**Project 1 - MA205** **The LAPES Problem** **Due 18 October 1996**

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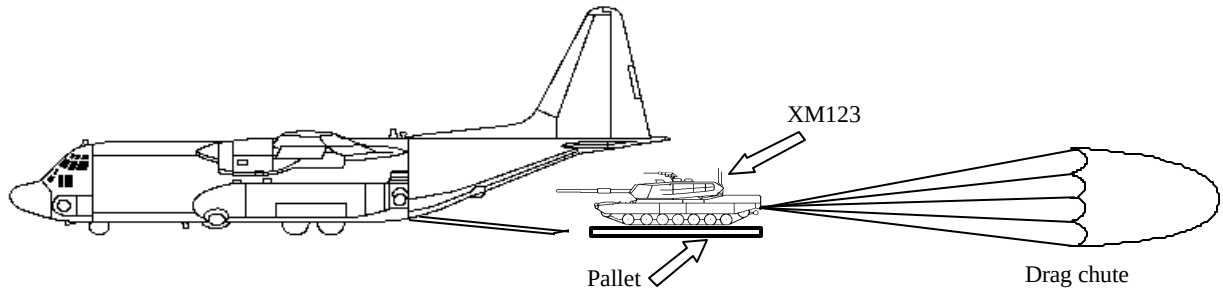
## Introduction

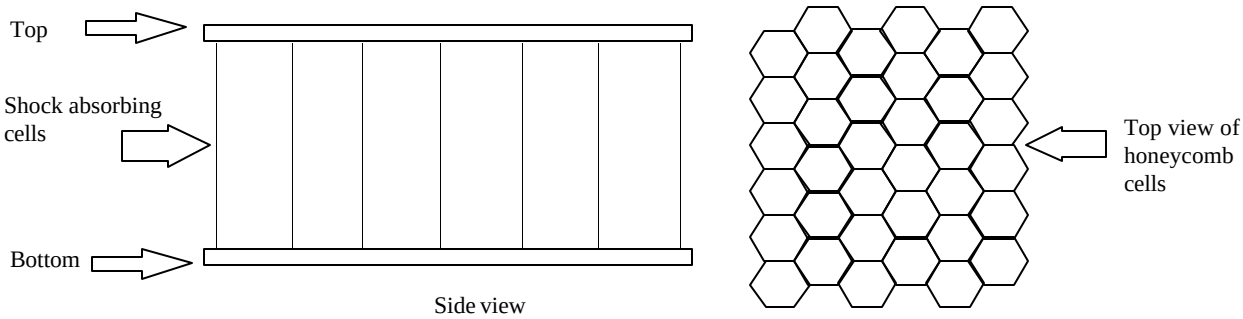
Low altitude parachute extraction systems (LAPES) are used extensively by airborne units for the delivery of heavy equipment that cannot be air dropped. An aircraft, usually a C-130, makes a very slow and low pass over the drop zone, and a drag chute is deployed to pull the load from the rear of the aircraft. The load will be on a shock absorbing pallet which is sitting on rollers on the floor of the aircraft. When the chute creates enough drag, the load is pulled from the aircraft and falls a short distance to the ground. Hopefully, the pallet will slide on top of the ground until friction brings it to rest.




You are a project officer working on the specifications required for a LAPES capability demonstration involving the new XM123 Light Tank. With the initial test coming up shortly, you have been tasked to determine some parameters for the event. There is not enough time or resources to conduct mock extractions with dummy loads. You will get one shot at this so make sure your calculations are complete and accurate!

## Requirement 1: The Pallet

a. You must first determine some parameters for the rigging of the XM123. The pallet used is made of cardboard with a honeycomb cell layer. There are 500 cells arranged in the pattern shown below. Each cell will compress upon impact and each can be modeled as a simple spring (Assume compressing force is evenly distributed over all 500 springs). The pallet is required to absorb 50% of the energy (work) generated by the falling tank. How much energy does the pallet have to absorb?

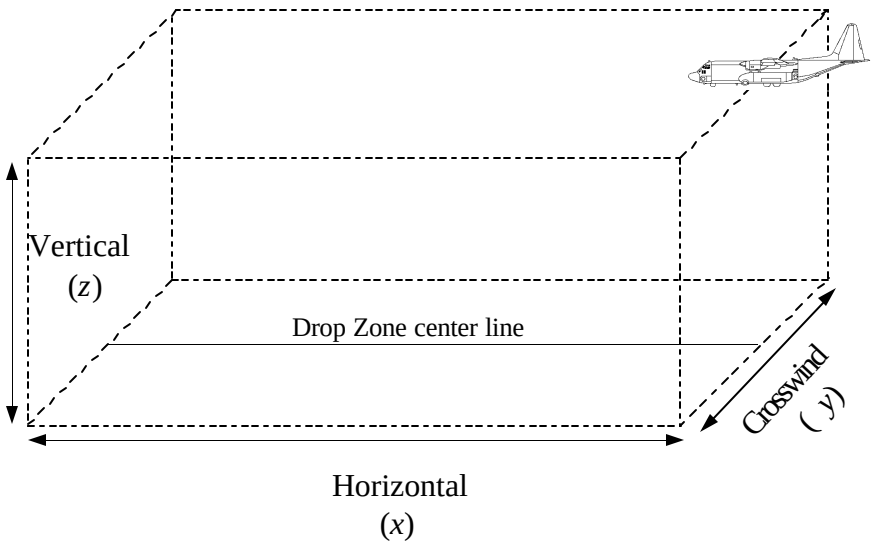



b. The thickness of the pallet is restricted by the maximum cargo height the aircraft can handle ("cargo" includes the load and the pallet). If the max height for a C-130 is 8.75 feet, determine

whether the current specifications provided will result in a rigging that will fit in the aircraft. What changes would you suggest to lower the overall height of your cargo?

**Requirement 2: The Drop Zone**

Before you load up the XM123 and let it fall to earth, you better make sure the drop zone you are using is big enough, otherwise trees or a lake might be the final resting place for your equipment!




For this part of the analysis use some simplifying assumptions:

1. The load exits the aircraft at the beginning of the drop zone with the aircraft's velocity. During the drop, the aircraft maintains level flight and constant speed.

2. As the load falls to earth, the only force acting on it in the vertical ($z$) direction is gravity. The drag chute only effects movement in the horizontal ($x$) direction during the fall. The force created by the drag chute is $F = cd_p\, v^2$, where $cd_p$ is the coefficient of drag due to the drag chute and $v$ is the velocity experienced in that direction. The force created by air resistance will only be considered in the crosswind ($y$) direction, and the coefficient of drag due to air resistance ($cd_a$) is listed in the specifications. The force due to air resistance is $F = cd_a\, v^2$.

3. When the load reaches earth, the only force acting to slow it down in the $x$ and $y$ directions is friction with the ground. You will also assume the coefficient of friction due to contact with the ground ($m_g$) is constant during this entire period. The force generated by this friction is given by $F = m_g\, m\, g$.

a. If the aircraft maintains its altitude in the specifications, how long will it take for the load to hit the ground once it exits the aircraft?

b. To determine the length of the drop zone required for this load, you must consider different phases as the load moves in the horizontal ($x$) direction. The first phase of horizontal travel is from exit of aircraft to contact with the ground. (Remember, the load exits the aircraft when the

aircraft reaches the beginning of the drop zone.) Determine the speed of the aircraft that is required to pull the load from the aircraft. To ensure a timely extraction, the C130 will fly over the drop zone at 10 knots per hour faster than this minimum speed. (This is the initial velocity of the load in the horizontal direction.) The coefficient of friction for the rollers in the aircraft ($m_r$) and the coefficient of drag for the drag chute ($cd_p$) are in the specifications.

c. Apply Newton's 2d Law of motion in the horizontal direction and develop the second order differential equation describing the load's motion from aircraft exit to ground contact.

d. Determine how far the load traveled in the horizontal direction from the time it exited the aircraft until it touches the ground.

e. Apply Newton's 2d Law of motion in the horizontal direction and develop the second order differential equation that describes the load's motion once it touches and slides along the ground. The coefficient of drag is in the specifications.

f. Determine the distance the load travels along the ground until it comes to rest.

g. What is the minimum length required for the drop zone?

h. When the load exits the aircraft, it has an initial velocity in the crosswind ($y$) direction. You will use the maximum allowable crosswind speed for LAPES (for a "worst case" analysis) to determine displacement in the $y$ direction. As above, develop the differential equations for both phases of the drop. Determine how far the load moves from the center line of the drop zone. How wide would you make the drop zone?

**<u>Requirement 3: The Ammo Drop</u>**

a. Not all of the ammunition can be stored in the XM123 during the LAPES. It is bundled and tossed out the rear of the aircraft at the same time the tank exits. The velocities in each direction ($x$, $y$, and $z$) are given in the specifications. The external forces acting on the ammo bundle that you should consider are gravity in the vertical ($z$) direction, and drag due to air resistance in both the horizontal ($x$) and crosswind ($y$) direction. The drag coefficient for air resistance is the same as used in Requirement 2. Develop the differential equations that describe motion in the three component directions.

b. If the position of the bundle when it is thrown from the plane is [0, 0, 0], then where does the bundle impact with the ground?

c. Assuming the bundle does not move once it lands, how far apart are the bundle and XM123?

## Specifications

**XM123:**

Mass: _____ slugs
Height: _____ feet
Gravity constant: 32 ft/sec$^2$

**Extraction system:**

$cd_p$: _____
$cd_a$: _____
$m_r$: _____
$m_g$: _____
Individual cell compression constant (k): _____ lb/ft
Height of extraction: _____ feet
Maximum allowable crosswind speed: _____ knots per hour

**Ammo Drop:**

Initial velocities: [ _____ knots, _____ knots, _____ knots]
Mass: _____ slugs