Welcome to

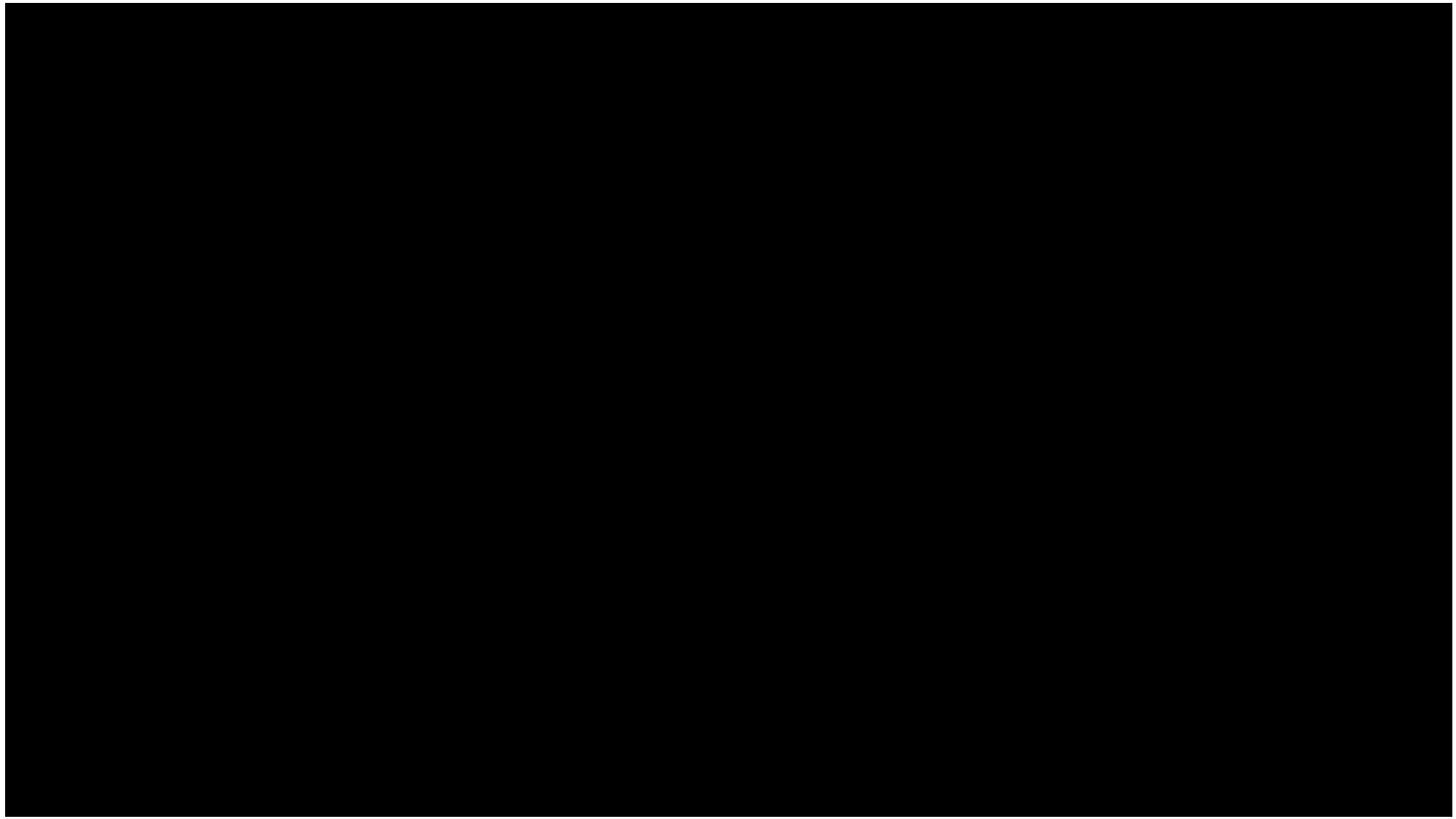
Advanced Textiles EXPO

ORGANIZED BY ATA

LCP Fiber and Space Exploration

Matthew Reid
Kuraray America Inc., Vectran™ Fiber Division

Vectran™



Video courtesy of Sierra Space Corporation

Matthew Reid | LCP Fiber and Space Exploration | Oct. 31, 2023

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LCP Fiber Technology

"Polyarylate Fiber"

Polyamides - Aramid

- High Performance
  - aromatic PA or “aramid” fibers
  - acid spinning from monomers
  - copolymers
- High temperature
- Requires drying
- Low flex/abrasion resistance

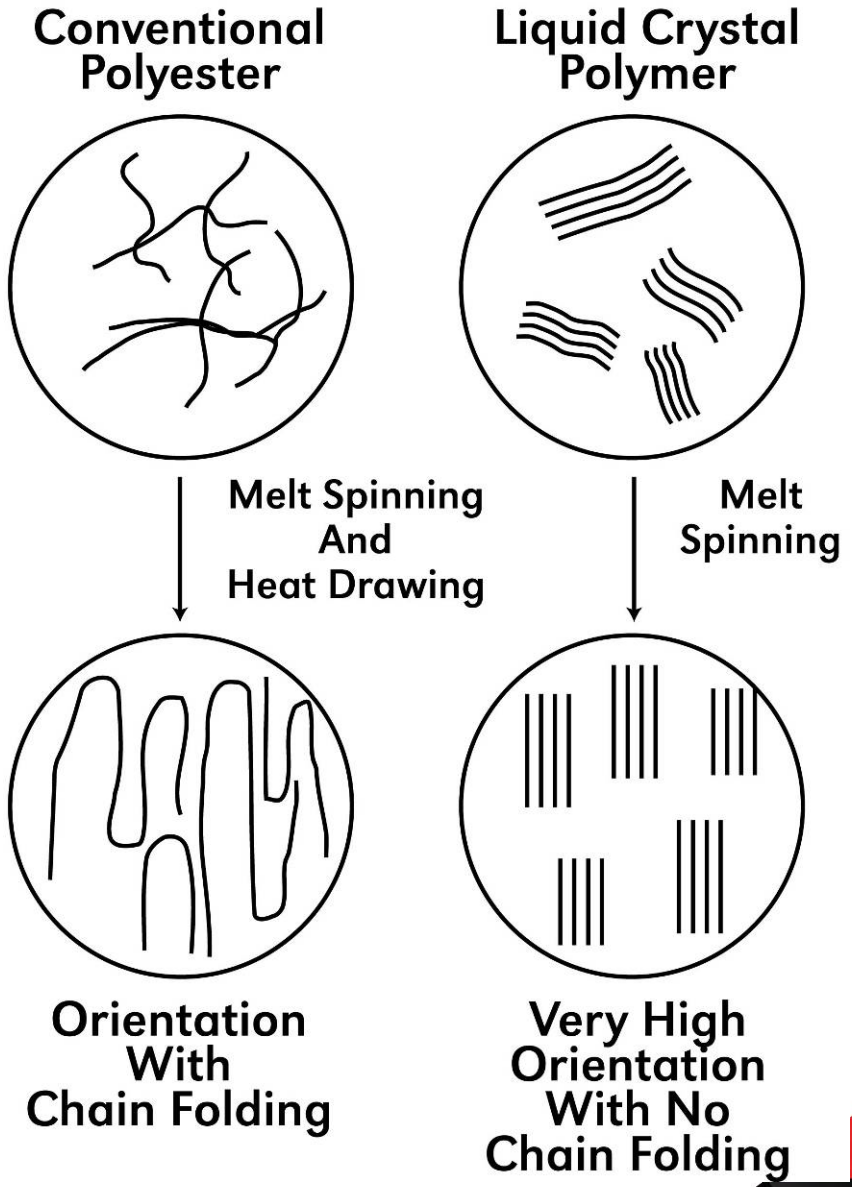
Polyolefins - HMPE

- High Performance
  - UHMWPE polymer “HMPE” fibers
  - gel spinning from polymer
  - slit tape
- Lightest weight
- Very tough/durable
- Temp sensitive
- Creep sensitive

Polyesters - LCP

- High Performance
  - aromatic PES “LCP” or “arester”
  - melt spinning from polymer
  - copolymers
- Thermal stability
- Flex/abrasion tolerant
- No moisture issues
- Dynamic applications

Liquid Crystal Polymer Morphology



Benefits of LCP Fiber

(for extreme environments i.e. space exploration)

- Light weight/High strength-cut/tear/puncture
- Excellent abrasion resistance
- Flex/fold durability (optimal choice)
- Dimensional stability (low creep, low shrinkage)
- Thermal stability (wide range performance)
- Vibration damping
- High impact resistance
- Chemical resistance (wide range exposure, bleach resistance)
- Extremely low moisture absorption
- Excellent off/out-gassing characteristics
- Radiation exposure-no impact

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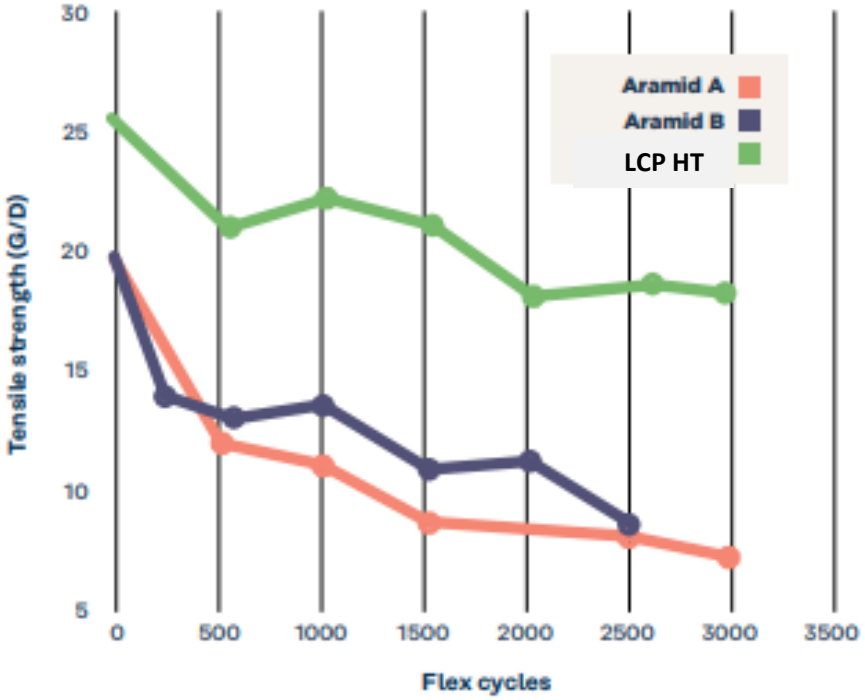
LCP Fiber Properties

	Density (g/cm^3)	Tensile Strength (GPa)	Tensile Modulus (GPa)	Uptake Moisture %	Elongation %
LCP (HT grade)	1.40	3.4	70	<0.05	~4
Polyester (PET)	1.38	1.1	14	<0.5	~15
Aramids	1.44	3.0	65	4-6	~4
Polyamide (nylon)	1.14	1.0	10	6-8	~20
HMPE	0.97	3.4	110	<0.05	~4
LLDPE	0.95	0.5	8	<0.5	~22

Offgassing and outgassing test results for LCP HT Fiber

Vectran™ fiber with:	TML%	CVCM%	WVR%	Toxic hazard index
No finish	*	0.00	0.00	2.226**
T97 finish	*	0.00	0.00	0.009
T150 finish	0.30	0.00	0.00	0.015

* Test results exceeded precision limits required to produce a statistically meaningful average. Individual samples measurements: fiber without finish, 0.21 and 0.07%; fiber with T97 finish, 0.13 and 0.19%.
** The contribution of benzyl alchohol to this T-value is 2.214. the concentration in the sample was 0.31µg/g; no measured SMAC value was available, therefore a conservatively low value of 0.14µg/g was assumed.



Fatigue testing of coated fabrics

Base material	Tenacity loss at failure location 100 cycles, %	Failure location
LCP HT	0.8	Away from fatigued crease
Aramid	22.9	At Crease

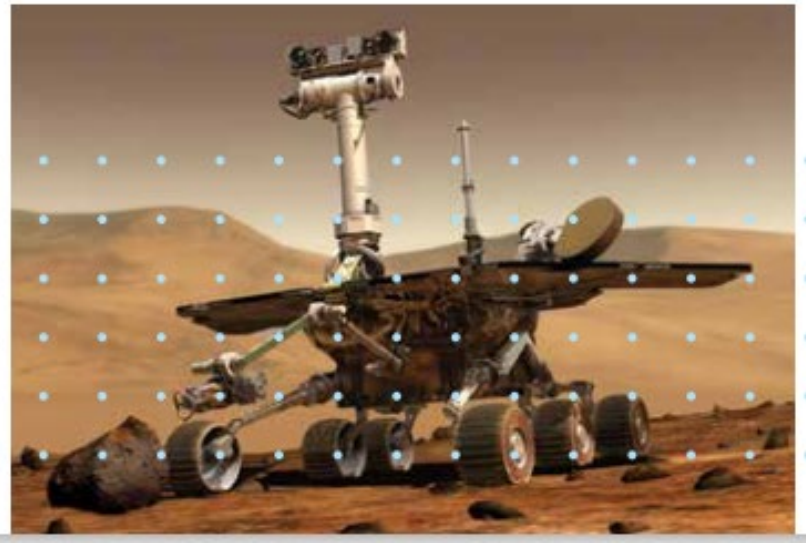
Flex: Tinius Olsen/MIT Modified ASTM D2176

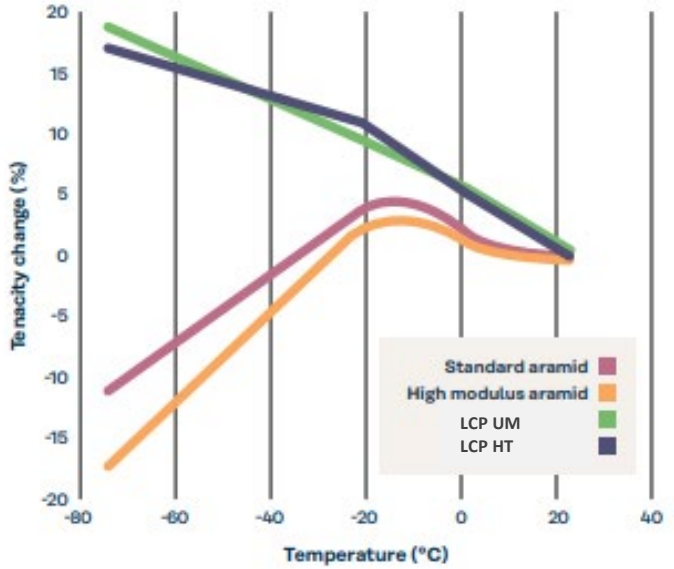
Equilibrium moisture regain

Temperature (°C)	Relative humidity (%)	LCP		Aramid	
		HT	UM	Standard	High modulus
20	65	<0.1	<0.1	4.2	4.1
20	80	<0.1	<0.1	4.8	4.8
20	90	<0.1	<0.1	5.4	5.5

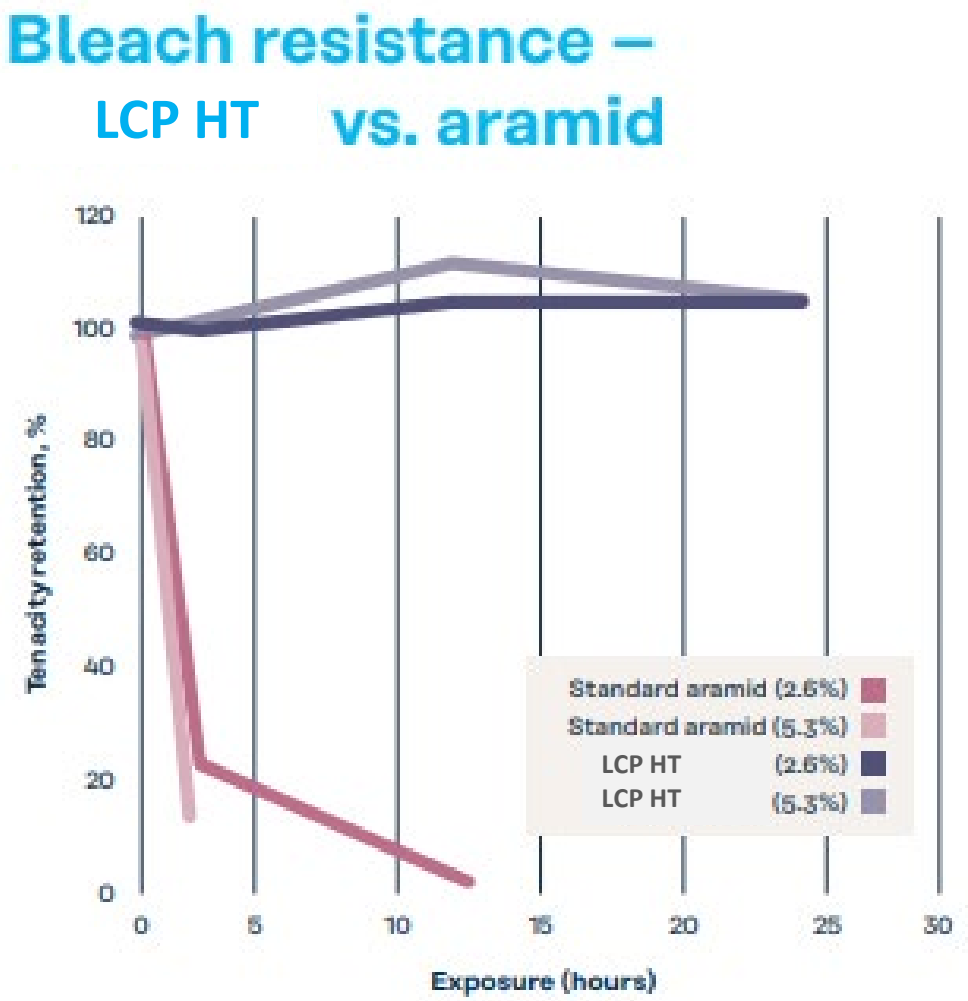
LCP Fiber at low temperature

Evaulated by ILC Dover during the design of the airbag system for the 1997 Mars Pathfinder mission, ILC reported LCP fiber increased in strength in tests at -62°C, leading to its selection for the airbag fabric and external assembly tendons.

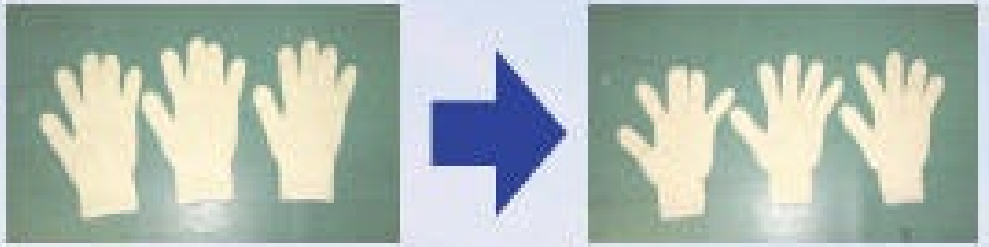




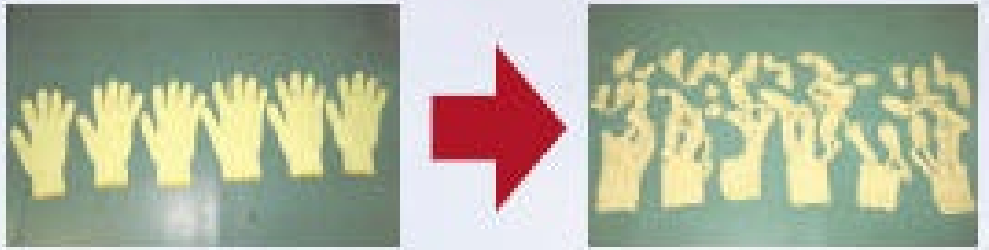
Chemical Resistance



LCP HT Fiber

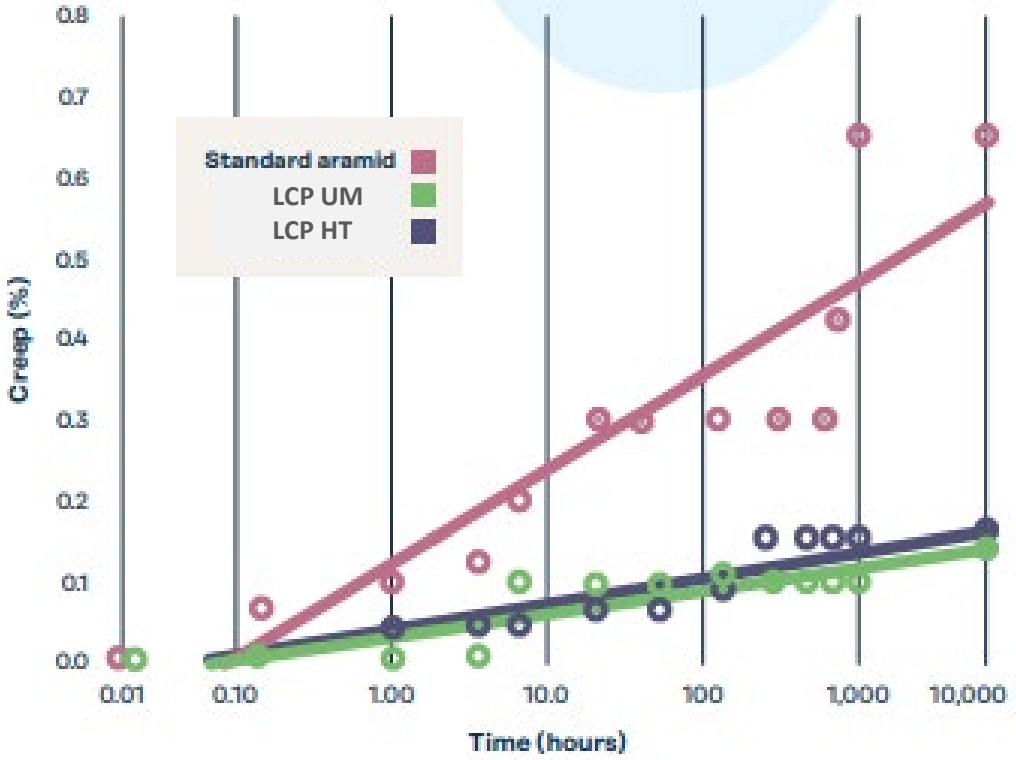


Para-Aramid



Washing at 80 degree C for 30 min → Bleaching (10% NaClO) → Drying at 80 degree C for 30 min (10 cycles)

Creep behavior at ambient temperature (30% of break load)



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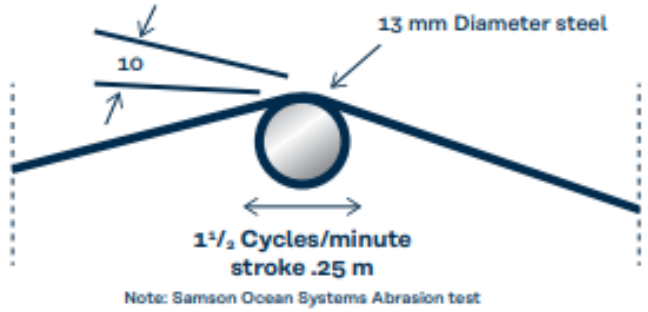
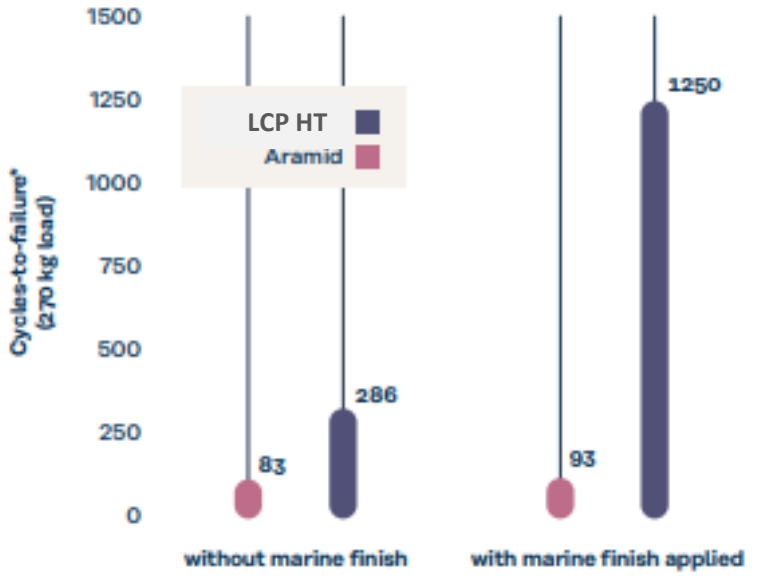
With or without marine finish on the braid, Vectran™ outperforms aramid materials.



Note: Samson Ocean Systems Abrasion test



* Eight-strand plain braid, 64x1500 denier threadlines. All tests dry

Comparative testing of yarn-on-yarn abrasion resistance

Yarn	Average cycles-to-failure	
	Dry	Wet
LCP HT T97, 1500D	16,672	21,924
Aramid 1, 1500D	1,178	705
Aramid 2, 1500D	1,773	759
Aramid 3, 1500D	974	486
PBO, 1500D	2,153	–
HMPE, 1500D	8,518	23,619

Test method CI-1503: 1.5 wraps, 500g load, 66 cycles/min, no twist.

LCP Fiber Applications

- Ropes/Cables
- Hoses/Umbilicals
- Heavy Lift / Industrial Slings
- Aerospace/Flexible Composites
- Protection/Gloves/PPE
- Advanced Textiles

Space Exploration

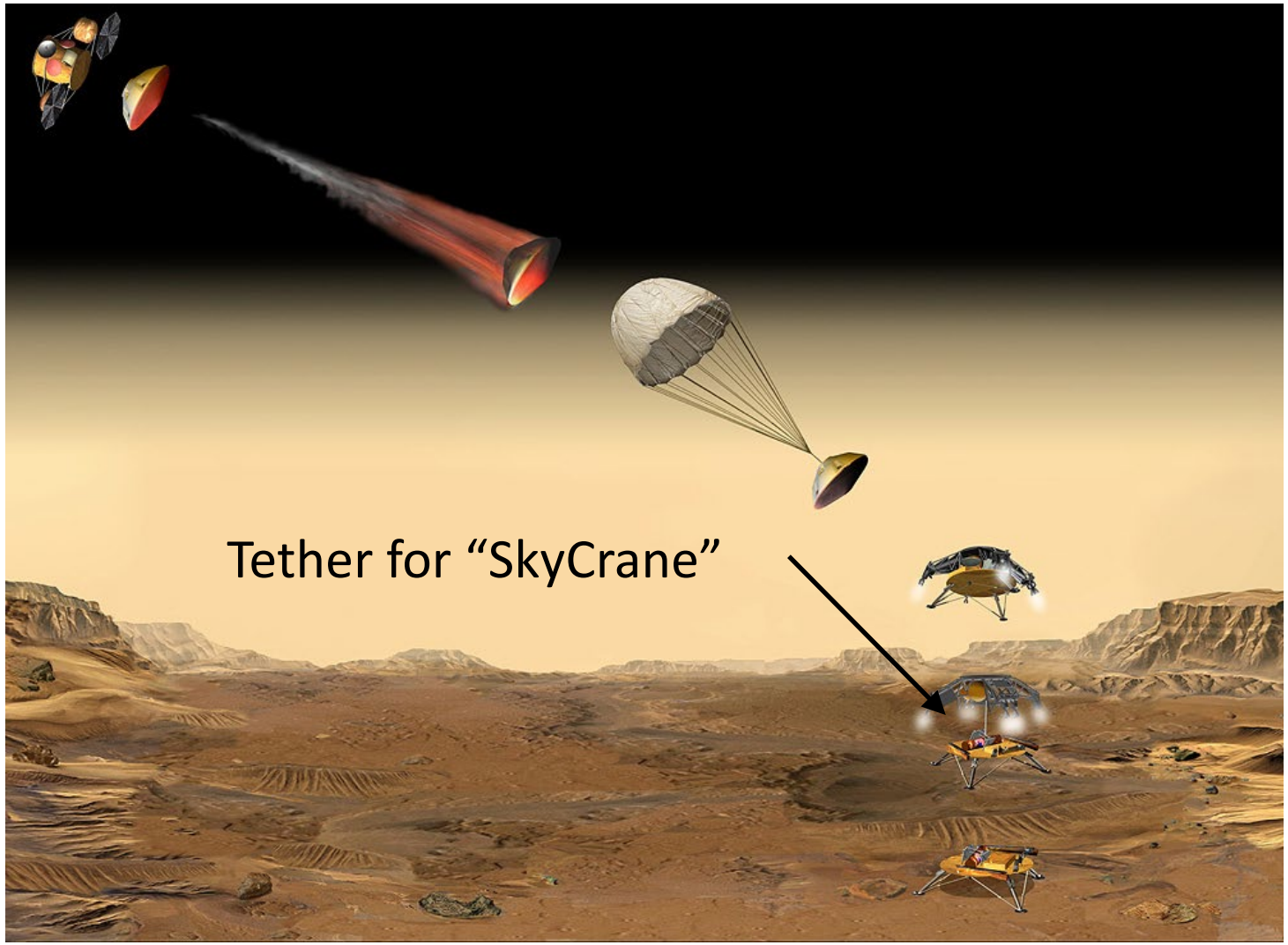


Photo courtesy NASA

NASA’s Mars Exploration Rover Projects

- Pathfinder, Sojourner, landed July 1997
- Spirit and Opportunity, April 2004

Photos courtesy NASA / ILC-Dover

Pathfinder Mission

- Sent to Mars to explore surface
- Landed July 4, 1997
- First ever robotic rover on Mars- 23lbs
- New method of landing- parachute & airbag shell
- Show low-cost method of exploring other planets
- Retrieve data from free-ranging robot (last transmission Sept 27, 1997)
  - 2.3 billion bits of info
  - 16,500 images (lander), 550 (rover)
  - 15 chemical analyses

Image courtesy of NASA

Pathfinder

Images courtesy of NASA

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Pathfinder Landing

Image courtesy of NASA

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Spirit and Opportunity

- Twin solar powered rovers sent simultaneously to opposite sides of Mars
- Primary mission- 90 day (92 sols)- look for geological evidence of water that may have been hospitable environments for past life
- Spirit launched June 10, 2003; Opportunity launched July 7, 2003
- Design based on Pathfinder, Sojourner but 384lbs (17 times heavier than Pathfinder and 2X length)
- Opportunity hit the jackpot first!
- Spirit's primary mission showed evidence of inhospitable environment
- Spirit traveled 2.25 miles, Opportunity 1 mile

Image courtesy of The Planetary Society

BY THE NUMBERS

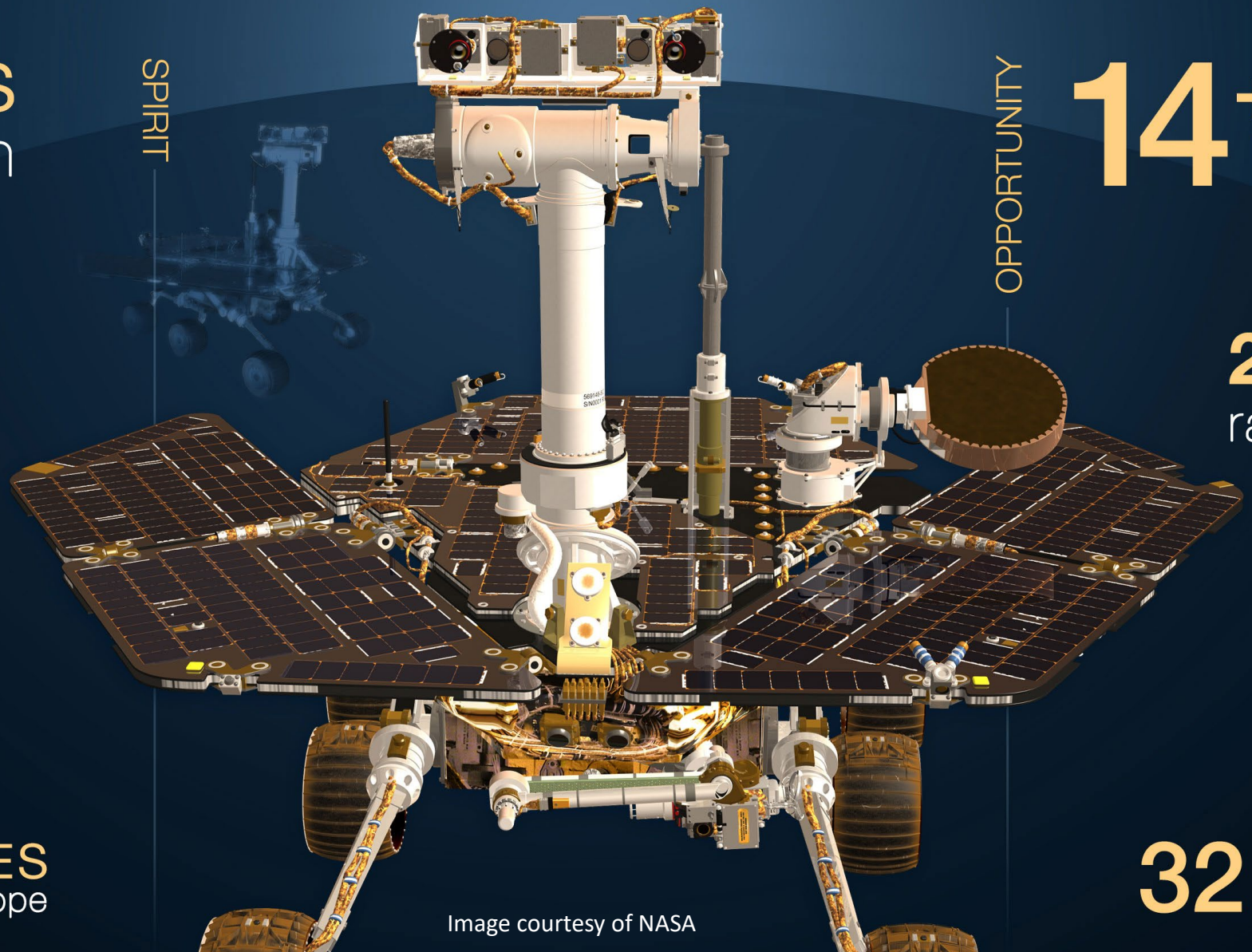

Image courtesy of NASA

SPIRIT

6 YEARS lifespan

124,838 raw images

4.8 MILES traveled

30 DEGREES steepest slope

OPPORTUNITY

14+ YEARS lifespan

217,594 raw images

28 MILES traveled

32 DEGREES steepest slope

LIFE Habitat- Large Integrated Flexible Habitat

Image courtesy of Sierra Space Corporation

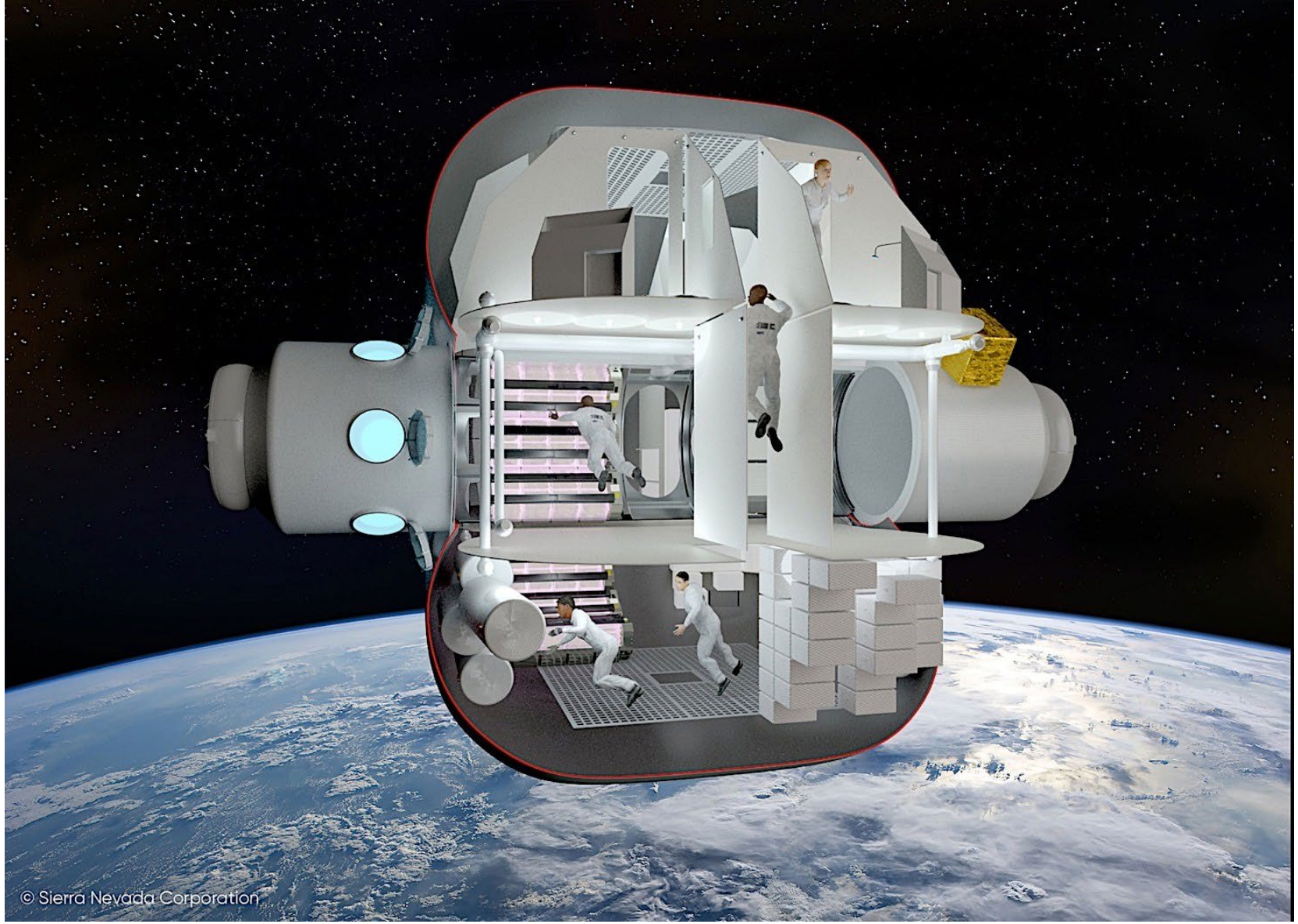

Image courtesy of Sierra Space Corporation

Image courtesy of Foster and Partner Architects

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Other LCP Fiber Applications

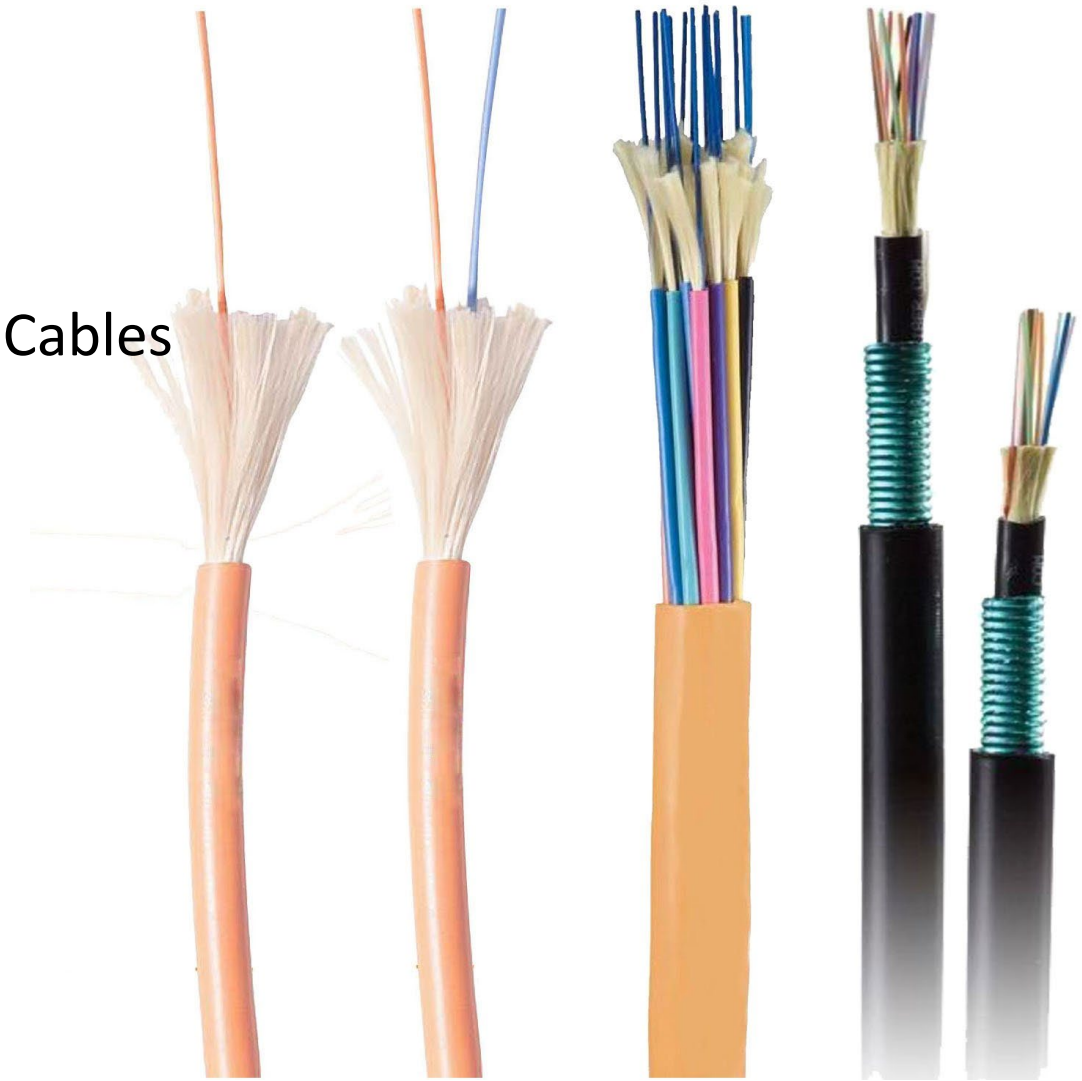
Industrial Rope & Cordage

– high temperature, bending/dynamic applications

NASCAR safety tethers

Image courtesy of Roush Racing, NASCAR

Electrical
Optical
Mechanical Cables



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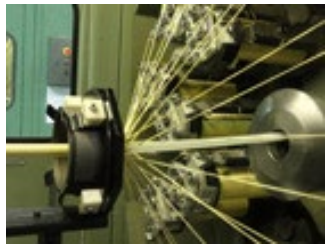
Umbilical Cables/Hoses



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Heavy Lift Slings/Straps

Photo courtesy I&I Sling / Slingmax

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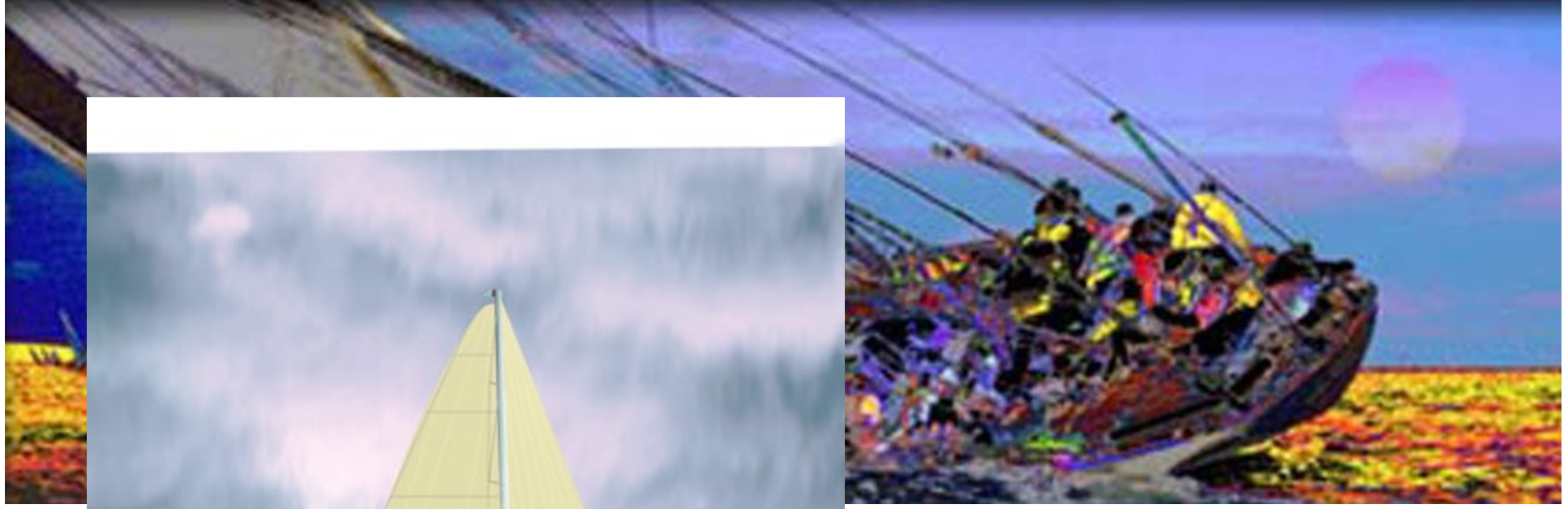

Megayachts,
cruising sails, round-the-world races

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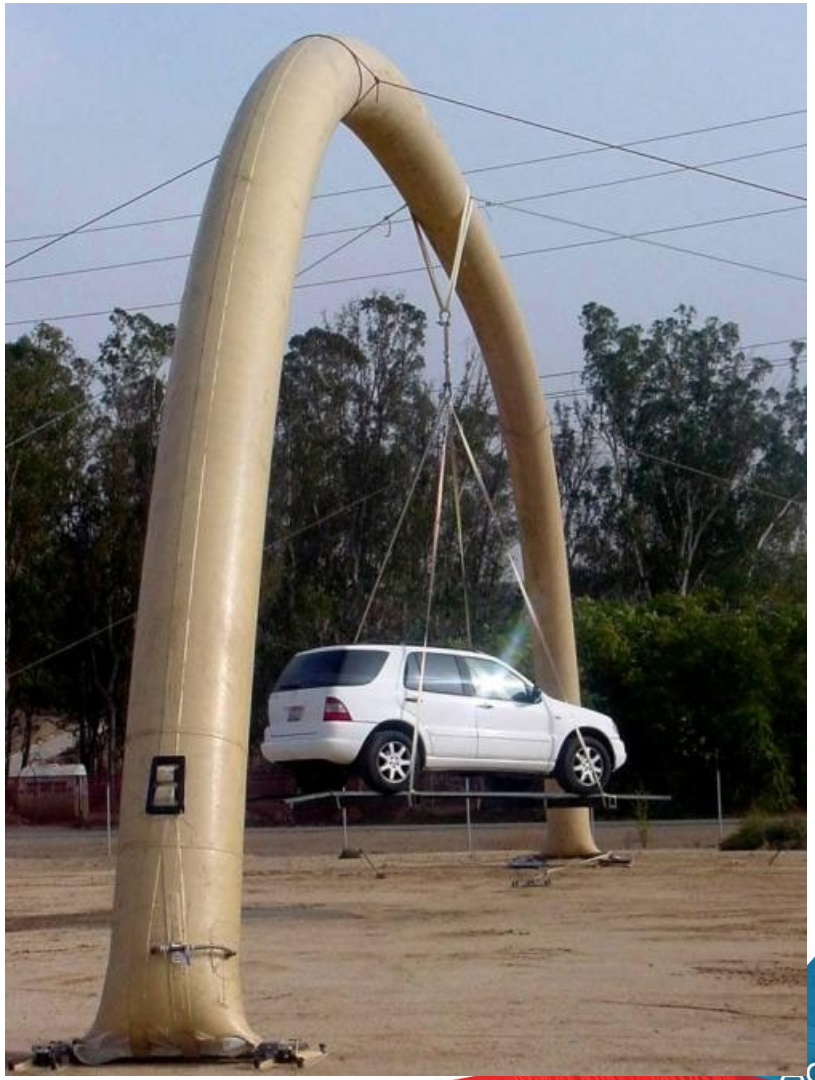
Airbeam & shelter photos courtesy HDT Global



Inflatable Tunnel Plug

Photos courtesy West Virginia Univ.

Air-Supported Radome

Photo courtesy
ILC-Dover

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Large Airships / Aerostats

Photos courtesy
Lockheed, TCOM, ILC
Dover, Northrup

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Specialty footwear, industrial stitching threads

Image courtesy of Nike

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Workwear, e.g. gloves, protective knitwear, aprons

Applications law enforcement, industrial apparel, meat cutting

Images courtesy of Wells Lamont Glove

Klim® Motorcyle Gear

- Highest Level Motorcycle Apparel Abrasion Resistance
- AAA rating on the Darmstadt abrasion testing

Images courtesy of Klim®

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Conclusions-Space Application

Vectran™

- Several great fiber technology choices- LCP is an optimal choice
- LCP fiber is a proven technology
- Depends on your design and goals
- LCP excels in several critical performance areas-
  - flex fatigue
  - off/out gassing
  - low moisture absorption
  - thermal stability
- LCP works where other fiber technologies fail


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See You Next Year
Sept. 24–26, 2024
Anaheim, California

See you next year!

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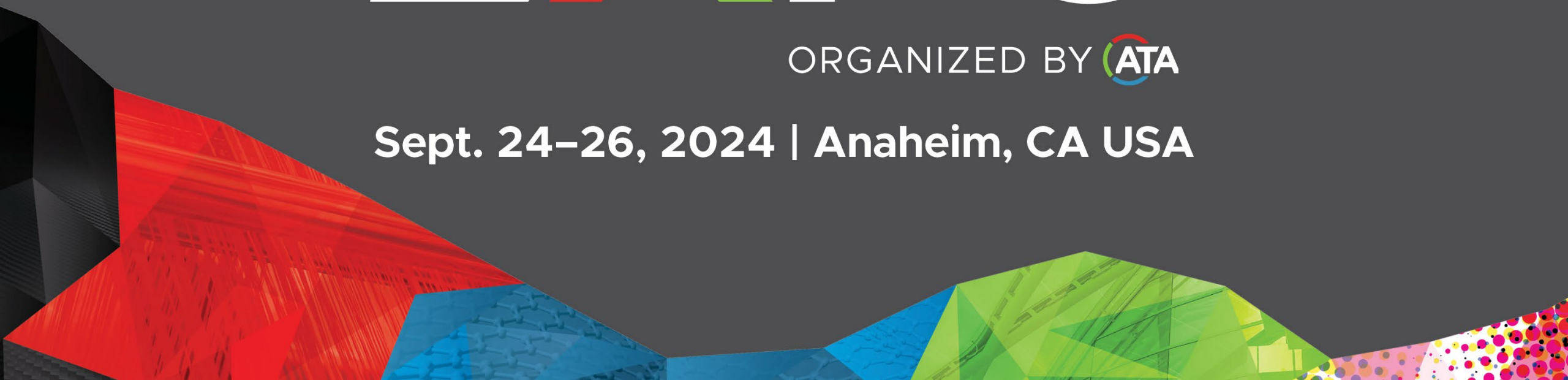
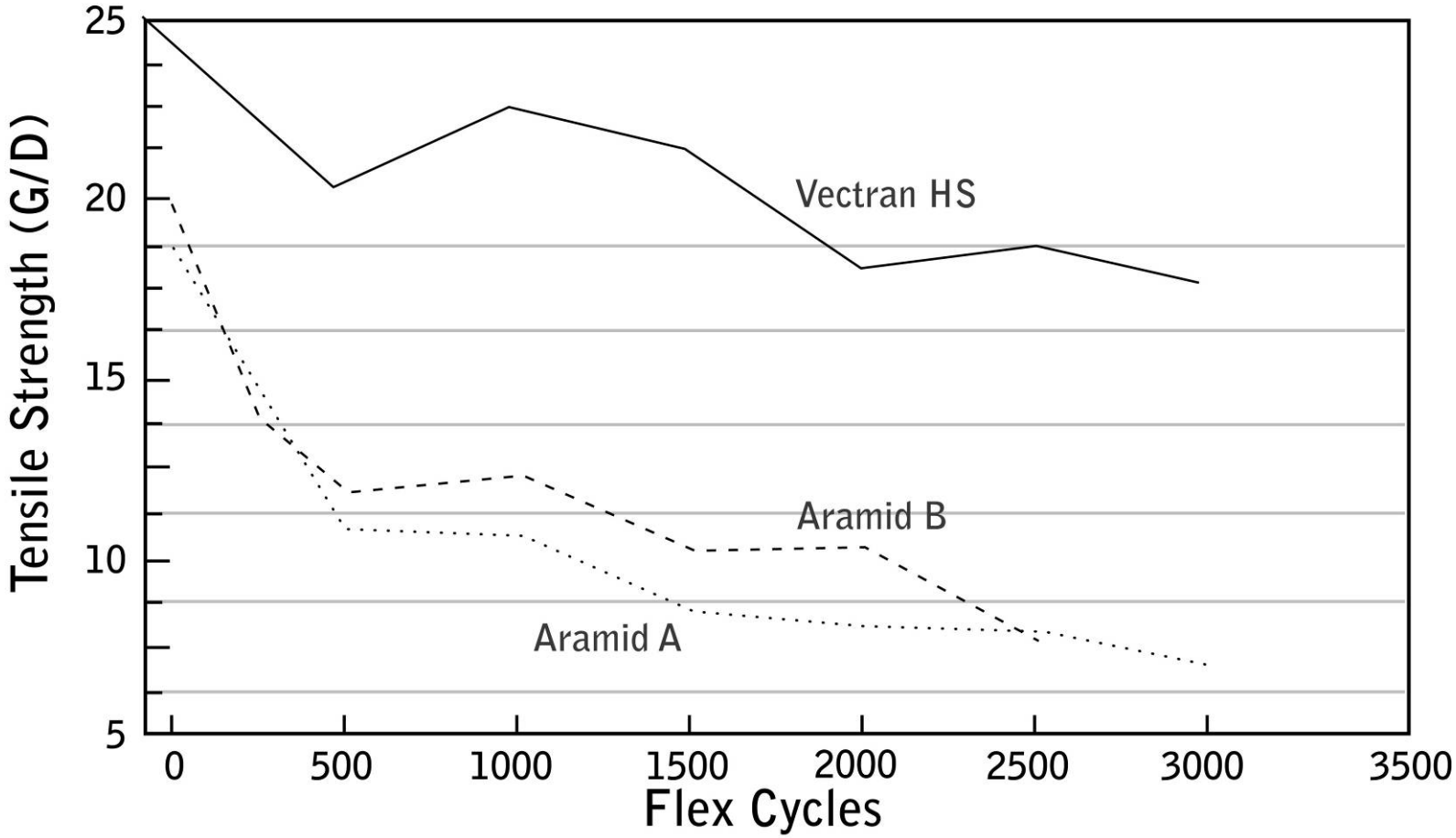


Appendix

Flex/Fold (Compression) Fatigue



Flex: Tinius Olsen/MIT, Modified ASTM D2176

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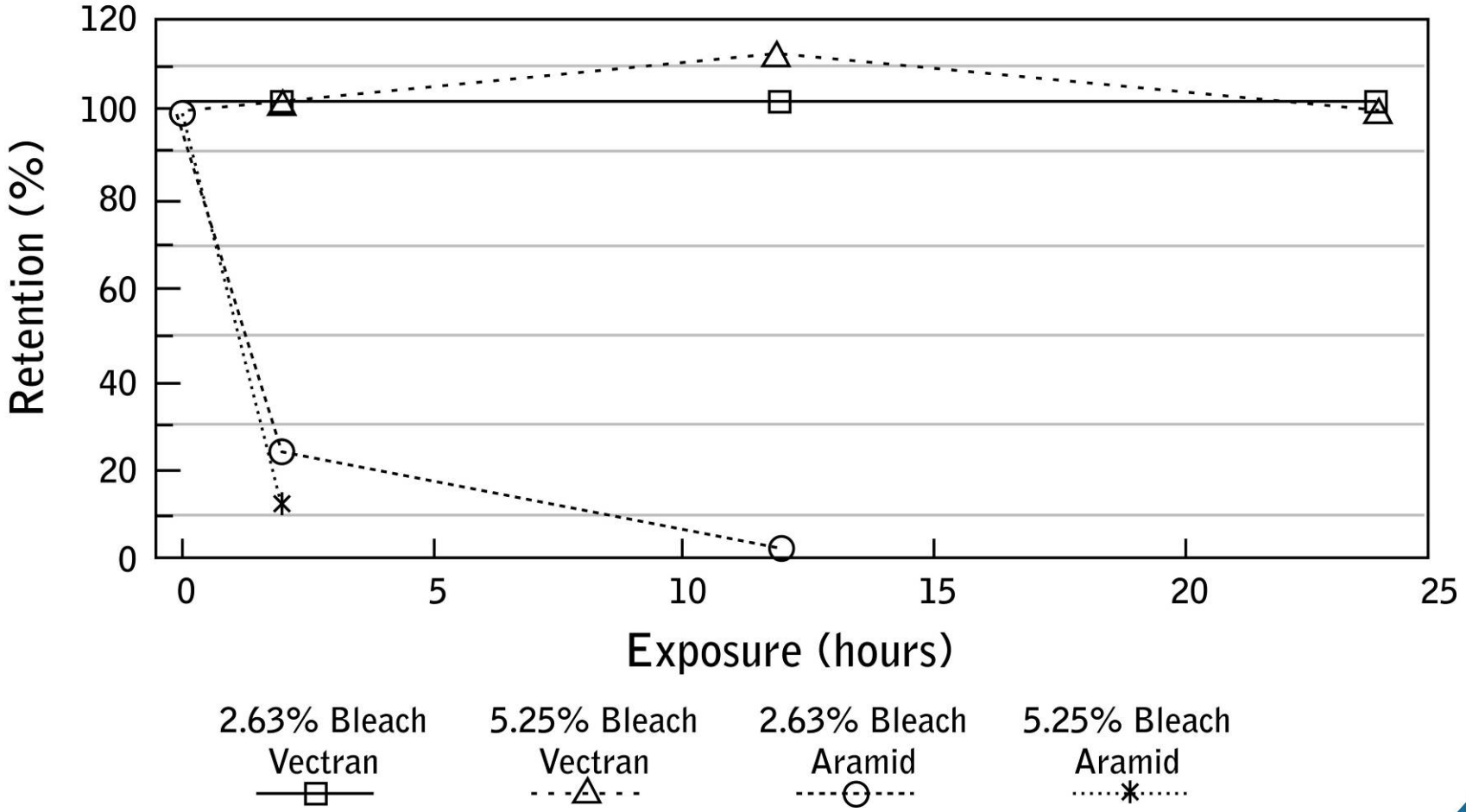
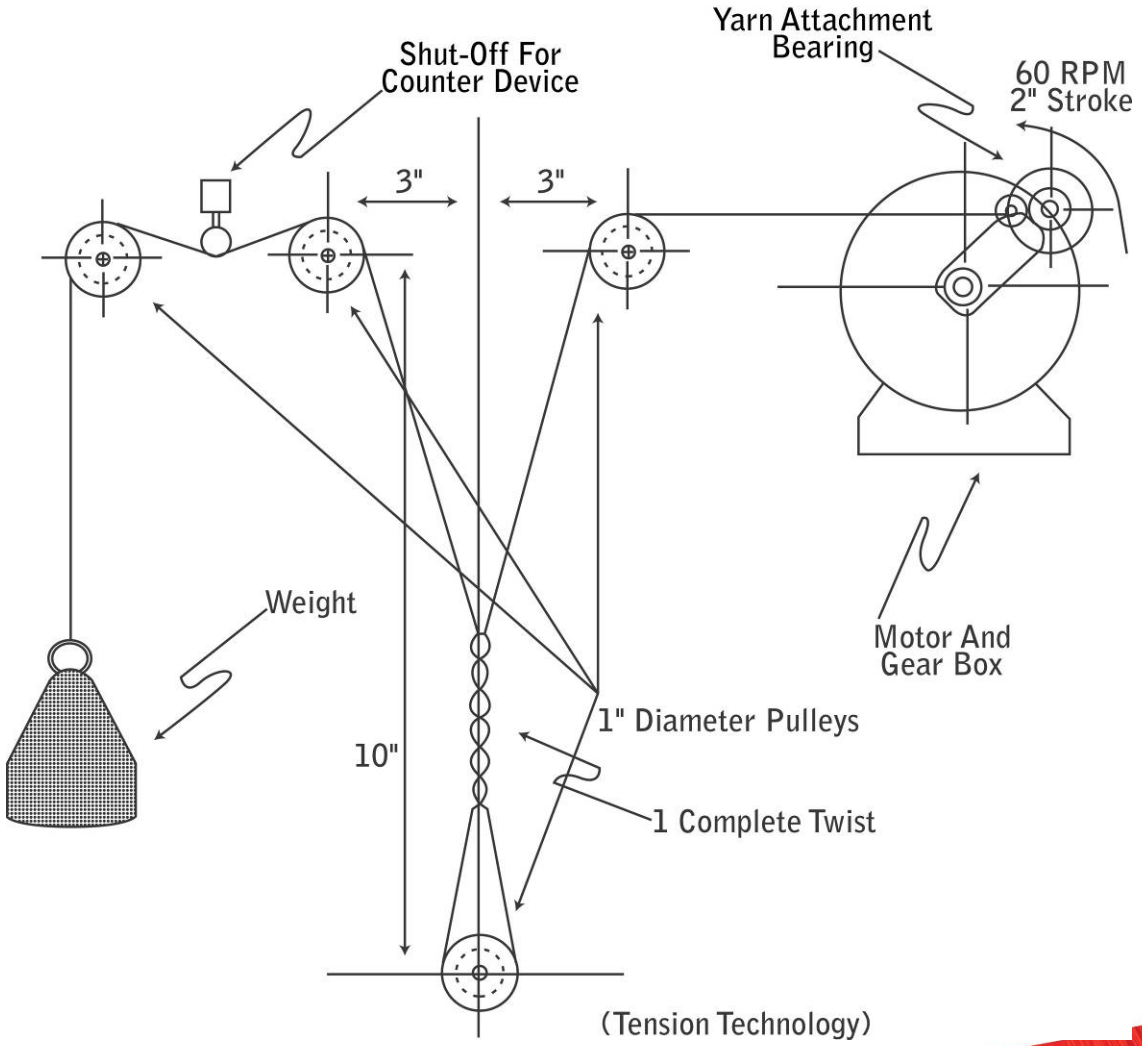


- Yarn-to-Yarn Abrasion



- Yarn-to-Yarn Abrasion