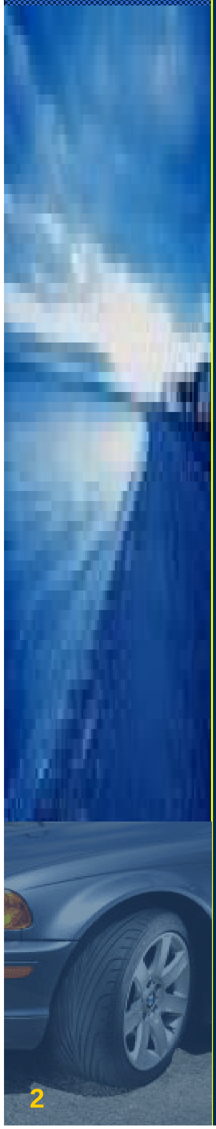
Technology Challenges: Materials & Manufacturing

The Goodyear Tire & Rubber Company

April 24, 2008

Goodyear: Quick Facts



- Founded in 1898 by Frank Seiberling (bicycle tires, carriage tires and horseshoe pads), Headquarters in Akron, Ohio
- Goodyear operates more than 60 plants in 26 countries
- Goodyear has about 70,000 associates globally
- Five Strategic Business Units: North American Tire; European Union Tire; Eastern Europe, Middle East and Africa Tire; Latin American Tire; and Asia Pacific Tire
- Net Sales Year 2007 = $ 19.6 BB
- Approximately 50% of manufacturing based in North America

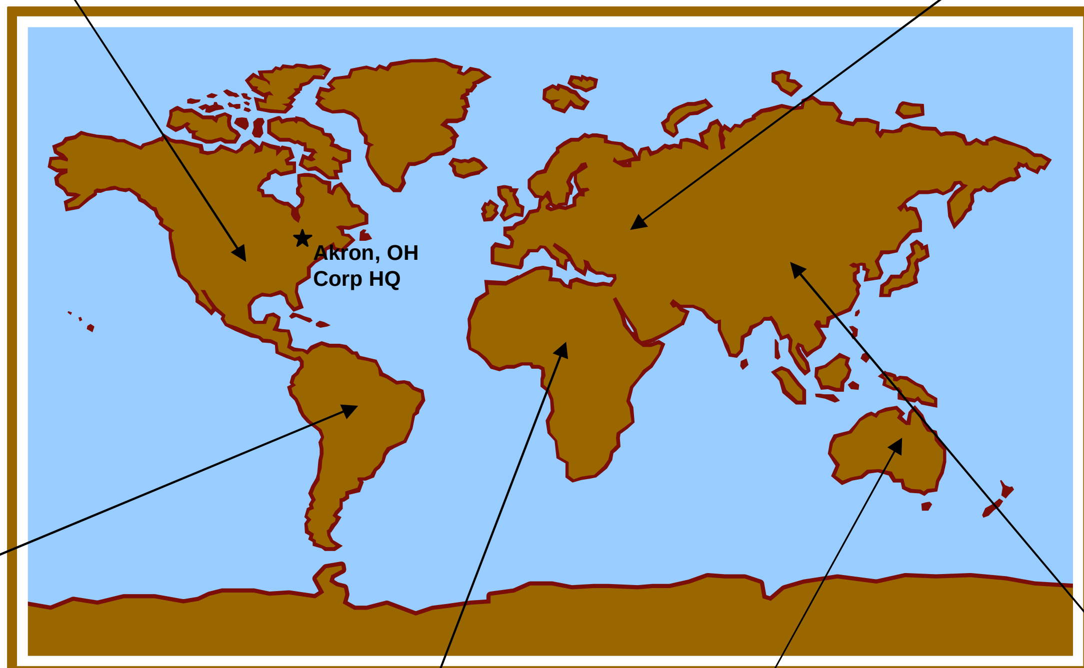
Global Manufacturing Facilities

NORTH AMERICA

United States
Akron, OH
Asheboro, NC
Bayport, TX
Beaumont, TX
Danville, VA
Fayetteville, NC
Gadsden, AL
Houston, TX
Lawton, OK
Niagara Falls, NY
Statesville, NC
Tonawanda, NY
Topeka, KS
Union City, TN
Canada
Medicine Hat, Alberta
Napanee, Ontario

SOUTH AMERICA

Brazil
Americana
Sao Paulo
Chile
Santiago
Colombia
Cali
Peru
Lima
Venezuela
Valencia



AFRICA

South Africa
Uitenhage

AUSTRALIA

Somerton

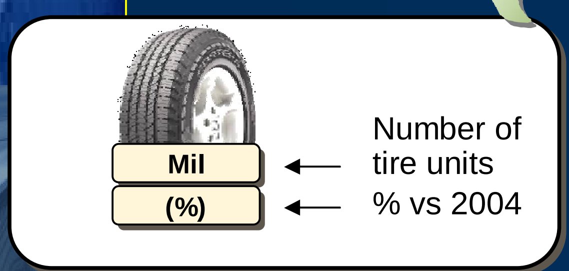
EUROPE

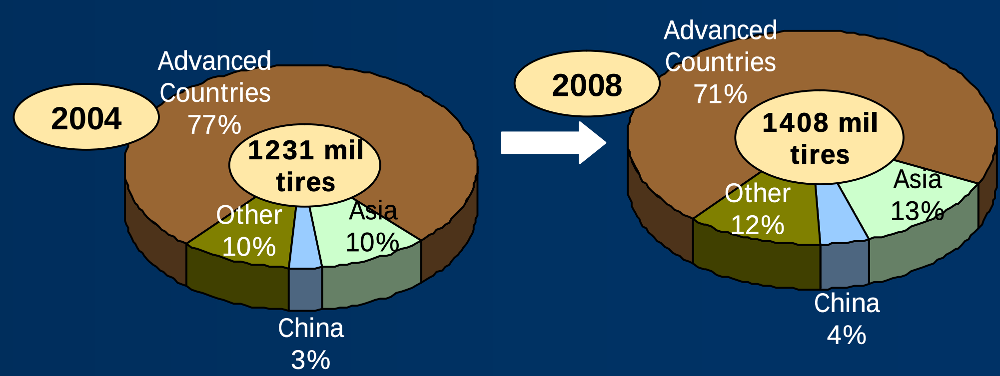
France
Amiens
Montlucon
Germany
Furstenwalde
Fulda
Hanau
Philippsburg
Riesa
Wittlich
Luxembourg
Colmar-Berg
Poland
Debica
Slovenia
Kranj
Turkey
Adapazari
Izmit
United Kingdom
Birmingham

ASIA

China
Dalian
India
Aurangabad
Ballabgarh
Indonesia
Bogor
Japan
Tatsuno
Malaysia
Kuala Lumpur
Philippines
Las Pinas
Taiwan
Taipei
Thailand
Bangkok

2008 World Tire Market

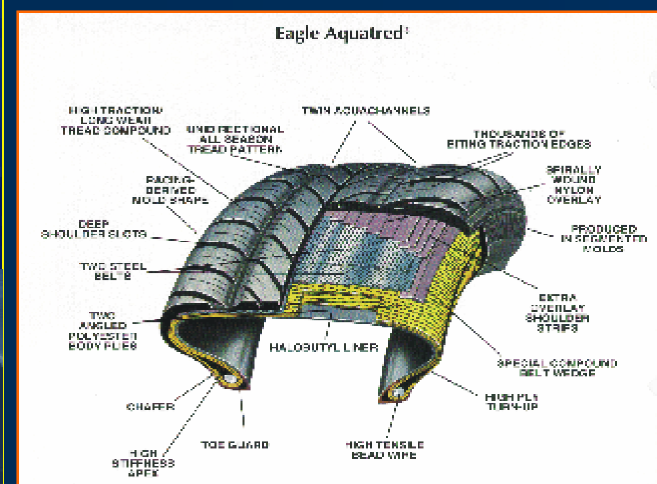




Source: SRI

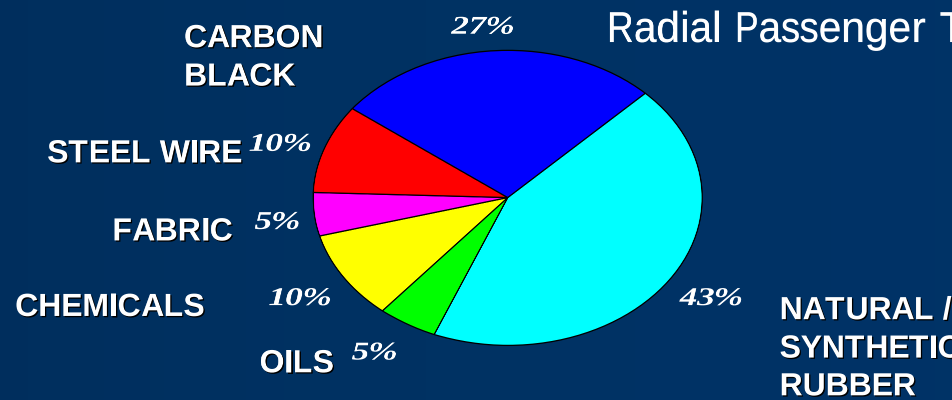
Consumer, Commercial, Off-The Road

- Goodyear manufactures over 200 MM tires annually
- Expenditures on materials exceed $15 billion



<u>Composition</u>

Radial Passenger Tire



Drivers & Trends for Vehicles

Environmental: • Global Warming – reduce CO_2 and other greenhouse gas emissions • Conservation of resources – non-renewable sources of energy, improve efficiency and waste energy re-use, alternative energy sources • Health – pollutant reduction • Waste materials reuse, recover and recycle	**Political:** • Government initiatives – transport plans • CO_2, energy, safety, recycling, carbon, emissions, noise legislation • NHTSA – pressure monitoring, aged tire limits, endurance standards • REACH
Social: • Choice – more vehicle design/manufacturing variance • Mobility – access and use of transport systems • Aging population, congestion • Safety – accident prevention, accident effect mitigation • Security – vehicle and occupant security, prevention of vehicle use in acts of terrorism	**Technological:** • Innovations in fuel, engine and power systems • IT explosion, communications technology • Innovations in sensors, electronics, communication, control systems (vehicle and infrastructure) • Innovations in materials (weight, strength, processing, intelligence…) • Innovations in high-value design, manufacturing
Economic: • Manufacturing cost reduction • Increasing manufacturing complexity and flexibility • Reduce development time and increase value • Reduce or contain cost of ownership – increased vehicle life, reduced maintenance cost	**Infrastructural:** • Information and communication – capable of interfacing with emerging vehicle technologies • Development of alternative energy distribution infrastructure • Real-time traffic management

Source: Foresight Vehicle Ver 2.0

Technology Directions for Vehicles

- **Engine and Powertrain:**
  - Focus: **energy efficiency**, performance, emissions, weight, **reliability**, speed-to-market and cost
- **Hybrid, Electric, Alternatively-Fueled Vehicles:**
  - Focus: emissions, energy efficiency
- **Advanced Software, Sensors, Electronics & Telematics:**
  - Focus: smart vehicle systems (integration of vehicle/road infrastructure, security, safety, **active noise control**)
- **Advanced Structures and Materials:**
  - Focus: **light weight**, **configurability/flexibility**, **environmental impact**, safety, reliability, **cost**, energy efficiency, **recyclability**, **silent tire**
- **Design and Manufacturing Processes:**
  - Focus: **energy efficiency**, **emissions**, **material consumption**, reconfigurability/flexibility

Vehicle Technology Impact on Tire Technology?

Source: Foresight Vehicle Ver 2.0
FURORE, earpa

Key Attributes for Tires

Light Weight Low RR Tire

- Manufacturing processes to enable thinner gauges at high yield
- Advanced materials
- Energy efficiency

Tire Noise, Vibration and Handling

- Improve noise/vibration characteristics
- Maintain noise/vibration characteristics over tire life
- Tire uniformity (manufactured at high yield)

Intelligent Tire

- Intelligence, Sensors, Telematics, Condition monitoring

Safety/Longevity

- Traction: dry, ice, snow, wet, wet-handling, wet-braking, aquaplaning
- Worn tire performance, ROF
- Environmental burden: re-use and recycling, reliability

Flexibility

- Meet proliferation of vehicles
- Flexible manufacturing w/o complexity
- Predictive model performance of tire/vehicle as a system

Energy-Efficient Manufacturing

- New manufacturing processes
- Process modeling

Technology Focus

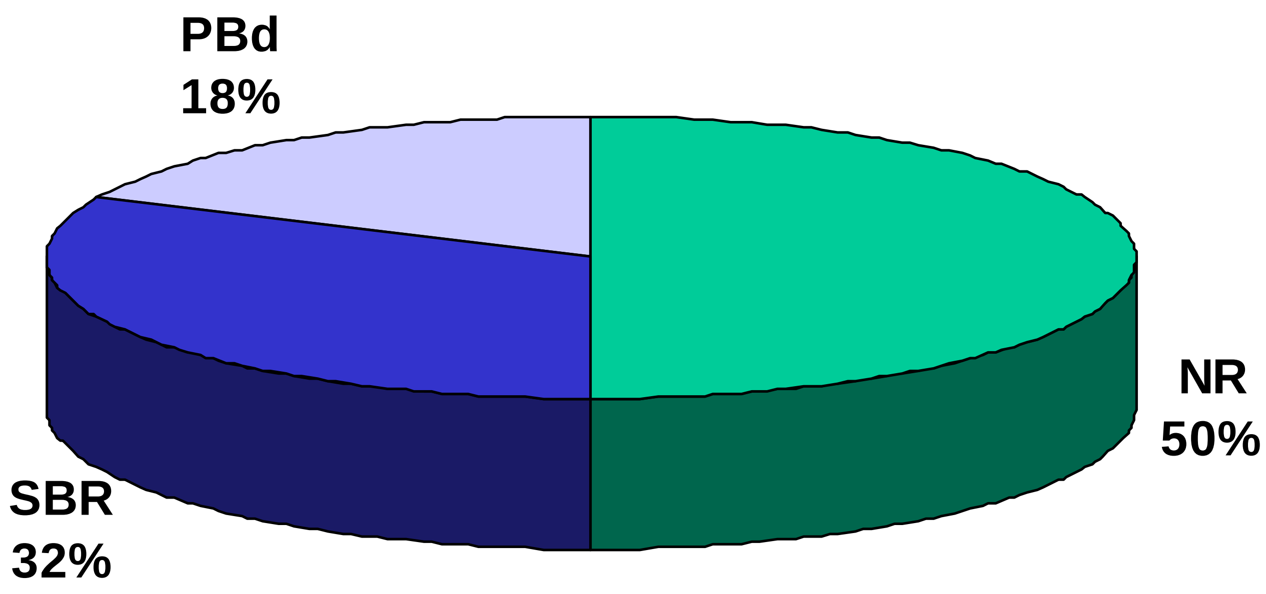
- **Materials:** Alternate source of natural rubber, non-oil based monomers, butadiene, nano-materials, smart materials, bio-inspired materials

- **Manuafcturing:** Energy-efficient manufacturing highly flexible, high viscosity compound processing, manufacture process modeling

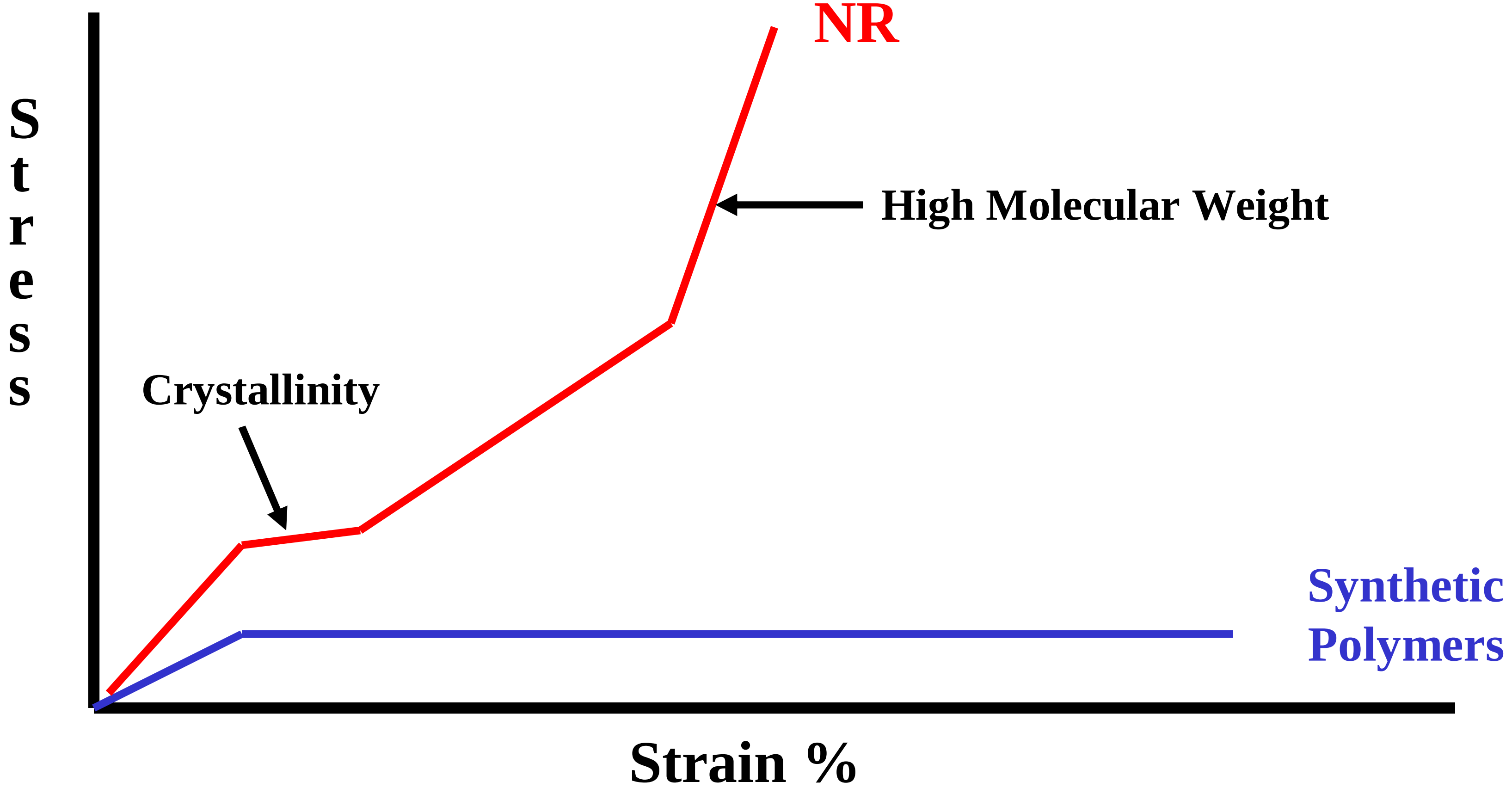
- **Intelligence:** Tire pressure/temperature monitoring systems, tire diagnostics and performance, vehicle control/interaction

- **Modeling:** Product performance prediction through tire life manufacturing process modeling concurrent engineering

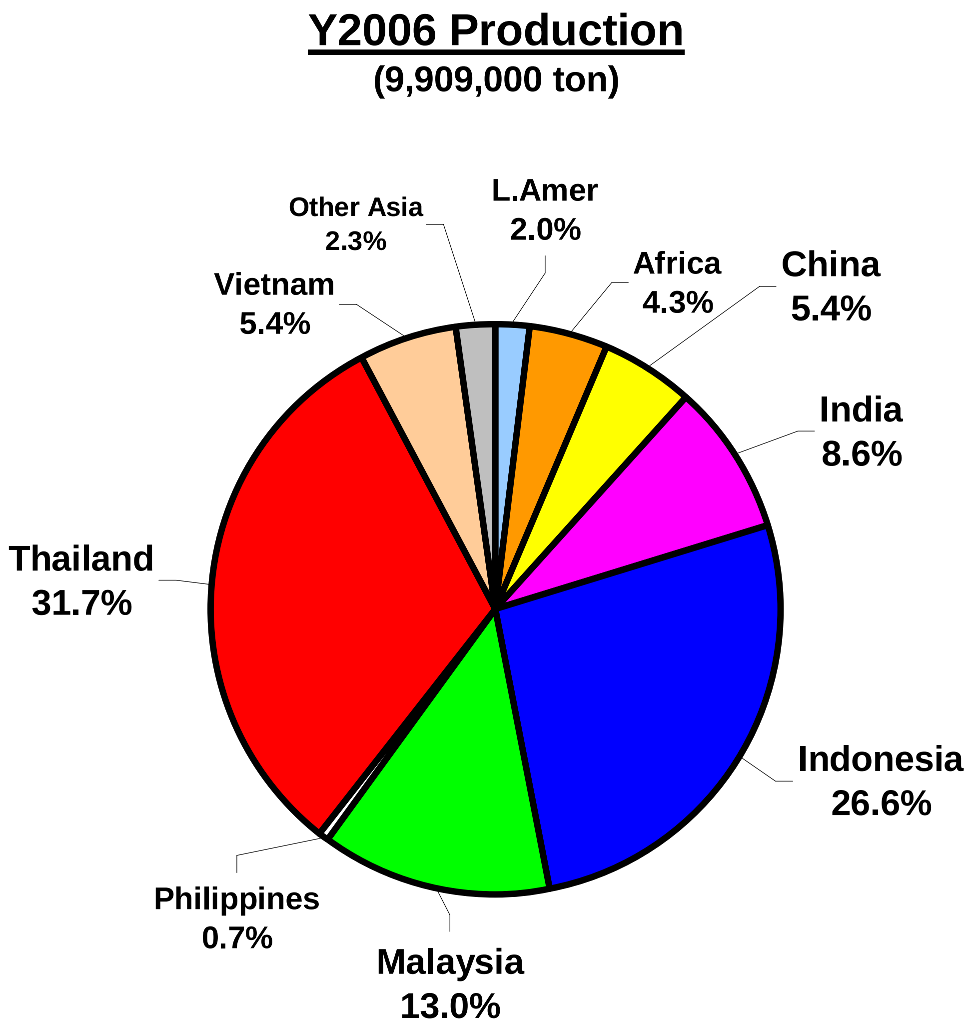
NR Usage in Goodyear Tires vs. Other Polymers



Unique Properties of NR



2006 NR Production by Country

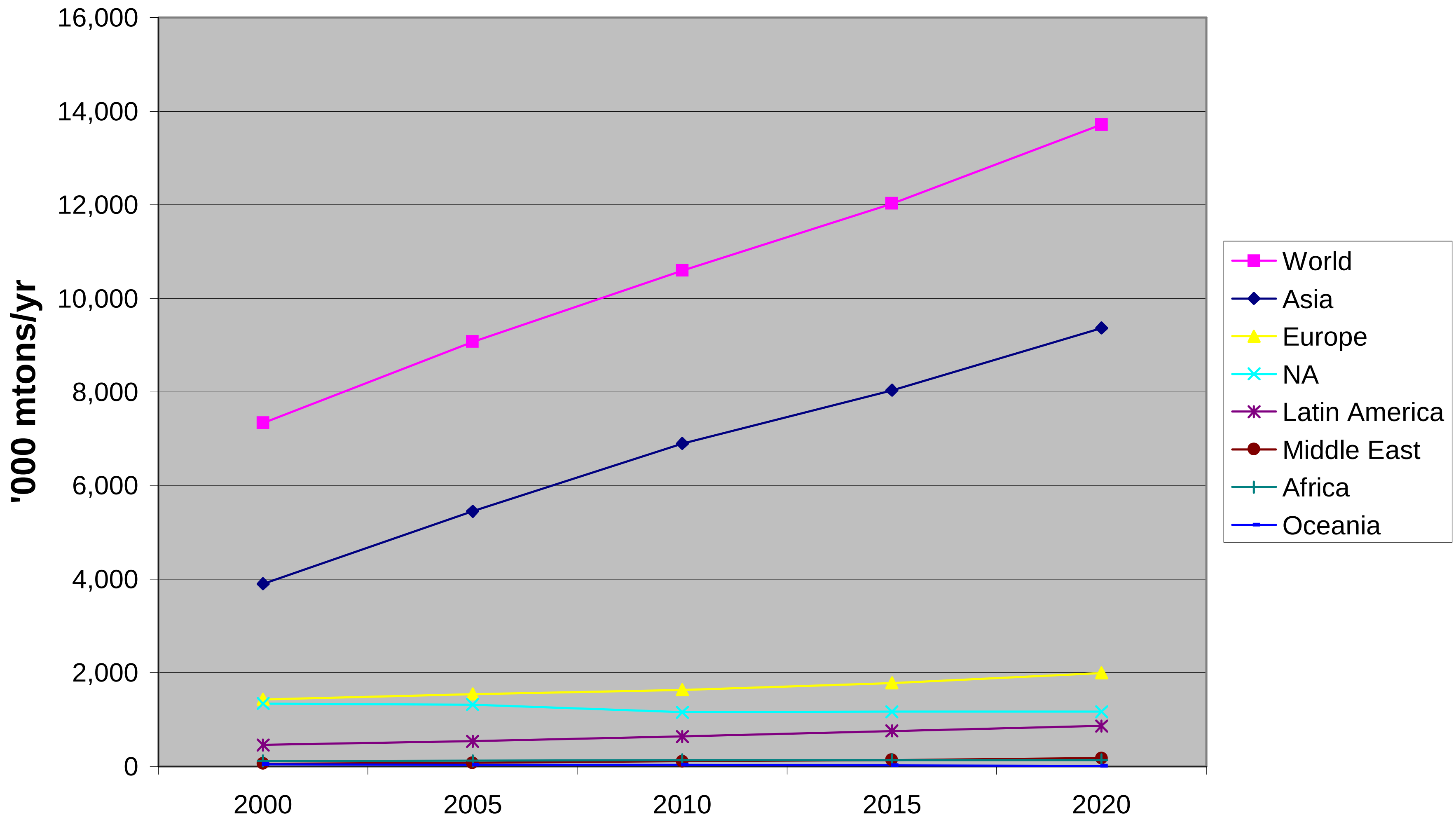


Region/County	' 000 ton
Thailand	3,137
Indonesia	2,637
Malaysia	1,284
India	853
Vietnam	540
China	533
Africa	423
Other Asia	226
L.Amer	203
Philippines	74
WORLD TOTAL	**9,909**

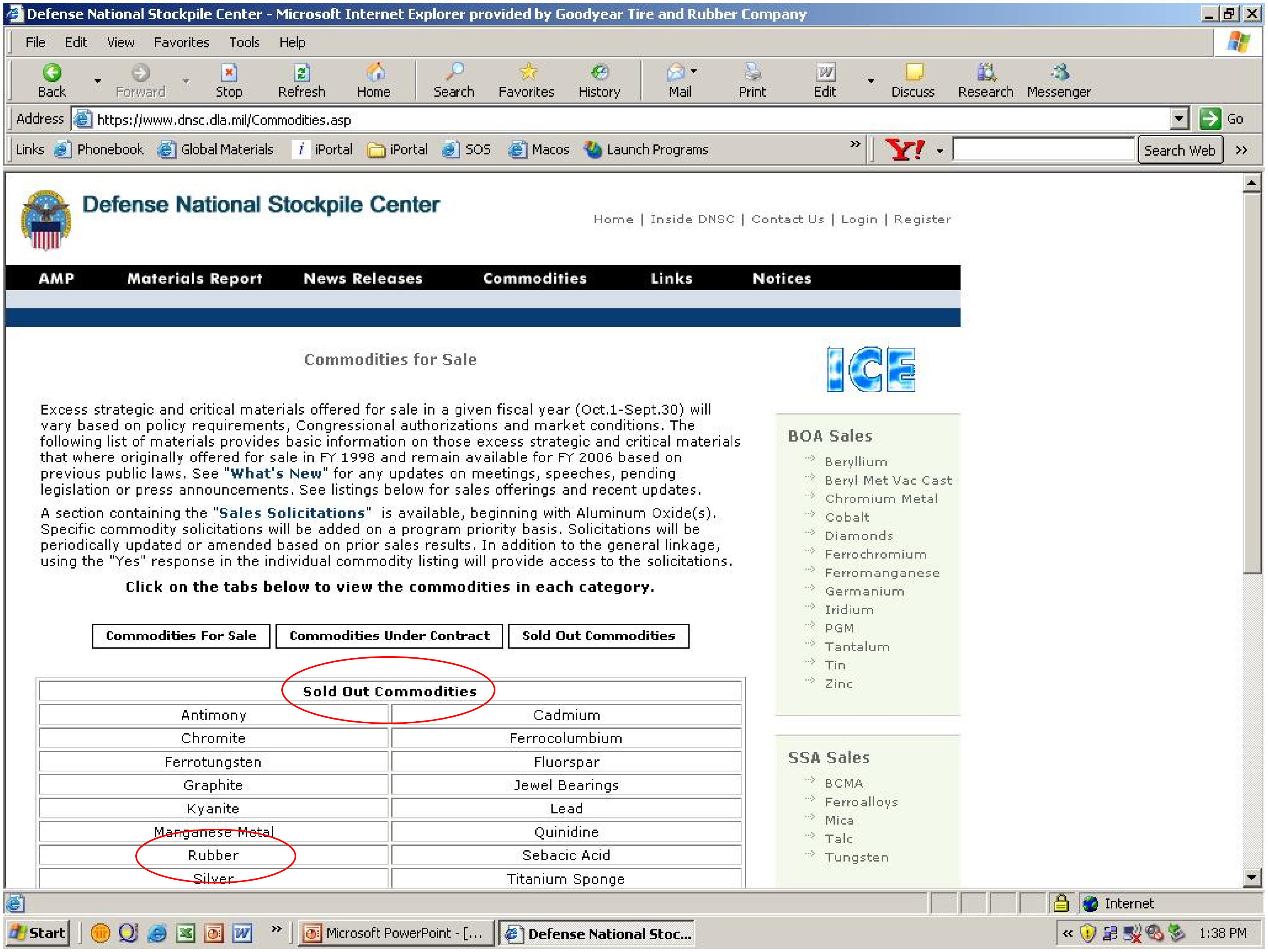
source: IRSG

21.8 billion lbs./yr.

Worldwide NR Consumption Projection ('000 mtons/yr)



Natural Rubber



World War II Rationing

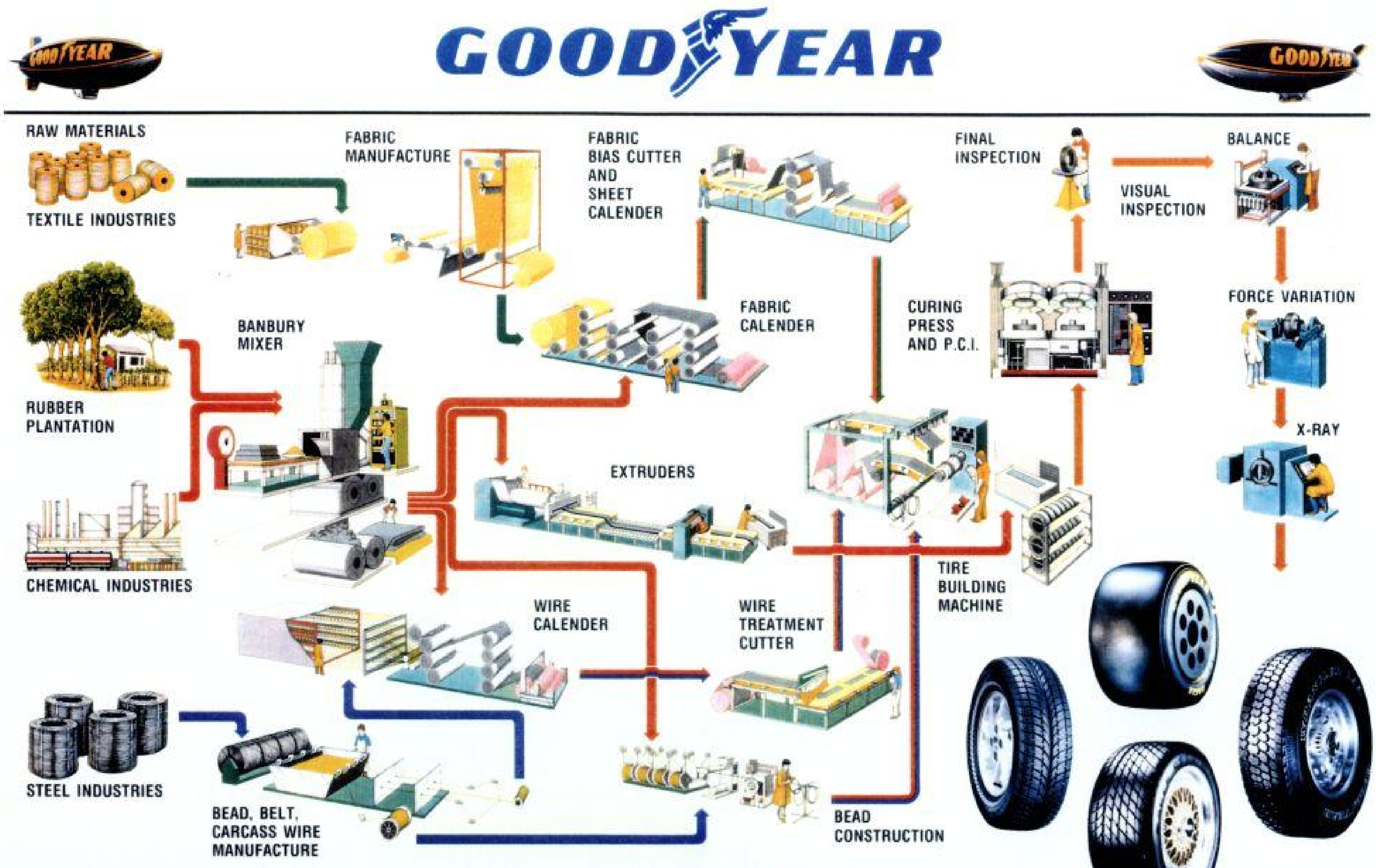
"The onset of World War II cut off U.S. access to 90 percent of the natural rubber supply. At this time, the United States had a stockpile of about one million tons of natural rubber, a consumption rate of about 600,000 tons per year." . . . 1 ½ yrs. supply of NR on hand

"Four days after Pearl Harbor, the use of rubber in any product that was not essential to the war drive was banned. The speed limit on US highways fell to 35 miles an hour, in order to reduce wear and tear on tires countrywide . . . Even President Franklin Roosevelt's pet dog Fala saw his rubber toys melted. This was the largest recycling campaign ever recorded in history."

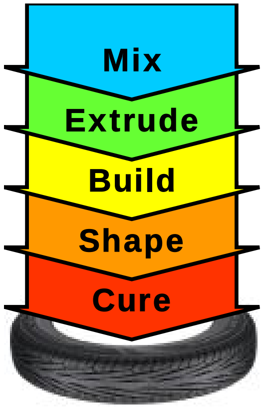
"All car makers were ordered to stop civilian car production not long after Pearl Harbor. The initial order wasn't so much to cause the conversion to war production, but because the access to rubber from S.E. Asia was cut off by the Japanese advance.

"The OPA established the Idle Tire Purchase Plan, and could deny mileage rations to anyone owning passenger tires not in use. Voluntary gas rationing proved ineffective and by the spring of 1942 mandatory rationing was needed."

"By the end of 1942, half of U.S automobiles were issued an 'A' sticker which allowed 4 gallons of fuel per week. That sticker was issued to owners whose use of their cars was nonessential."



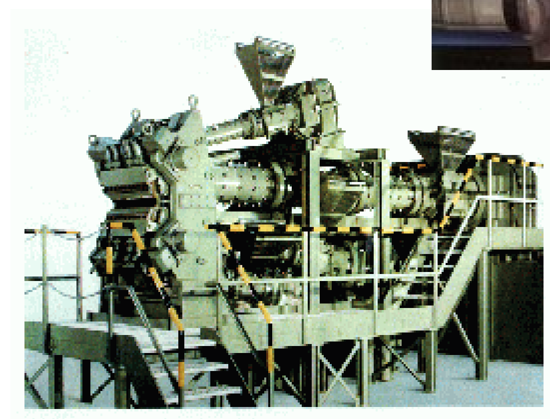
THE TIRE MANUFACTURING PROCESS



Manufacturing Process Modeling

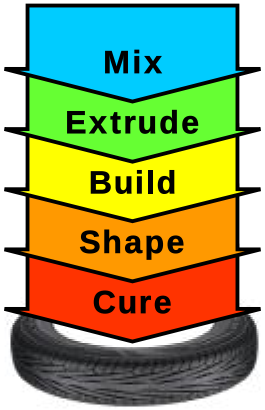
Scope of modeling:

- Mixing
- Extrusion
- Tire building (including stitching)
- Tire shaping (including bladder design)
- Cure



Objectives:

- Produce tires as designed
- Improve efficiency and quality
  - cycle time, uniformity, scrap
  - hardware design, operating variables



Manufacturing Process Modeling

- Disciplines Involved and Approach

- Involves diverse scientific disciplines: solid mechanics, fluid dynamics, heat transfer and reaction, material characterization, constitutive models, rheology, mixing theory, experimental mechanics, numerical methodology and algorithms.
- Many technical issues are still subjects of open research (e.g., wall slip, viscoelasticity, curing reaction kinetics, flow front tracking, etc.)

Fundamental and comprehensive approach with application focus

Modeling

Goodyear/Sandia Strategic Partnership

CRADA - Cooperative Research and Development Agreement

Initiated under DOE's Technology Transfer Initiative in early 90s

Only US-based, global tire company

Exceptional service in the national interest

CRADA Focus

Focus

Co-develop technology that complements the missions of both partners.

Goodyear -- stay competitive in a very tough business environment

Sandia -- meet national needs for scientific and engineering solutions related to nuclear weapons.

First major areas of technical exchange were computational mechanics, structural dynamics, and advanced materials. Later, advanced manufacturing, process reliability, and computer security were added.

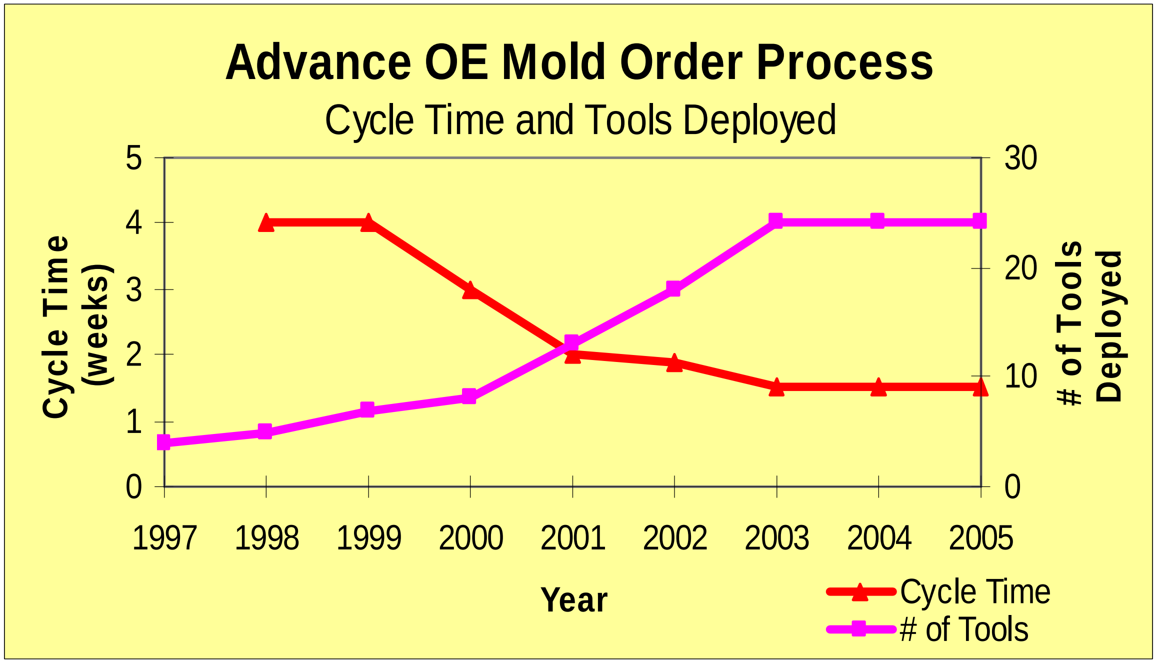
Key

CRADA results are protected, giving Goodyear an opportunity to stay competitive with major tire competitors which are owned by French and Japanese.

A unique partnership with a history of developing technology critical to weapons systems and to tire design & manufacturing.

Measuring Success

Reducing design cycle time with modeling tools



With the deployment of more modeling cycle time has improved.

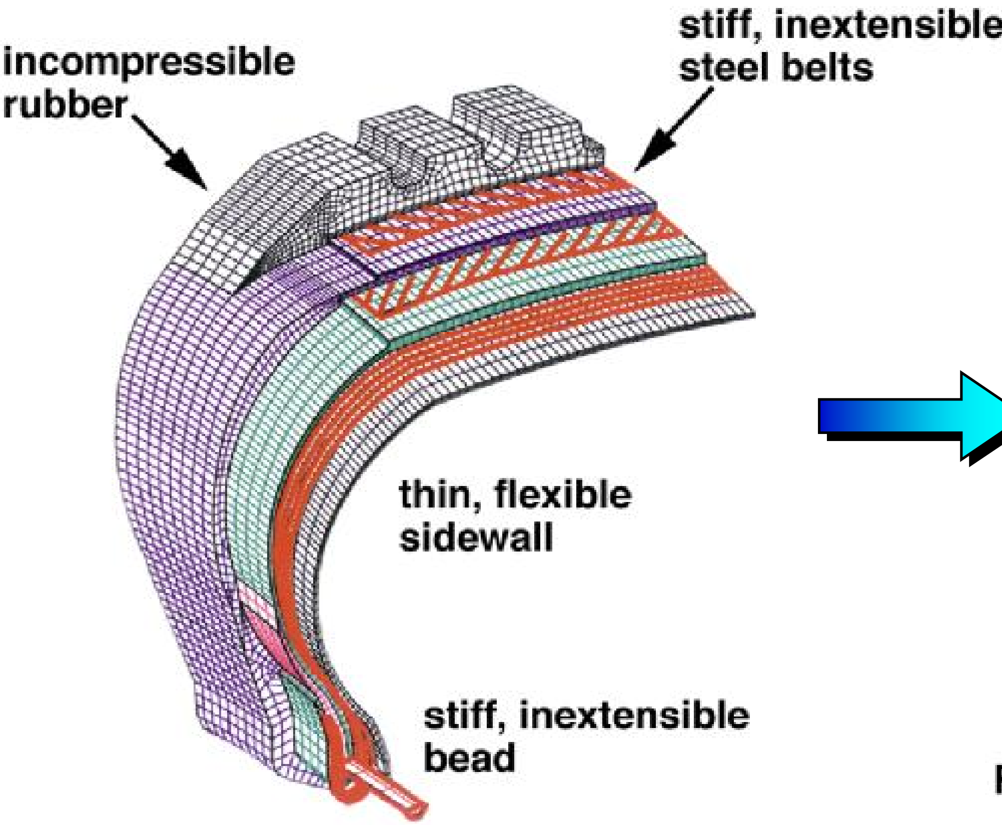
100% of the tire molds designed in Goodyear are now modeled before being ordered. So now, new modeling is focused on design "constructions", i.e. materials, thicknesses, and locations of components within the mold.

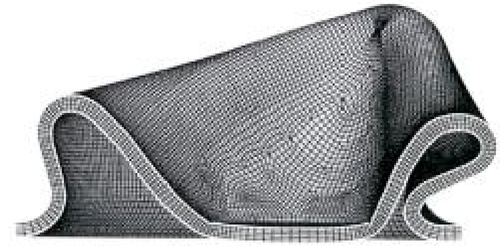
- **R&D 100 Award** for Extensive Use of Modeling & Simulation to Bring New Products from Concept to Market in 8 Months in 2005
- **CIO 100 Award** for its virtual design technology in 2006

Modeling Breakthroughs

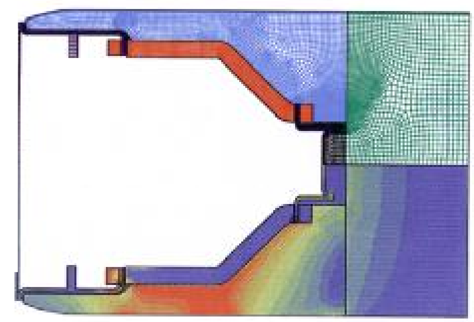
CRADA Results - DOE Benefits

Intrinsic Complexities of Tire Modeling Have Enabled New and Improved DP Simulation Capability





Exclusion Region Barrier Crush



Neutron Generator Encapsulation

Forming and Deformation of Thin Structures

The Goodyear/Sandia interaction is mutually beneficial. Goodyear gets "rocket science" applied to tires. Sandia gets real-world development and testing of simulation technology.

Benefits to Sandia

Why is Sandia interested in working with Goodyear?

- Enhance Sandia's computational mechanics capabilities for weapons applications by developing synergistic capabilities for difficult non-weapon applications such as tires.
- Learn from industry partners, i.e. Goodyear, about the process of integrating simulation into design and qualification.
- Increase the robustness and confidence in Sandia's computational mechanics tools by using them for diverse applications.
- Broaden the intellectual engagement of Sandia staff on the complex problems of advanced simulation
- Return value to the taxpayer