SUSPENSION LINES COMPARISON

Any parachute system needs to be suspended via lines, the so called suspension lines. Early lines were made out of hemp while the parachute fabric was usually silk and the harness built out of leather. In the early 1880s, Sir Joseph Swan invented the first synthetic fiber. The idea of a synthetic fiber is the one of the understanding of the building blocks of a natural fiber and make it better. All natural fibers have impurities and weaker bonds in them by nature's own default. These weaknesses can be overcome by making a fiber that has strong bonds between the building blocks and those latter ones being all equal. Additionally, by having control of the building environment, impurities can be totally minimized during the chemical process. Since the early 1900s, synthetic fiber technology has grown to a multi-billion dollars industry that will still grow to the end of humanity. Any industrialized civilization cannot be without textile fibers.

In 1935, Wallace Carothers working at DuPont, invented Nylon. Nylon is a polyamide, poly means many and amide is a compound with a functional group of $R_nE(O)_xNR'_2$. Nylon completely revolutionized the parachuting industry. Nylon was a great substitute for all three organic materials used in building parachuting systems, i.e. silk, hemp, and leather. Fiber for fiber, nylon is stronger than any natural textile, it retains the wrinkle-resistance and luster of silk, and some of the durability of leather. Soon after nylon was introduced, parachutes, suspension lines, containers, and harnesses were all made out of nylon. Fast-forward to the next millennium, and we still make all parachutes systems with nylon! Nylon is just that good! Nylon's luster, wrinkle-resistance, affordable price, strength, and variety are still great reasons why nylon is here to stay as major role player for many aerospace applications.

As far as suspension lines are concerned, nylon is still a great choice for round canopies, however it is not an acceptable fiber for any ram-air canopy. The issue with nylon suspension lines is the embedded elasticity of the fiber, so that the ram-air airfoil gets distorted when loaded. Canopy designers go through lots of work in order to develop a precision parachute airfoil; it is a shame to allow a fiber to stretch to the point that the shape of the airfoil becomes irrelevant! In the late 1960s, early ram-air airfoils were lined with Dacron. Dacron is polyethylene terephthalate, a type of polyester. While not as strong as nylon, Dacron offers less elasticity, excellent UV and abrasion resistance, superior to nylon in that regard. In today's world, parachutes are lined with mainly four different types of materials: Dacron, Spectra, Vectran, and Technora (High Modulus Aramid [HMA]). Spectra is ultra-high-molecular-weight polyethylene. Vectran is an aromatic polyester while HMA is a aromatic polyamide. Aromaticity describes the unusual orientation of atoms rings so that the bonds formed between the monomers are very strong. As an analogy, we took hemp and silk and made it better with nylon, then we took nylon and made it better with HMA.

Fiber	Color	Initial modulus (grams per denier)	Breaking Strength (grams per denier)	UV (Time for 50% strength loss)	Chemical Resistance	Abrasion Resistance	Shrinkage After Heating	Cost ($/Kilo)	Pros & Cons
Dacron	white, red, black, and others	100	5	6 months	good	very good	good	$6-8/kilo	**Pros:** Tough, durable, inexpensive, many weights and finishes. **Cons:** Relatively stretchy compared to Vectran
Technora	gold, black or while	550	52	1.5 mo. (gold) 2.0 mo. (black) 3.0 mo. (white UV treated)	good	very good	very good	$90/kilo	**Pros:** Light, low stretchy. **Cons:** Poor UV resistance when untreated. Very expensive.
Spectra	white	300	35	6 months	good	good	poor	$70/kilo	**Pros:** Light weight, low stretch, excellent durability and UV resistance **Cons:** Shrinkage due to heat exposure. Expensive
Vectran	light bold/ brown	600	25	1.5 months	good	poor	very good	$80/kilo	**Pros:** Light weight, low stretch, excellent flex resistance **Cons:** Very low UV resistance. Poor abrasion resistance. Very expensive.

TABLE I: Lines Comparison Chart

It is important to know the proper nomenclature used to describe these kinds of fibers. The initial modulus is a measure of the initial fiber elasticity: The higher the number, the less the stretch; it is measured by grams per denier. Breaking strength is self explanatory and again it is measured grams per denier. UV measures the time, usually in months, of UV exposure such that the fabric loses 50% of its initial strength. Chemical resistance generally refers to the capacity of the fabric to retain its strength after having been in contact with various chemicals usually strong alkaloids and strong acids. Abrasion and shrinkage should be self explanatory.

So what can we interpolate from Table I? Dacron stretches quite a bit, it is not as strong as Spectra (hence bigger lines for the same strength), it has good UV protection, and it is affordable. Dacron thus is good for people who desire softer openings due to the stretch, do not care for the added drag of the bulkier lines, and want an overall durable, cheap line set. Dacron is not recommended by Nitro Rigging to be used in high performance canopies because its stretch can distort the airfoil.

Spectra also known as Microline is much stronger than Dacron (7X) it does not stretch as much, it has good UV protection, but it does change in dimensions after heat exposure like the friction created from the slider grommets, for instance. Highly-loaded canopies are expected to show significant line shrinkage in as few as 100s deployments. Nitro Rigging does not recommended Spectra to be used in any parachuting application.

Vectran is even less 'stretchy' than Spectra, a little less strong, and does not shrink after heat exposure. The drawbacks are the poor abrasion and UV resistance and the high cost.

Technora (HMA) does not stretch much (almost like Vectran) is about twice as strong as Vectran, hence the nickname 'spaghetti lines', it has a very good abrasion resistance, and does not change dimensionally when exposed to heat. The problems are that it is very expensive and when left untreated it has poor UV resistance.

Dacron still has its role in today's parachuting. It's good for BASE canopies, some Tandem applications, Student, Military, and CRW canopies. For the rest of the population of canopies the best choice is HMA treated with UV coating. HMA is thin, actually almost unbelievably thin so that one can build non-cascaded line sets with it and still have a dramatic reduction in parasitic drag. Technora has very good abrasion resistance and the canopy will stay in trim for the duration of the line set. It is expensive but about the same as Vectran though. It is true that untreated Technora loses 50% of its original strength after 1.5 months of UV exposure. Said that, if you pack indoor and the lines are exposed to the Sun rays for only the duration of the jump 1.5 months translates into 13,000 jumps if you assume 5 minutes/jump! No line-set will last 13,000 deployments! Technora lines are nowadays

readily available with a UV coat on them and that should take care of any worries.

The Technora line Nitro Rigging purchases for its continuous sport canopies line sets it has a tensile strength of 375 LBS, it is treated with a UV coat, and should last you 1,000 jumps, thus in the long-run it becomes even cheaper than a Spectra reline. We make the lower control lines of HMA 900 LBS (and we recommend to change those ever 500 jumps). The continuous line set not only are easier to field-install but they are also stronger than the equivalent 525 LBS Spectra line set. Spectra is normally cascaded so each lower line has twice the load as a non-cascaded line hence using Technora non-cascaded lines equals of using Spectra 750 LBS. Also, in the event of a line breakage, you will lose only one canopy attachment point not two like in the case of a cascaded set. All Nitro Rigging deployable canopies feature continuous line sets. Nitro Rigging gliders are lines with HMA span-wise cascades.