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Effects of Damage on Long-term Displacement Data of Woven Fabric Webbings Under Constant Load for Inflatable Structures

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Outline

- Background
  - Inflatable Structures
  - Problem Statement
- Approach
- Hardware and Test Facility
- Test Results
- Summary

Inflatable Structures

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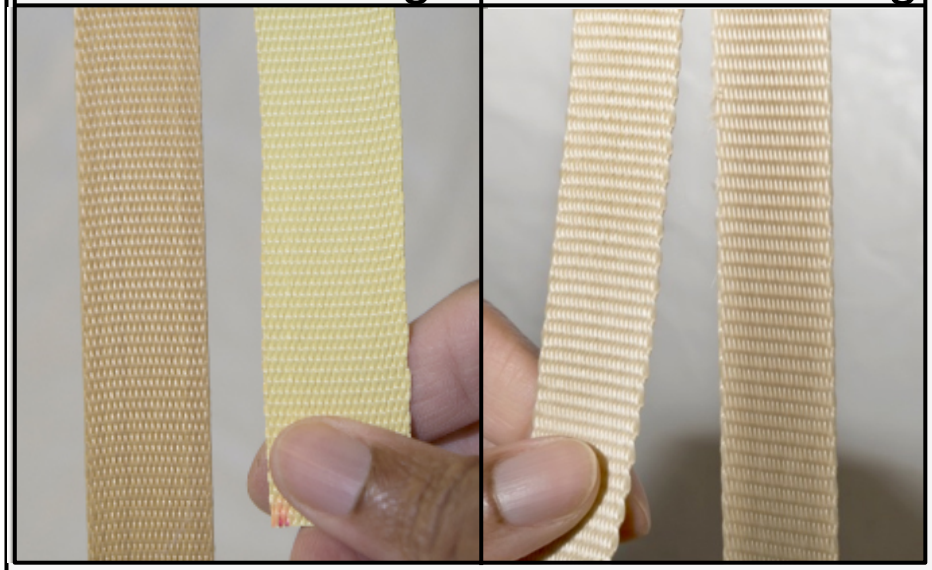
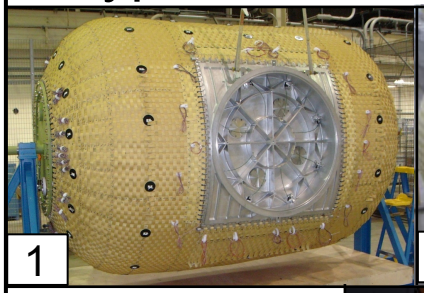
Research Materials:

Kevlar Webbing	Vectran Webbing



Typical Roll of Webbing Material (Flexible Structural Restraint Layer)

Typical Inflatable Structures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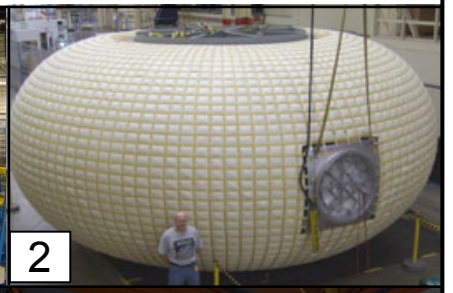
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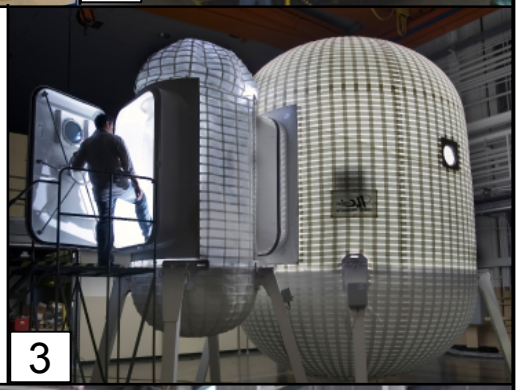
- Lightweight
- Small Storage Volume
- Fast Build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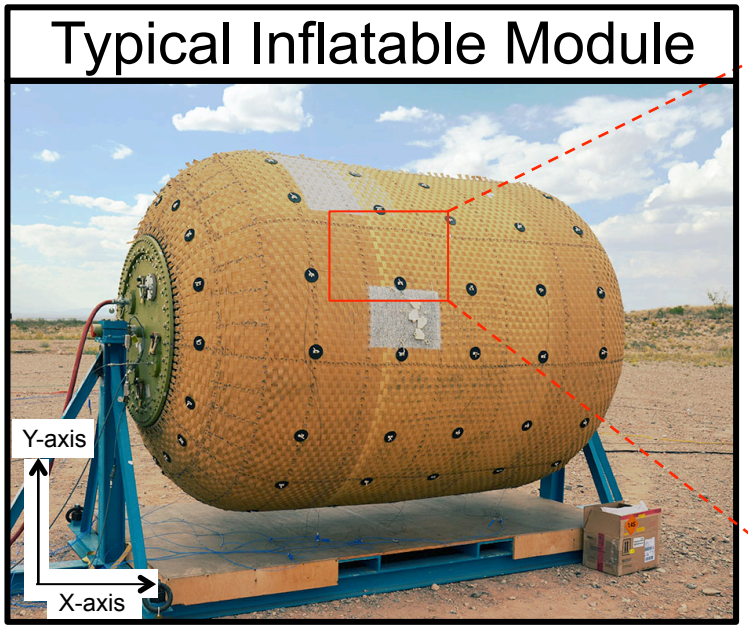
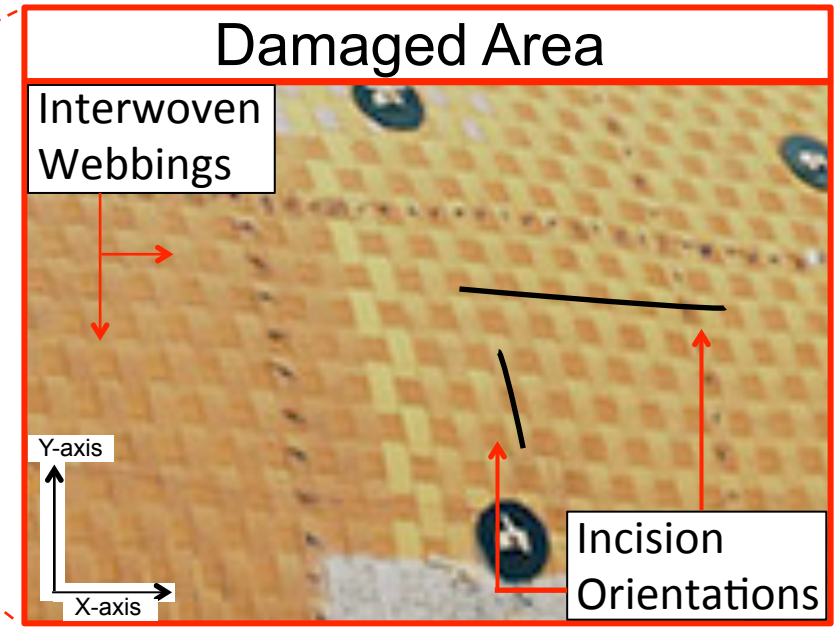
Problem Statement

- Goal: Conduct an experimental creep study to identify effects of damage on webbing performance over extended time period
- Causation: Damage due to deployment and/or service
- Definition: Damage is defined as vertical incisions of varying length and number
- Analytical analysis: Inaccurate for nonlinear materials over time
- Time period: Study was conducted over an 18-month time period





Research Approach

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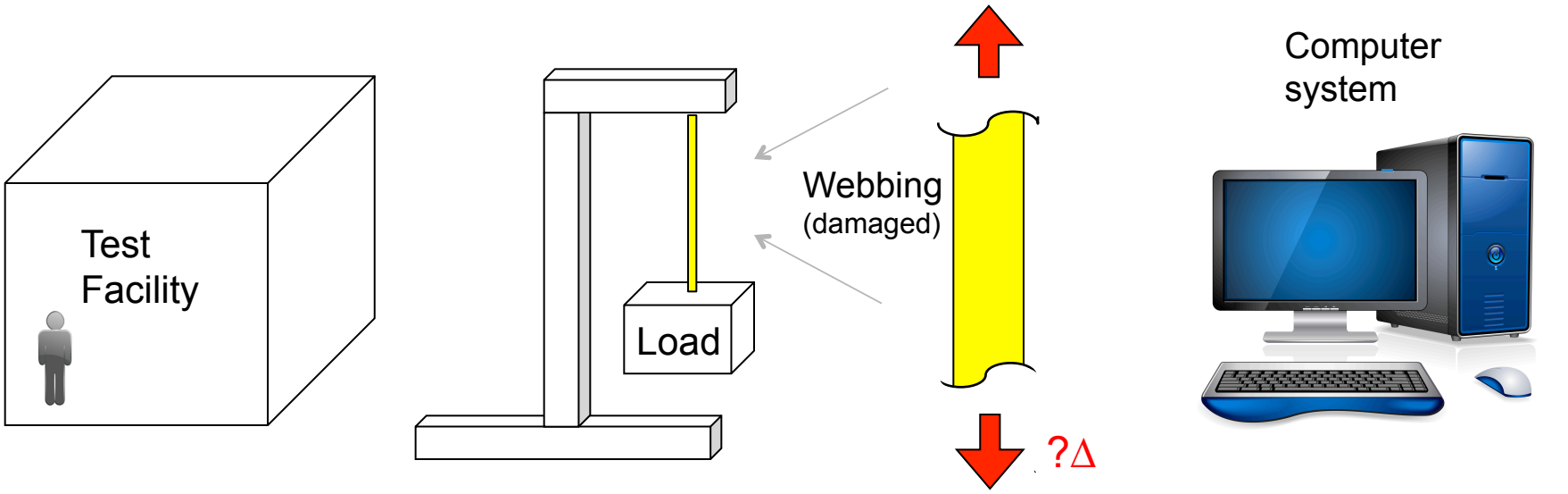
Goal: Generate long-term displacement data from webbings under load



Test Facility

- Large
- Overhead crane
- Available for multiple years

Test Hardware

- High load capacity
- Quick assembly

Displacement Measuring Device

- Accurate
- Continuous measurements

Data Acquisition

- Variable rate
- Continuous recordings over multiple years

Creep Test Facility

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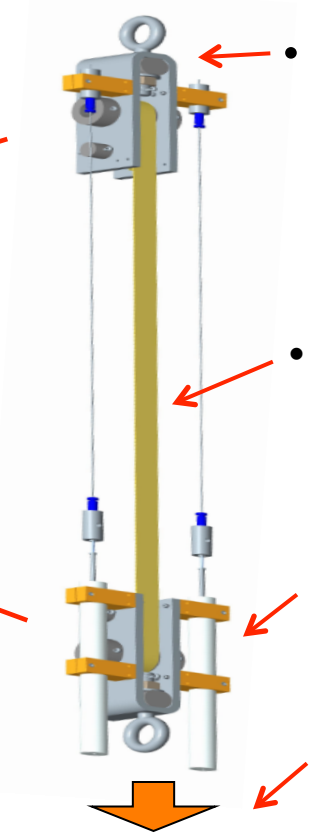
- Initial creep test, Feb 2012
- Creep test hardware (3 rows)
  - I-beam structures
  - Concrete weights
- Typical displacement sensor



- Webbing displacement measuring and support fixture
- Webbing material
- Transducer sensor
- Applied load

Magnified Webbing Images

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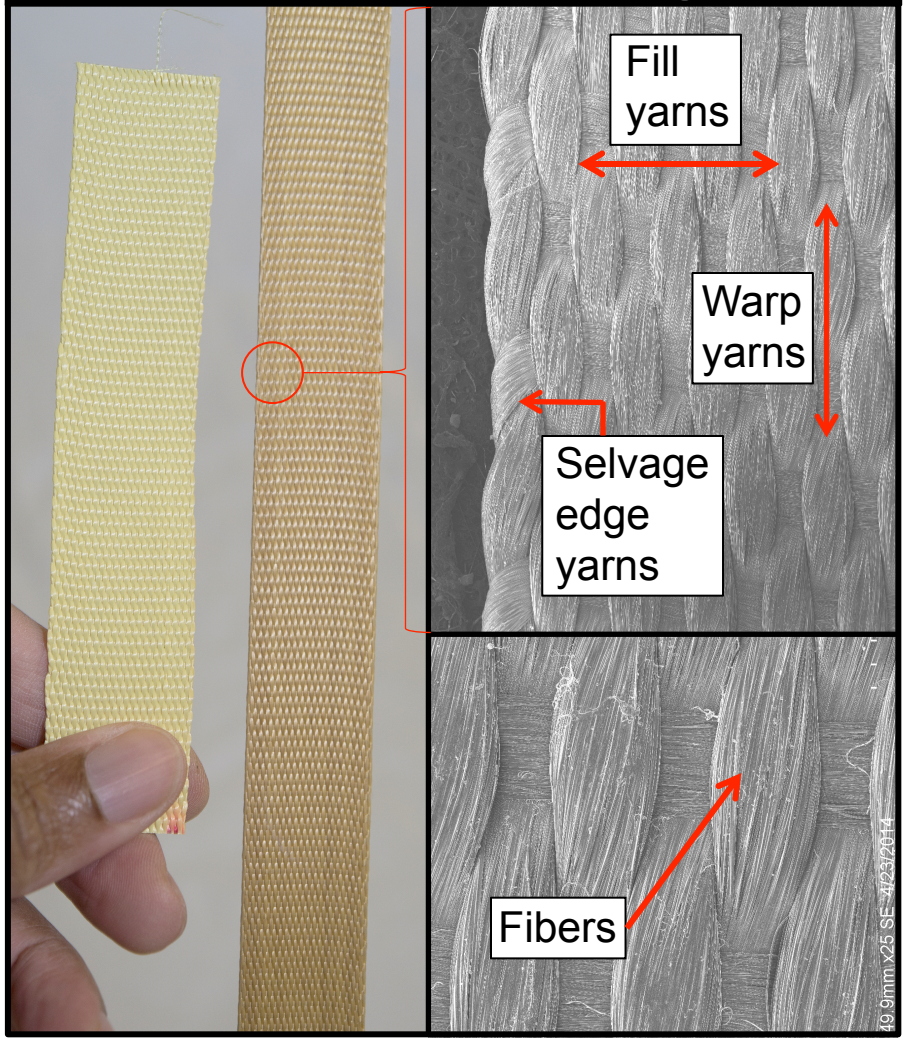
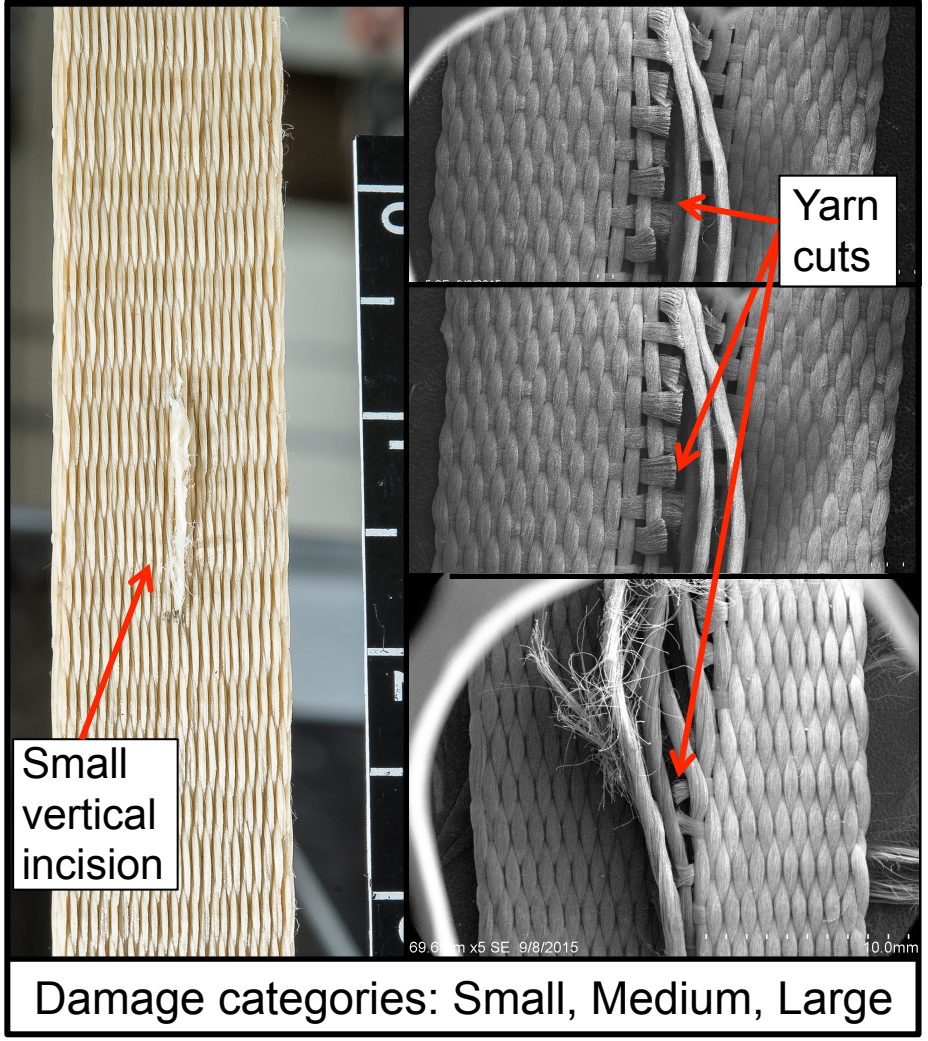
Pristine Webbing



Damaged Webbing



Damage categories: Small, Medium, Large

- Eleven test groups defined by test material, applied load, and damage
- Horizontal incision: Known to have an adverse effect on strength proportional to length

Test Matrix

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Pristine Webbings

Group #	Webbing materials	Webbing #	UTS (%)	Webbing length	Length of test (months)
1	6K Kevlar	1 2	20 20	144 144	34 34
2	6K Kevlar	1 2	20 20	60 60	3 3
3	6K Kevlar	1 2 3 4	43 43 50 50	68 84 82 80	39 39 35 35
4	6K Vectran	1 2 3	50 50 50	80 80 80	34 34 34
5	12.5K Vectran	1 2 3	29 29 29	116 116 116	29 29 22
6	6K Vectran	1 2 3 4 5	25 25 25 25 20	66 66 66 66 66	44 44 44 44 44

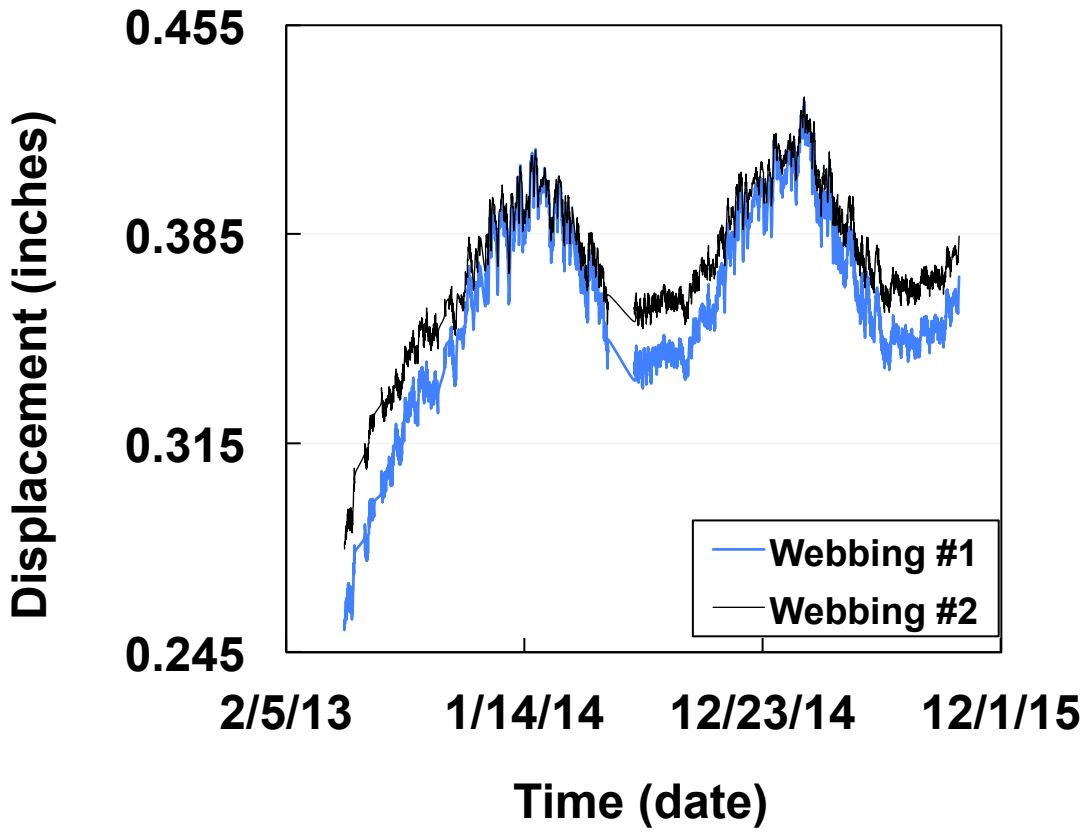
Damaged Webbings

Group #	Webbing materials	Webbing #	UTS (%)	Webbing length	Length of test (months)	Incision length (inches)
7	6K Kevlar	1 2	20 20	60 60	18 16	5 5
8	6K Kevlar	1 2 3	6.7 6.7 6.7	60 60 60	14 14 14	1 1 1
9	6K Kevlar	1 2 3	20 20 20	62 62 62	3 3 3	5 5 5
10	6K Vectran	1 2 3	20 20 20	60 60 60	18 18 18	5 (multiple) 5 (multiple) 5 (multiple)
11	12.5K Vectran	1 2 3	29 29 29	48 41 43	18 18 18	1 1 1

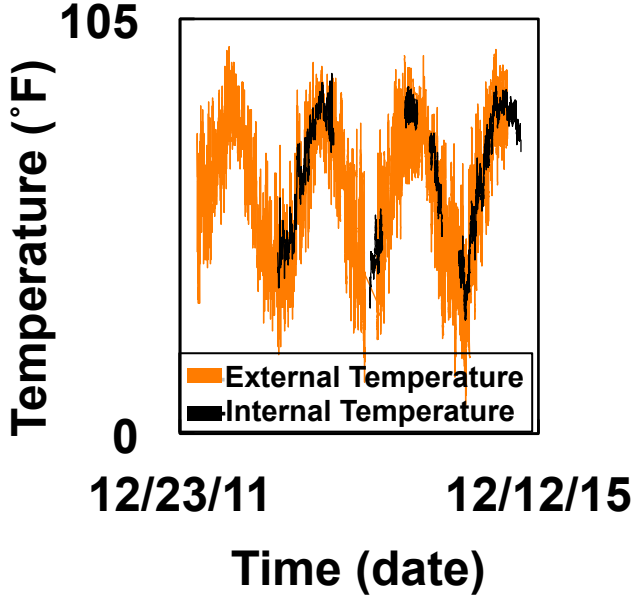
*Ultimate tensile strength (UTS)

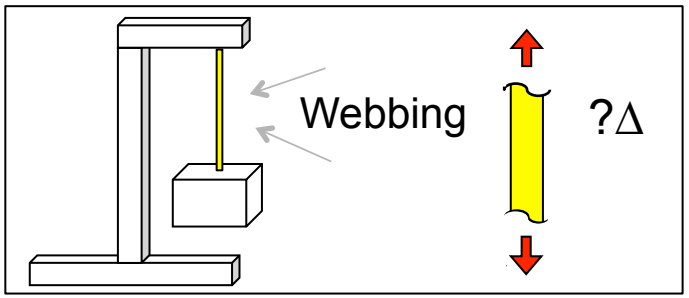
Environmental Influences on Displacement

Displacement Data



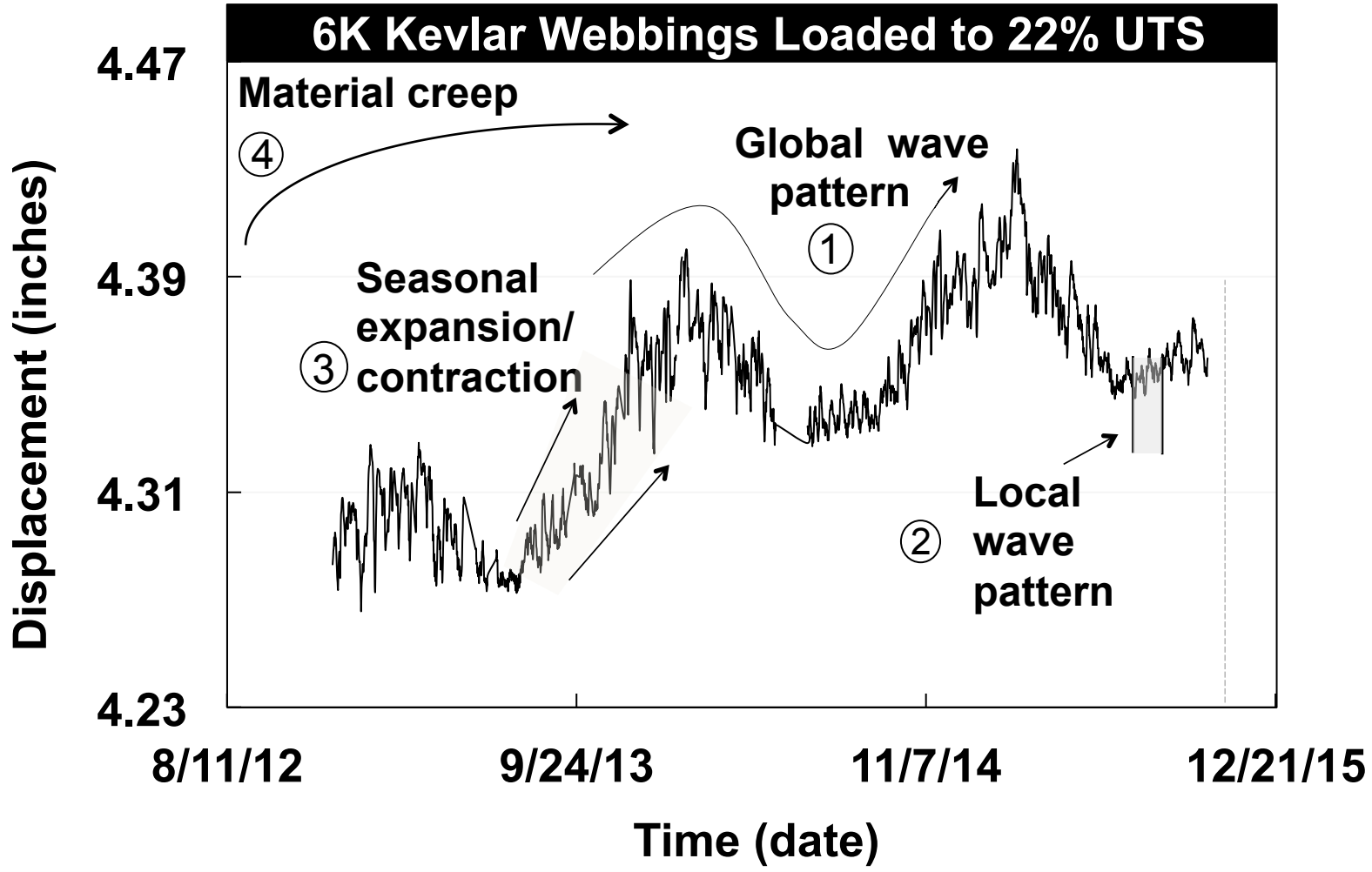
Temperature Data



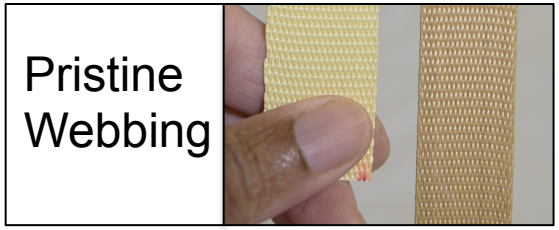


- Daily, seasonal, and yearly temperature and humidity effects influence the creep displacement curve
- Webbings exhibits negative coefficient of thermal expansion (CTE)

Characteristics of Displacement Curve



- 3-year time period
- Four characteristic curve patterns
- Failure experienced above 50% UTS



Effects of Damage

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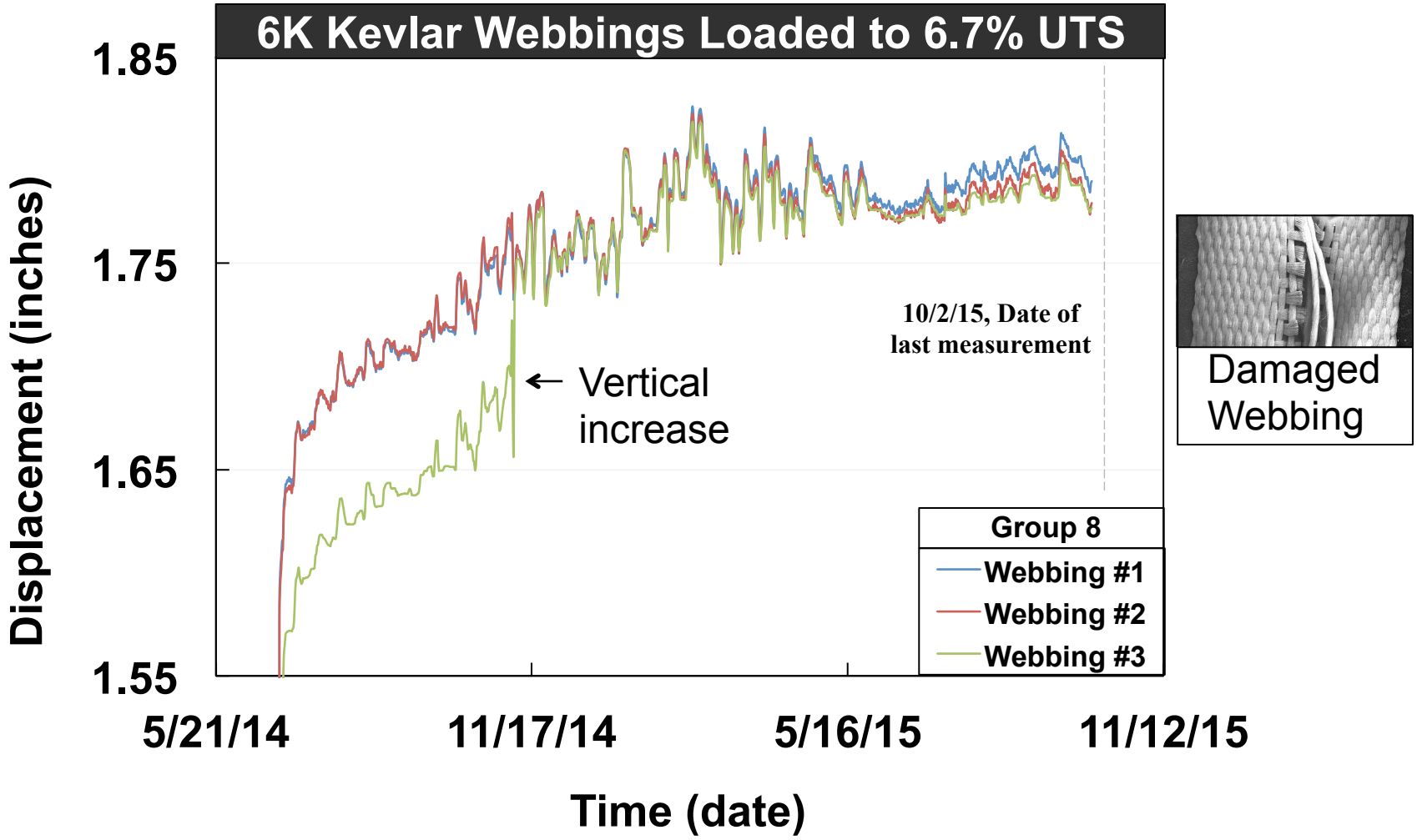

- Damage introduces vertical spikes into local wave pattern
- Damage doesn't effect strength over time

Effects of Damage

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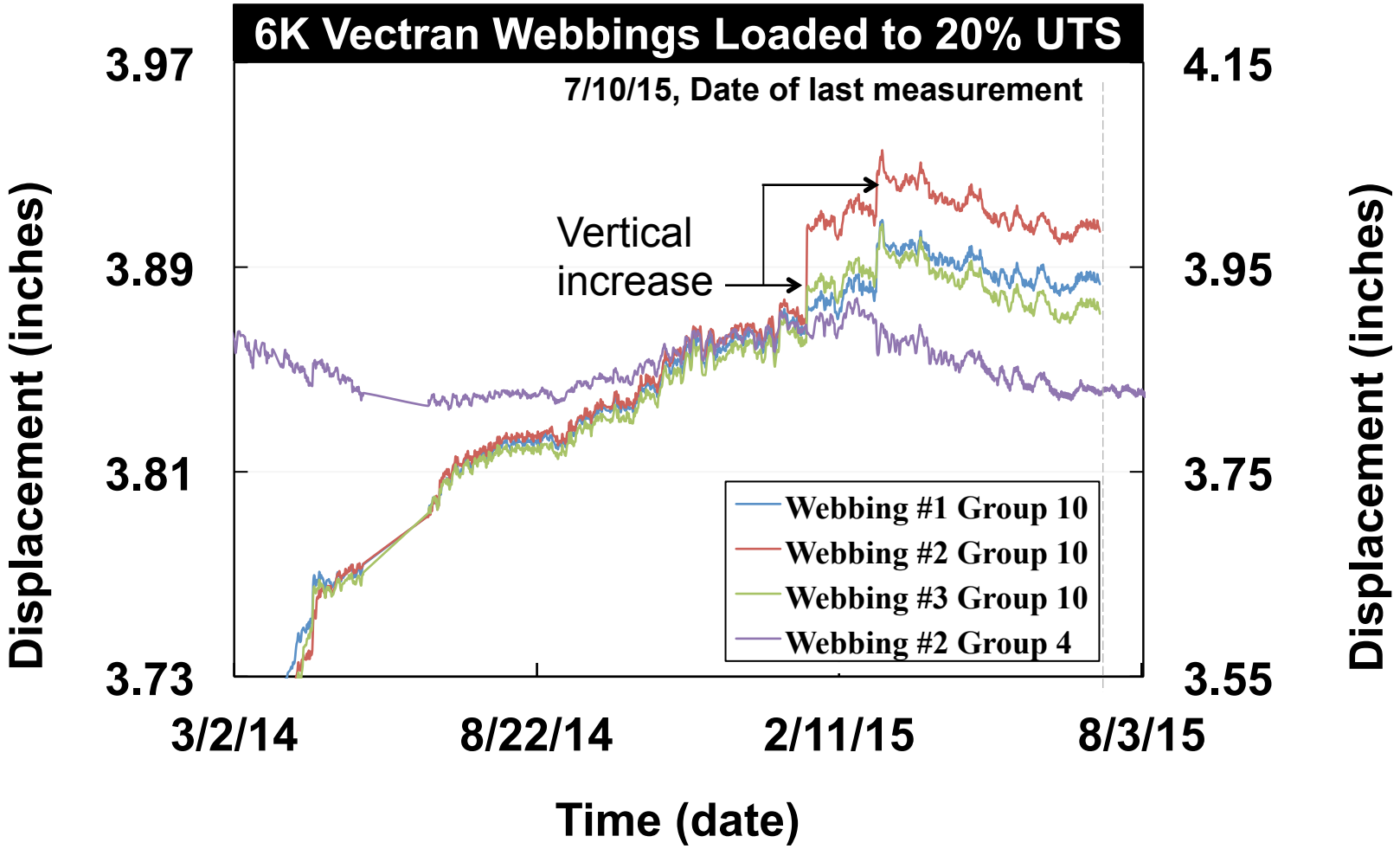
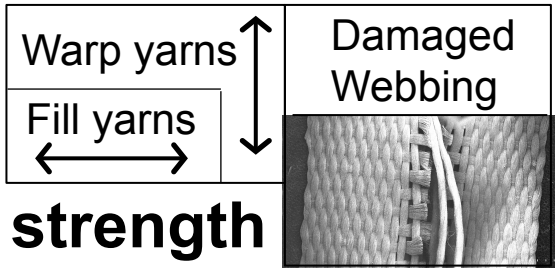


- **Vertical spikes are due to transfer of load from damaged to pristine warp yarns**
- **Cut fill yarns have little effect on webbing strength**



Effects of Damage

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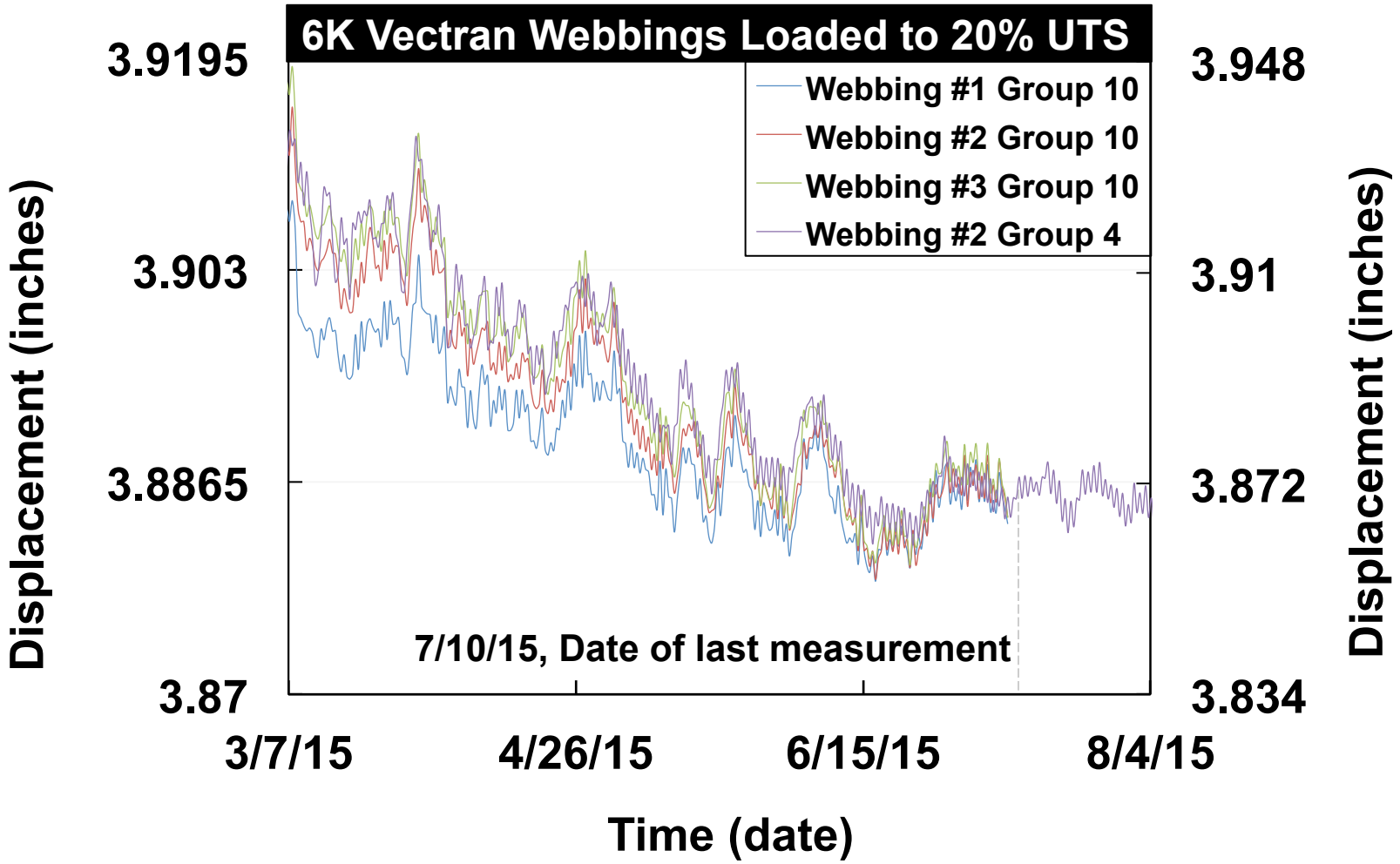

- **Magnified view of damaged webbing wave patterns relative to baseline pattern indicates insignificant effect of damage**

Effects of Rotation

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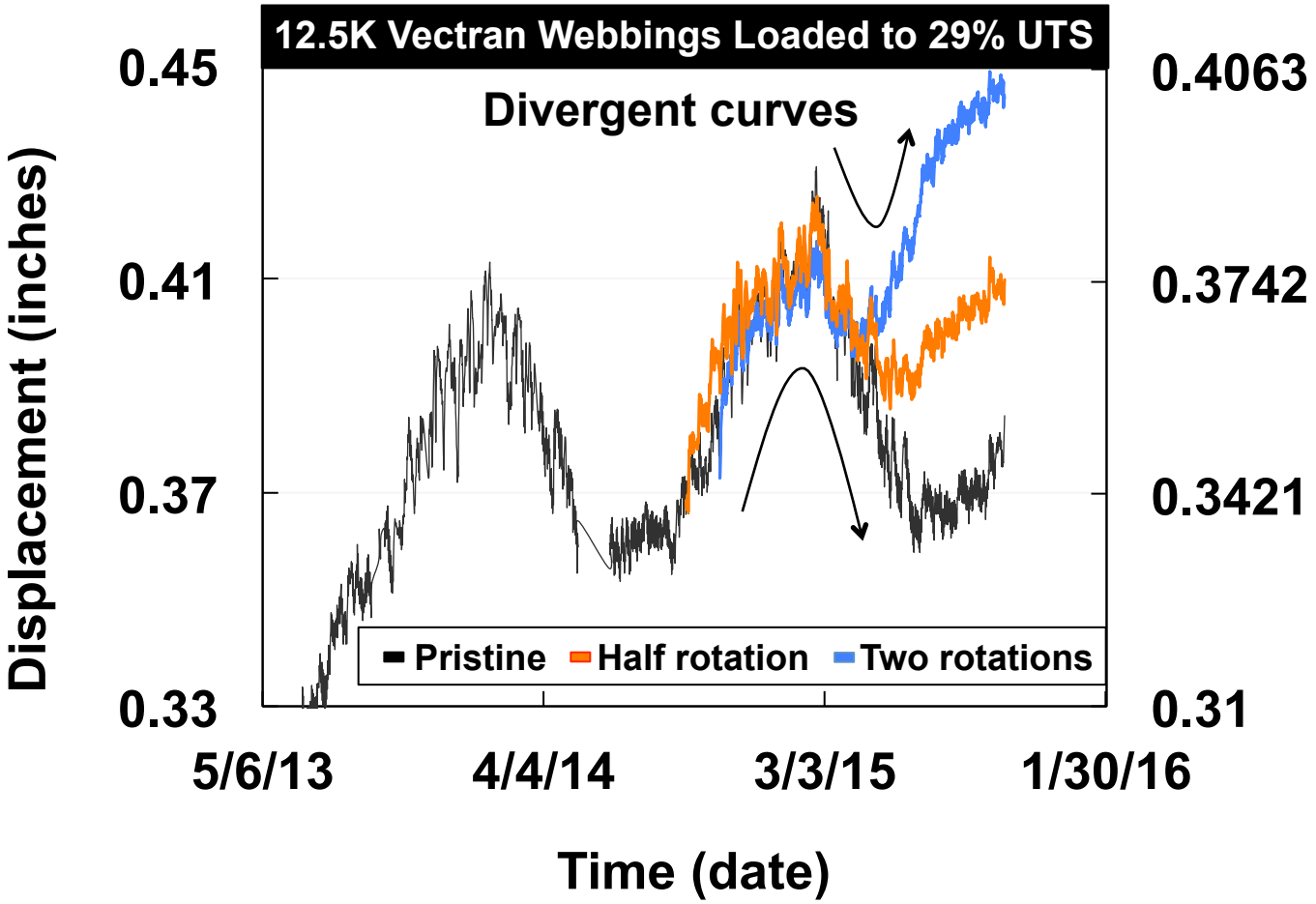

- Rotation introduces a divergent global wave pattern
- Rotation has a significant effect on strength over time

Running Sum Calculation

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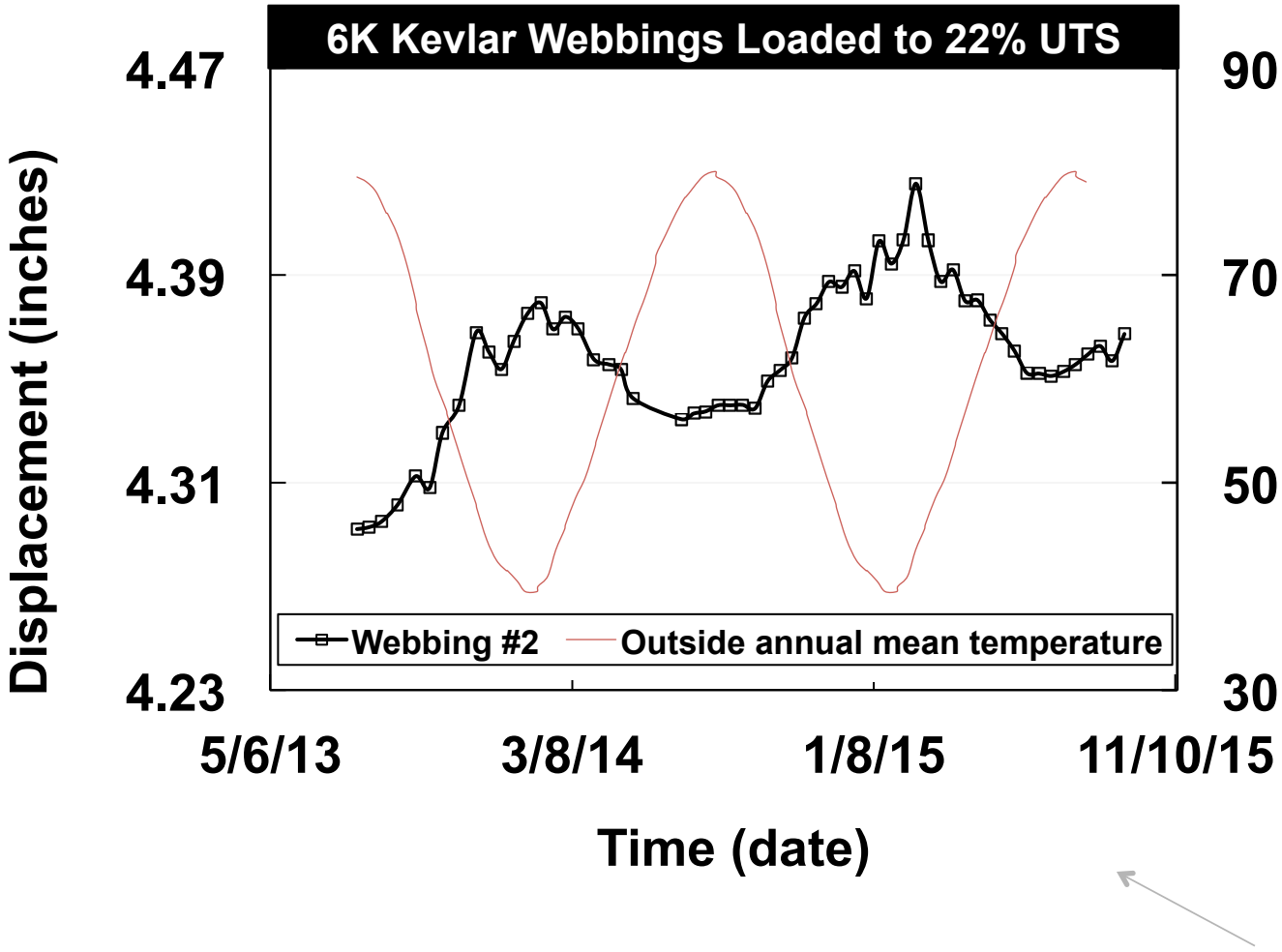
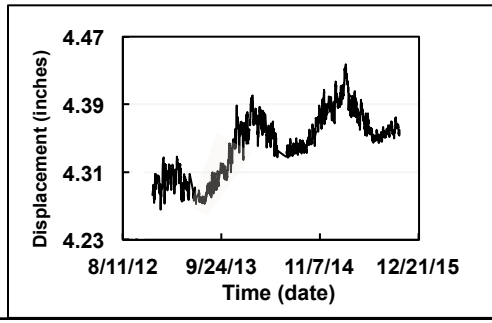
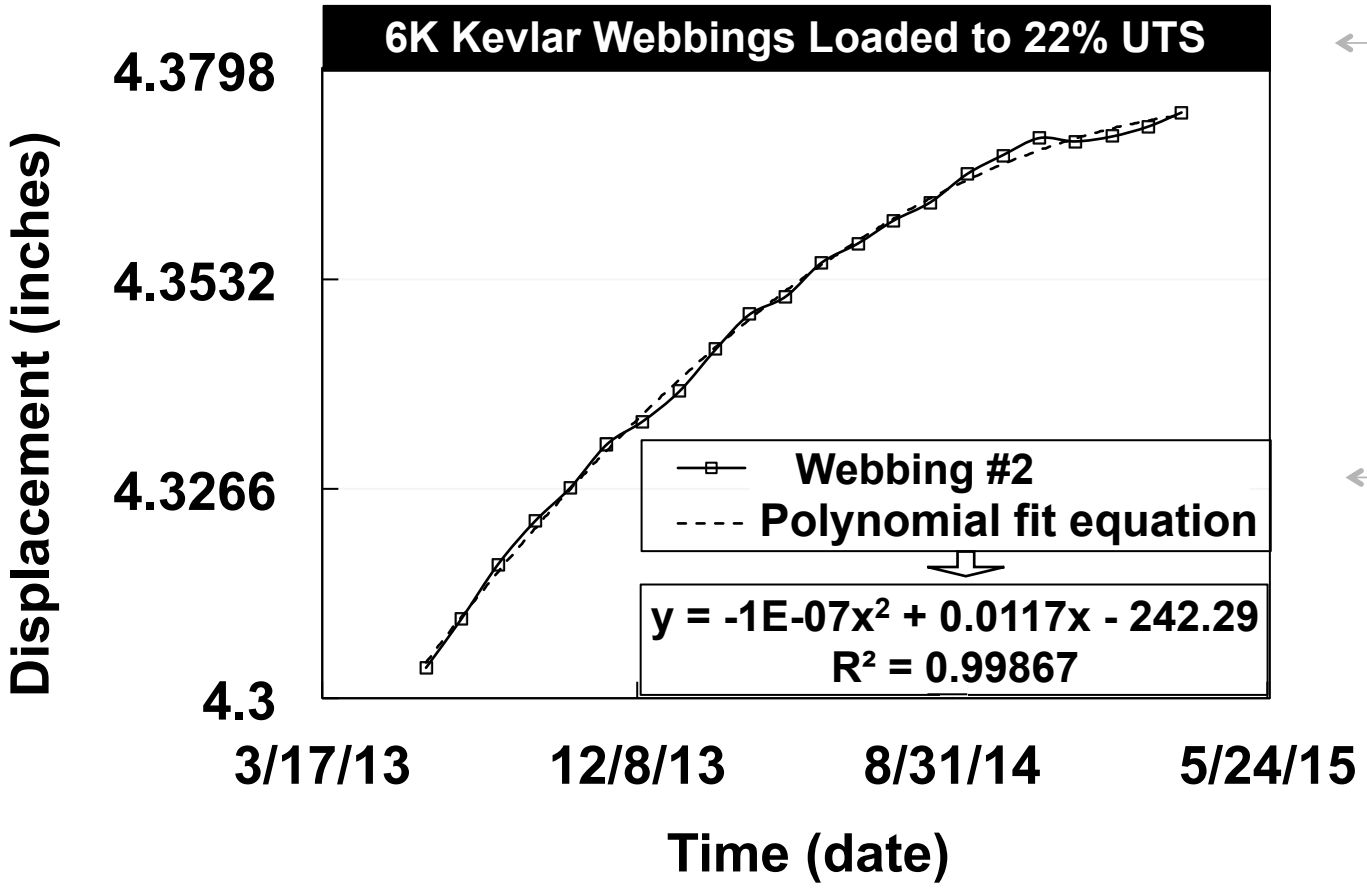
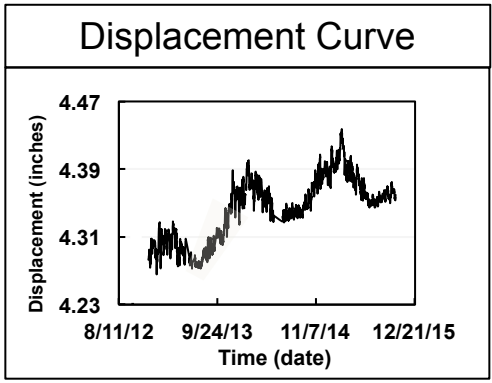


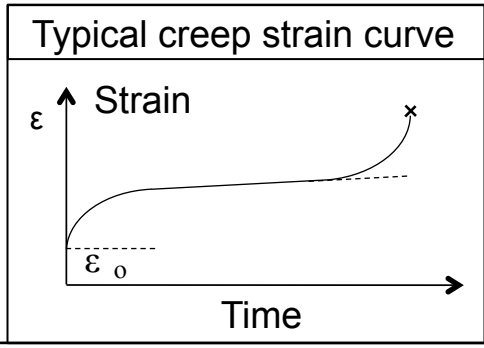


- Local wave patterns can be eliminated and global wave patterns highlighted through the use of running sum data
- Each data point in presented graph consist of 20 days of data

Running Sum Calculation







- All wave patterns can be eliminated and a continuous curve generated through the use of running sum calculations
- Each data point in presented graph consist of 1 year of data
- Running sum curve is comparable to a classic creep curve

Summary

- Numerous Kevlar and Vectran webbings have maintained strength and supported a range of loads below 50% UTS over a four year period
- Cumulative visual and displacement data from the webbings indicate limited wear over the four year period
- Damage defined by vertical incisions generate minute increases in displacement without detrimentally effecting long term strength
- Rotation has a detrimental effect on webbing strength
- Utilization of running average calculations can smooth out short-term variations and highlight long-term trends

Future: Webbing Studies

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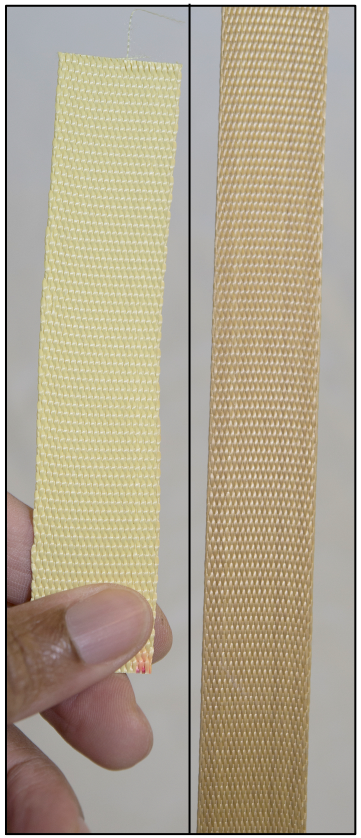
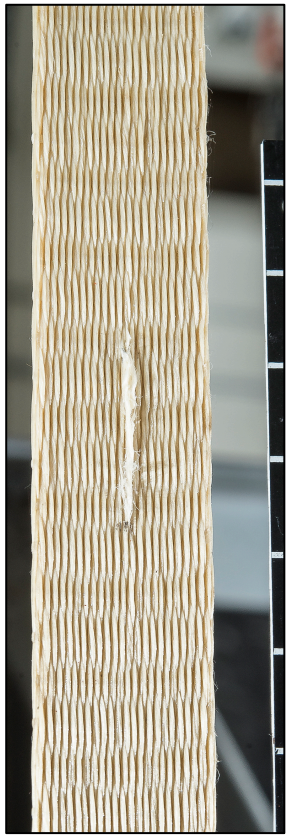
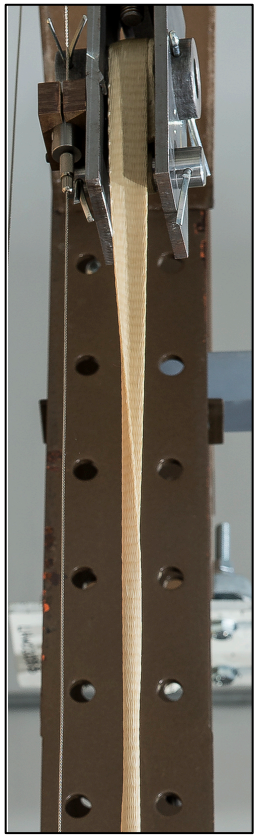
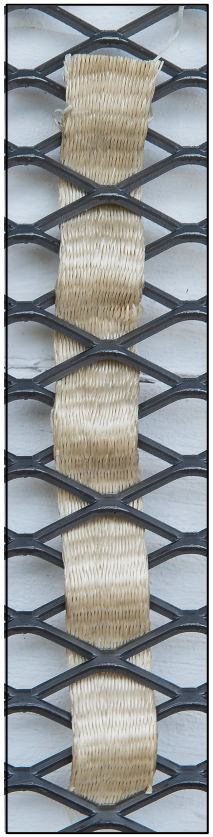
Test Matrix

Environment	Pristine (2012)		Damaged (2014)		Integrated Grid (2016)	
Ambient (Current) ⇨						
Cryogenic (2018)						
Ultraviolet (2020)						
	New	2-years	Incisions	Rotation	Square	Diagonal

Goal: Experimentally validate long life and identify potential failure modes of webbings.