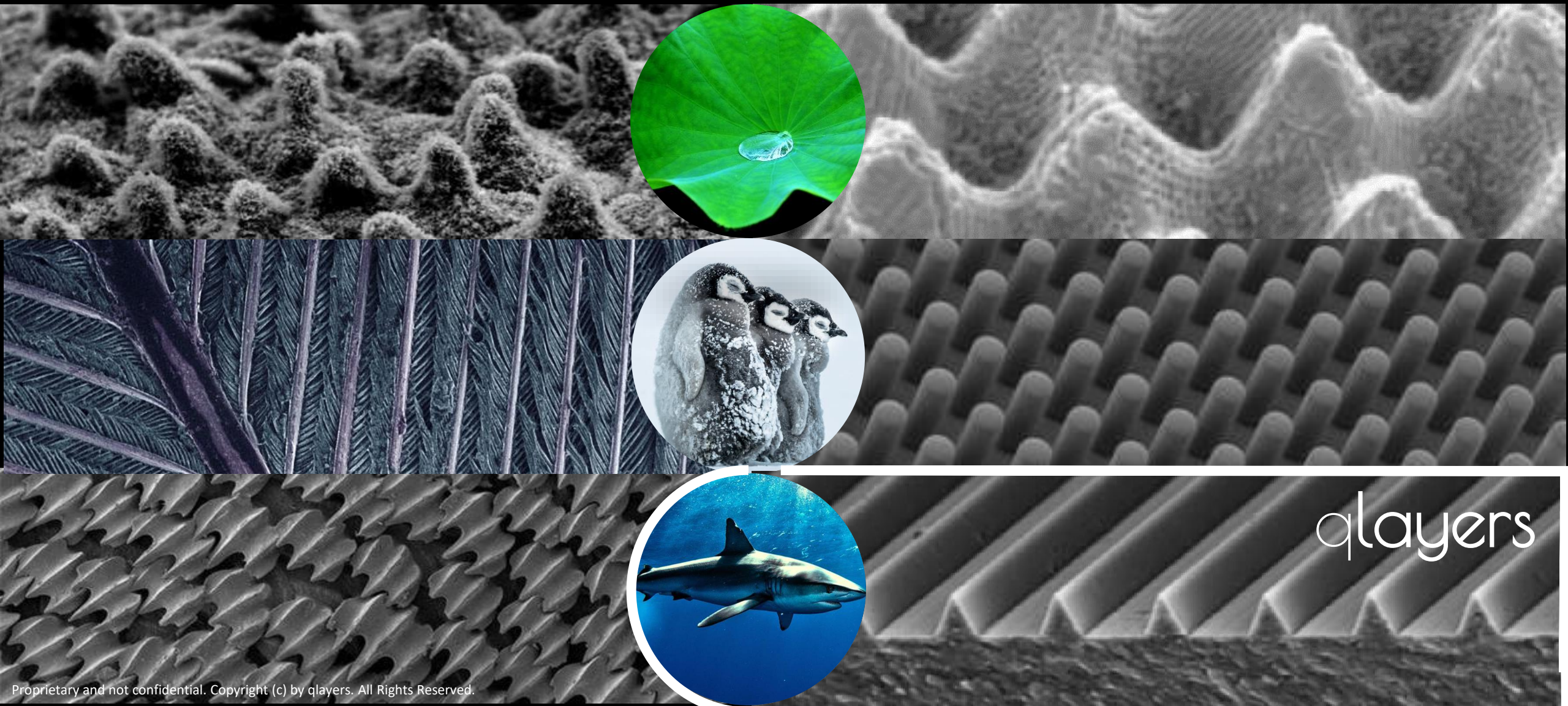


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Small layers reshaping the future

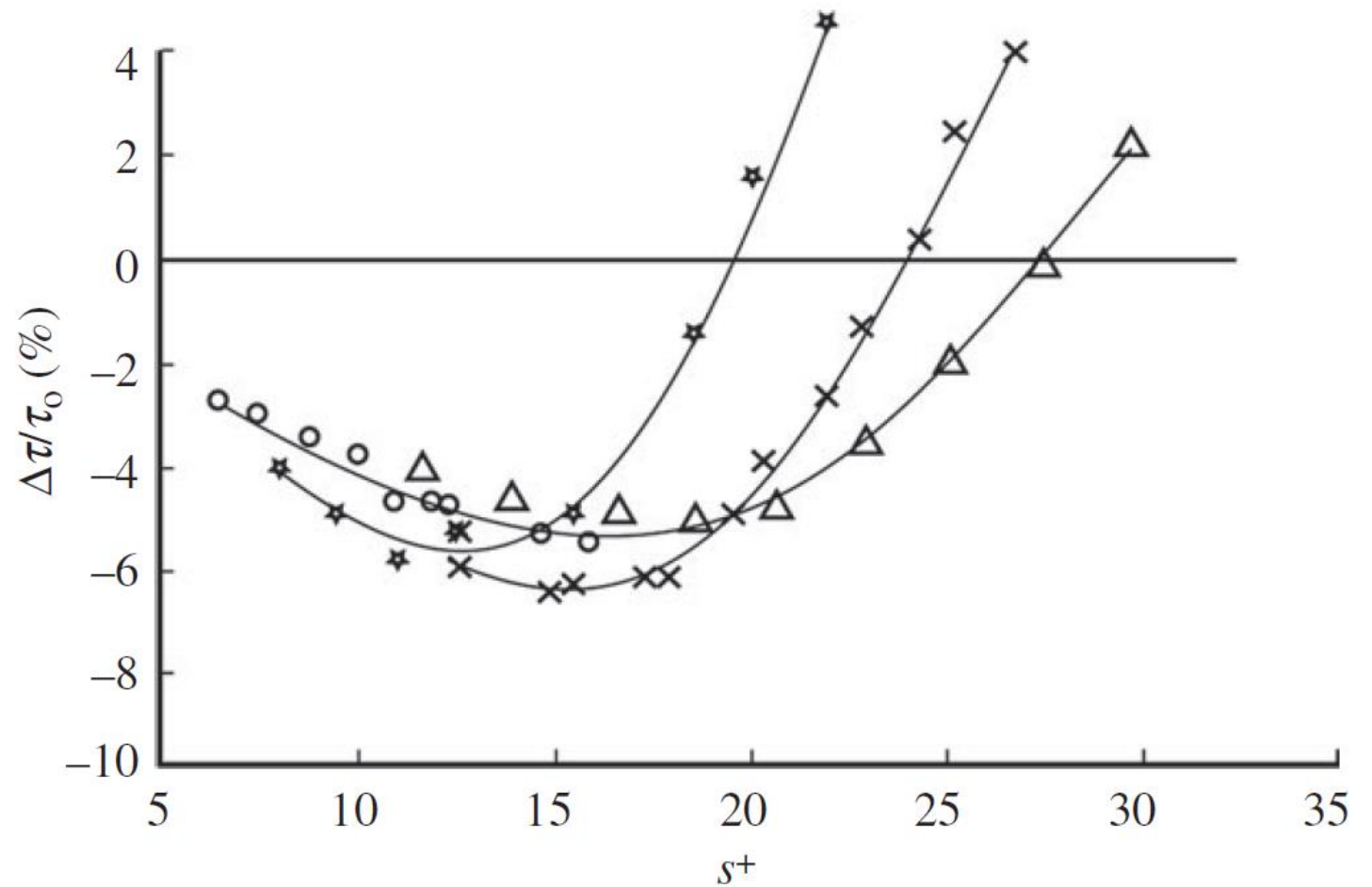
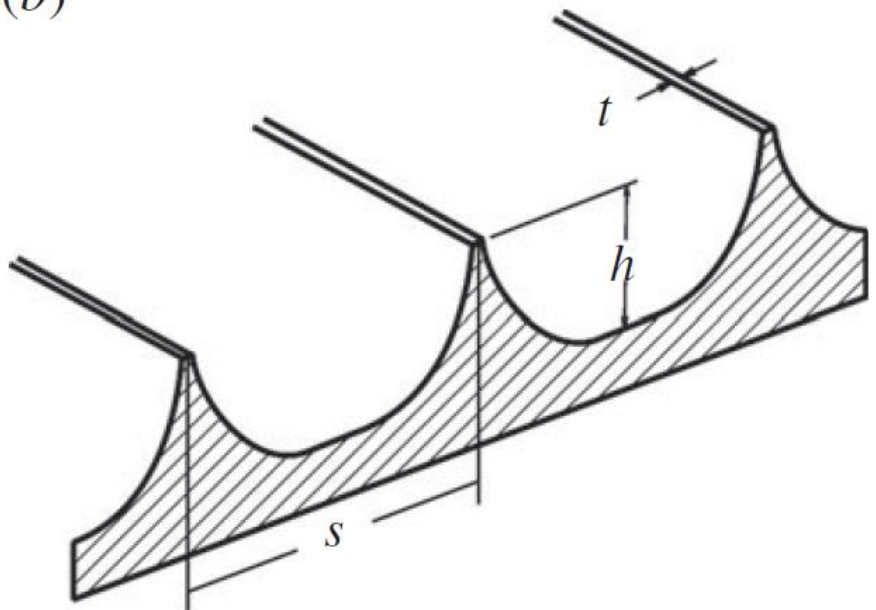


Microstructured surfaces are everywhere...

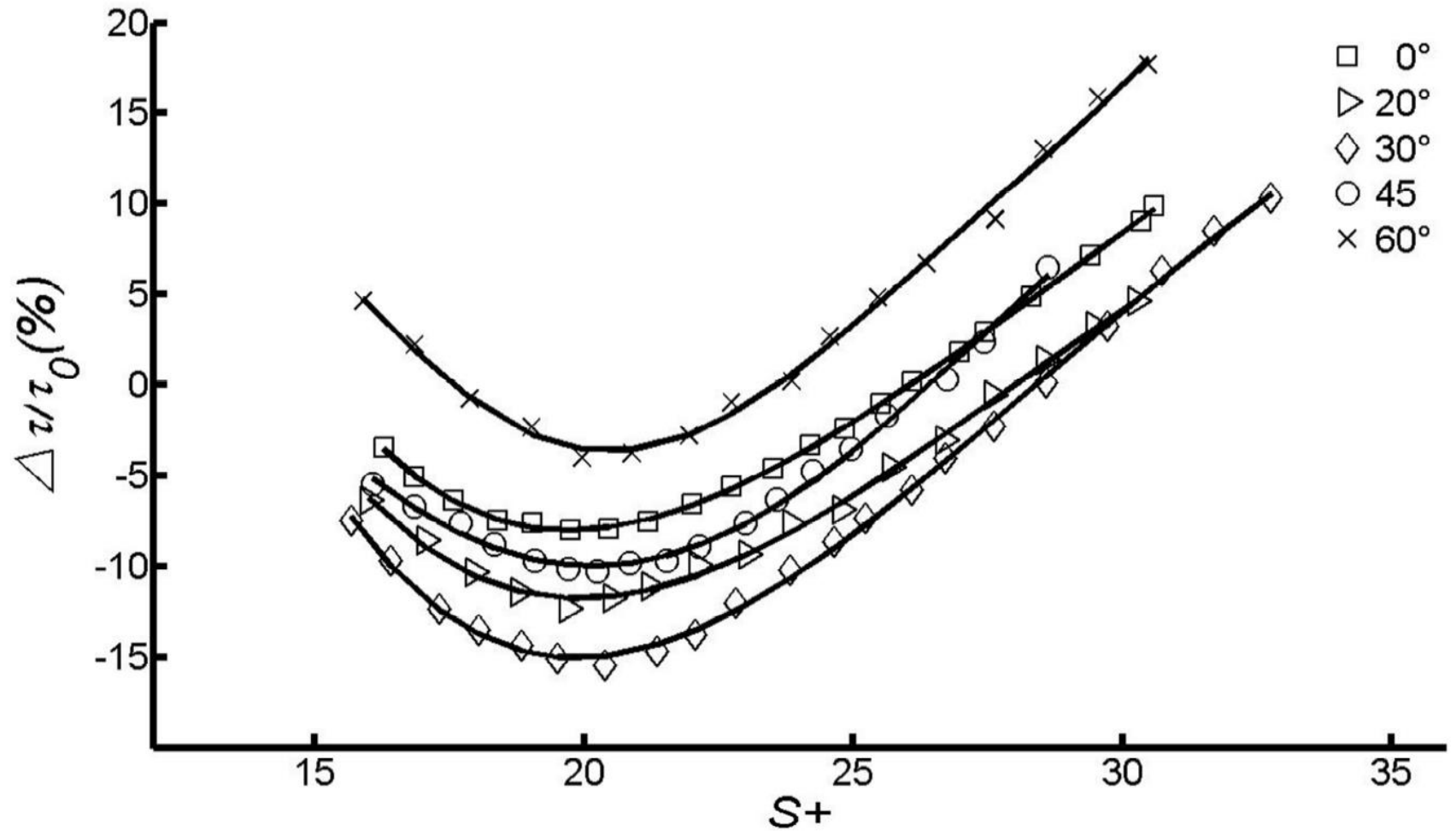
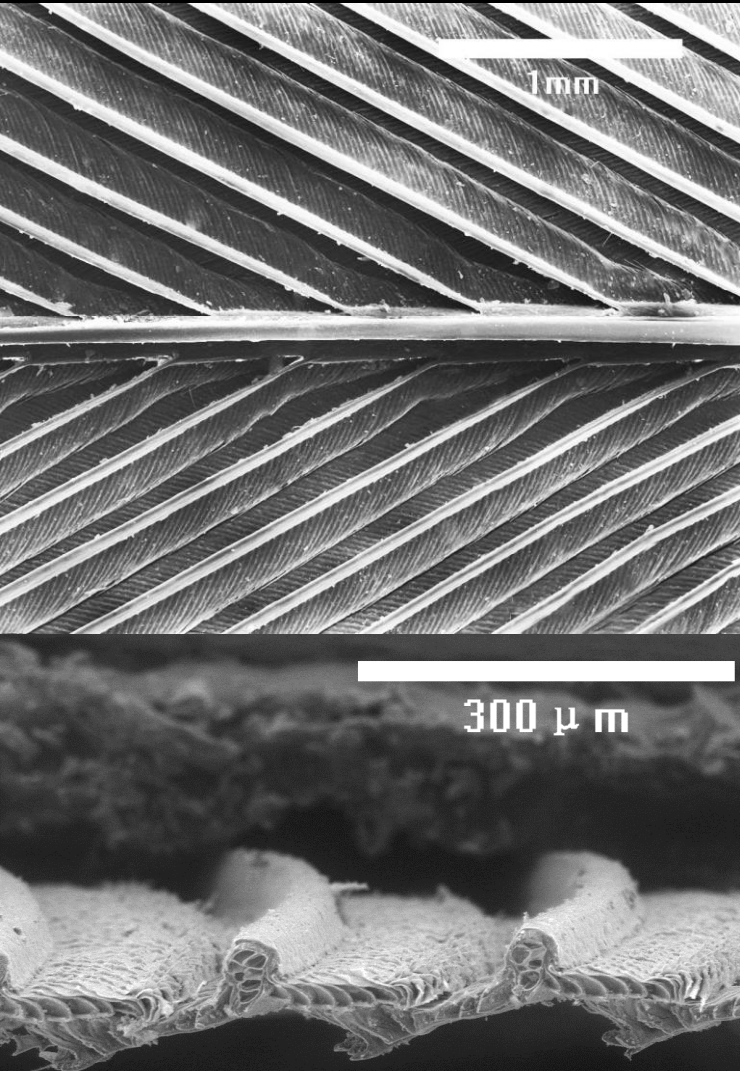


1990's: Friction drag reduction of 10%

(b)



2014: Friction drag reduction of 16%







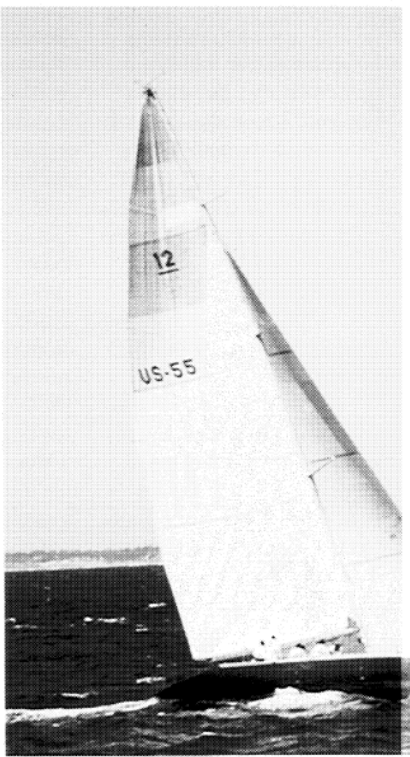
Riblets for Stars & Stripes

On February 4, 1987, Skipper Dennis Conner and his 10-man crew guided the blue-hulled racing yacht *Stars & Stripes* past the finish line at Fremantle, Western Australia and brought the America's Cup back to the United States.

Representing the San Diego (California) Yacht Club, Conner and *Stars & Stripes* scored a 4-0 clean sweep in the best-of-seven finals over Australia's *Kookaburra III*, after a lopsided 4-1 semifinal victory over *New Zealand*. Rarely headed in those last nine races, *Stars & Stripes* performed magnificently in a variety of wind and wave conditions. There were many contributing factors to *Stars & Stripes*'s convincing superiority, such as overall boat design, tactics, sail selection and, most importantly, the impressive seamanship of the 11-man team. An additional factor was NASA technology.

In a Fremantle press conference, *Stars & Stripes* design coordinator John Marshall disclosed the boat's "secret weapon": the hull's underside was coated with "riblets," a technol-

A racing yacht adaptation of NASA drag reduction technology heads a selection of spinoff applications for consumer, home or recreational use



Stars & Stripes (US 55), with Dennis Conner at the helm, rounds a buoy in America's Cup competition off Fremantle, Australia. The American boat's hull incorporated a NASA drag-reducing technology called "riblets."

of computerized design technique, offshoots of the aerospace-originated practice of creating a mathematical model of a design and "flying" it by computer simulation to study the performance and structural behavior of many different designs before settling on a final configuration. Aided by a number of aerospace companies, who developed special "flow codes" for computerized measurement of water forces on a hull design, and in some cases by NASA-developed computer programs, the 12-meter yacht developers employed advanced fluid dynamics techniques to optimize their designs.

In addition, most America's Cup yachts—including *Stars & Stripes*—

1987: T-33

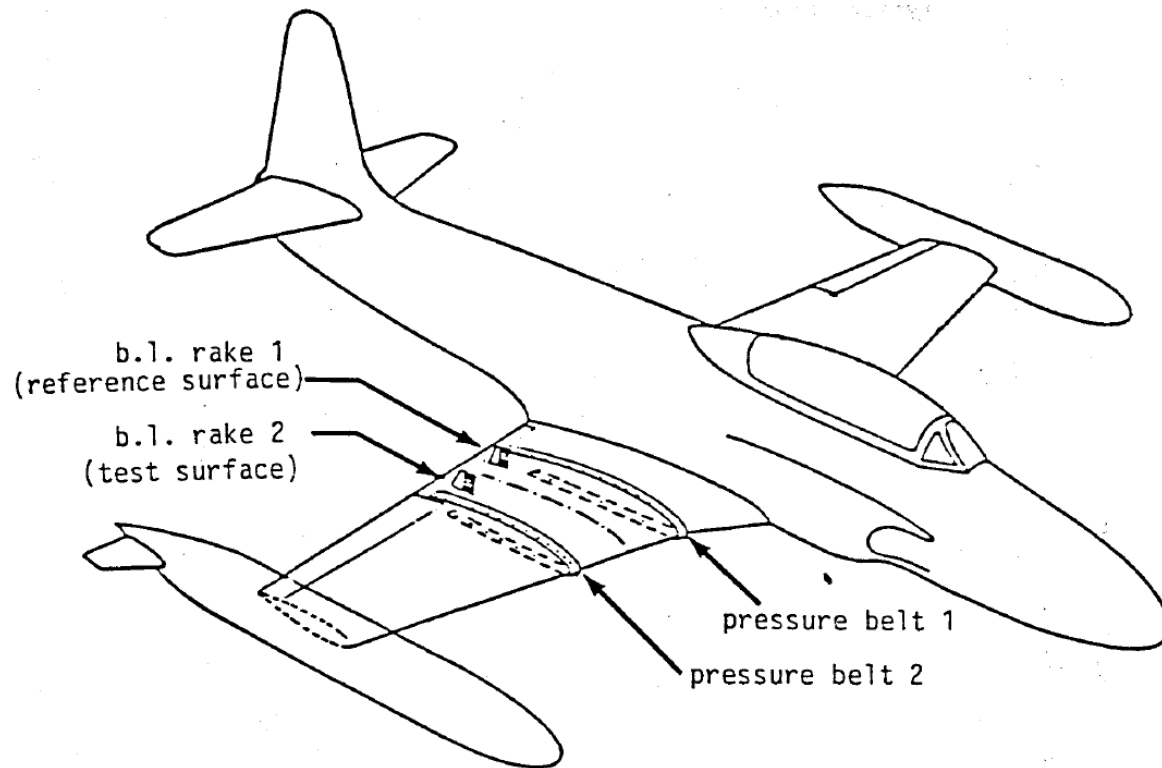


Fig. 2 Test surface and instrumentation on T-33 airplane.

1988: Learjet



Figure 1a. Photograph of the test aircraft

Source left: J.D. McLean et al., **Flight-test of Turbulent Skin-friction Reduction by Riblets**, 1987.Source right: M.J. Walsh et al., **Riblet Drag Reduction At Flight Conditions**, 1988.

Step 1: TU Delft Solar Boat Team



Step 2: Storage Tanks



Step 3: Wind Turbines





Racing



2017

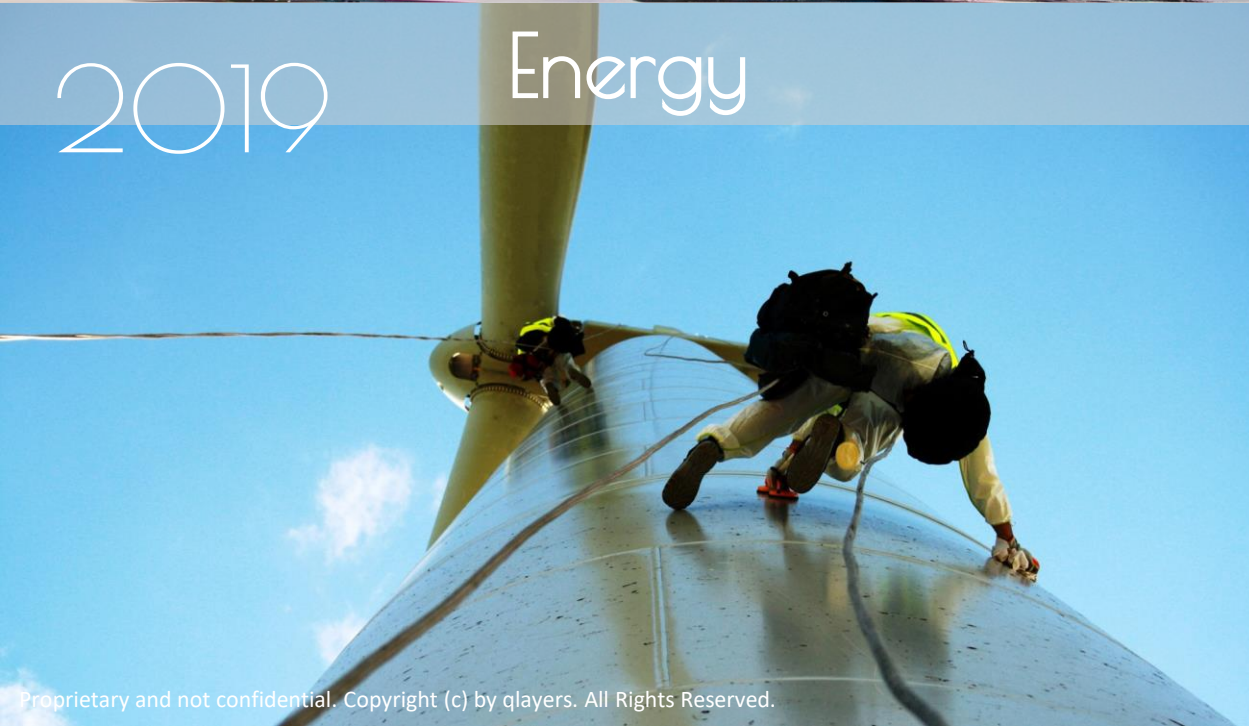
Storage

qlayers



2019

Energy



2021

Transportation



Business Case

For Coating Companies

- **Goal:** Automate coating of off-shore wind turbines
- **Pricing:** Semi-annual maintenance service contract
- **Revenue increase per month: €1.8M**
- **Payback time: 3 months**

For 2 MW Wind Turbine Owners

- **Goal:** Reduce downtime and increase energy output
- **Increasing output with sharkskin:** 4 – 6% in energy production + increasing full-load hours
- **Annual revenue increase: €10K – 25K**

Current Coating Cost

€15/m²

Cost of coating during manufacturing

€75 - 250/m²

Cost of coating during (off-shore) maintenance

€100K - 340K

Total cost of coating (off-shore) wind turbine

Josefien

Amber

Ruben





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