



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

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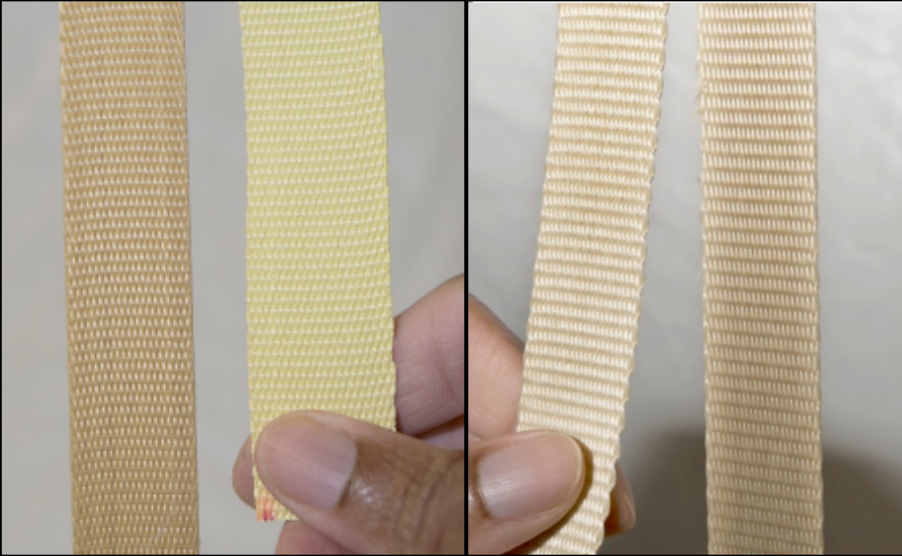


- Background
  - Inflatable Structures
  - Problem Statement
- Approach
- Hardware and Test Facility
- Test Results
- Summary

## Research Materials:

Kevlar Webbing

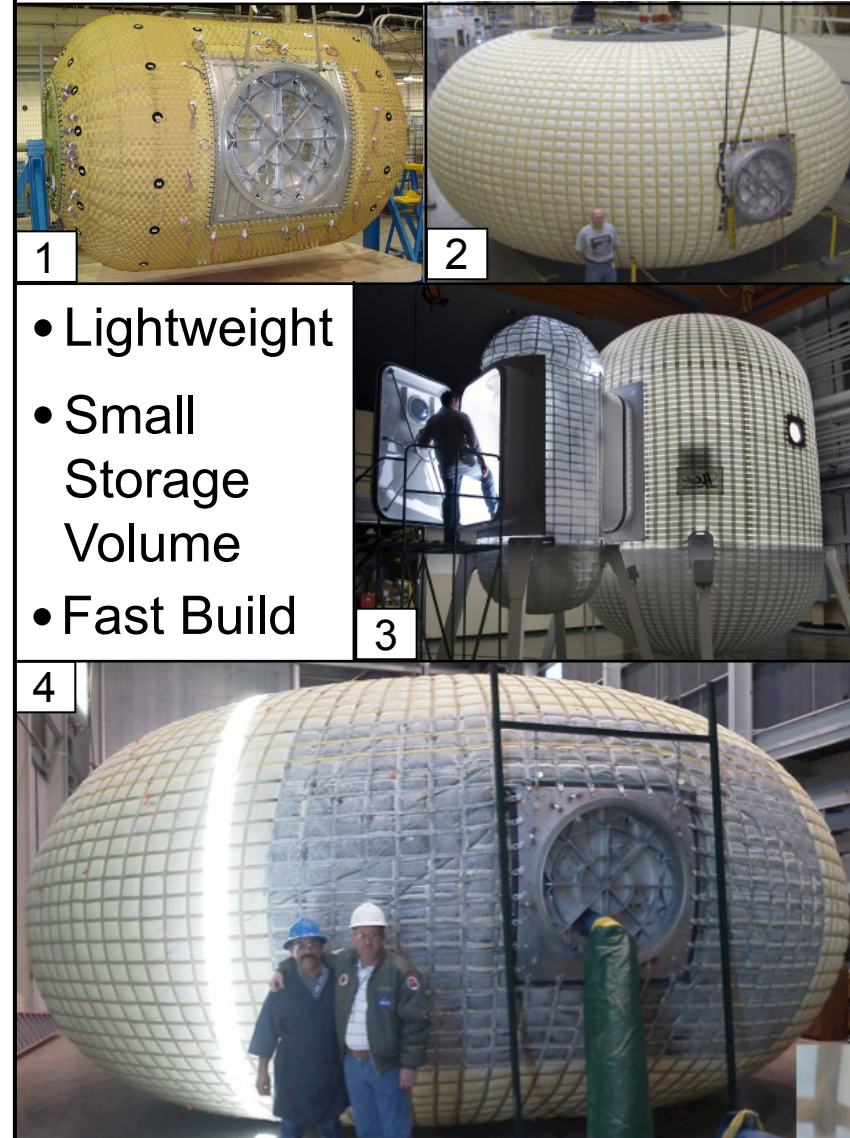
Vectran Webbing



Typical Roll of Webbing Material  
(Flexible Structural Restraint Layer)



## Typical Inflatable Structures

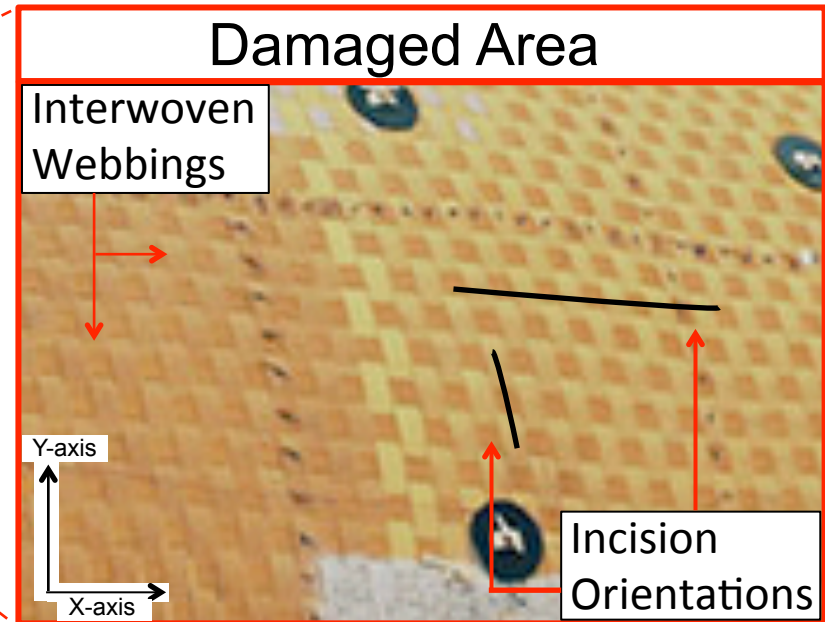
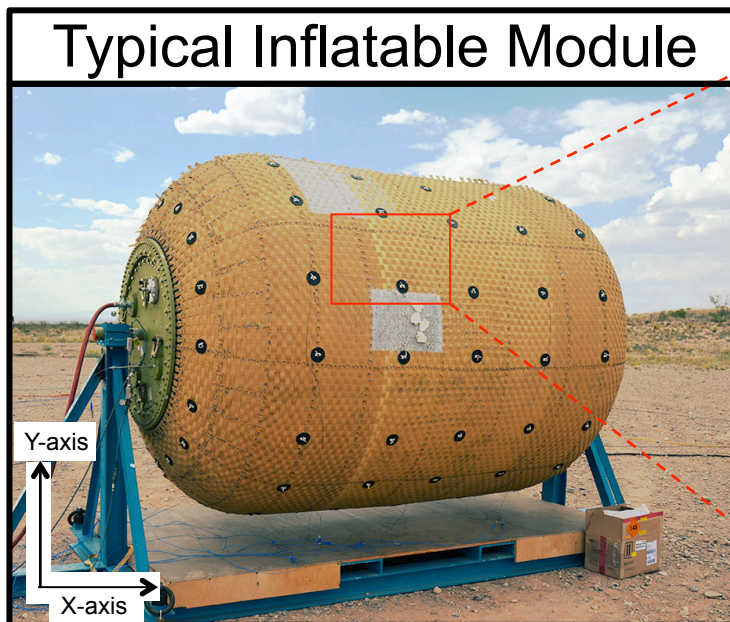


- Lightweight
- Small Storage Volume
- Fast Build

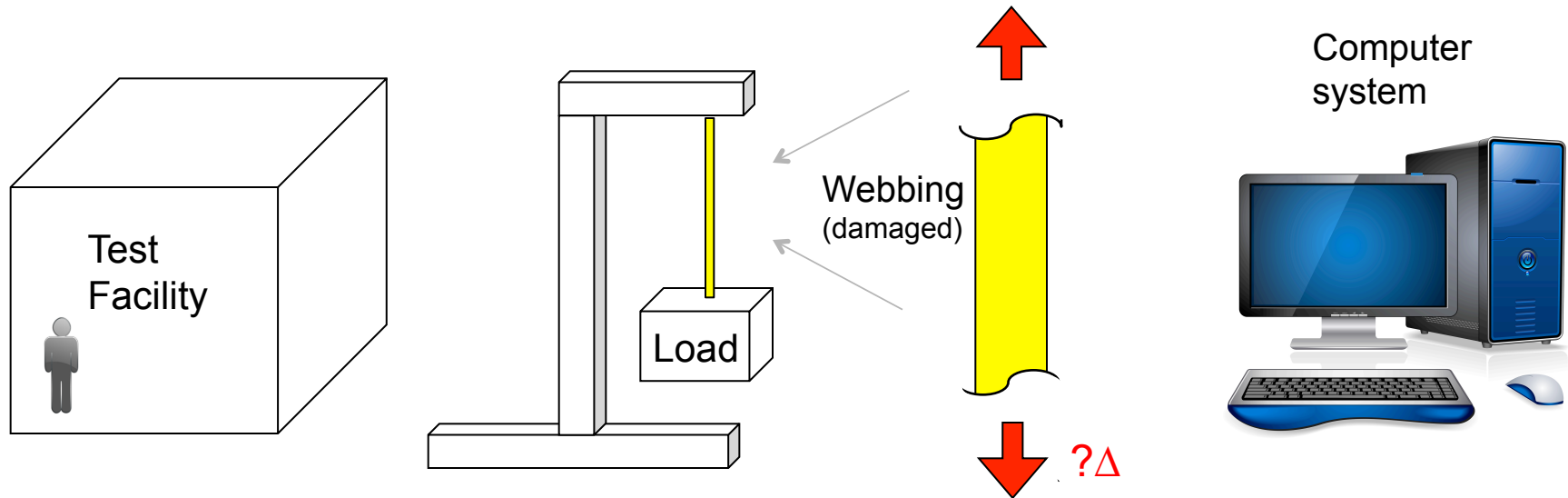


# Problem Statement

- 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



**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

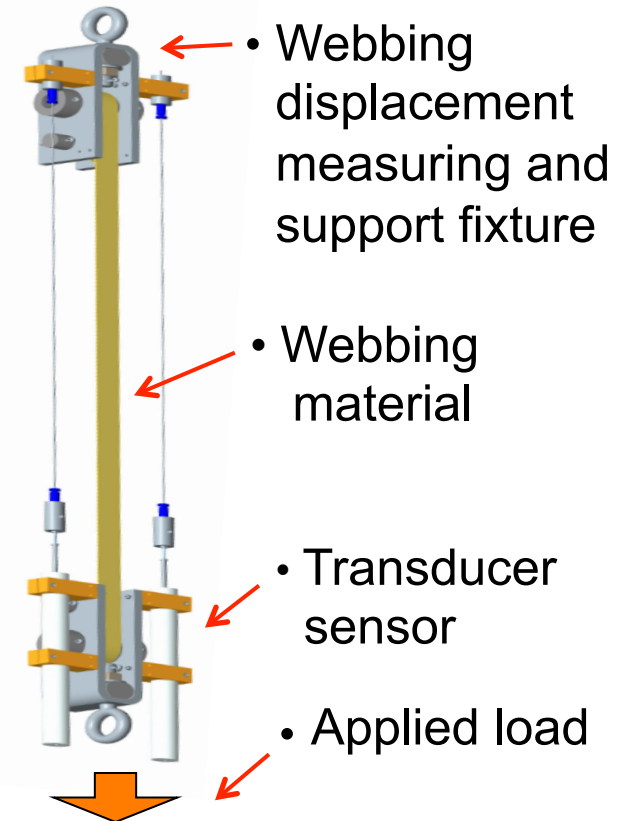
## Data Acquisition

- Variable rate
- Continuous recordings over multiple years

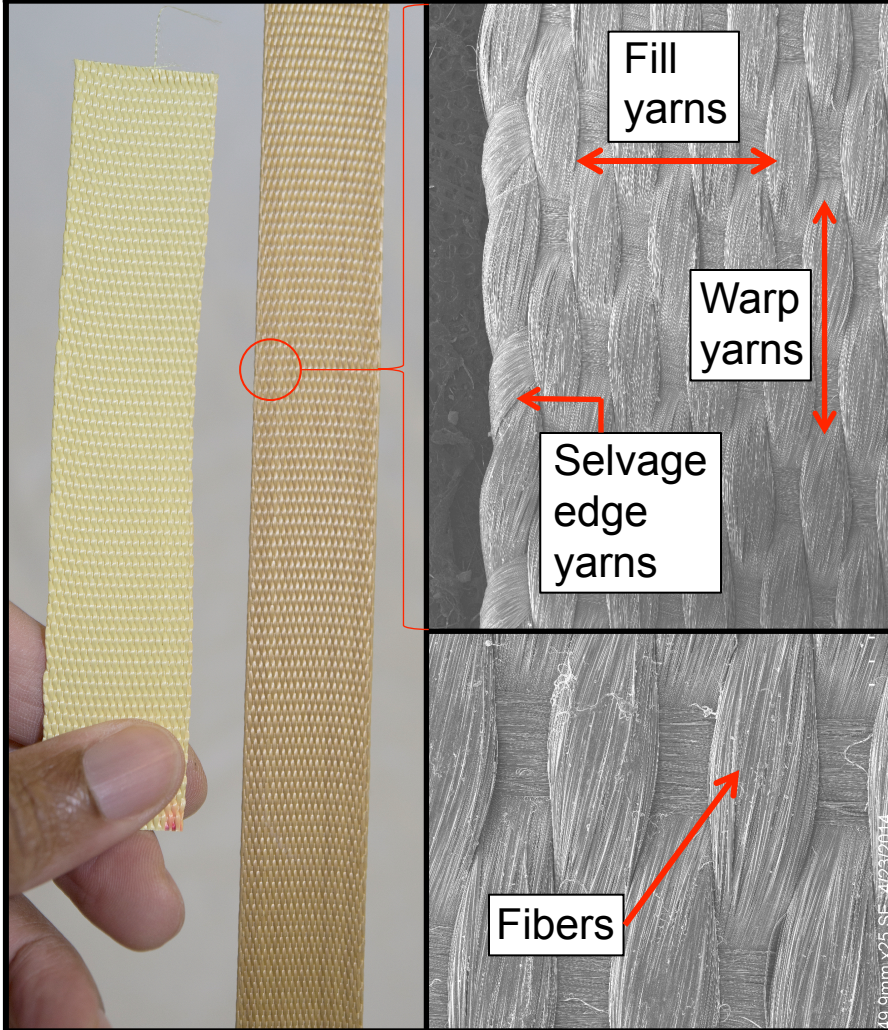
# Creep Test Facility



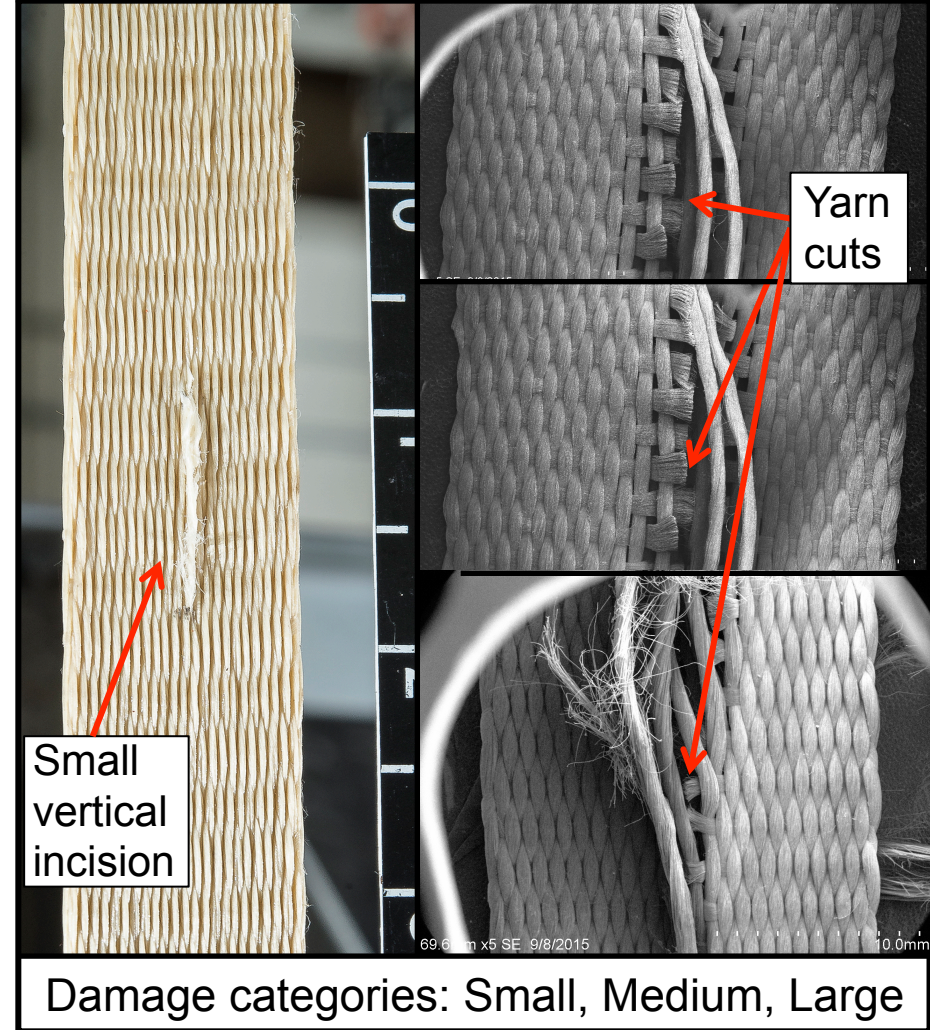
- Initial creep test, Feb 2012
- Creep test hardware (3 rows)
  - I-beam structures
  - Concrete weights
- Typical displacement sensor



## 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



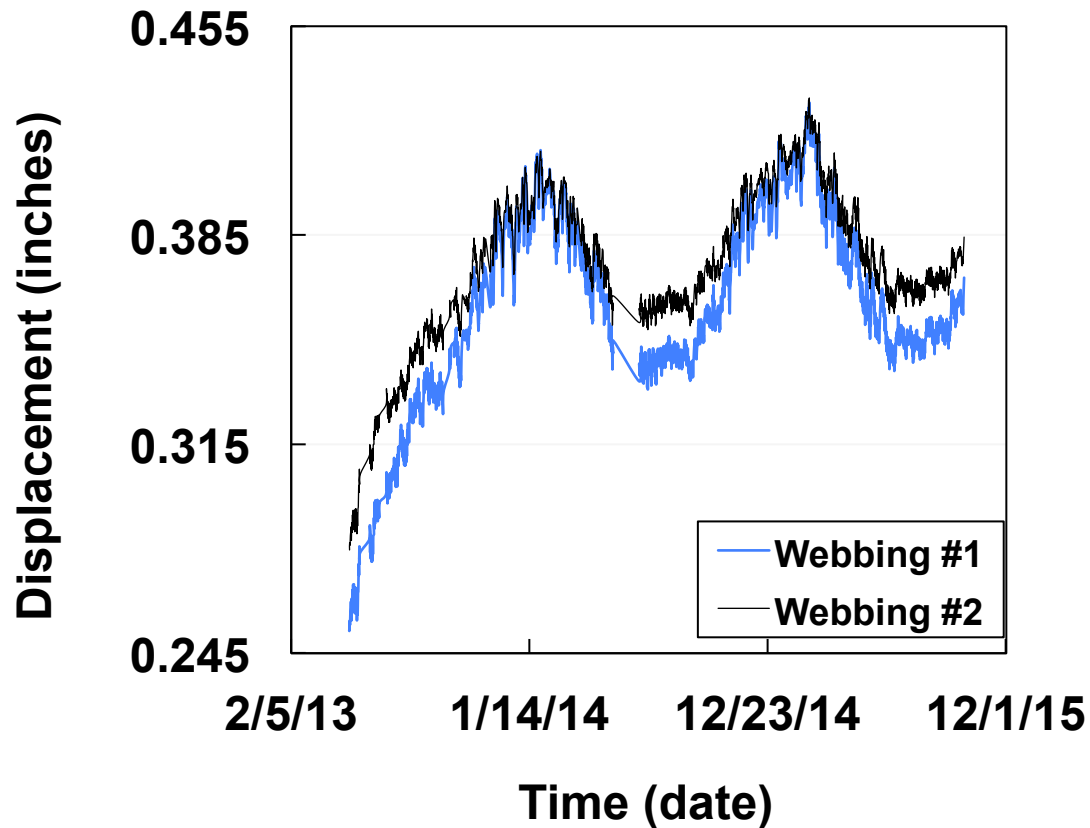
Pristine Webbing					
Group #	Webbing materials	Webbing #	UTS (%)	Webbing length	Length of test (months)
1	6K Kevlar	1	20	144	34
		2	20	144	34
2	6K Kevlar	1	20	60	3
		2	20	60	3
3	6K Kevlar	1	43	68	39
		2	43	84	39
		3	50	82	35
		4	50	80	35
4	6K Vectran	1	50	80	34
		2	50	80	34
		3	50	80	34
5	12.5K Vectran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

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

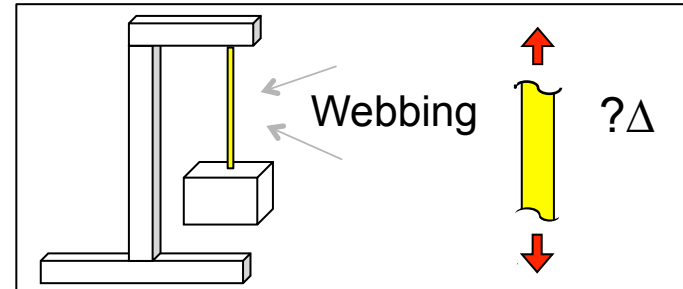
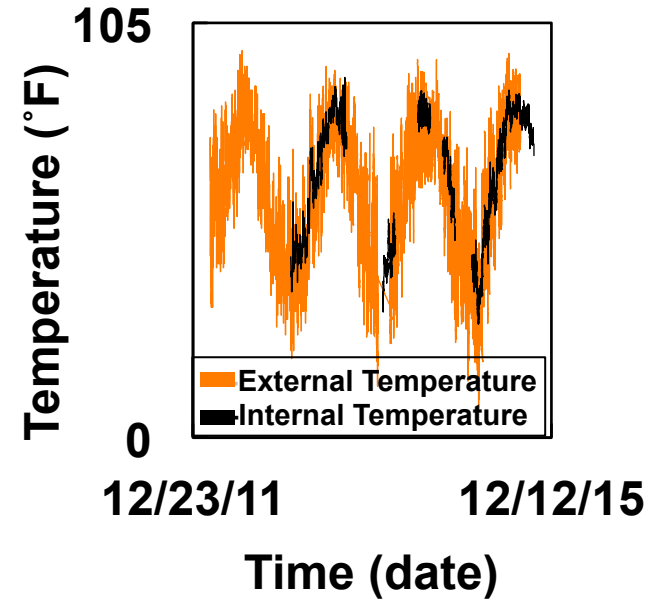
\*Ultimate tensile strength (UTS)



## Displacement Data

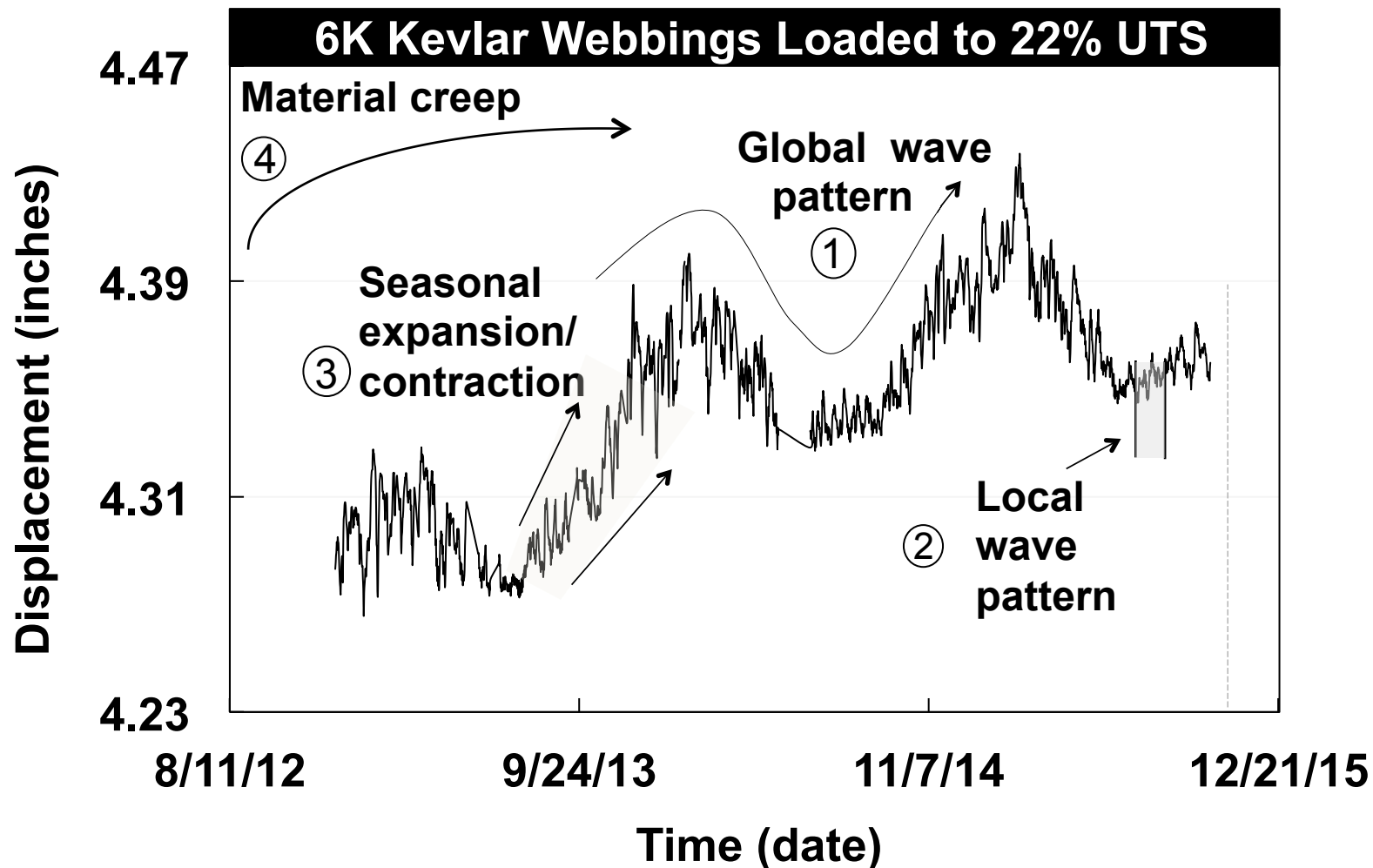


## Temperature Data

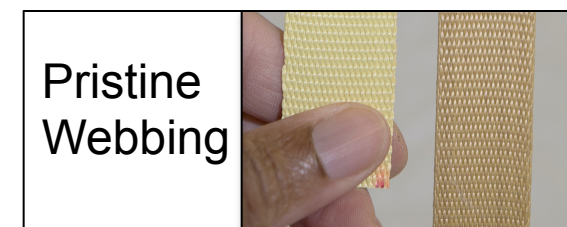


- Daily, seasonal, and yearly temperature and humidity effects influence the creep displacement curve
- Webbing exhibits negative coefficient of thermal expansion (CTE)

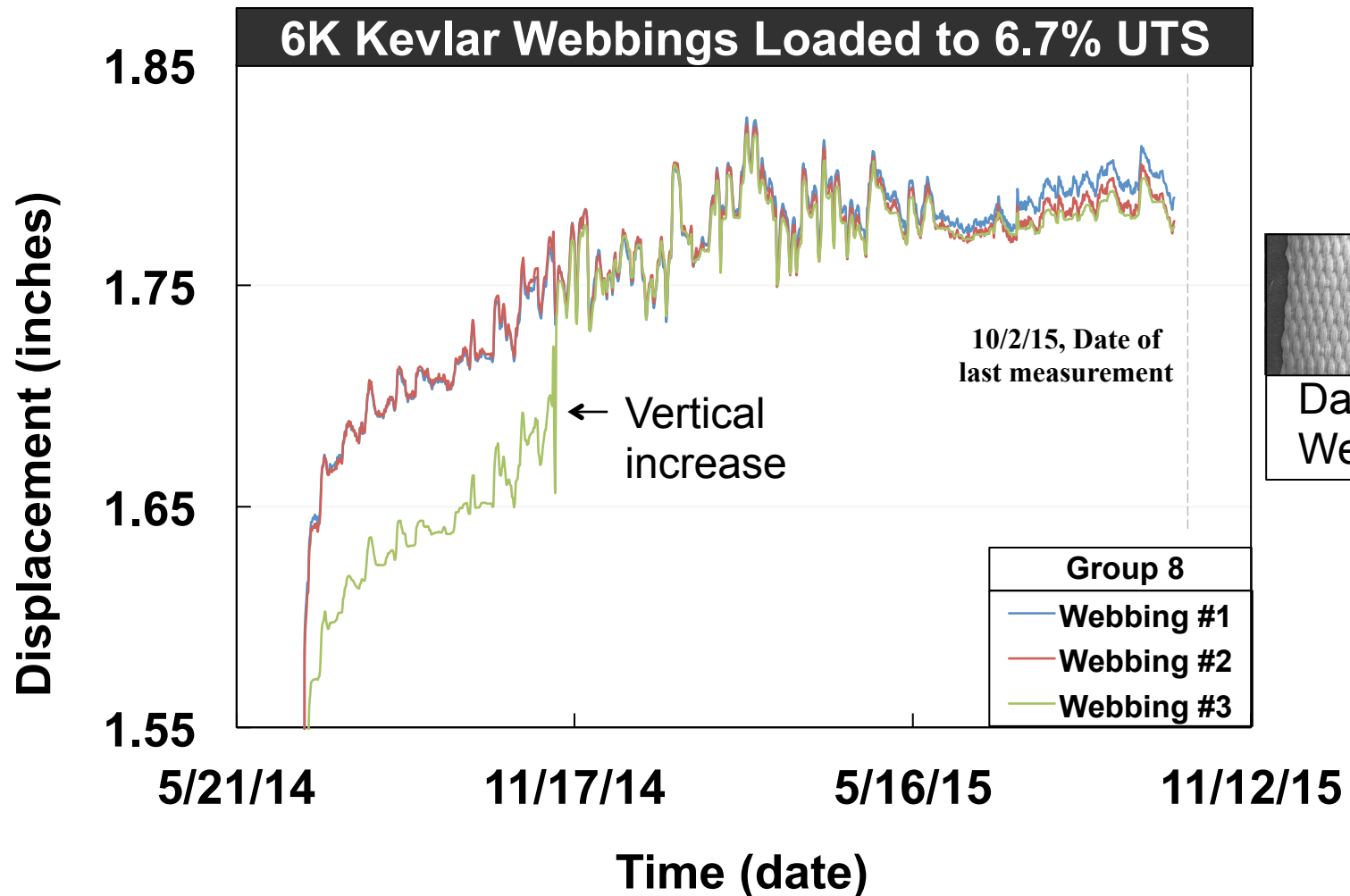
# Characteristics of Displacement Curve



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

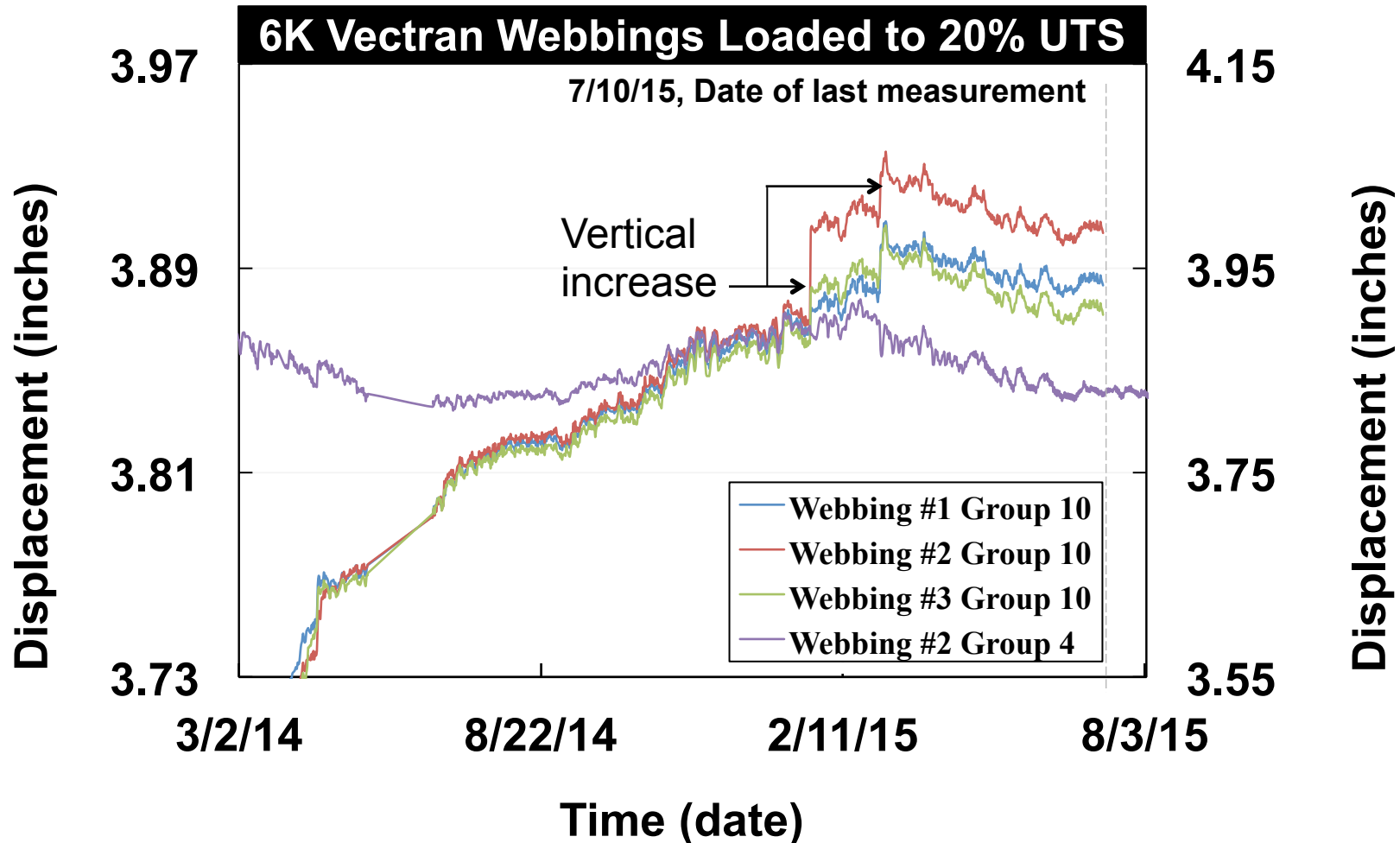


# Effects of Damage



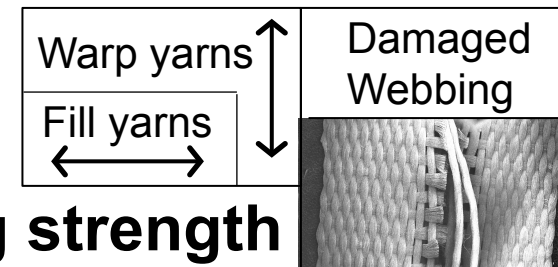
- Damage introduces vertical spikes into local wave pattern
- Damage doesn't effect strength over time

# Effects of Damage

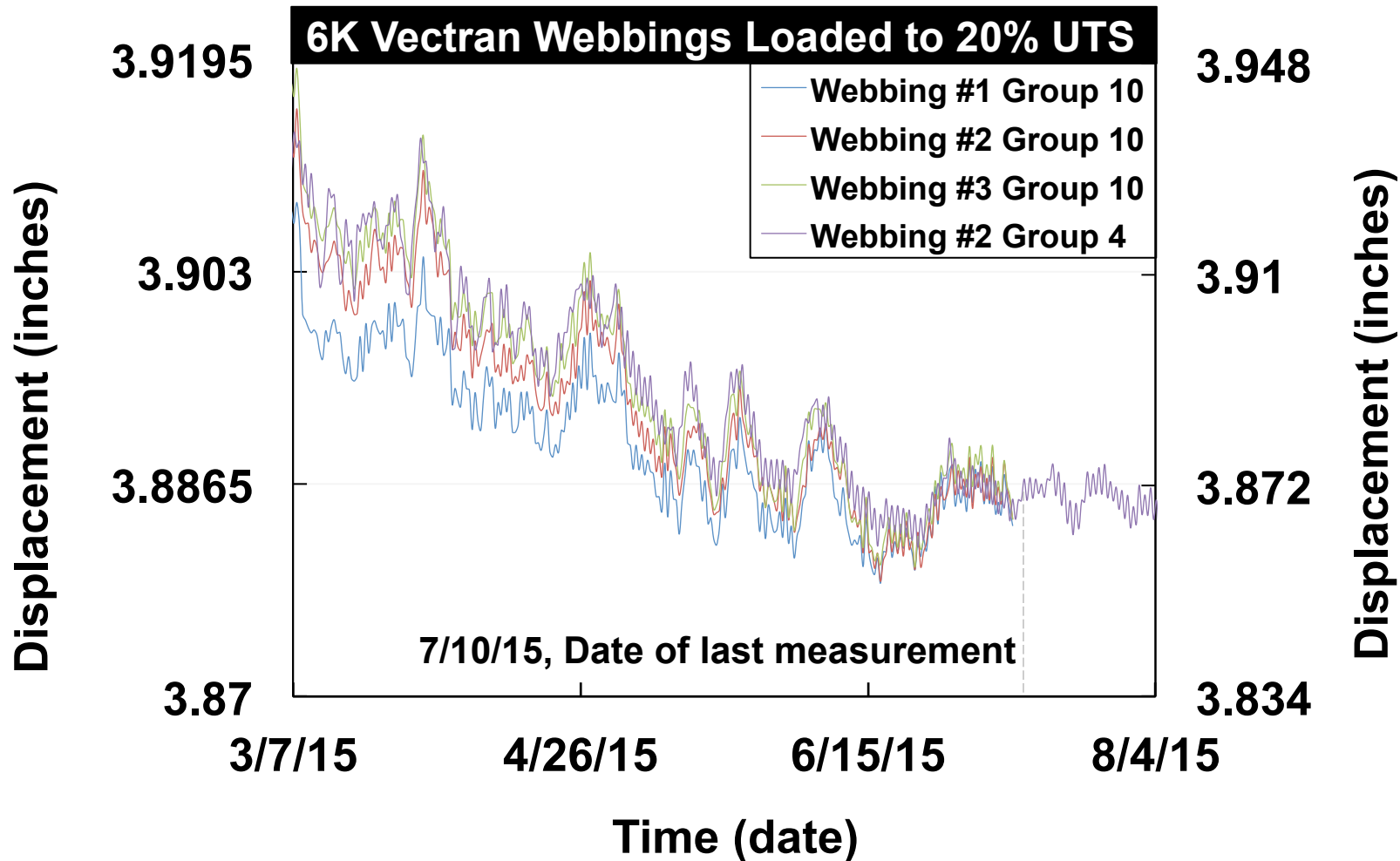


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- **Vertical spikes are due to transfer of load from damaged to pristine warp yarns**
- **Cut fill yarns have little effect on webbing strength**

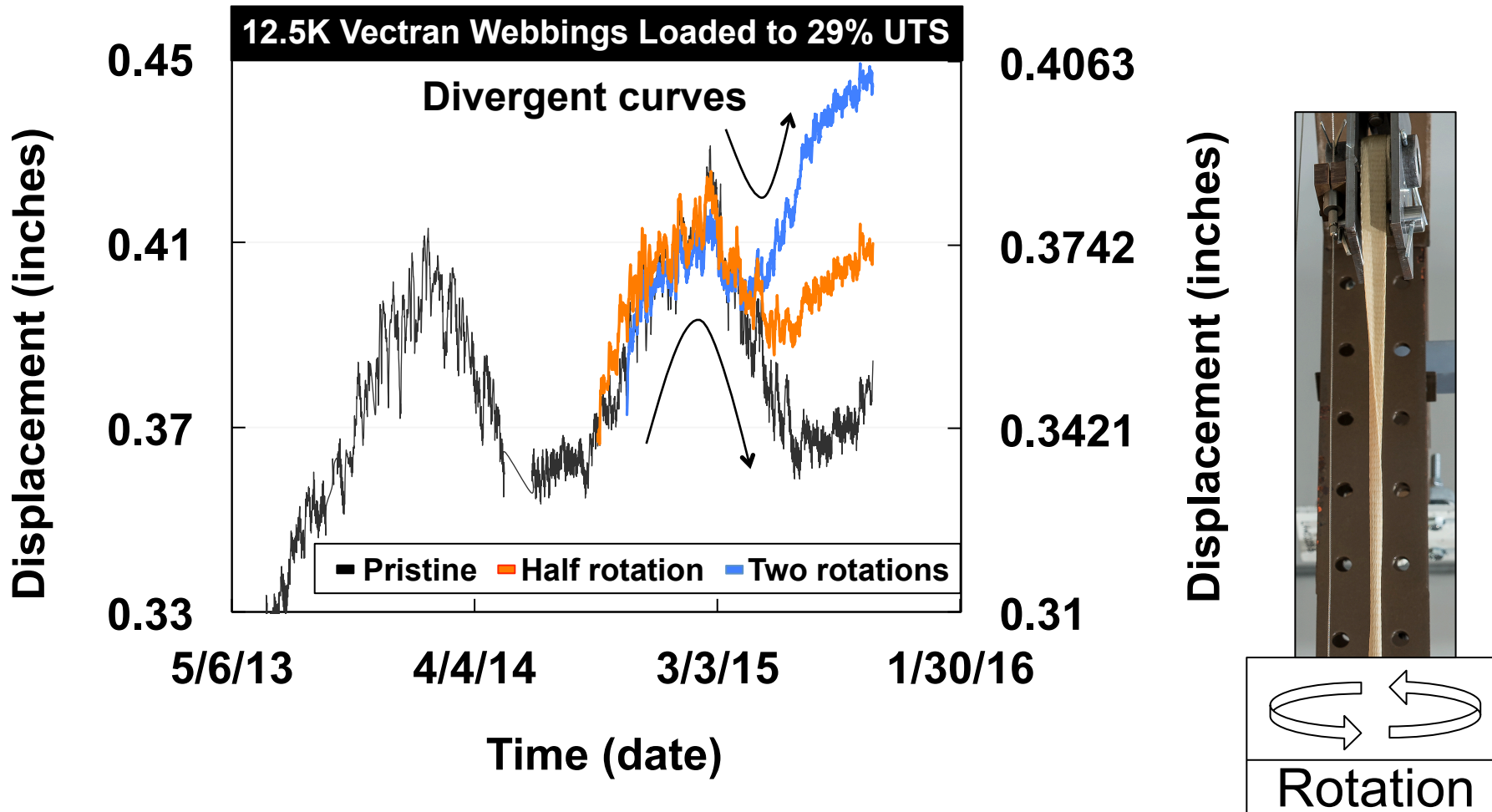


# Effects of Damage



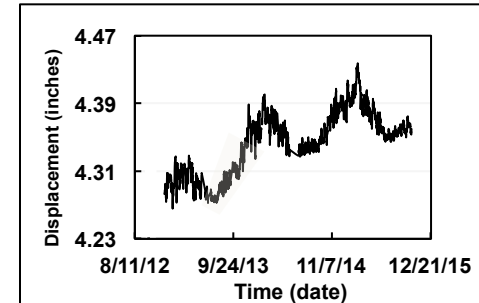
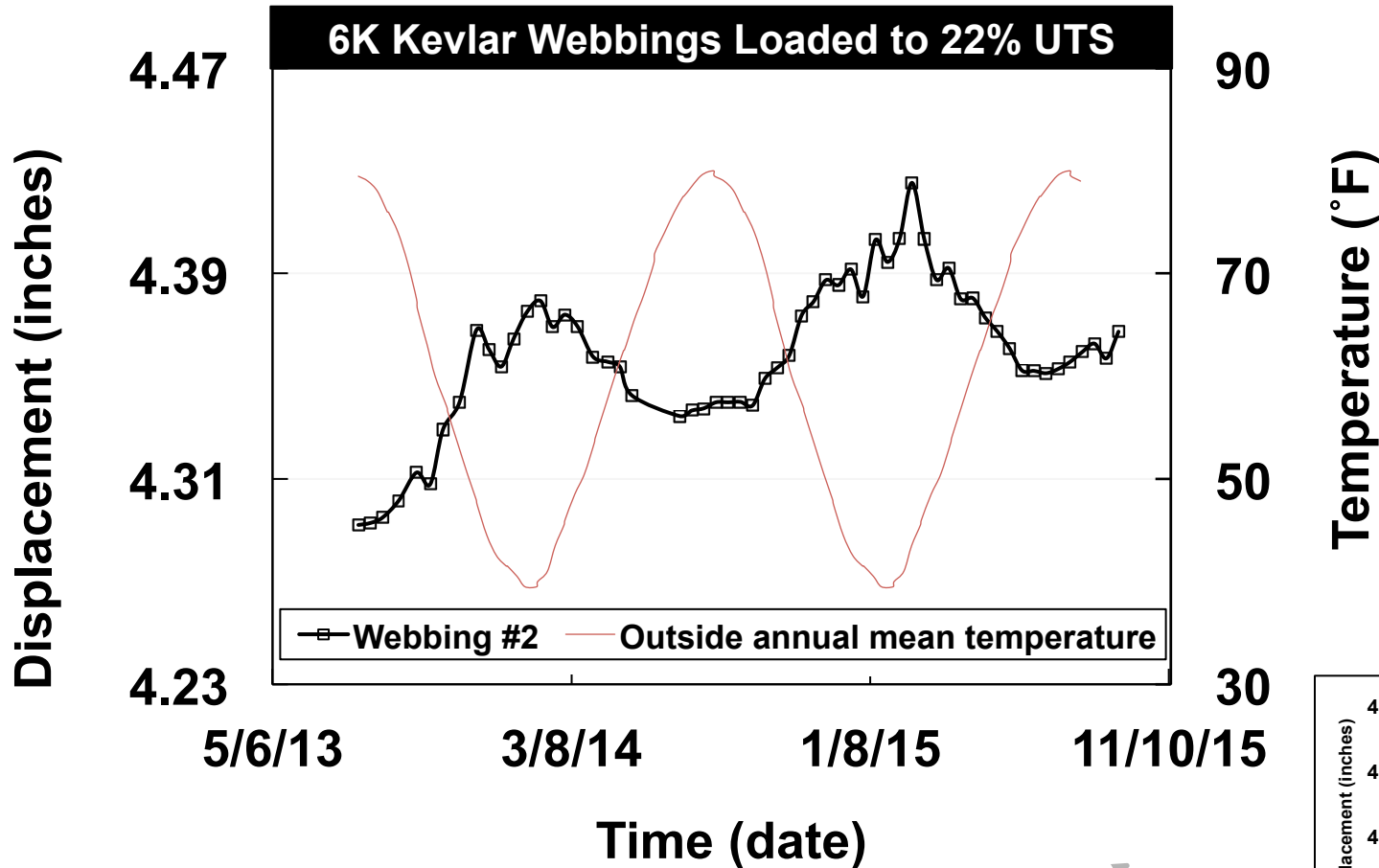
- Magnified view of damaged webbing wave patterns relative to baseline pattern indicates insignificant effect of damage

# Effects of Rotation



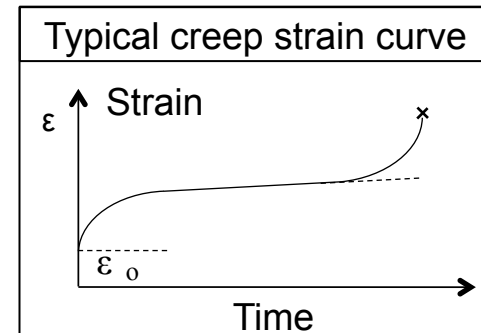
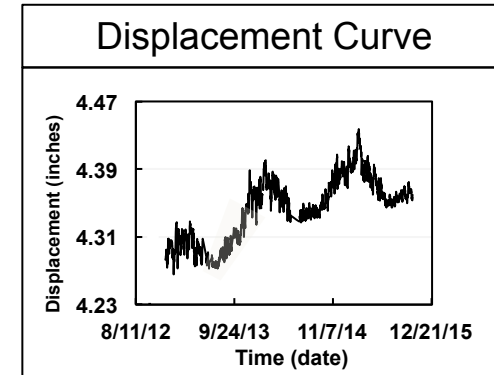
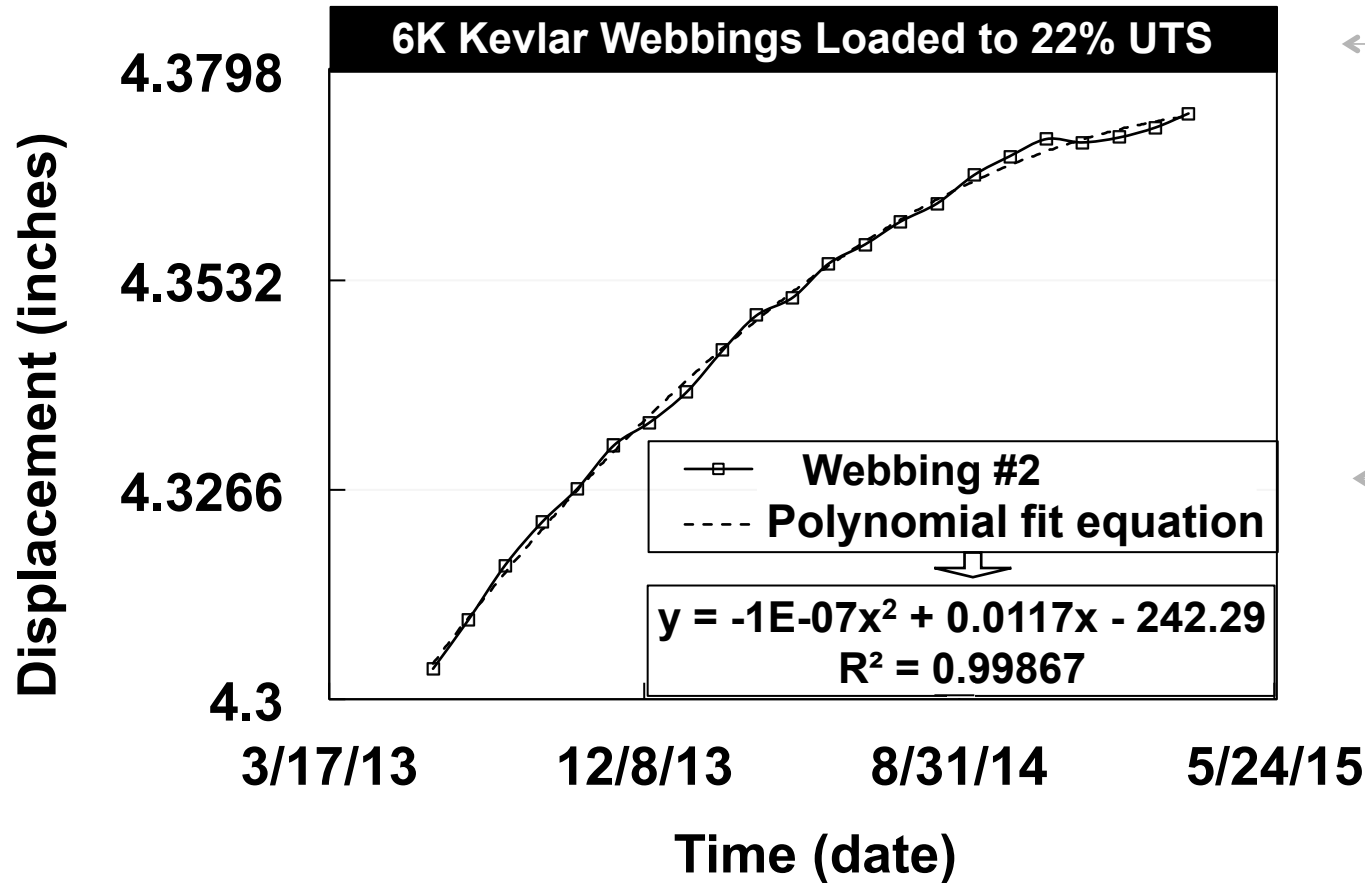
- Rotation introduces a divergent global wave pattern
- Rotation has a significant effect on strength over time

# Running Sum Calculation



- 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




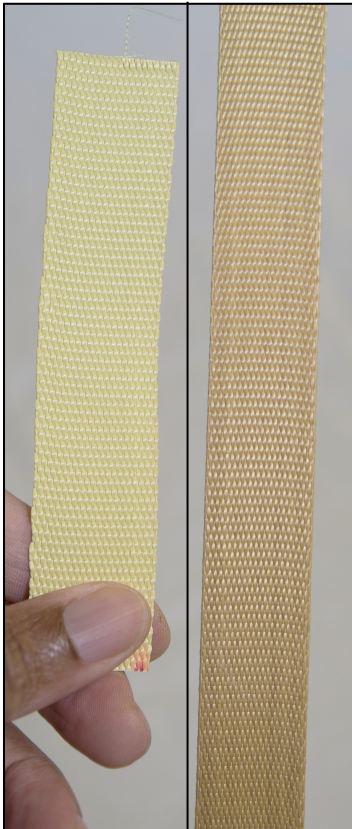
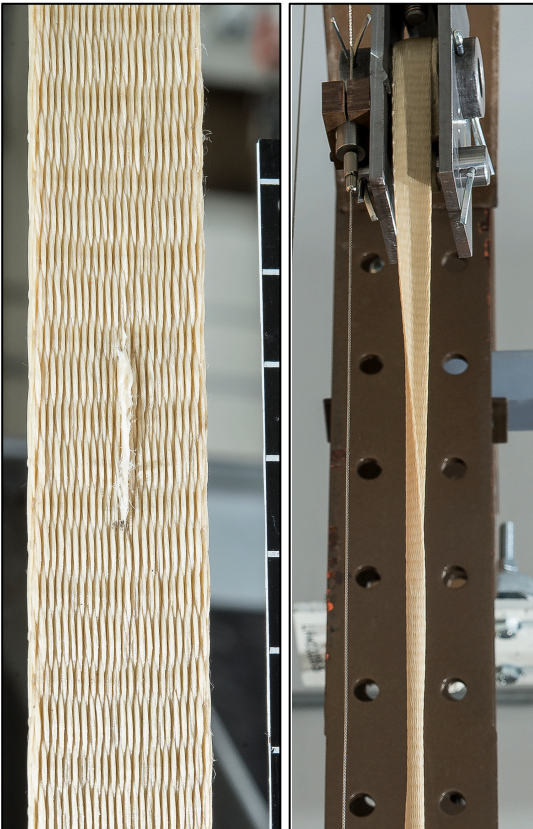
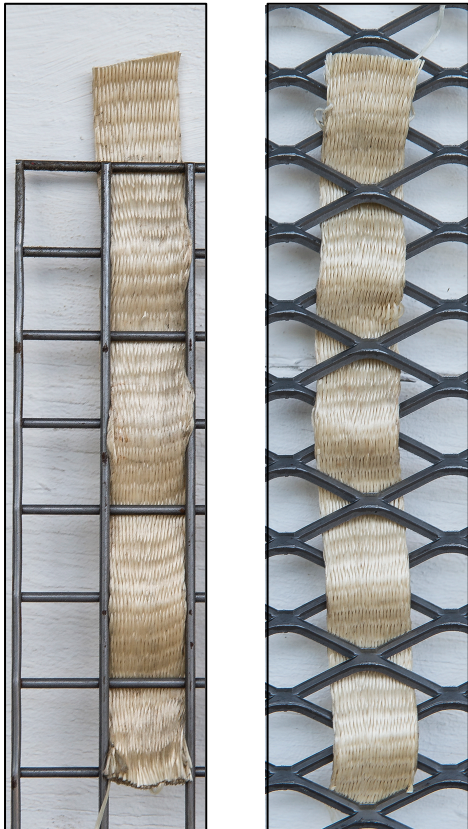
- All wave patterns can be eliminated and a continuous curve generated through the use of running sum calculations
- Each data point in presented graph consist of 1 year of data
- Running sum curve is comparable to a classic creep curve





- **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**

## Test Matrix

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

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