The Attacker's Advantage

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My Background

- While at Goodyear, director of
  - Physics-based computational product performance prediction
  - High performance computing
  - Physics research
- Now President, DataMetric Innovations, LLC
  “Intersection of Science, Engineering, & Information Technology”
- The opinions expressed are my own and do not necessarily reflect the views of The Goodyear Tire & Rubber Company.

Goodyear Tire

- Founded in 1898 in Akron, OH
- One of the world's leading tire companies
- 56 production facilities in 22 countries
- $18.8 B in 2010

Tires: A Competitive Oligopoly

- 1986 takeover attempt drained Goodyear's cash reserves.
- In 1992, CEO charged VP's of R&D to cut development expenses.
- Competition had more test tracks and laboratory facilities.
- VP's chartered study of solutions. Three alternatives were identified.
  - More efficient **building and testing prototypes**
  - More extensive use of **predictive testing**
  - **Physics-based computational performance prediction**

Physics-based computational performance prediction was the only alternative that might substantially reduce costs over time.

Difficult Technical Problem

- Tires are surprisingly complex.
  - Tread geometry
  - Internal structure
  - Service conditions
  - Material properties
- In 1992, state-of-the-art performance prediction took months.

By the time designers got answers, they'd forgotten their questions.

Internal Structure

"The pneumatic tire represents one of the most formidable challenges in structural design."

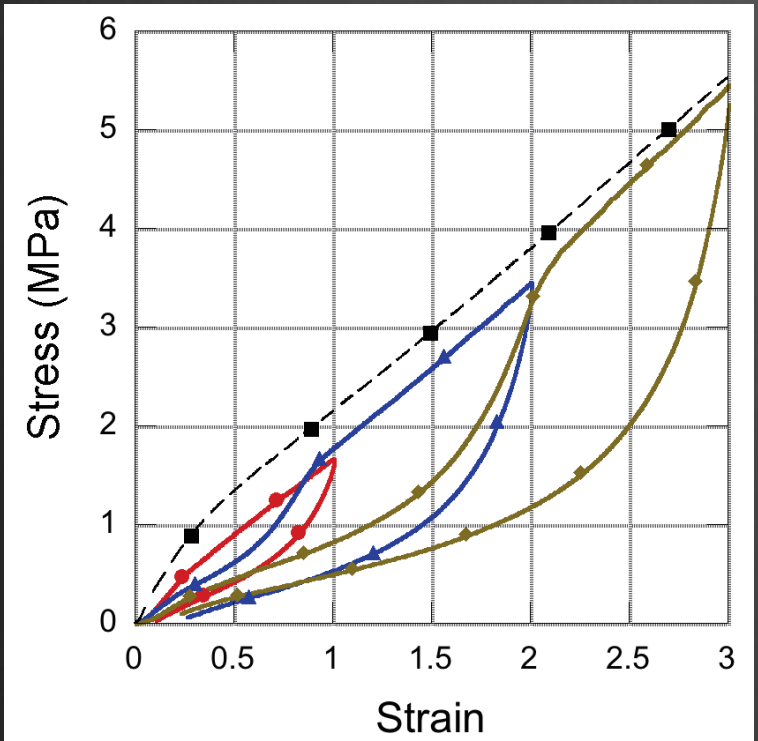
Professors Noor and Tanner, Journal of Computers and Structures

~ 60 Million Cycles During an 80,000 Mile Tire Lifetime

Modeling Challenges

- **Incompressible, non-linear visco-elastic material with high (~100%) cyclic strains (rubber)**
- **Inextensible fiber reinforcements (steel belts & polyester ply)**
- **Flexible structures (sidewall)**
- **Detailed tread patterns**
- **Wide eigenvalue spectrum**
- **Expensive, low fidelity solutions**

Material Complexities



Hanson, Hawley, and Houlton,
Los Alamos National Laboratory,
"A Mechanism for the Mullins Effect," 2006.

- First tensile pull to 100% - red circles
- Second pull to 200% - blue triangles
- Third pull to 300% - brown diamonds
- Initial stress/strain for sample pulled to 300% - black squares

Extraordinarily complex material properties.

Unacceptable Solution Times

- **Static**, 90,000 degrees of freedom, **smooth, axisymmetric tire** model took **months to converge** using the best commercial non-linear solver.
  - Solution times increased as the cube of the model size, $\mathbf{n^3}$.
- Estimated minimum model size required to simulate tire wear:
  250,000 degrees of freedom. ~3x the smooth, static model.
  - Tread wear requires a **tread pattern, rolling, at varying slip angles!**
  - **Solution time estimated at 15.6 years** on a Cray Y-MP.
  - (Build ar x months.)

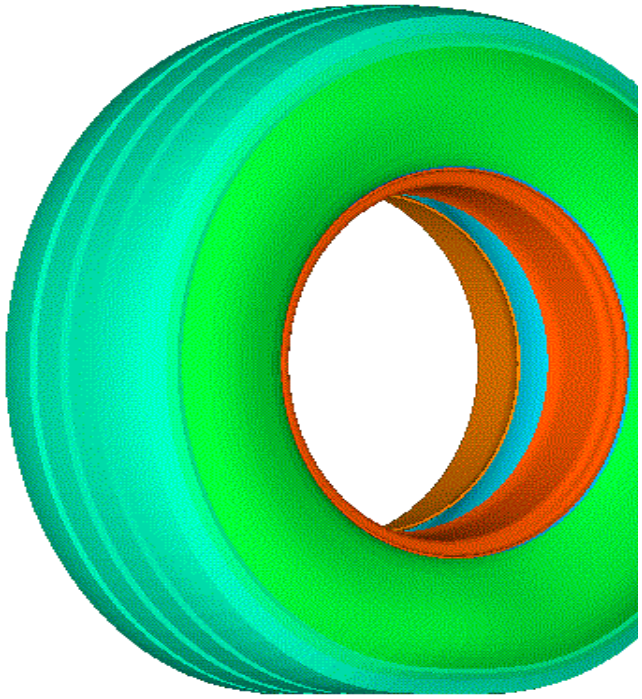
No commercial code was capable of solving this problem.

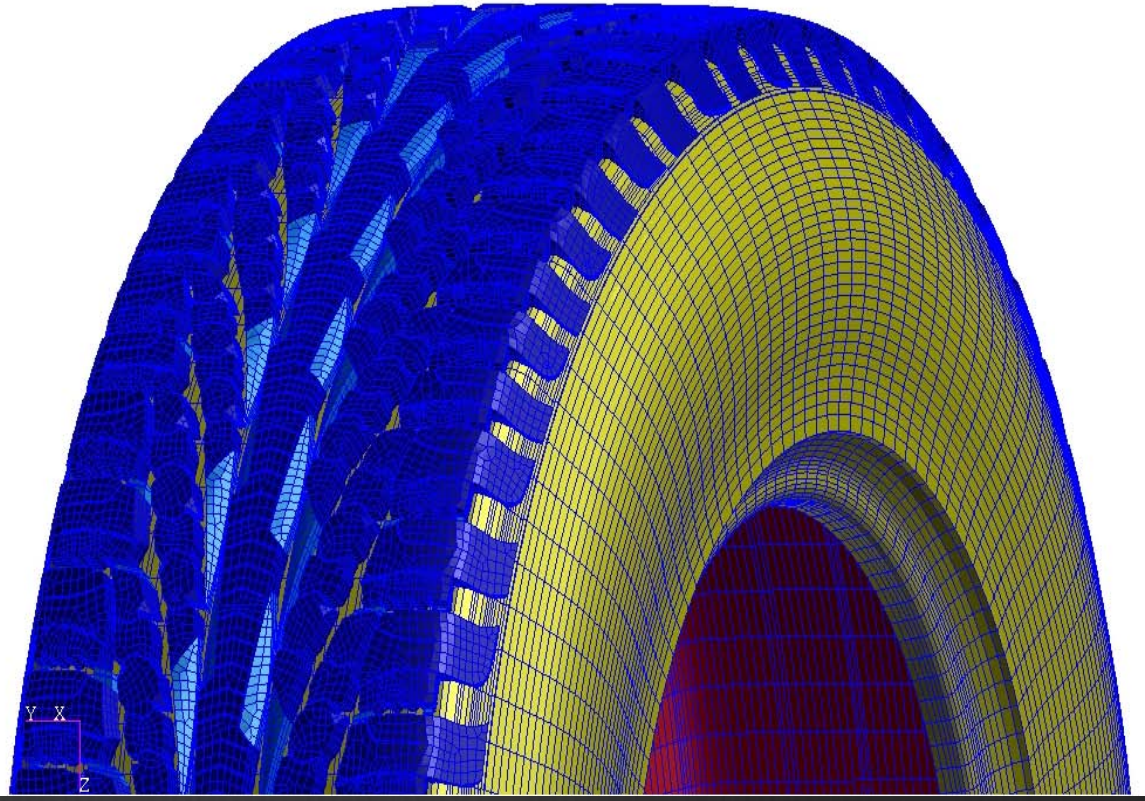
Industry/Government Partnership

- Goodyear partnered with Sandia National Laboratories to develop new technologies to solve its “intractable problem.”
- CRADAs included both experimental and computational projects.
- **Extraordinarily successful collaboration!**
  - Enabled Goodyear to solve intractable design problems.
  - Enabled Sandia to solve intractable design problems.

Win-win collaboration!

Model Fidelity & Solution Time





Solution time compressed from 32.2 years to 5 days!

Award-Winning Technology

1 of 5 most innovative IT solutions!

Bottom Line Results

- **Product development times were reduced 67%**, from three years to one.
- **Prototype building & testing costs dropped 62%,** $100 M annually.
- **Unprecedented string of award-winning new products,** by evaluating many more new product alternatives computationally.
- "**Our innovation engine, again, delivered in 2010. The percentage of new products in our overall lineup is the highest ever…**" Rich Kramer, Chairman and CEO, February 10, 2011.
- "Our new product engine is poised to take advantage of the demand for high-value-added tires and to do so with **unmatched s** ired CEO, 2009 Annual Report.

Unmatched speed to market!

"The Attacker's Advantage"

Richard N. Foster, *Innovation: The Attacker's Advantage*, 1986.

- Which foreign power would attempt to build more test facilities, proving grounds, and defense laboratories than the U.S.?
- Imagine a security situation in which competing interests could develop and deploy more imaginative and capable systems faster than the U.S. can – for less money!
- **How would you cut time, cost, and risk out of the weapons system development process?**

What will you do?