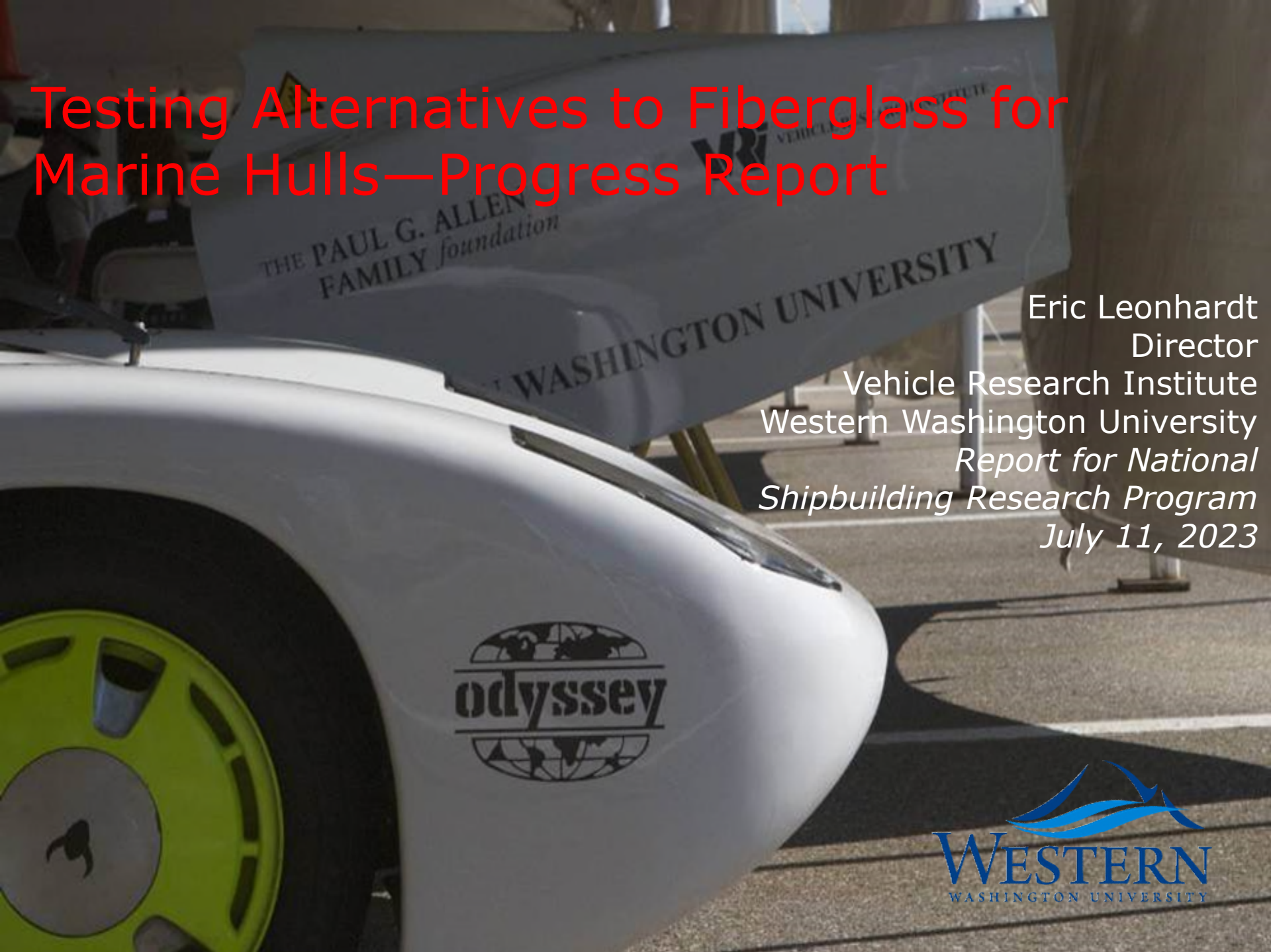
Testing Alternatives to Fiberglass for Marine Hulls—Progress Report

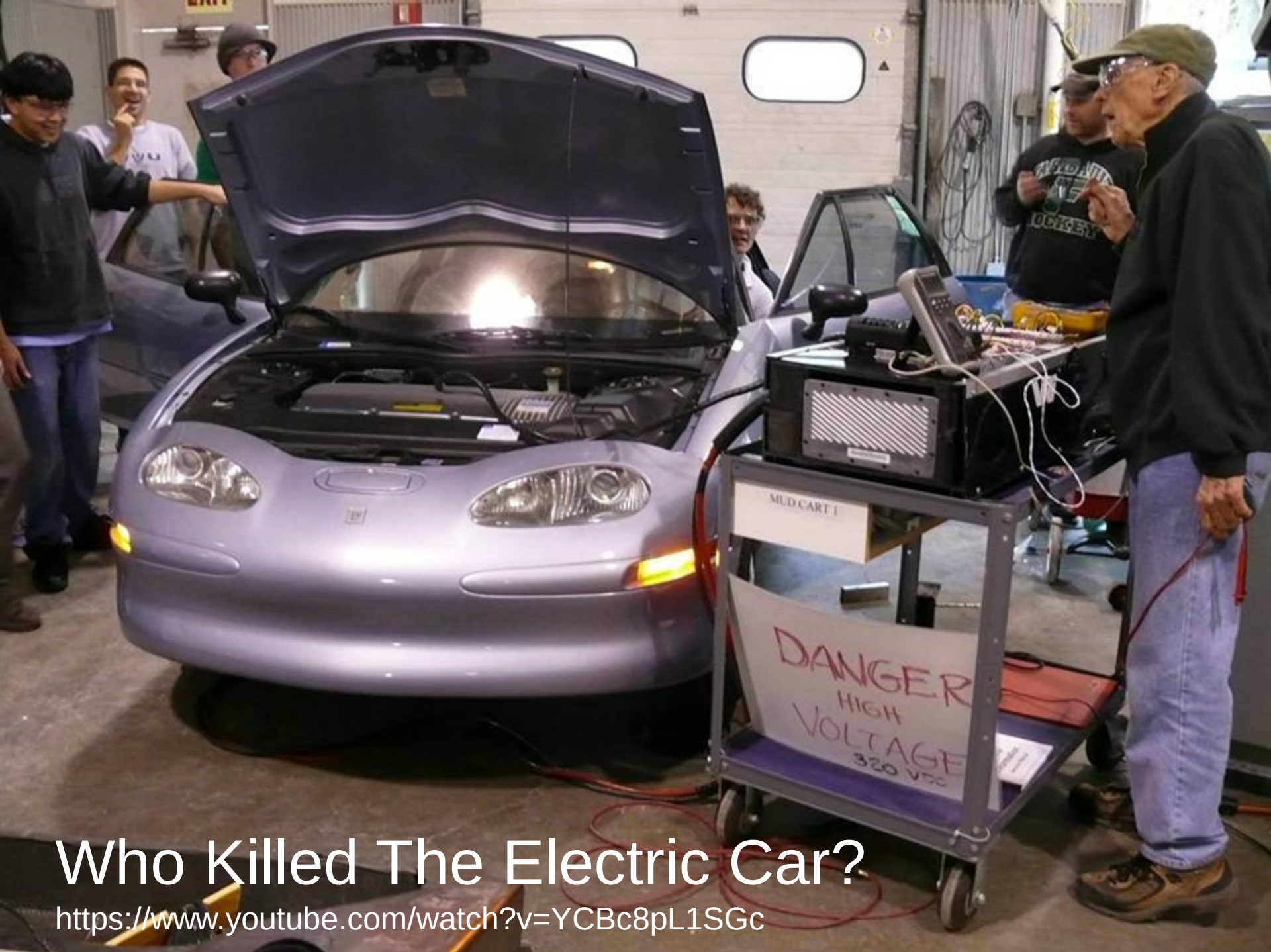


Eric Leonhardt
Director
Vehicle Research Institute
Western Washington University

Report for National Shipbuilding Research Program

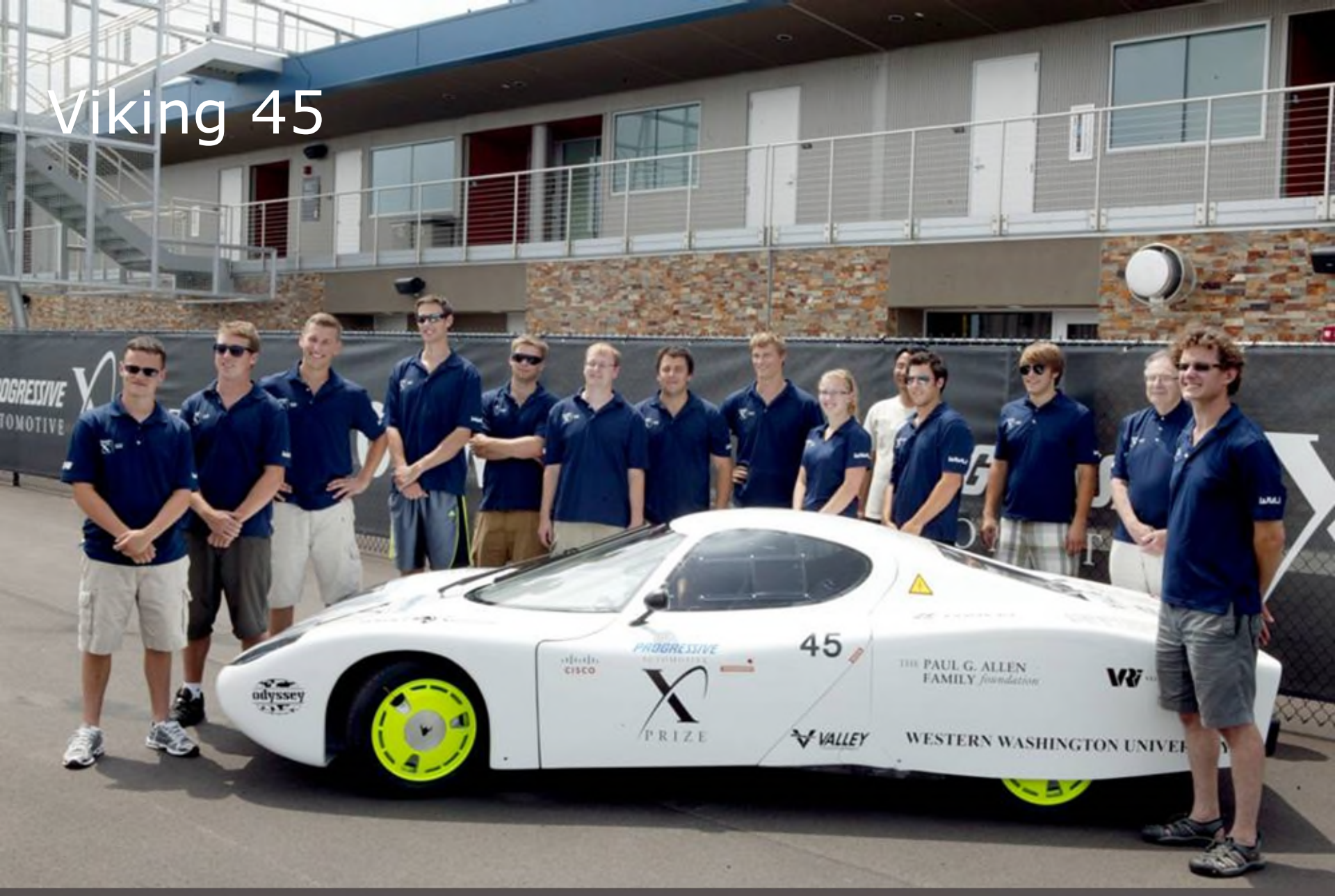
July 11, 2023


Vehicle History
Renewable Fuels
Composite Projects
Material Testing
for Hull Materials

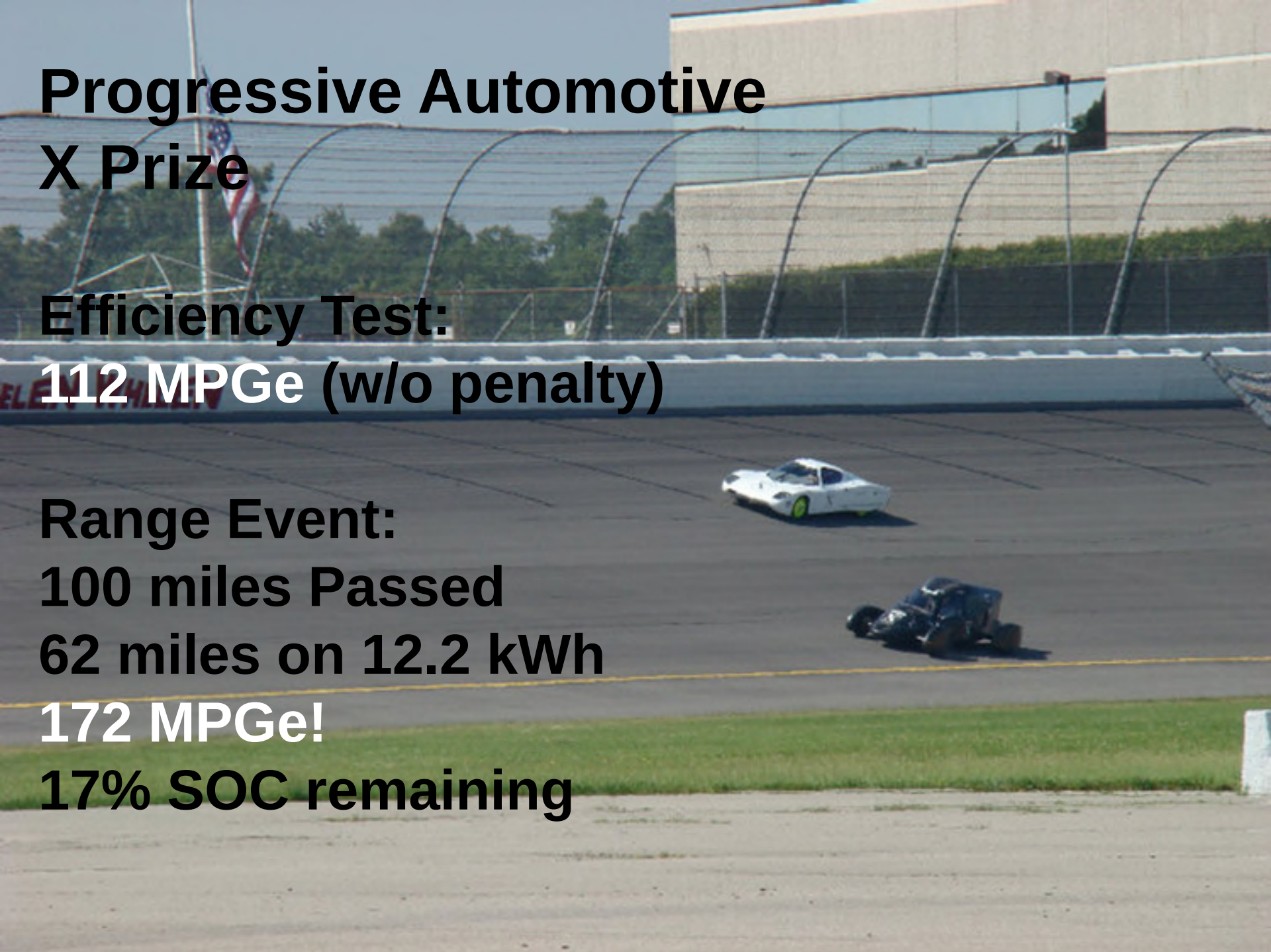


Who Killed The Electric Car?

https://www.youtube.com/watch?v=YCBc8pL1SGc



Progressive Automotive X Prize

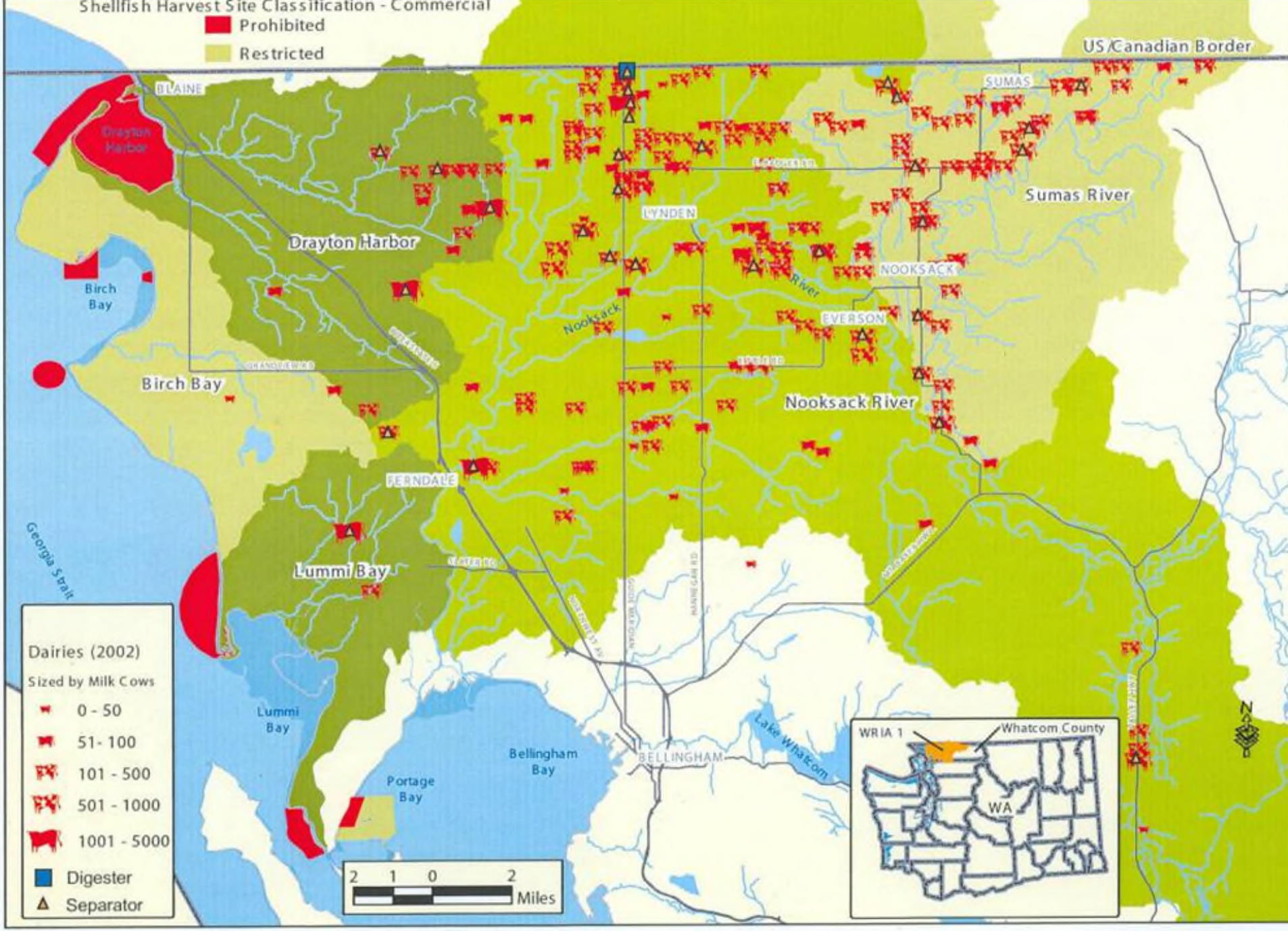


Progressive Automotive X Prize

Efficiency Test:
112 MPGe (w/o penalty)

Range Event:
100 miles Passed
62 miles on 12.2 kWh
172 MPGe!
17% SOC remaining

Tour de Sol



Whatcom Conservation District

NRCS Natural Resources Conservation Service

Dairy Farms in Whatcom County

March 20
Cartographer: Andrew Ph

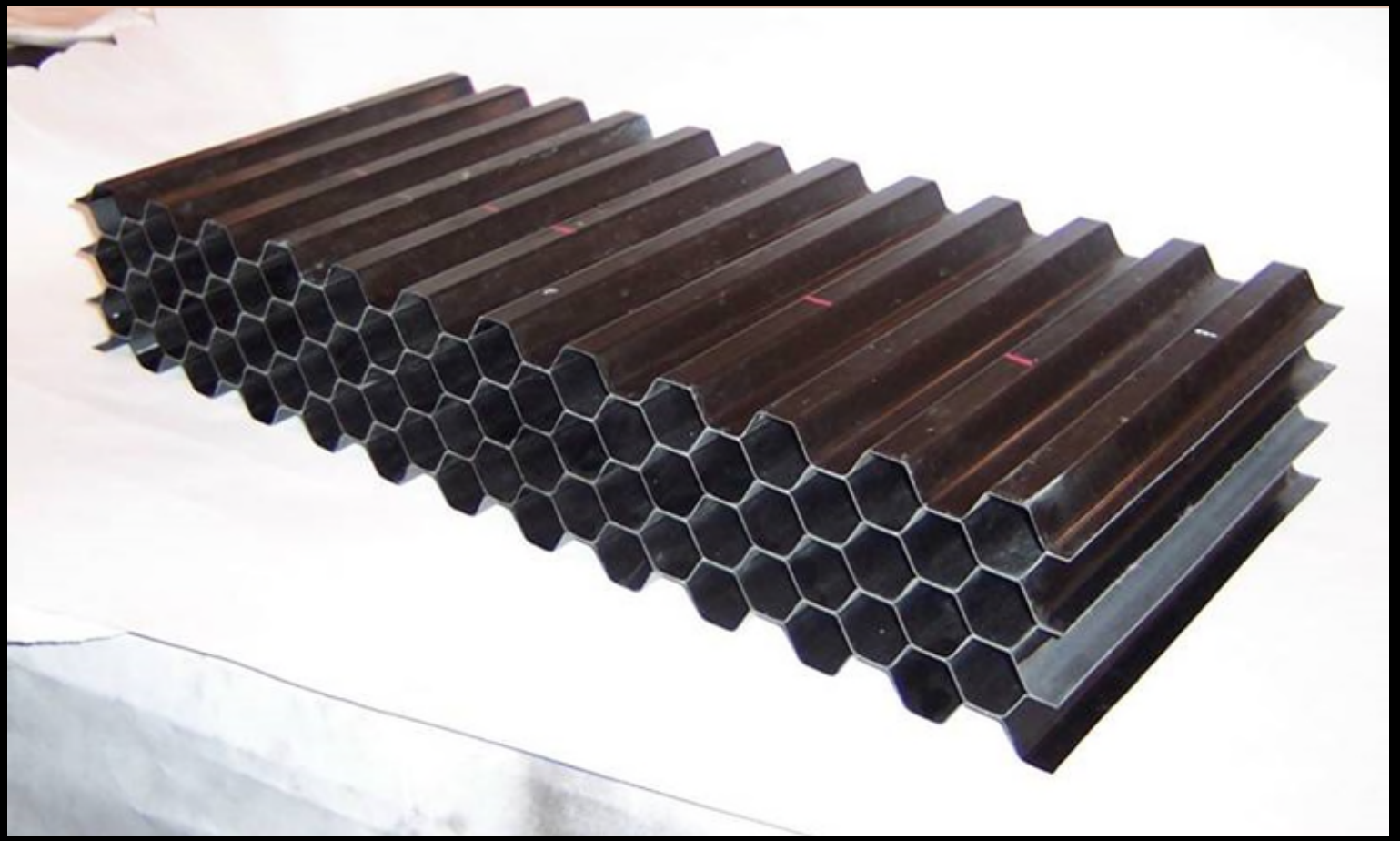

BELLAIR
AIRPORTER SHUTTLE

Composites Projects

Hood Jig Tool
Impact Structure
Bus Chassis
Kayak


VRi
VRi

Carbon Fiber Impact Attenuator



"Six pounds absorbs 100,000 lb impact force at the front of Viking 32. Slowing the vehicle from 50 mph at 40G."


VRI
VIKING 55

24 Hour Kayak Distance Record: “CA-125”

LOA: ~7.0m Hour
Beam: 457 mm
Lightship: 7.7 kg
Distance: > 227 km


24 Hour Kayak
Distance Record:
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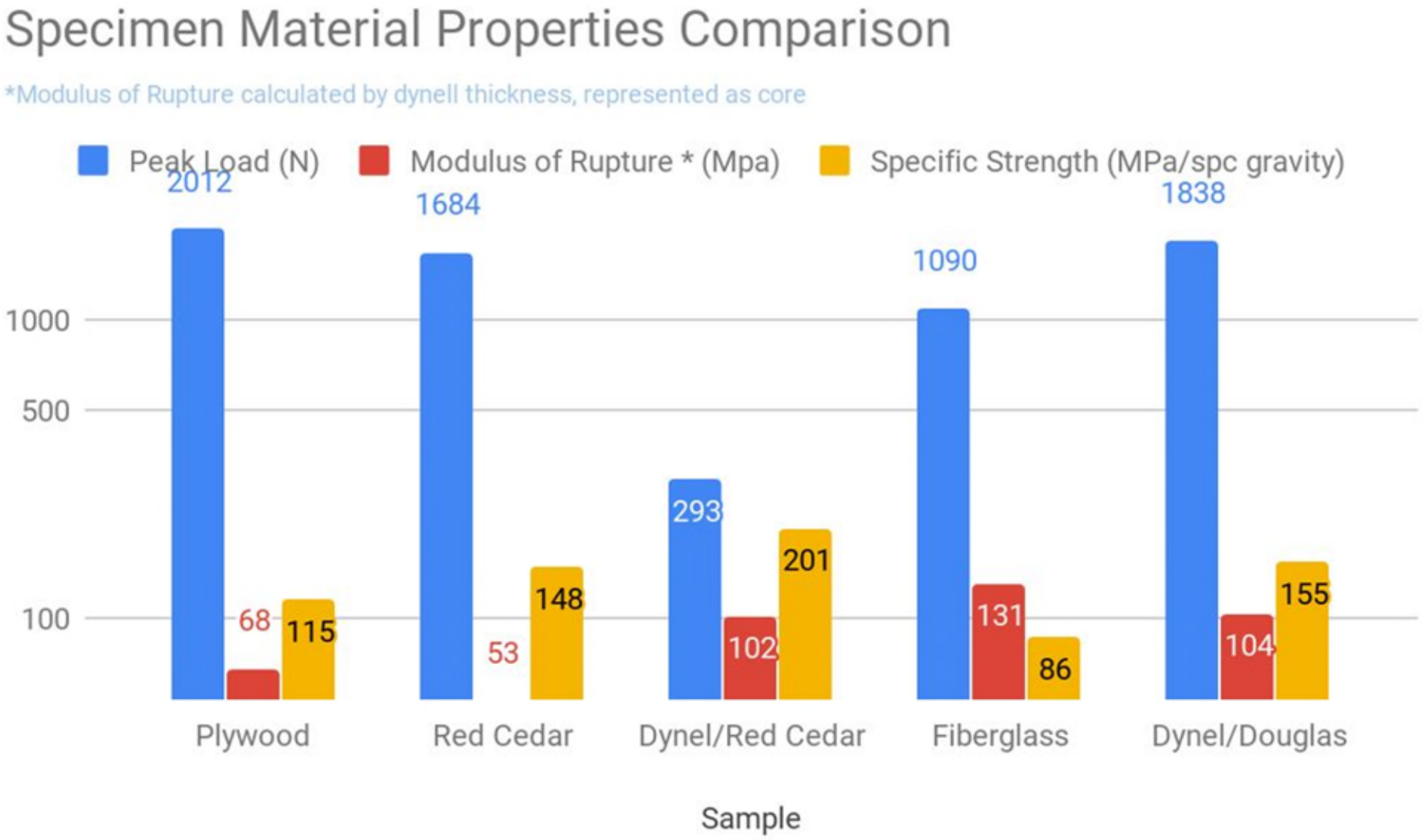
What alternatives to fiberglass and advanced composites exist for light, low carbon-footprint hulls?

Lindsay Lord - Classic Boat Library (fiberglassics.com)

Why is Dynel/Epoxy facing over a wood core compelling?

Sample	Peak Load N (Std. Dev.)	Modulus of Rupture MPa (Std. Dev.)	Specific Strength MPa/spc. gravity (Std. Dev.)	Maximum strain in outer layer mm/mm (Std. Dev.)
Plywood	2012 (278)	68 (9)	115 (16)	0.0069 (0.0008)
Red Cedar	1684 (239)	53 (10)	148 (21)	0.0098 (0.0006)
Dynel /Red Cedar	293 (60)	102 (18)	**201 (27)**	0.0119 (0.0021)
Fiberglass	1090 (13)	131 (5)	86 (3)	0.0277 (0.0007)

Mean of 5 Samples Built to Equivalent Scantling Rules
Four-Point Bend Test



Mean of 5 Samples Built to Equivalent Scantling Rules
Four-Point Bend Test

Why is Dynel/Epoxy facing over a wood core compelling?

Percentage of Ultimate Tensile Strength	Sample	Number of Cycles	Failure Notes
80%	Fiberglass 1	1	Instant Failure
80%	Fiberglass 2	1	Instant Failure
80%	Fiberglass 3	1	Instant Failure
60%	Fiberglass 1	1	Instant Failure
60%	Fiberglass 2	661	Delamination Left Side
60%	Fiberglass 3	763	Delamination Right Side
80%	Dynel 1	36325	Delamination Right Side
80%	Dynel 2		Delamination Right Side
80%	Dynel 3	27135	Delamination Left Side

Dynamic Axial Testing of Fiberglass and Dynel Samples
West Systems Epoxy, Vacuum Bagged

Experimental Method

Scantling Rules
Testing Standards
Axial Load Tensile Testing
Axial Load Dynamic Testing
Future Work

Gerr, David, *The Elements of Boat Strength for Builders, Designers, and Owners*. Camden, Maine: International Marine McGraw Hill, 2000, 27-39.

Scantling Rules

Scantling Number, Sn	Sn	Boat Length Overall,	Beam, widest portion of hull	Hull Depth (midships from sheer to keel top inside hull)
Sn=LOA(ft.)*Beam(ft.) *Depth of Hull(ft.)/1000	1.02	32 ft.	8 ft.	4 ft.
Sn=LOA(m)*Beam(m) *Depth of Hull(M)/28.32	1.02	9.75 m	2.44 m	1.22 m

A hypothetical hull size is chosen to allow different materials to be compared using equivalent scantling values.

Gerr, David, *The Elements of Boat Strength for Builders, Designers, and Owners*. Camden, Maine: International Marine McGraw Hill, 2000, 27-39.

Scantling Rules

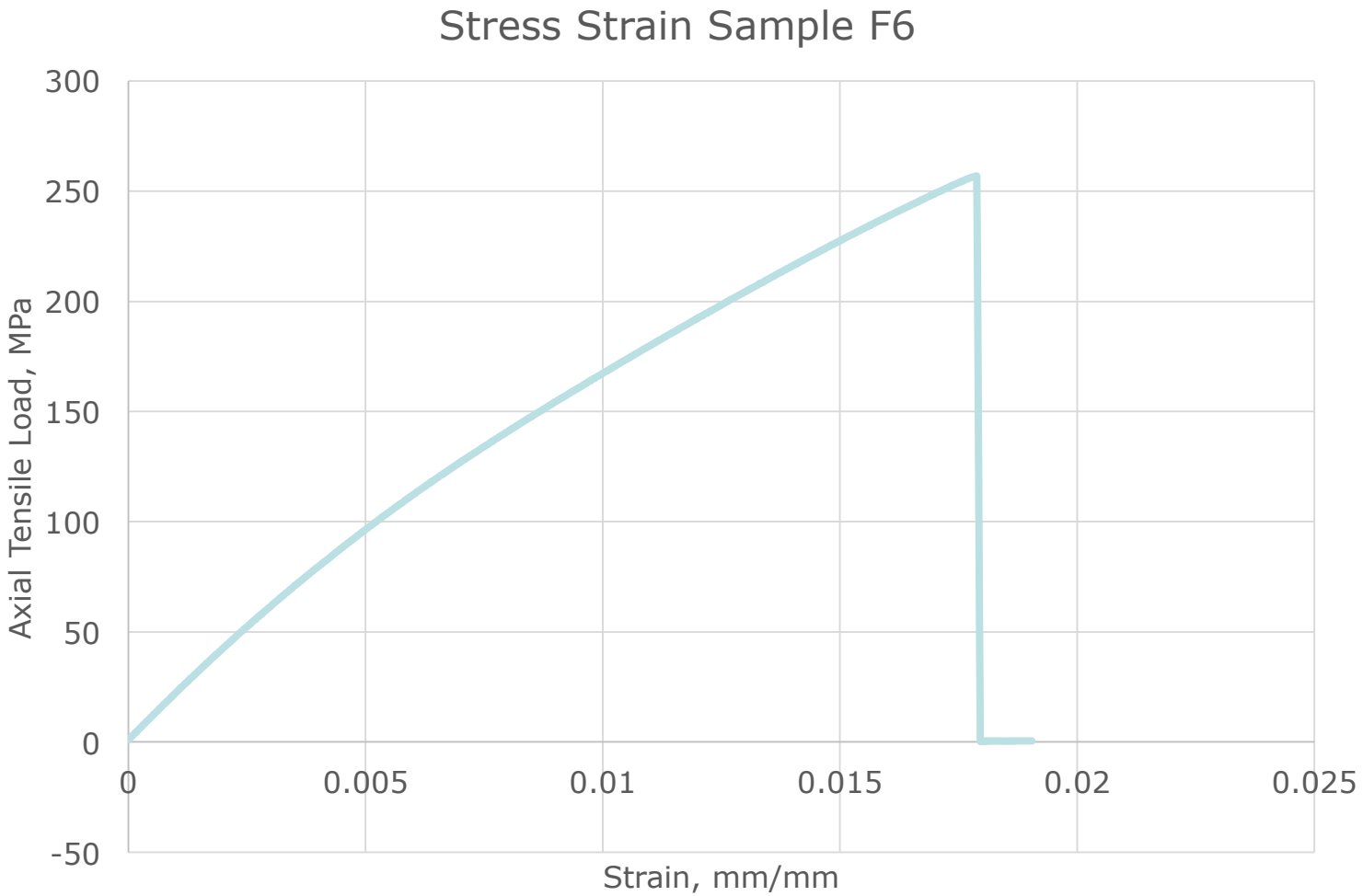
Material	Basic plank or Laminate Thickness Formula	Results S. I. units	Notes
FRP	= 0.25 * $\sqrt[3]{(Sn)}$ (in.) [10]	0.25 in. 6.40 mm	Hand lay-up woven and/or fabric glass. Not chop strand or mat alone.
Plywood	= $0.74*(Sn)^{(0.4)}$ (in.) [11]	0.75 in. 19 mm	Same thickness as basic wood planking.
Dynel Outside Hull Fabric Thickness	$=11.1*(Sn)^{(0.43)}$ oz./sq. yd. [12]	11.2 oz./yd^2 380 g/m^2	Dynel comes as a 4 oz. / sq. yd. fabric, use three layers.
Dynel Inside Hull Fabric Thickness	$=7.36*(Sn)^{(0.36)}$ oz./sq. yd. [13]	7.4 oz./yd^2 252 g/m^2	Dynel comes as a 4 oz. / sq. yd. fabric, use two layers.
Cedar Strip Core	= $0.34*(Sn)^{(0.44)}$ (in.) [14]	0.34 in.* 9 mm	*Minimum size is 0.375 in. or 9.5 mm. Softwood can be low grade planking epoxy grouted together [15]

Gerr, David, *The Elements of Boat Strength for Builders, Designers, and Owners*. Camden, Maine: International Marine McGraw Hill, 2000, 27-39.

ASTM Standards

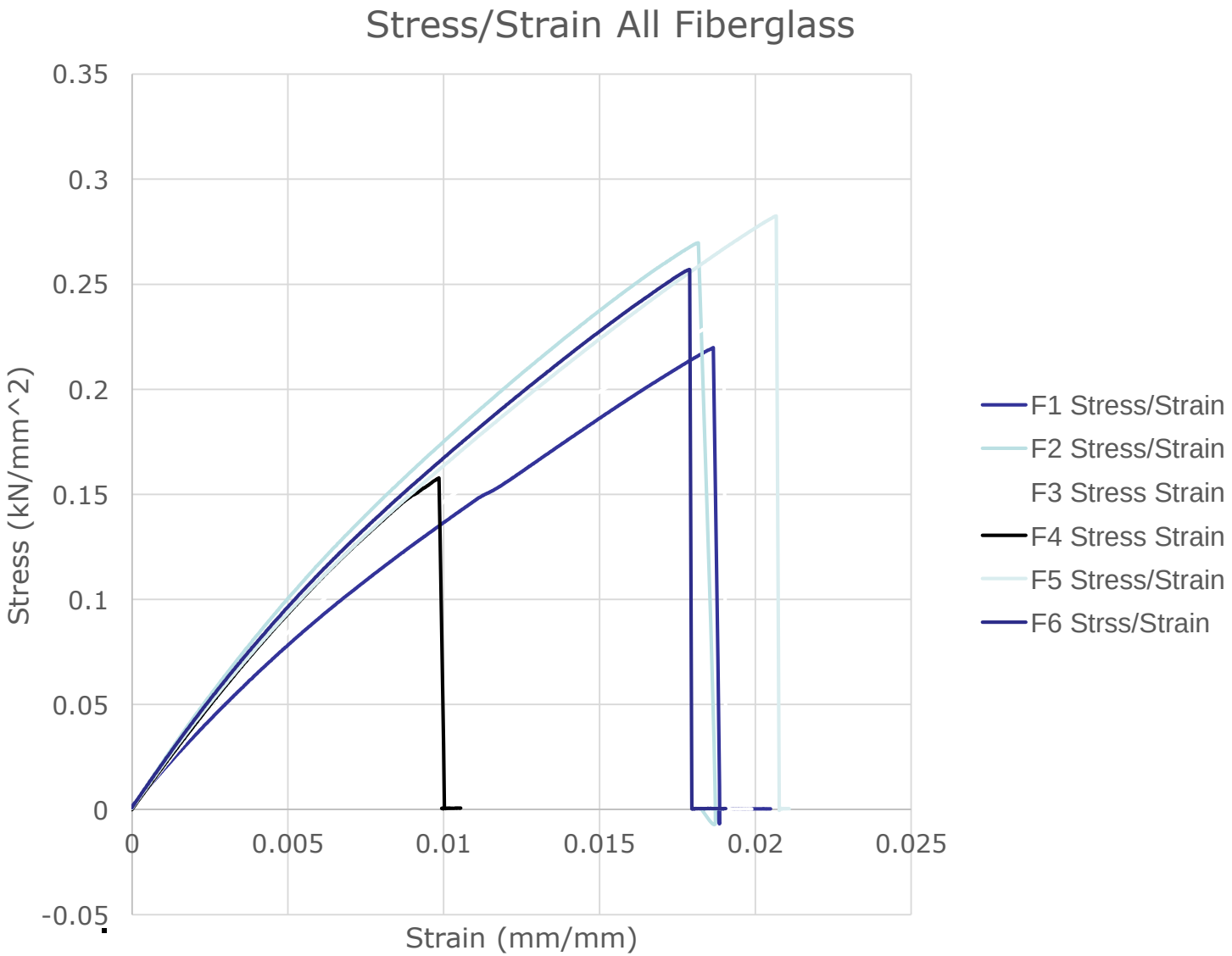
Sample type tested	ASTM Standard(s) followed
Plywood	D3043
Western Red Cedar	D3043
Dynel with cedar core	D7249/D7249M – 12, D5467
E-glass reinforced epoxy	D7264/D7264M – 15, D6272

Fiberglass Tensile Test

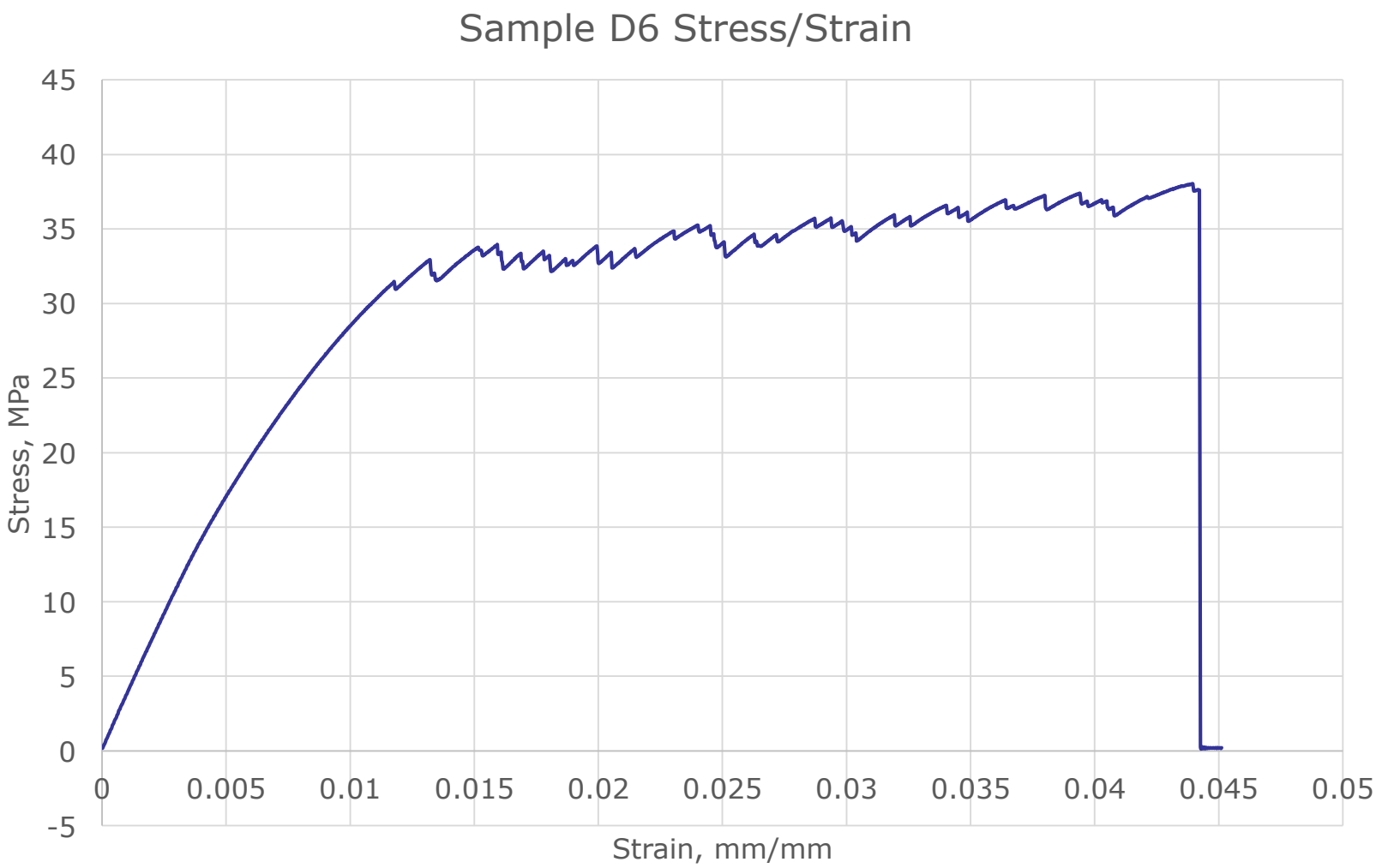


Fiberglass epoxy composite vacuum-bagged wet layup.

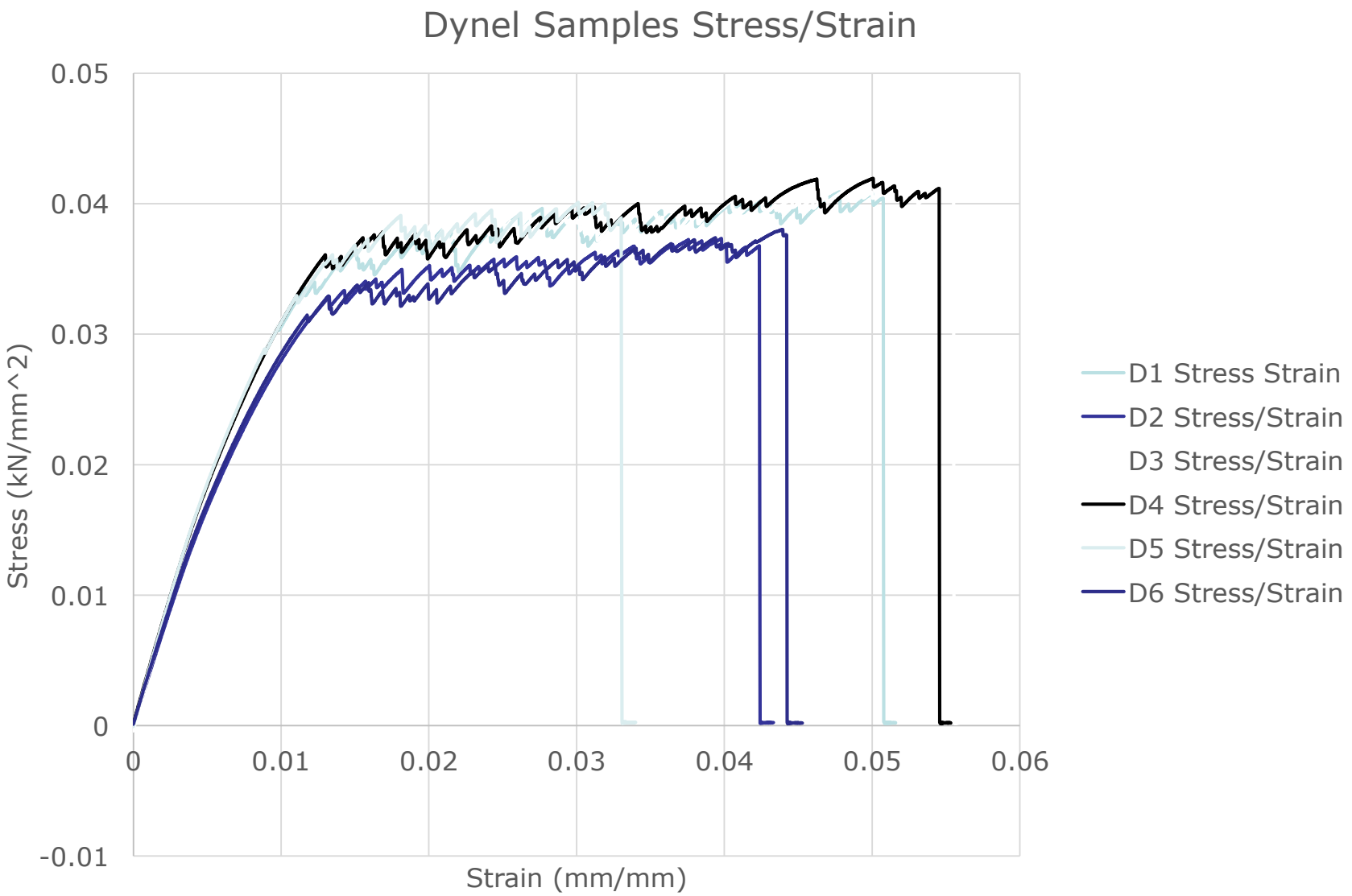
Fiberglass Tensile Test



Dynel/Epoxy Tensile Test

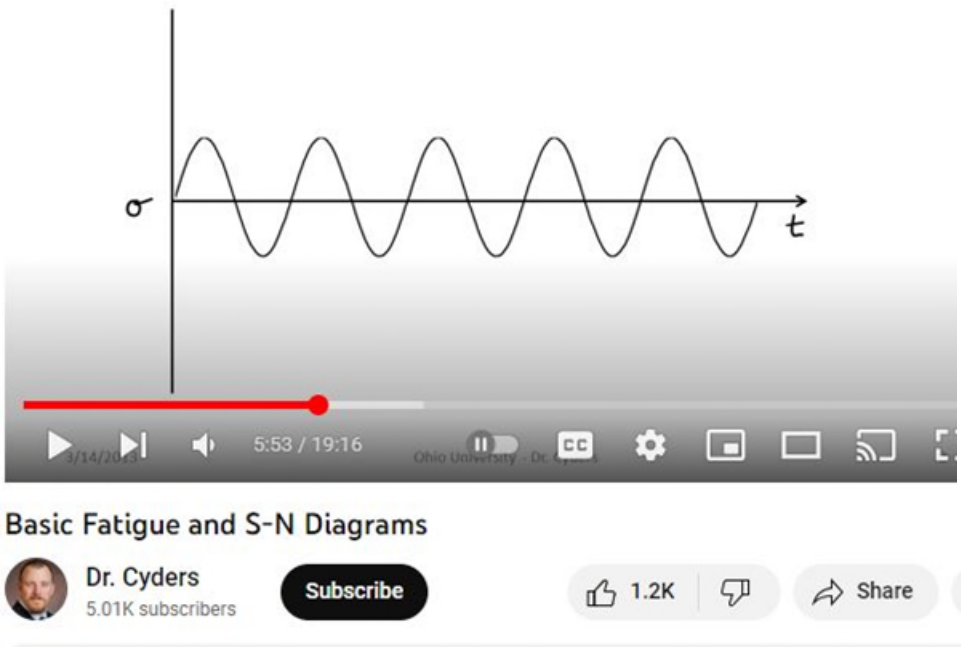


Dynel/Epoxy Tensile Test



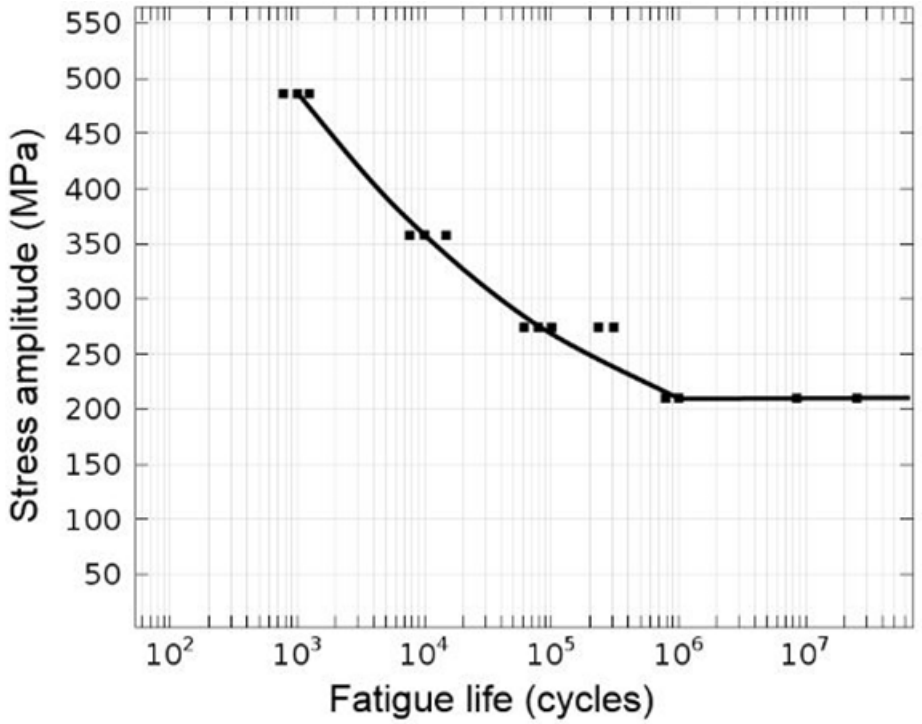
Standard Dynamic Testing

Dr. Cyders Explains Basic Fatigue and S-N Diagrams



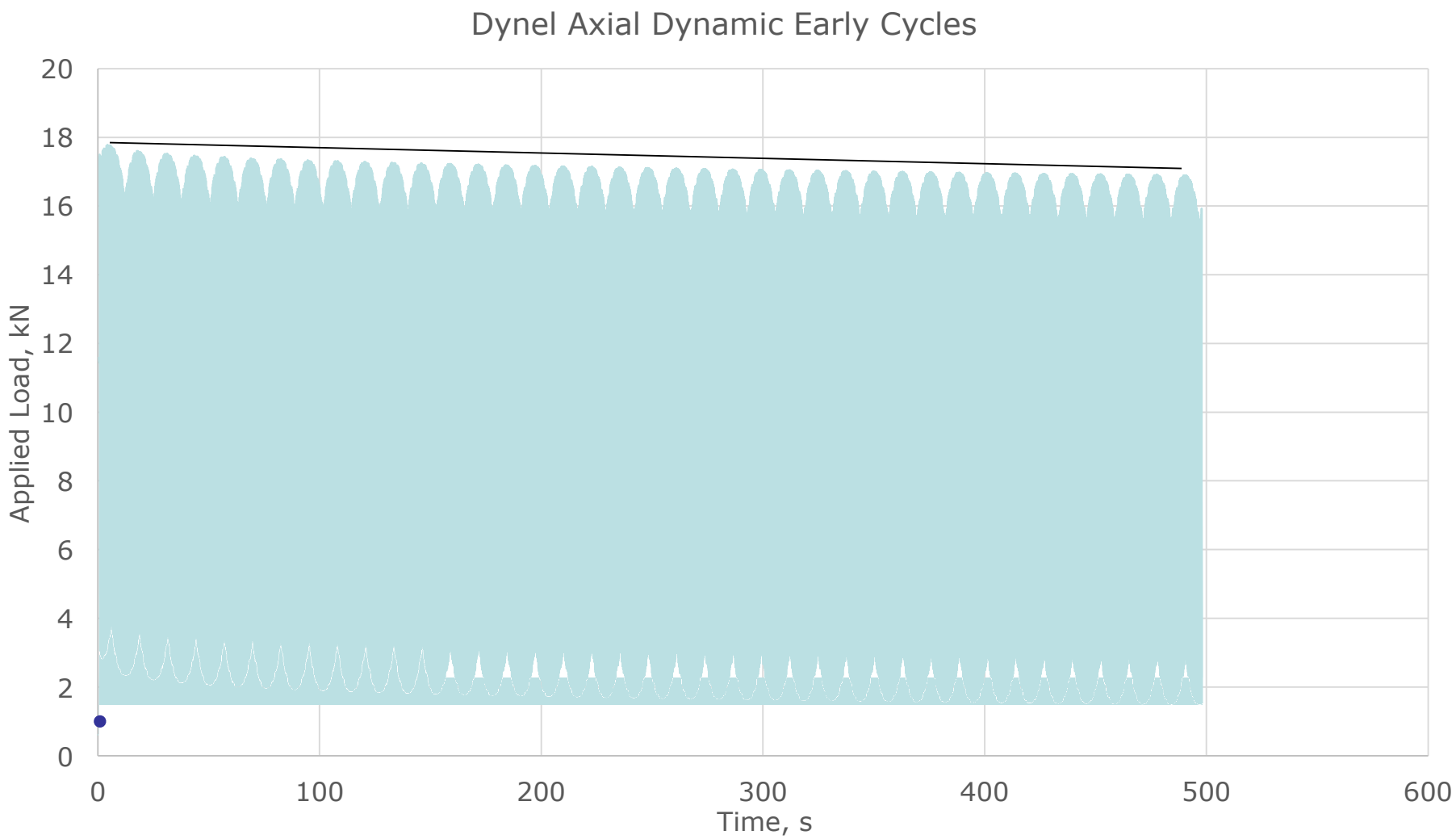
https://www.youtube.com/watch?v=bo4TdlQWSY4

COMSOL Explains S-N Diagrams

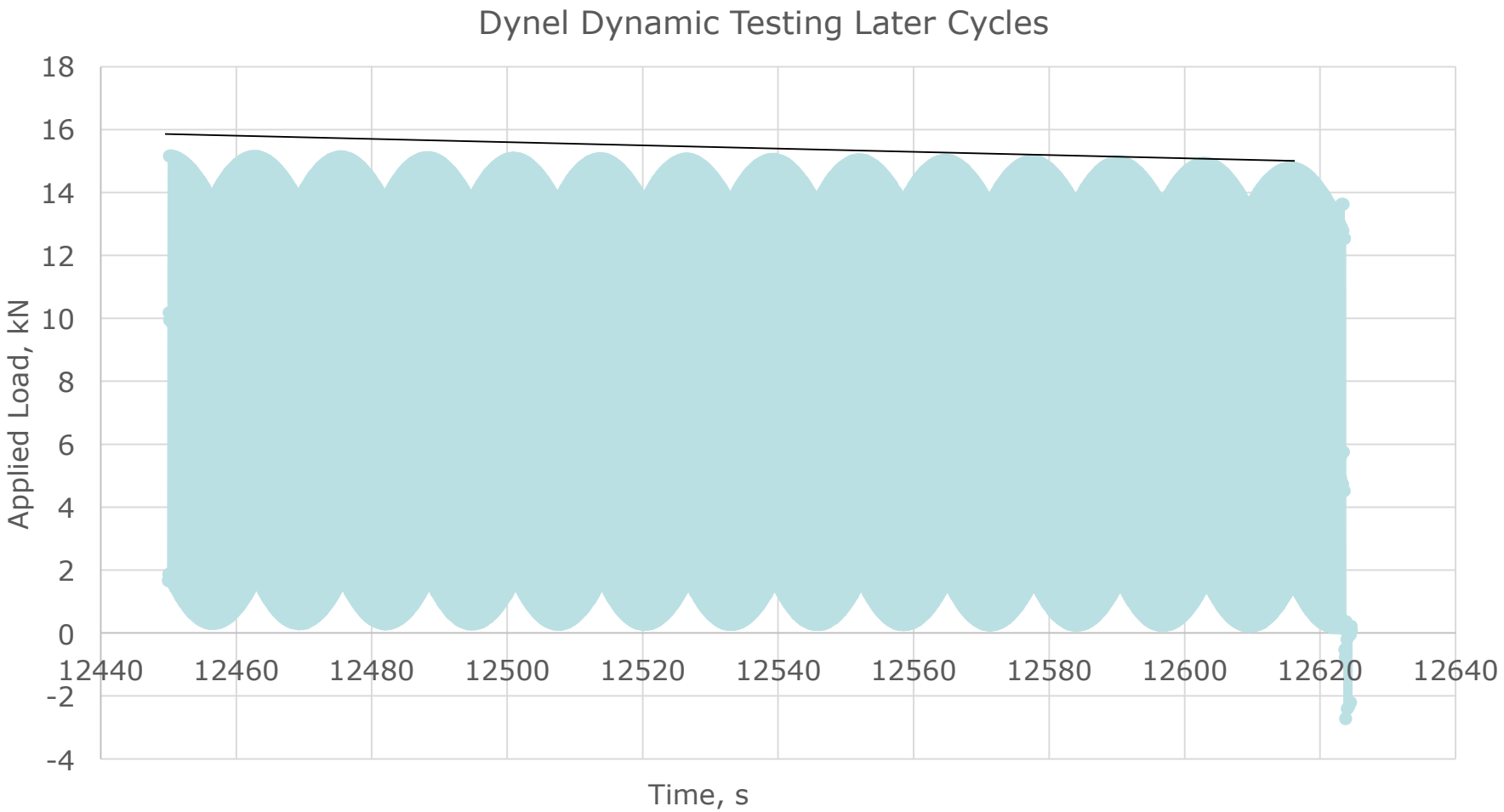


https://www.comsol.com/blogs/how-to-obtain-fatigue-model-parameters/

Dynel Dynamic Testing



Dynel Dynamic Testing



Dynel Dynamic Testing

Show Movie

Future Work

Complete 40% UTS Dynamic Axial
Complete 20% UTS Dynamic Axial
Automate Data Manipulation
Build S-N Curves
4 Point Bend Dynamic Testing
Repeat Process with Innegra

Special Thanks

Dr. Tanveer Chawla
Steven Evans
Charles Nash
Taylor Bentley
Zena Moran
Erik Foss
Nathaniel Herbert
Adam Hess


Thank You!
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Western Washington University
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