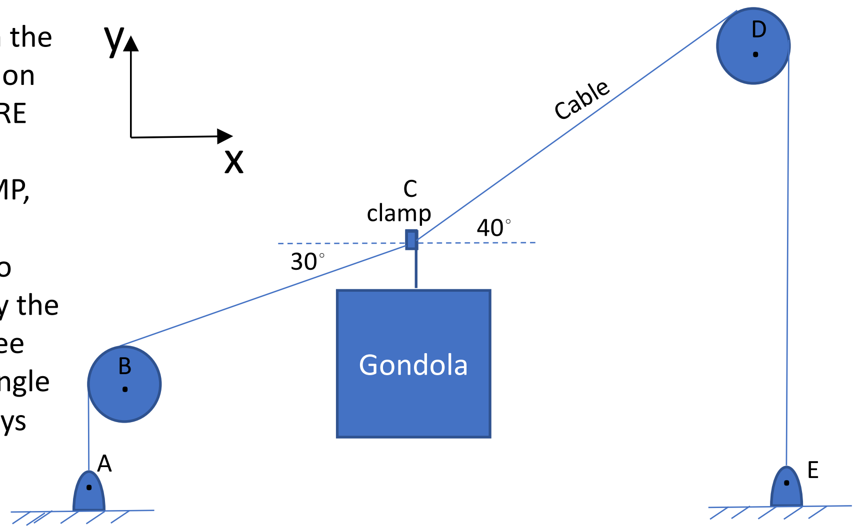


Fig. 5: Real Life Design Inclined Cable, Clamp

Fig. 6: Free Body Diagram of Inclined Cable, Clamp

2) Compare the loads you found in the cables as a team. What was the range?
What were some of the assumptions (FBDs, operating conditions) that lead to these differences?

We assumed:
- There is infinite friction
- The system is static
- Frictionless pulley
- Weightless cable

In addition to these assumptions we each had different weight values which lead to a range in tension values. The range of values we got was from 10587.54lbf to 13,234lbf for tension on BC and 11969.38lbf to 14961lbf for tension on CD. The friction between the clamp and cable is what keeps the gondola stationary.

$$\mathrm{F}_{net} = T_{DC}\sin(40) - T_{BC}\sin(30)$$
$$T_{BC} = \frac{weight_{gondola}}{\tan(40)\cos(30) - \sin(30)} = 11359.55lbf$$
$$T_{DC} = T_{BC}\frac{\cos(30)}{\cos(40)} = 12842.15lbf$$

3) How does the tension of the cable compare to the weight of the gondola?
Why do you think this is?

The tensions were roughly 6.5 times greater than the weight of the gondola. As shown in our force diagram the tensions are not acting along the same line as the weight force, therefore the tension had to be larger to hold the gondola in place.

Problem 5: Distributed loads and point loads

The figure below shows a schematic and initial free body diagram of a Ram Air Turbine.

Assume the following:

1) The RAT has been deployed on a F-105Ddue to all engine failure
2) You are modeling the RAT at the instant it is deployed, BEFORE the turbine blades start rotating. Therefore, it is NOT YET a dynamic system.
3) The wind pressure is constant across the surface. (This does NOT mean a constant force distribution)
4) The wind is only hitting the blade directly perpendicular to the surface
5) The turbine blade is completely flat, and therefore lift can be neglected.

You can model the turbine blade as an isometric triangle with dimensions below.

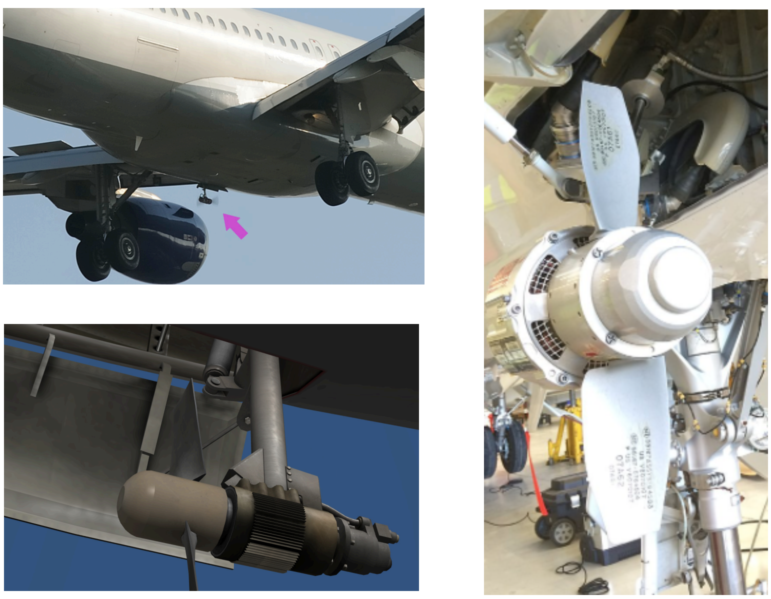


Fig. 8: Front View: Real Life RAT

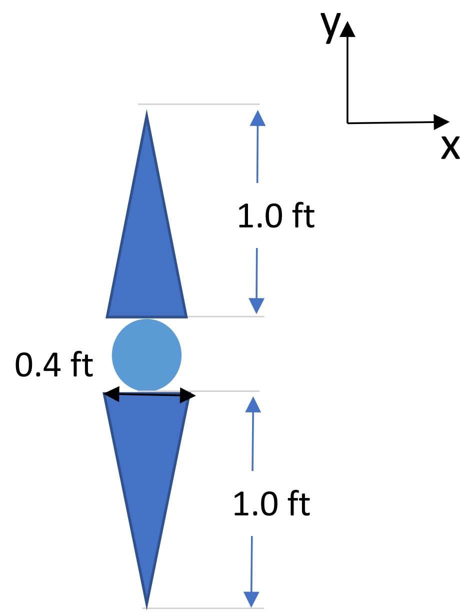


Fig. 9: Front View FBD RAT

Side View

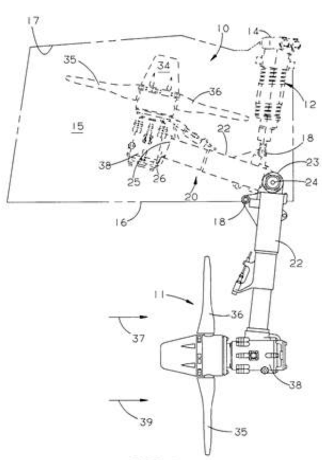


FIG. I

Fig. 10: Side View: Engineering Drawing RAT

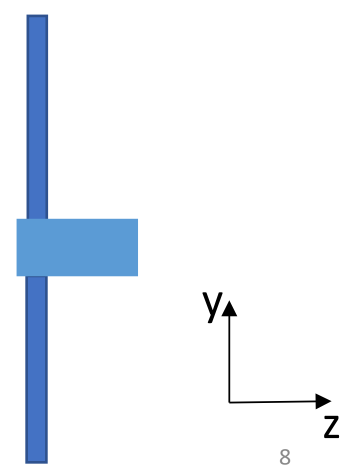


Fig. 11: Side View FBD RAT

Problem 5: Distributed loads and point loads

Given the following:

To calculate a point load on the turbine due to airflow, use the following equation:

F = A x Q x Cd

Where:

A is the surface area of the turbine blade

Q is the dynamic pressure

Cd is the drag coefficient, and can be assumed to be ~ 1.2 for a flat plate

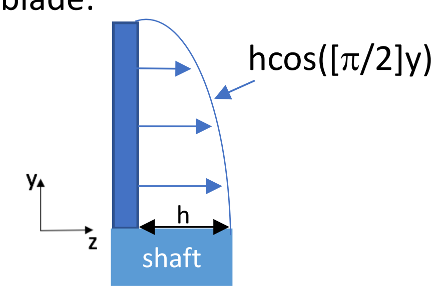
$Q = \frac{1}{2} \rho v^2$

Where:

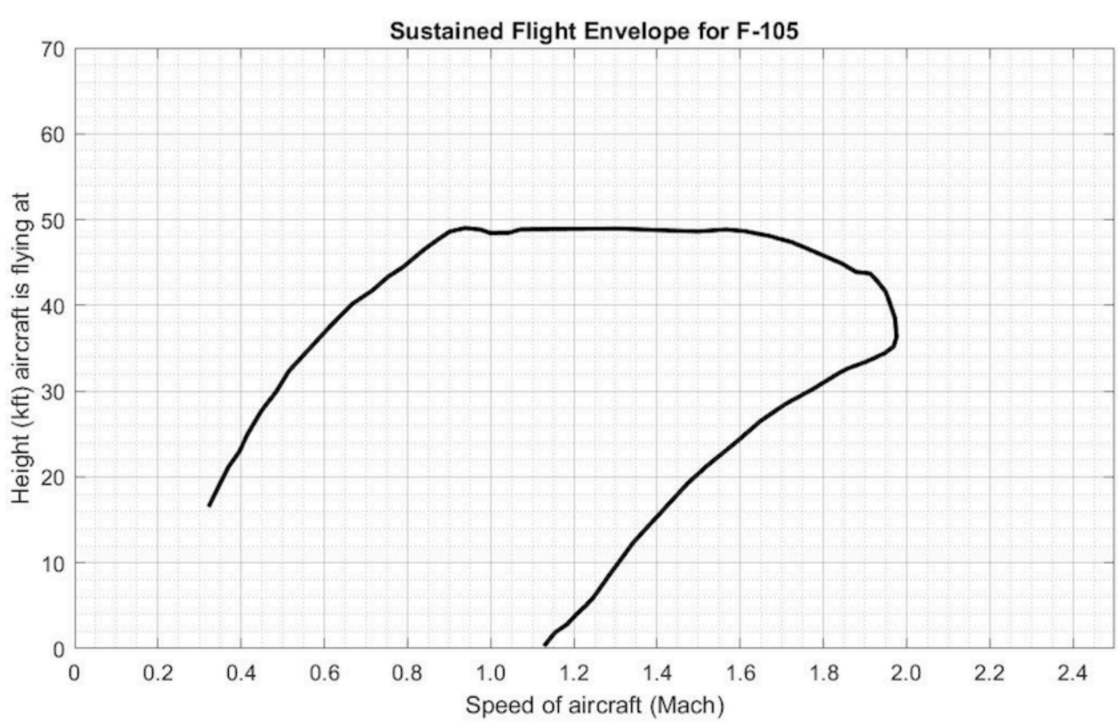
ρ is the density of the air at the flight altitude

v is the speed of the aircraft

And assume the following force distribution along the turbine blade:



And assume 1G level flight and the altitude speed curve below. Note that the '0' rainbow contour is the sustained flight envelope. This is where the aircraft can fly and sustain the altitude and airspeed without having to descend or slow down- the F-105 can sustain 1G, level flight anywhere within this contour.

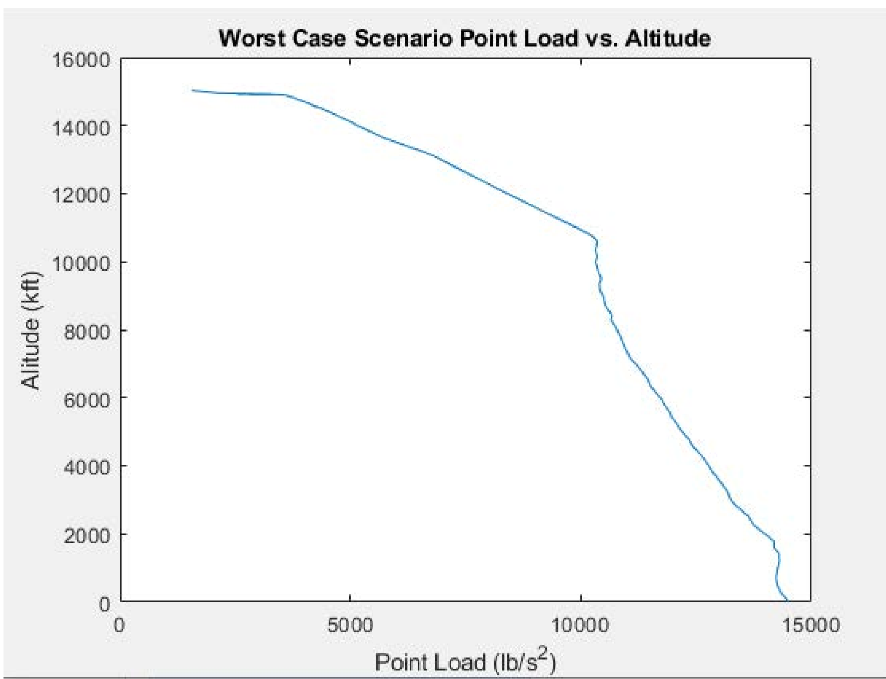


Problem 5: Distributed loads and point loads

Your TEAM is assigned to determine the worst case scenario point load on a single RAT blade due to dynamic pressure of the airflow

Examine the plots of the curve of the worst case scenario point load vs altitude for the F-105that you and your teammates have developed.

1) As a team, determine the maximum point load on the turbine blade, and what altitude and aircraft speed does it occur at.
   The maximum point load on the turbine blade was 1.45*10^4 lbf/s^2 and it occurred at 0kf.

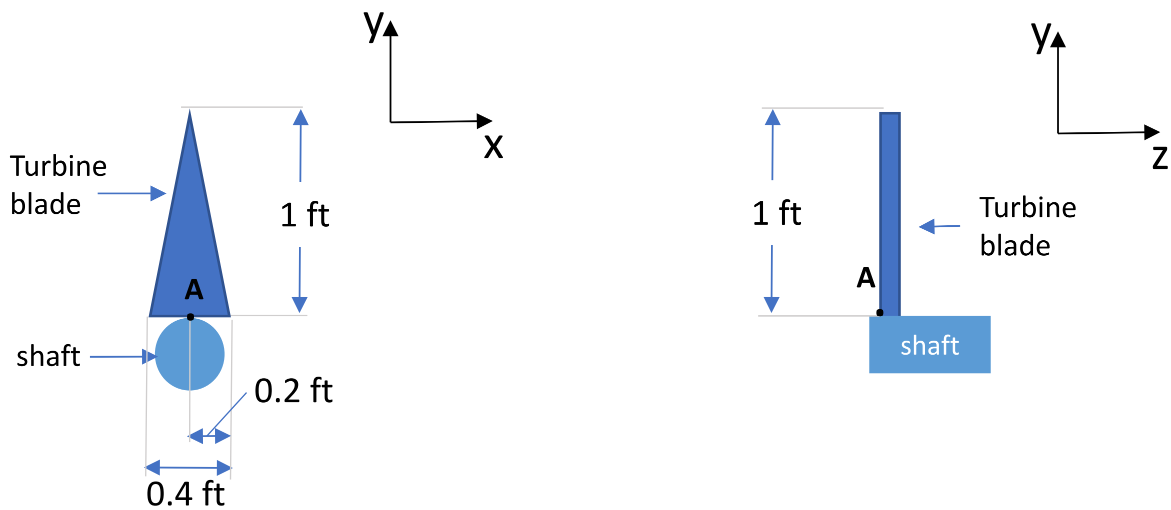


2) What are the critical assumptions your team made to determine this?
   We assumed the system was static, we were only flying in our 1g flight envelope, and we included all assumptions listed in the problem.

Problem 5: Distributed loads and point loads

Continued.

4) As a team, given the distributed load distribution and the maximum point load, where should you apply the maximum point load when modeling the turbine? Show X and Y distances. Assume the origin (0,0) is at point A.



The maximum point load occurs at approximately (0,0.363).

$$\overline{y} = \frac{\int y\omega(y)dy}{\int \omega(y)dy} = \frac{\frac{2}{\pi} - \frac{4}{\pi^2}}{2/\pi} \approx 0.363$$

Problem 5: Distributed loads and point loads

Continued.

6) As a team, examine the entire system of the RAT with two turbine blades. What would the reaction forces and/or moments be at the shaft? Where would they occur on the shaft? Draw the reaction and external forces/moments and necessary dimensions on the schematic below.

The reaction force at the shaft would be at point A and it would have a value of two times the force of the wind on each turbine blade. In addition to this force there are two equal and opposite moments at point A caused by the force of the wind on each blade.

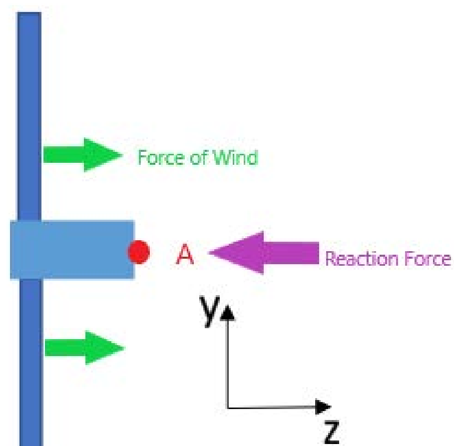


Fig. 11: Side View FBD RAT