

# Trek Bicycle Corp.

Carbon Fiber Composites in Bicycles,  
A Revolution



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Advance Concepts Group (ACG)

I will start with Brief company overview



Privately held company

Founded 1976 Small red pole barn building performance touring bicycles

Steel brazed lug frames

Grown into the 2<sup>nd</sup> largest bicycle company in the world

Brands include: Trek, Gary Fisher, Klein, Bontrager components, In Europe Villager, Diamant,

\$700M annual sales

1,230 Employees world wide, 451 outside the USA

Involved in everything bicycle related

Road, Mountain, Kids, Etc.

Clothing

Components and accessories

Bicycle and fitness advocacy



World Headquarters Waterloo, WI is also main manufacturing facility

Assembly plant in Whitewater WI and Hartmansdorf Germany

Subsidiary offices in 10 countries

Distributors in 85 countries

Test facilities in USA, China, and Taiwan

Parts made around the world

Bikes sold around the world

Clearly a global company

## Guiding Principles

- Bicycles are key to solving world issues
  - Transportation
  - Carbon foot print
  - Fuel
  - Obesity
- World Bike Relief
- One World Two wheels
- Go by Bike



Trek is deeply committed to bicycle and fitness advocacy part of what defines and drives us as a company

Some sobering facts

Transportation: 40% of all trips are made within 2 miles of home

Fuel: In the US 462 mil. gallons of gas could be saved in one year if we made an improvement in bike trips from 1% to 1.5%

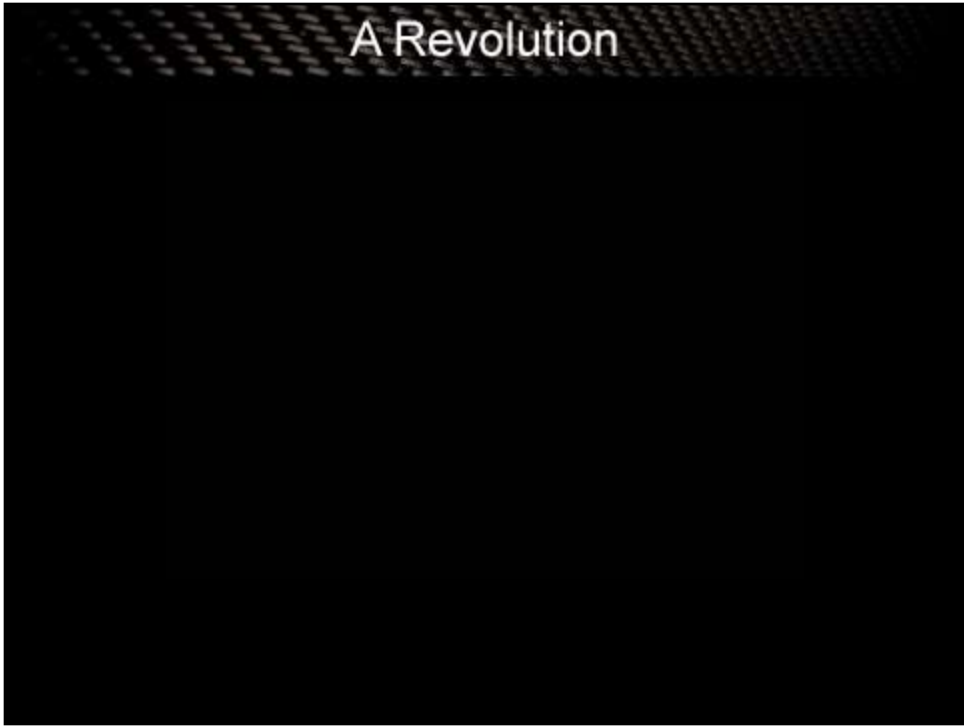
Obesity: 1964 50% of kids rode bikes to school obesity rate was 12%, in 2004 3% of kids rode to school obesity rate was 45%

We can all help and if you would like to make a difference

For trips 2 miles or less.....Go by Bike

Please feel free to pickup a brochure on your way out





This video will give you a feel for the environment we design, engineer, and manufacture bicycles in.



## History

We have been designing and building composite bicycles for over 20 years

1990 Trek major commitment to an all carbon frame bike

This was the beginnings of truly new technology for bicycles. Steel had been refined for 100 years

Developed 5500/5200 for 1992 model year at 2.5 Lb frame lightest production frame

Over sized aluminum frames along with other materials were being developed at the same time Starting the move away from steel

Aluminum frame of the day was 3.5 Lb and steel was 4.5 Lbs

Trek was one of a very few companies making carbon bikes successfully

Working on an 8 to 10 year model run design cycle



Industry down in mid late 90's 97-98

1999 Lance Tour win

Renewed commitment to development of composite bikes for Lance

The original Madone was launched for 2003 at 2.2 Lb's

Other companies realized the potential and were getting into the business big time

Couple this with lower cost Asian manufacturing

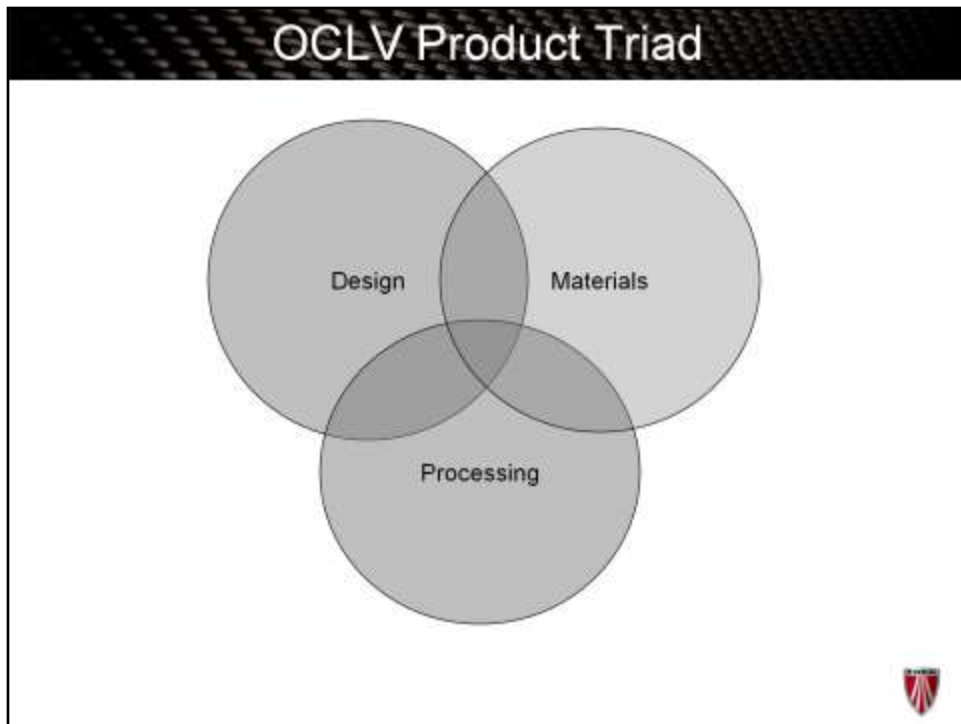
Carbon fiber frames are now King in the high performance bike sector, all other materials basically no longer used

Call it the carbon era

Company embraced a paradigm shift to a 4 to 8 year design cycle



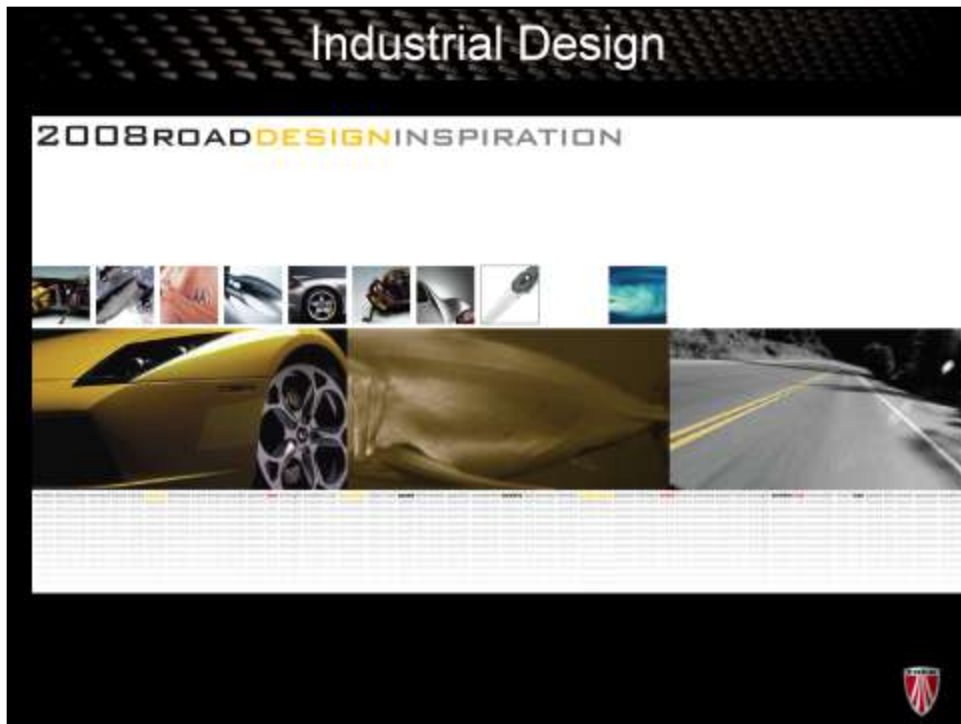
Fast forward to our 2008 Madone road bike  
Bikes have won 8 Tour De France  
World Championships  
Ironman Triathlons  
Olympics  
Trek and Fisher Mtn. Bike Team success



Here is a snapshot of what we do

We need to have, we focus on a balance of all 3 aspects

Lacking in any one area = poor final product



Starting with Industrial Design and Engineering Collaboration

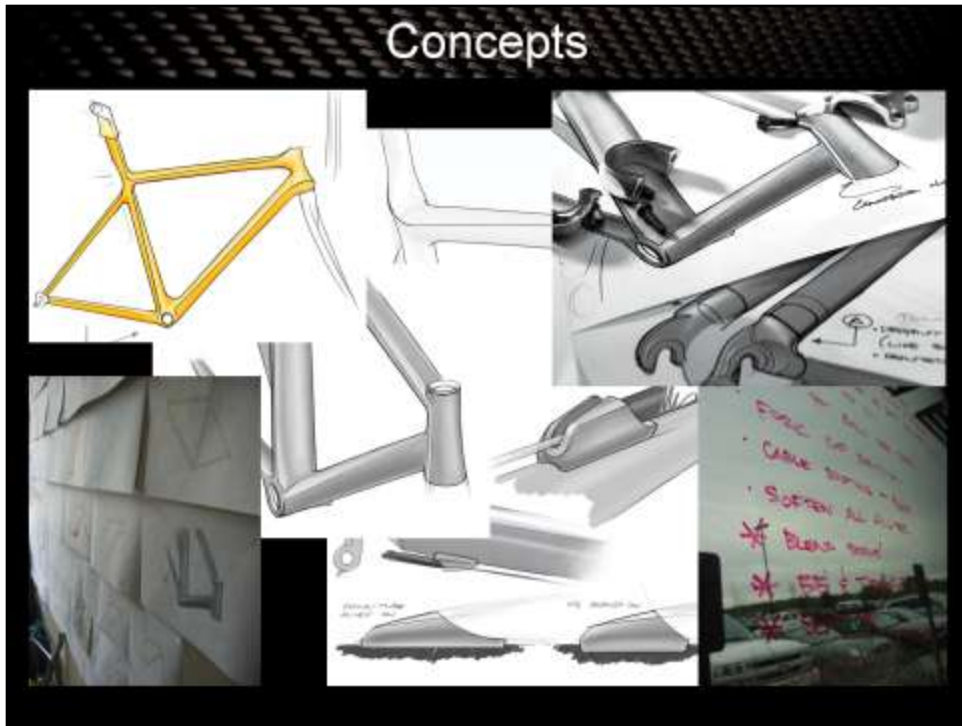
ID uses Visual clues from many sources.... like the auto industry

The design and graphics, "The Look", is a key factor in bikes today

The bicycle is no longer viewed as a toy, it has become a status symbol, a lifestyle

Ride performance is a given

The 08 Madone is a complete new bike in all aspects Design, engineering, processing



Even in 2003 we were using basically straight round tubes  
This made our job pretty simple

## Layout Sketches



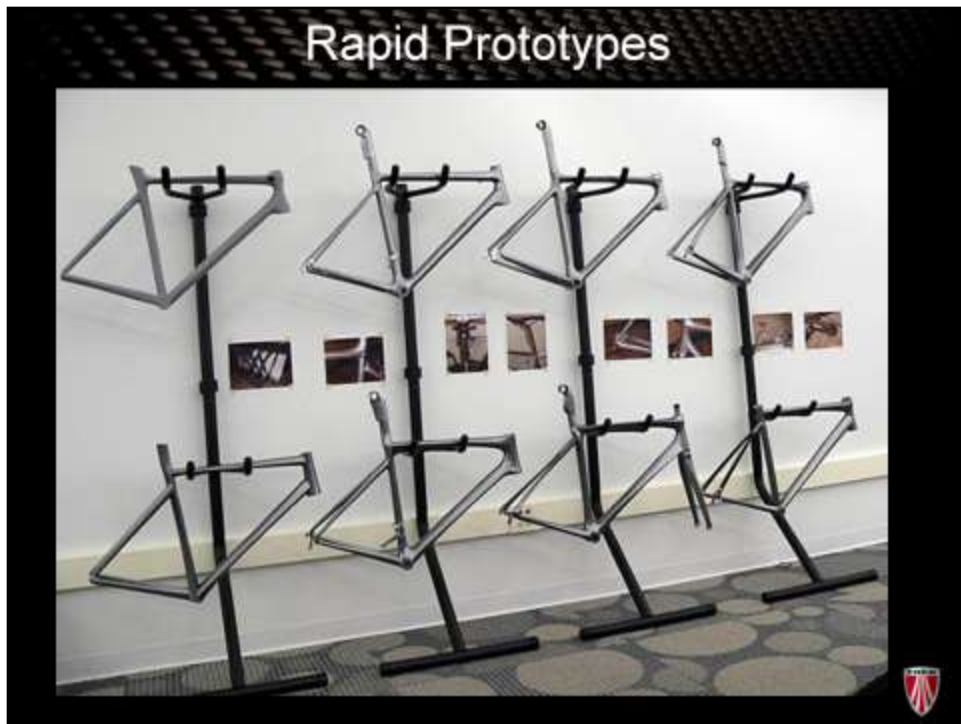
Now it is all Sweeping lines with lots of shape and highlights

With this comes lots of sketches and concepts

This has made our job much more difficult

I am talking about our Madone road bike but we follow same paths for Mtn. bikes and other products





Bicycles are really a fashion industry,  
a “traditions” industry,  
and an attention to details industry

8+ rapid prototypes for new look

Frame is both structural member and visual aesthetic/cosmetic this fact  
creates engineering and manufacturing challenges



Every aspect of bringing product to market has become very compressed  
we are now working on a 3 to 4 year design cycle

Good basic engineer and understanding of composite materials in the past  
Time compression, performance, and our need to leap frog the competition  
Finite Element Analysis (FEA) is key to taking us to the next level

We start with shape comparisons

Use analysis to guide ID styling and cross sections

Use history and tradition to guide centerlines and geometry

We also have size specific stiffness requirements

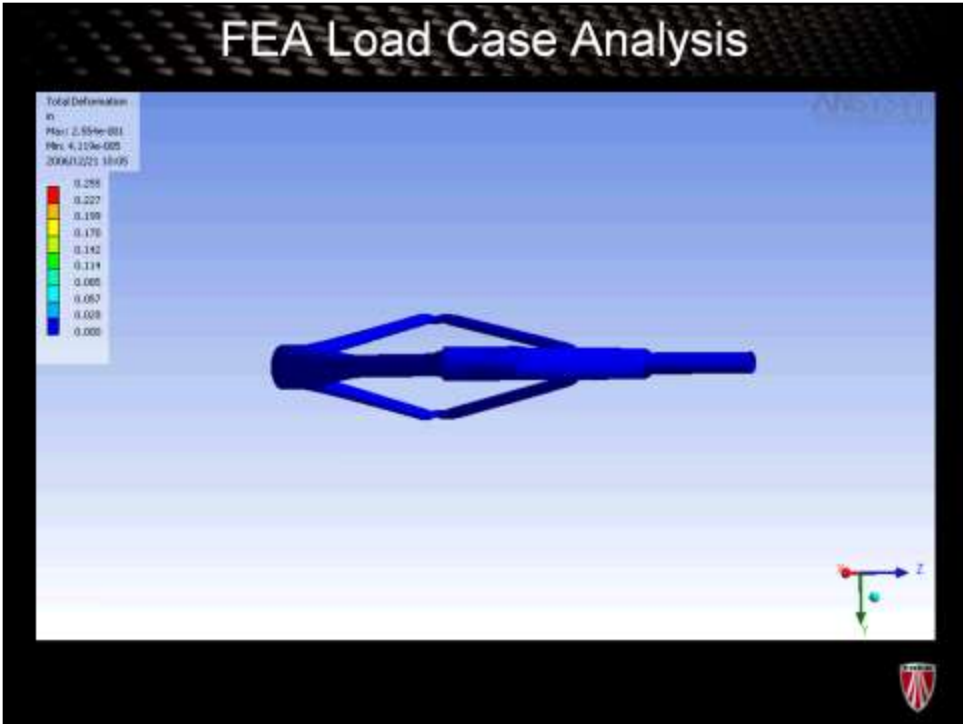
This is an iterative process to converge on the best solution

We are really designing around the strengths and benefits of carbon fiber now,  
not simply replacing one frame material with another.

## Strain Gage Bike

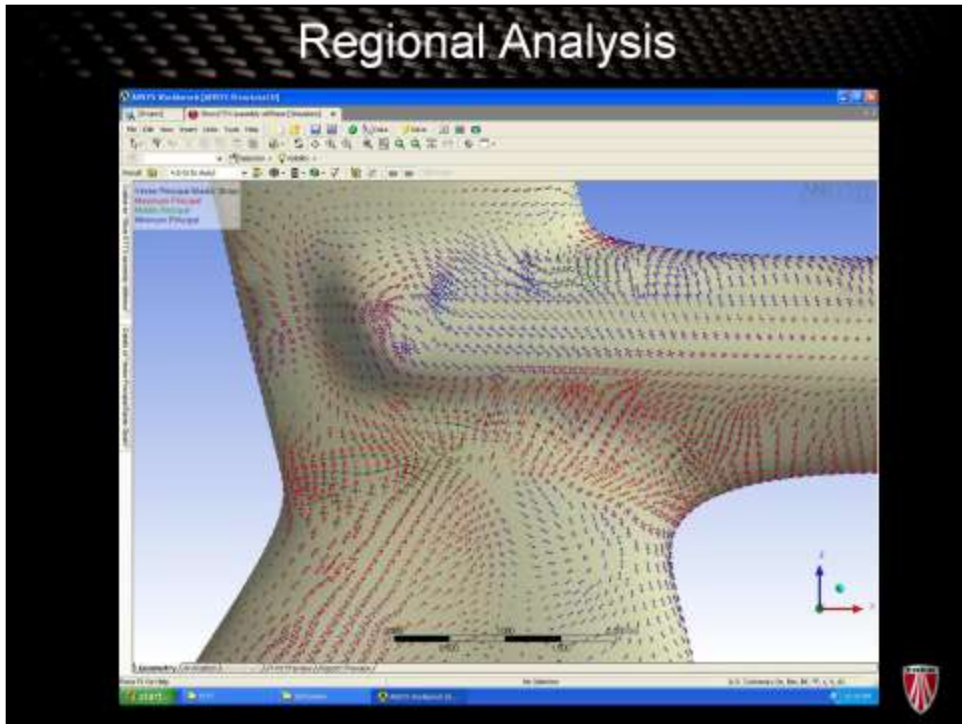


Collecting frame strain data for use with FEA  
This guides us in creating realistic load cases



Simulation of a rider sprinting

# Regional Analysis



Mesh refinements

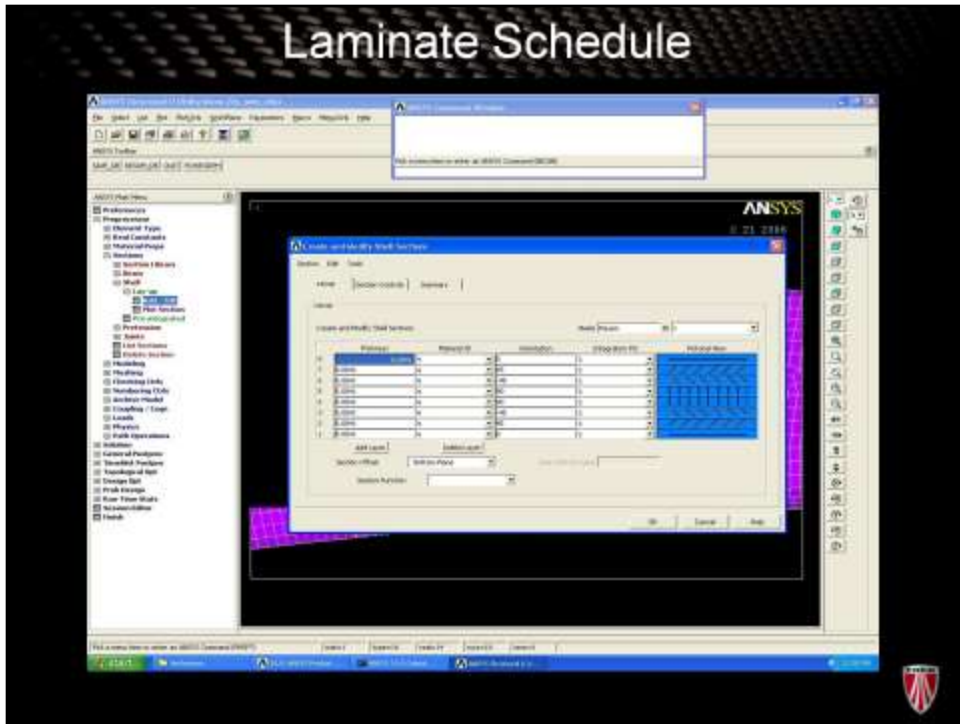
Analyze principle strain to locate areas needing reinforcement

Helps us with fiber direction and placement

Laminate schedules

High Performance Materials

# Laminate Schedule



This is where composites really shine

Our ability to tailor the fiber placement, angles, and thickness

For the Madone we tested 35+ material lay-ups virtually first

Picked those that were most promising to make into frames for testing

## Chain Stay Fatigue



We have to correlate FEA results with Physical testing

Perform thousands of tests

In the past we followed a make it and break it course

Industry standards, CPSC, CEN, DIN, JIS, ANSI

Comprehensive set of bike specific Fatigue, impact and Ultimate strength tests  
to determine if we've succeeded

Bench testing both destructive and non-destructive

Chain stay/seat stay fatigue



## Frame Fatigue



Full frame Fatigue  
Seat mast fatigue  
Competitors frames



# Impact Testing



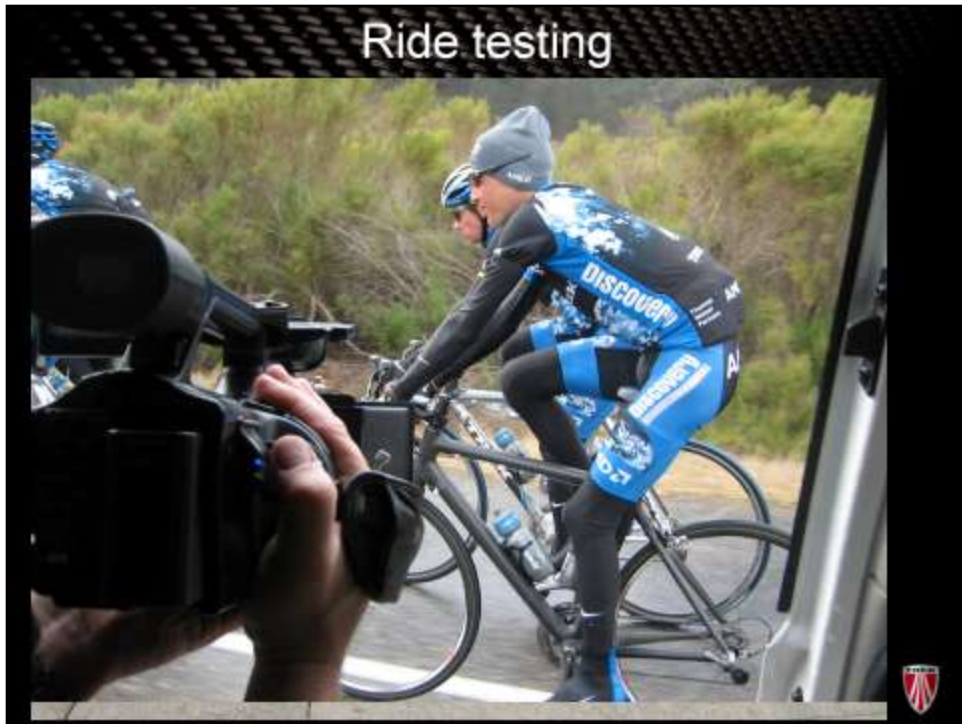
CEN Impact for forks

# Ultimate Strength

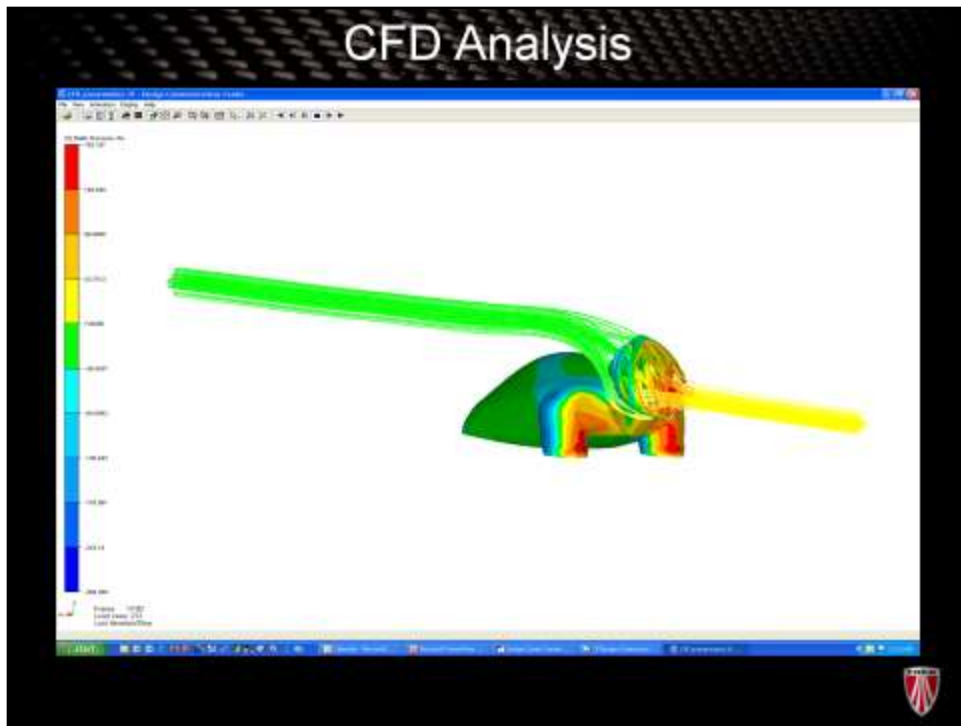


Full frame Ultimate strength

Force versus deflection calculate energy absorption



And finally Ride testing to ensure the elusive “feel”  
Over 20,000 miles of ride testing prior to release



Another tool in our quiver

Computational Fluid Dynamics (CFD)

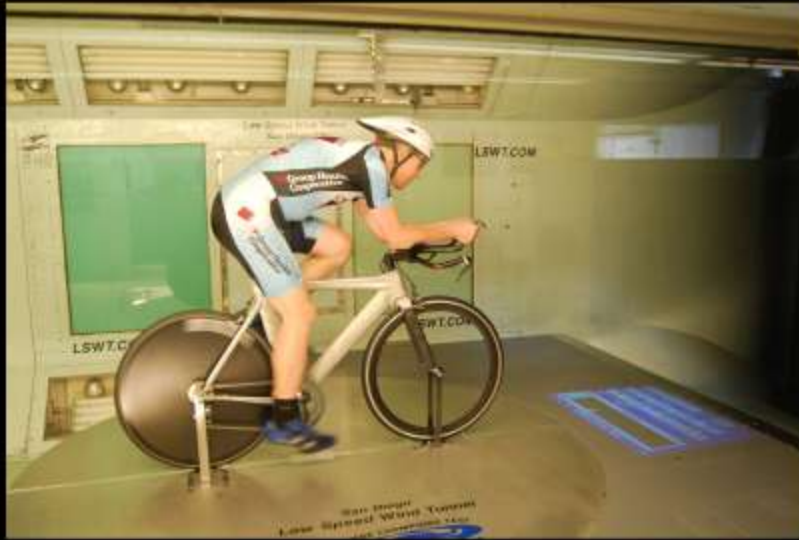
Particle trace and pressure map showing air flow

Aerodynamics

Thermal management

We use this for frame aerodynamics then go to wind tunnel to verify results

# Wind Tunnel



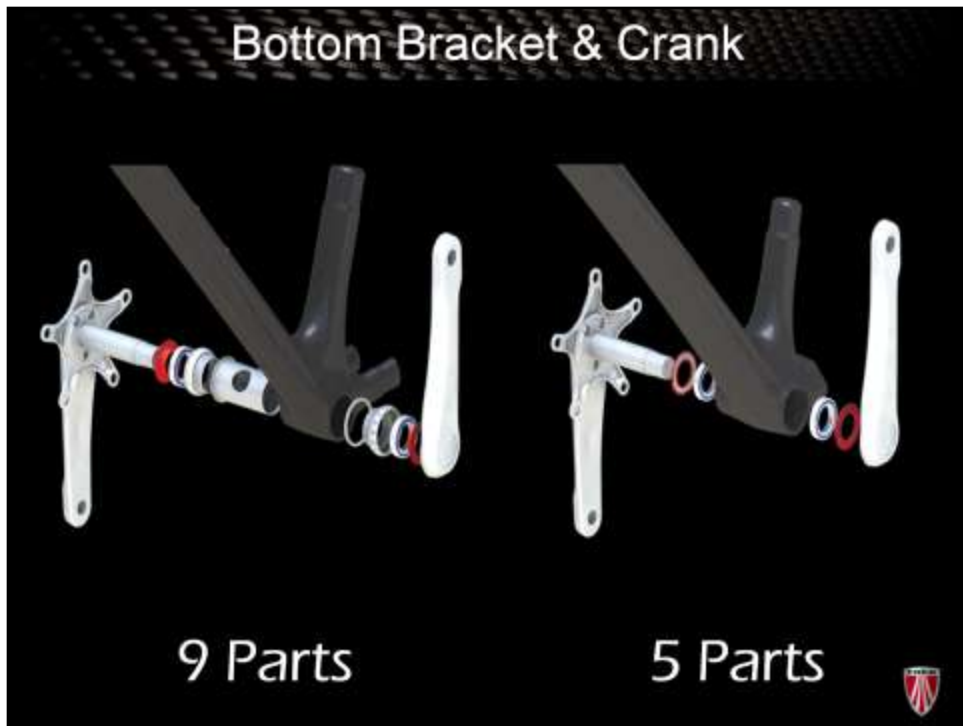


Carbon bearing interfaces have proven to be more durable than aluminum cups and steel bearing races

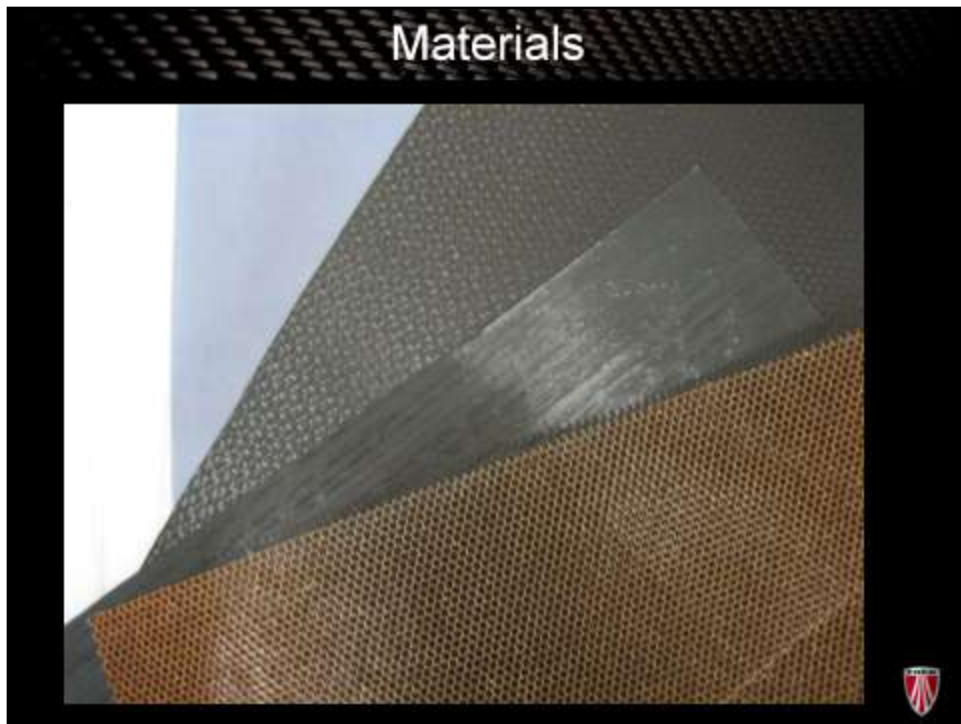
Precision Fit plug and Sockets provide Tighter tolerance control  
reduces waste and non value added processes like machining

Reduced parts and weight

Improved performance



Net molding allowed us to simplify the whole assembly, eliminating parts



## High Performance Materials

Thermo-set epoxy Prepreg

Continuous fiber reinforcement

Suppliers Hexcel, Newport, Mitsubishi, Toray

If it doesn't translate to the consumer, we won't use it.

## Many options available

Standard through Ultra-High Modulus Carbon fiber

HexMC 2" long fiber SMC-BMC material

55, 70, 110, 120, & 150gsm Range of aerial fiber weights

350°F and 250°F cure systems

Woven, uni-directional, Honeycomb, and Boron

## Emerging Technologies Nano Materials

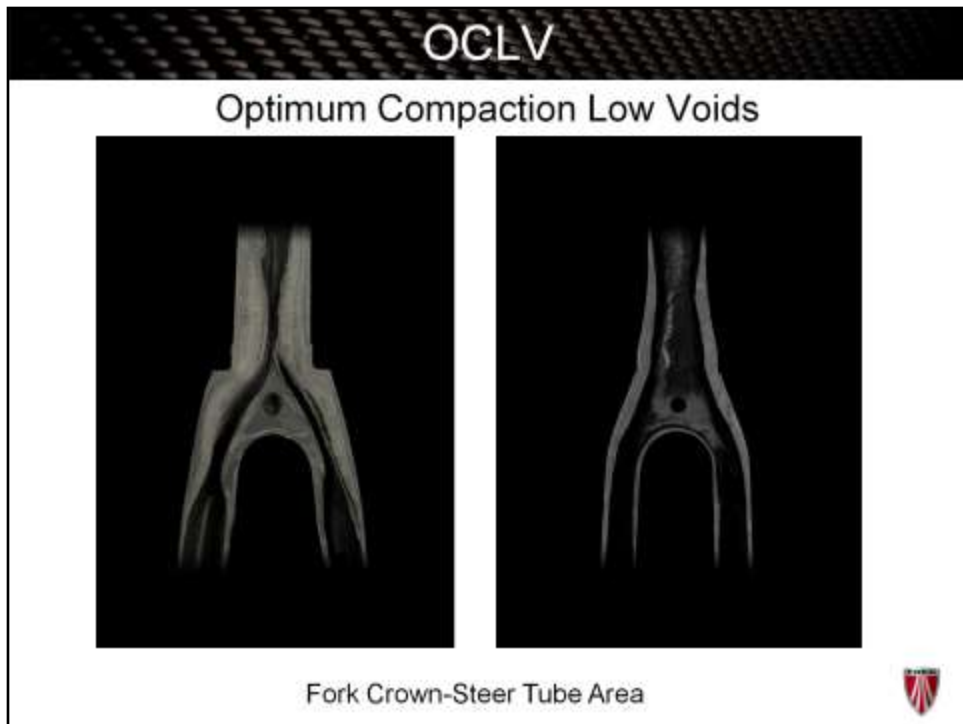
Carbon fibers and tubes

Particles, fillers, other additives

## Material Specifications

Certifications from the vendors





Optimum compaction low voids

Keeping fiber as straight as possible, few sharp bends

## OCLV Processing

- OCLV Value Stream

- Molding → Machining → Bonding → Finishing

- Molding Area Flow

- Lay-up → Preforms → Kitting → Molding



200 carbon frame sets per day, 1000+ carbon parts per day

### **Quality/Precision/Repeatability**

Process Documentation

Operator Training and Certification

SPC

Batch Testing

Control Plans

Precision Molded Technology (PMT)



Visual indicators Color codes for different materials

Flat ply collation

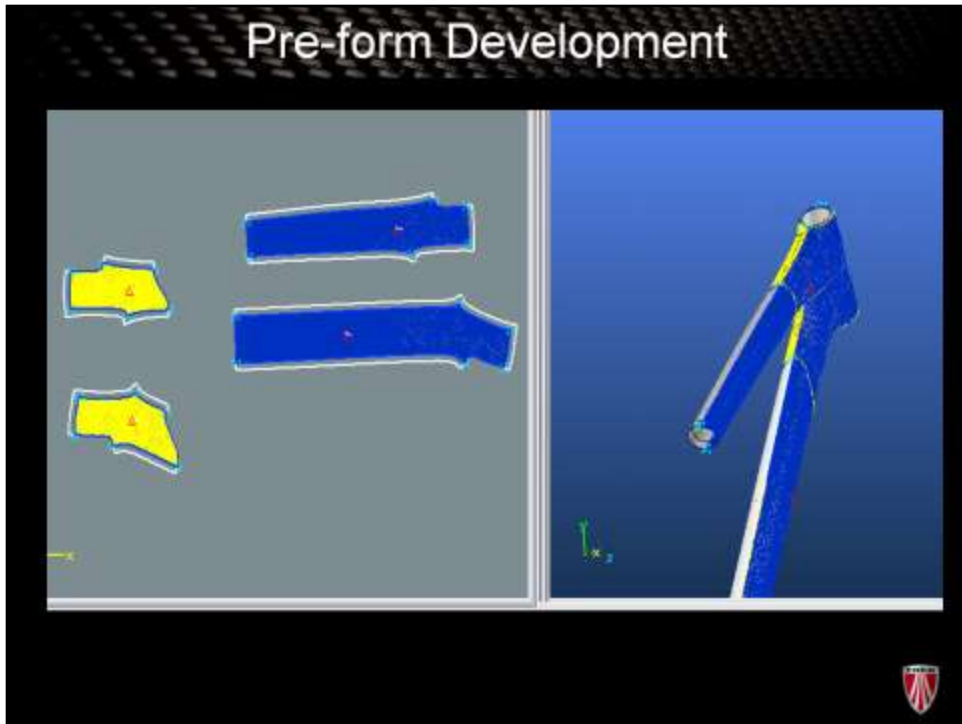
Multiple lay-ups

Laser Projection with Sequence display

Precise fiber angles

Bar-coding for material management, out time, and inventory

## Pre-form Development

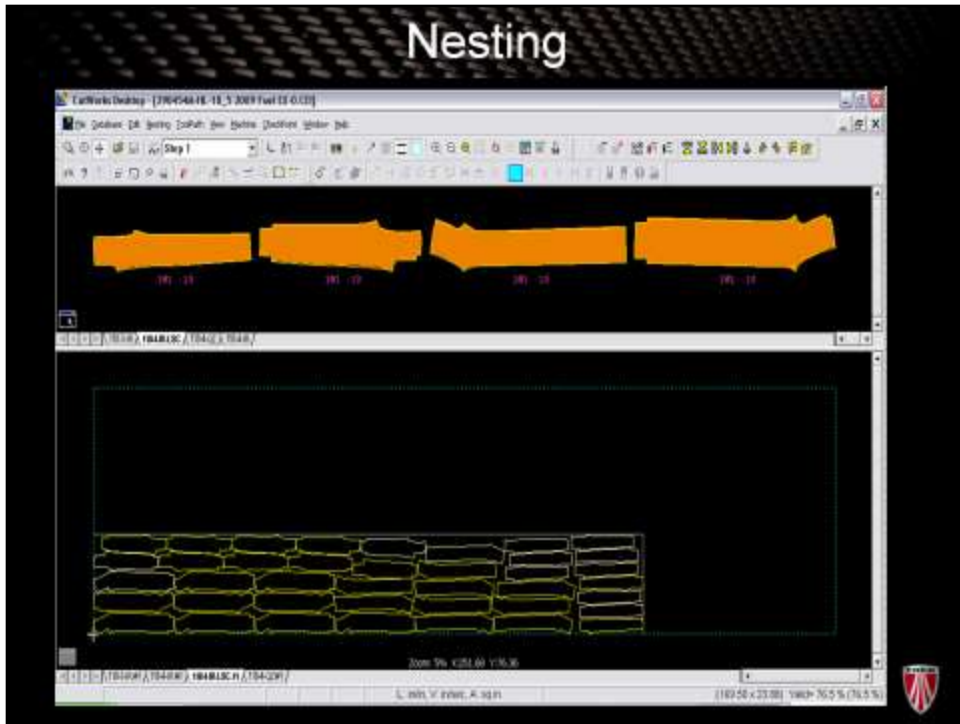


3-D Flattening software

3-D → 2D CAD files

Regions/boundaries to flat patterns

# Nesting



Tool path and nesting software

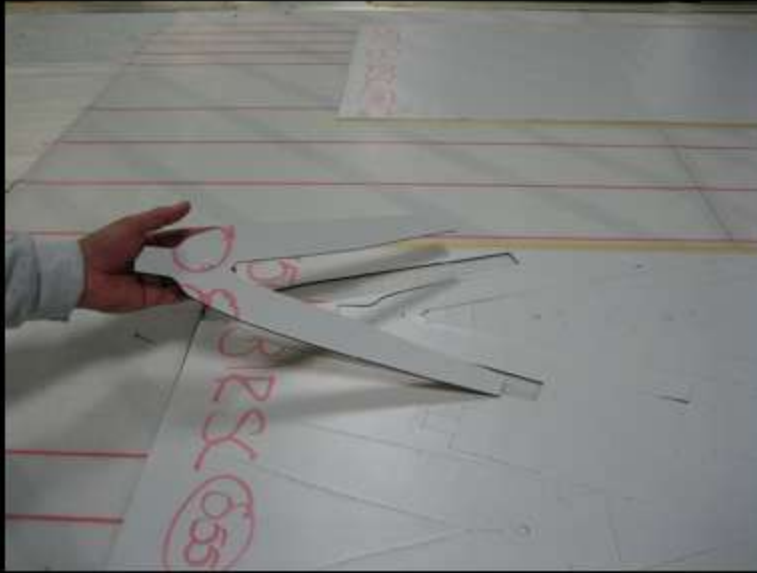
Material usage

Fiber alignment



CNC cutting machines

## Cut Pre-Form Piece



Precise cut preform

# Process Documentation



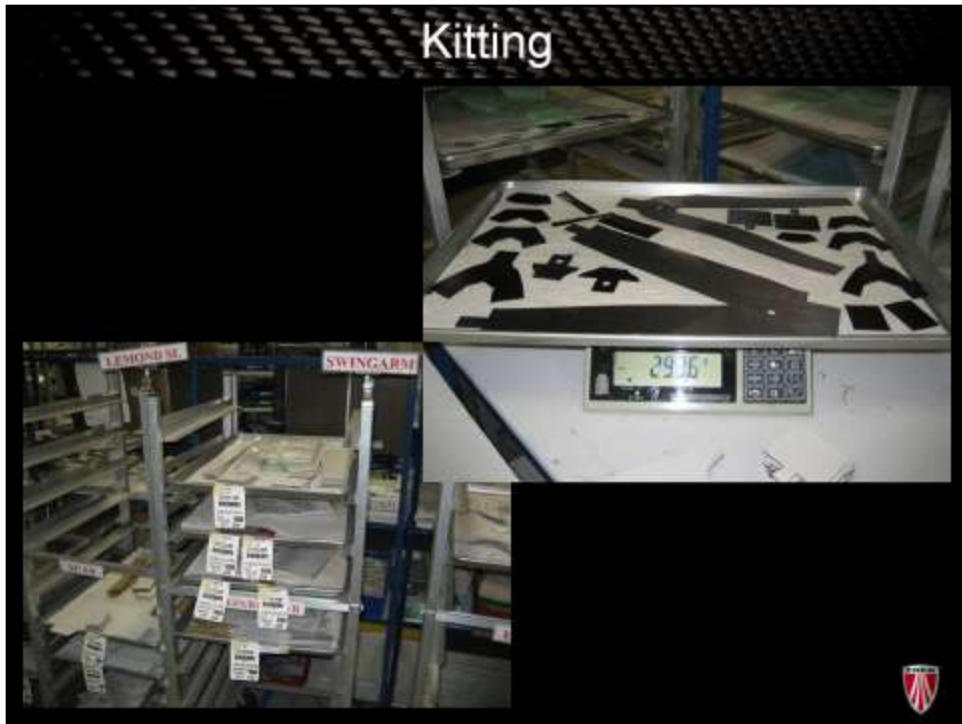
Process documents online

Revisions are immediately

No tracking of copies on the manufacturing floor

Fewer errors

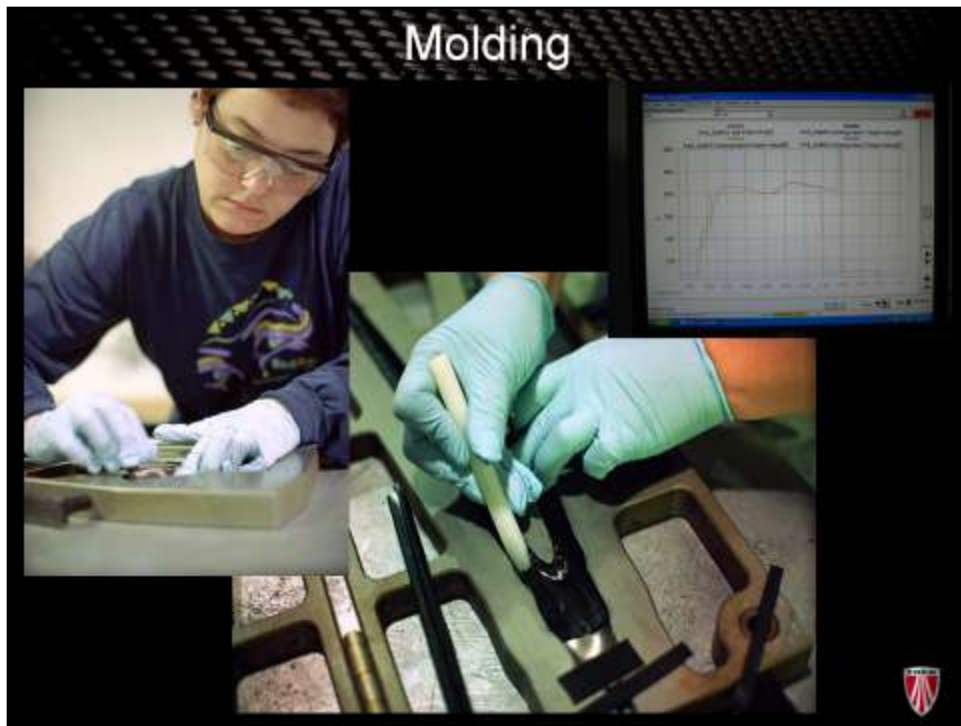




Tracking of weights for control

Correct parts to molding

Everything is done by work order in small batches



Hand crafted

Each preform piece is placed into the mold by hand

Operator Training and certification programs

Use programmable ramp & soak temperature controllers for processing and data logging



CNC Machining in Vertical machining centers and on Knee style mills

High Speed Spindles

Diamond bits

Dry machining with dust collection

Nest style fixtures

Pneumatic clamping

## Bonding Prep and Assembly



- Truly hand built and very labor intensive
- Sand blast for prep
- Work order staging
- Adhesive & pre-assembly
- Assembly and clean-up
- Carbon Cure fixtures

# Quality Inspection



Finally SPC for tracking frame alignment  
From here we go to finishing and paint



You can see how Design, Materials, and Processing comes together  
Final product 900g frame (sub 2 Lb),  
a full water bottle is the same weight  
Trek is committed to Innovation  
A blend of Elegance, Engineering, Materials, and Manufacturing  
With out Carbon fiber composites this **revolution** would not have been possible

# Trek Bicycles

- Thank you for your time
- Questions?

