Rocketry Recovery Technology

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NARCON 2013 was my chance to get up and talk about some of the cool stuff I've learned over the years. As of this date, we have made close to 2000 chutes and shipped all over the US as well as internationally to over 30 countries and counting. During this time and after helping so many hobbyists, universities and corporations with their projects, we've learned quite a bit! The subjects of the talk included:

• **Types of Parachutes** - Comparing the most popular chutes used in rocketry

• **Packing Density** – Predicting packing volume and density using chute weight

• **Packing Methodology** - Comparing the various types of parachute packing methods

• **Deployment Methodology** – Various ways to deploy your parachute

Types of Parachutes – We discussed and contrasted the most popular chutes used for rocket recovery and advantages and disadvantages of parachutes. These include:

• Cruciform – Shaped like a cross
• Flat Sheet Chutes – Like Top Flight
• Panel Chute – Rocket Man
• Elliptical and Spherical – Fruity Chutes and Spherachute
• Pull down Apex, Toroidal – Fruity Chutes' Iris Ultra Parachute

One of the challenges in comparing designs is there is no standard in how a parachute's diameter is measured. Additionally, the drag coefficient of the chute is based on the assumed projected frontal area. This affects the apparent efficiency of the chute or the drag coefficient (Cd). Below is a list of chute types and (to the best of my knowledge) how they are measured:

• Cruciform is distance across chute.
• Flat chutes are fabric diameter.
• Panel chutes are measured diagonally across the top. In some cases, diameter is not published.
• Spherachute is the circumference of the canopy.
• Fruity Chutes are measured based on projected frontal area, i.e the opening diameter when inflated.

The aerospace industry usually specs the Cd (coefficient of drag) in reference to the projected frontal area. This is considered the gold standard in measurement. For some chute types (e.g. a flat chute), it's difficult to predict the projected frontal area. So the chute measurement is simply based on the distance across the chute canopy.

Below is a table comparing different types of chutes with regards to how they are measured and various parameters:

Chute Type	Measure Type	Stability *	Cd	Cost	Use
Cruciform	Across Chute	Good at any speed	Low – 0.4	Medium	High speed drogue or chute
Flat Sheet	Across Chute	Ok at low speed, poor at high speed	Low – 0.7	Low	Main or drogue
Panel Style	Across top panels, usually on diagonal	Good vertical stability, can rotate or spin	Med – 1.1	Medium	Mostly as a Main
Elliptical (Classic Fruity Chutes)	Protected frontal area	Medium high speed, Good low speed	Med – 1.6	Medium	Main or Drogue chute
Toroidal (Iris Ultra	Protected frontal area	Good low speed	High – 2.2	High	High performance main chute. Best performance vs. weight

* The tendency of the chute to stay directly above the load. Some chutes move from side to side especially as the descent speed increases.

Packing Density - One of the more interesting parts of the discussion is packing density and calculation of packing volume by simply knowing the weight and dividing that by the density. In this case, the packing density is measured as oz per cu inch of weight. Dividing this factor into the chute weight measured as ounces gives you the volume in cubic inches.

A key fact is that packing density is not dependent on the chute design (as long as we're talking about nylon). This has been verified by a number of studies done by different research groups. One such study found that a density of 30 lb per cu foot (.28 oz/in^3) can be achieved by compressing the parachute at an equivalent force of 15 psi. Compressing at 100 psi yields a density of about 45 lb. However at this pressure, you start to damage the nylon. The Peregrine IDS uses this exact technique to get the small packing volumes featured by that product. We use 15 psi as an ideal pressure.

As a typical example that rocket folks can relate to, let's look at the packing density and volume you can achieve when you fold and wrap your parachute (see our How to Pack a Parachute tutorial for instructions). We have found that a typical density with this method is about 0.13 oz/in^3.

Let's look at packing the Iris Ultra 60 parachute with a weight of 10.9 oz. The packing volume is calculated as:

10.9 oz / 0.13 oz/in^3 = 84 in^3

To convert that to length in your airframe you use the formula:

$L = (V * 4) / (pi * D^2)$ or $L = V / (D^2 * .7854)$

L is length, D is diameter, and V is volume.

If we have a 3.9 inch inner diameter airframe, we get:

$L = 84 / (3.9^2 * .7854) = 7$ inch length

If you use a deployment bag you can achieve a higher density of about 0.18 oz/in^3 or maybe even higher depending on how hard you push. The Peregrine IDS has the highest packing density at 0.28 oz/in^3 by pressing the chute into the canister at 15 lb/sq^2. For the 6 inch Peregrine IDS, this means we use a pneumatic press that applies about 450 lb of force to the lid!

Parachute Packing Methodology – In this part of the talk, we discussed various ways to pack your parachute. Below is a table listing several of the methods discussed.

Packing Method	**Description**	**Packing Density (oz/in^3)**
Traditional Fold and Wrap	Traditional fold, roll and wrap chute. This is the common method used by most rocketry folks.	0.13
Deployment Bag	The chute is packed into a bag.	0.16 – 0.2
Pressure Pack	Chute is pressed into a canister. Used by the Peregrine IDS.	0.28

Then we contrasted the various methods:

· **Fold and Wrap** – The big advantage is its simplicity, anyone can do it! All small rocket parachutes are done this way. If you have enough space in your rocket, this will work well. One disadvantage for large parachutes is that it is easy to mis-pack the parachute, which results in a tangled deployment. Additionally, it is hard to consistently pack into a tight space using this method.

· **Deployment Bag** – Use this for larger chutes or where space is tight. By following a simple technique, it is easy to get a consistent packing density and reliable deployment without tangles. We recommend the use of a bag for any parachute diameter of 120 inches or larger. Also use a deployment bag when you have a long and narrow airframe space for your recovery gear.

· **Pressure Pack** – This is the most extreme method of packing a parachute, and it has by far the highest packing density. The military and many aerospace deployment systems are packed this way. Some use extreme pressure to pack huge parachutes into very small spaces. The Peregrine IDS uses this system and features an Iris Ultra parachute packed into a carbon fiber canister.

Parachute Deployment Technology – Finally, we discussed various ways to deploy your parachute. The two most common types are simple black powder, and CO2 ejection systems. We also talked about integrated systems such as the Peregrine IDS. The table below contrasts these two types:

Type	**Advantage**	**Disadvantages**	**Used with These Packing Types**
Black Powder	Easy, relatively low cost, reliable.	Black powder is hard to get and is regulated by the ATF. Tricky at high altitudes. Leaves corrosive residue. Heat can damage fragile nylon canopies.	Fold and Wrap, Deployment Bag
CO2	Clean and reliable. Will not damage your parachute. Can be used at high altitudes.	More costly. A little more complicated to prepare. Ground testing is critical.	Fold and Wrap, Deployment Bag, Pressure Pack
Integrated System	Very compact and high reliability.	Higher cost, may need special equipment to pack the parachute.	Pressure Pack

Most high power rocketry fliers use a simple black powder to deploy their parachute.

Some prefer CO2 because it is clean. Additionally if you fly to high altitudes, CO2 will provide reliable deployment.

The integrated systems are used where performance and packing density are critical requirements.