2006 HiMCM

Problem A
Inflation of the Parachute

A parachute is made from thin, lightweight fabric, support tapes and suspension lines. The lines are usually gathered through cloth loops or metal connector links at the ends of several strong straps called risers. The risers in turn are attached to the harness containing the load.

Deployment systems

Freefall deployed parachutes are pulled out of their containers by a smaller parachute called a pilot chute.

A way of deploying a parachute directly after leaving the aircraft is the static line. One end of the static line is attached to the aircraft, and the other to the deployment system of the parachute container.

Types of parachutes

Round parachutes

An American paratrooper using an MC1-1C series 'round' parachute

Round parachutes, which are pure drag devices (i.e., they provide no lift like the ram-air types), are used in military, emergency and cargo applications. These have large dome-shaped canopies made from a single layer of cloth. Some skydivers call them "jellyfish 'chutes" because they look like dome-shaped jellyfish. Rounds are rarely used by skydivers these days. The first round parachutes were simple, flat circulars, but suffered from instability, so most modern round parachutes are some sort of conical or parabolic.

Some round parachutes are steerable, but not to the extent of the ram-air parachutes. An example of a steerable round is provided in the picture of the paratrooper's canopy; it is not ripped or torn but has a "T-U cut". This kind of cut allows air to escape from the back of the canopy, providing the parachute with limited forward speed. This gives the jumpers the ability to steer the parachute and to face into the wind to slow down the horizontal speed for the landing.

Annular & pull down apex parachutes

A variation on the round parachute is the pull down apex parachute invented by a Frenchman named LeMoigne -- referred to as a **Para-Commander**-type canopy in some circles, after the first model of the type. It is a round parachute, but with suspension lines to the canopy apex that apply load there and pull the apex closer to the load, distorting the round shape into a somewhat flattened or lenticular shape.

Often these designs have the fabric removed from the apex to open a hole through which air can exit, giving the canopy an annular geometry. They also have decreased horizontal drag due to their flatter shape, and when combined with rear-facing vents, can have considerable forward speed around 10 mph (15 km/h).

Ribbon and ring parachutes

Ribbon and ring parachutes have similarities to annular designs and they can be designed to open at speeds as high as Mach 2 (two times the speed of sound). These have a ring-shaped canopy, often with a large hole in the center to release the pressure. Sometimes the ring is broken into ribbons connected by ropes to leak air even more. The large leaks lower the stress on the parachute so it does not burst when it opens.

Often a high speed parachute slows a load down and then pulls out a lower speed parachute. The mechanism to sequence the parachutes is called a "delayed release" or "pressure detent release" depending on whether it releases based on time, or the reduction in pressure as the load slows down.

Ram-air parachutes

Most modern parachutes are self-inflating "ram-air" airfoils known as a Para foil that provide control of speed and direction similar to Para gliders. Para gliders have much greater lift and range, but parachutes are designed to handle, spread and mitigate the stresses of deployment at terminal velocity. All ram-air Para foils have two layers of fabric; top and bottom, connected by airfoil-shaped fabric ribs. The space between the two fabric layers fills with high pressure air from vents that face forward on the leading edge of the airfoil. The fabric is shaped and the parachute lines trimmed under load such that the ballooning fabric inflates into an airfoil shape.

A U.S. NAVY display jumper landing a 'square' ram-air parachute

Reserves

Paratroopers and sports parachutists carry two parachutes. The primary parachute is called a main parachute, the second, a reserve parachute. The jumper uses the reserve if the main parachute fails to operate correctly.

Reserve parachutes were introduced in World War II by the US Army paratroopers, and are now almost universal. For human jumpers, only emergency bail-out rigs have a single parachute and these tend to be of round design on older designs, while modern PEPs (i.e P124A/Aviator) contain large, docile ram-air parachutes.

Deployment

Reserve parachutes usually have a ripcord deployment system, but most modern main parachutes used by sports parachutists use a form of hand deployed pilot chute. A ripcord system pulls a closing pin (sometimes multiple pins) which releases a spring-loaded pilot chute and opens the container, the pilot chute is propelled into the air stream by its spring then uses the force generated by passing air to extract a deployment bag containing the parachute canopy, to which it is attached via a bridle. A hand deployed pilot chute, once thrown into the air stream, pulls a closing pin on the pilot chute bridle to open the container, then the same force extracts the deployment bag. There are variations on hand deployed pilot chutes but the system described is the more common throw-out system. Only the hand deployed pilot chute may be collapsed automatically after deployment by a kill line reducing the in-flight drag of the pilot chute on the main canopy. Reserves on the other hand do not retain their pilot chutes after deployment. The reserve deployment bag and pilot chute are not connected to the canopy in a reserve system, this is known as a free bag configuration and the components are often lost during a reserve deployment. Occasionally a pilot chute does not generate enough force to either pull the pin or extract the bag, causes may be that the pilot chute is caught in the turbulent wake of the jumper (the "burble"), the closing loop holding the pin is too tight, or the pilot chute is generating insufficient force, this effect is known as "pilot chute hesitation" and if it does not clear it can lead to a total malfunction requiring reserve deployment.

Paratroopers' main parachutes are usually deployed by static lines which release the parachute yet retain the deployment bag which contains the parachute without relying on a pilot chute for deployment. In this configuration the deployment bag is known as a direct bag system and the deployment is rapid, consistent and reliable. This kind of deployment is also used by student skydivers going through a static line progression, a kind of student program.

Using the modeling process, build a mathematical model for the opening of the parachutes discussed above. We are concerned with how the parachute inflates. Use your model to explain how the geometry of the folding of the parachute affects the inflation and then discuss how we might affect the rate of inflation of the parachute.