Materials Selection and Design

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From the Need Statement to Product Specifications

- First step in design is to formulate “the need statement” e.g. device needed to perform task X
- This solution should be solution neutral (invite creativity and avoid narrow thinking & pre-conception)
- Between the need statement and product specification are the stages of
  - Conceptual design
  - Embodiment design
  - Detailed final design
- The product itself is a “technical system” that consists of assemblies, sub-assemblies and components

Project-based Problem Solving

- People **learn best by doing** and only knowledge applied has value
- Present systematic method for Project-based Problem-solving
- Each table forms a company to design a project to solve a problem

Design for Developing Countries

- The creative part of the design process is well brought out by the needs of developing countries
  - Energy
  - Water
  - Housing
  - Cooking
- Can you think of some concepts to provide solutions to these problems?
- Best use of **local materials**?
- **Life cycle costs** and addressing **sustainability**?

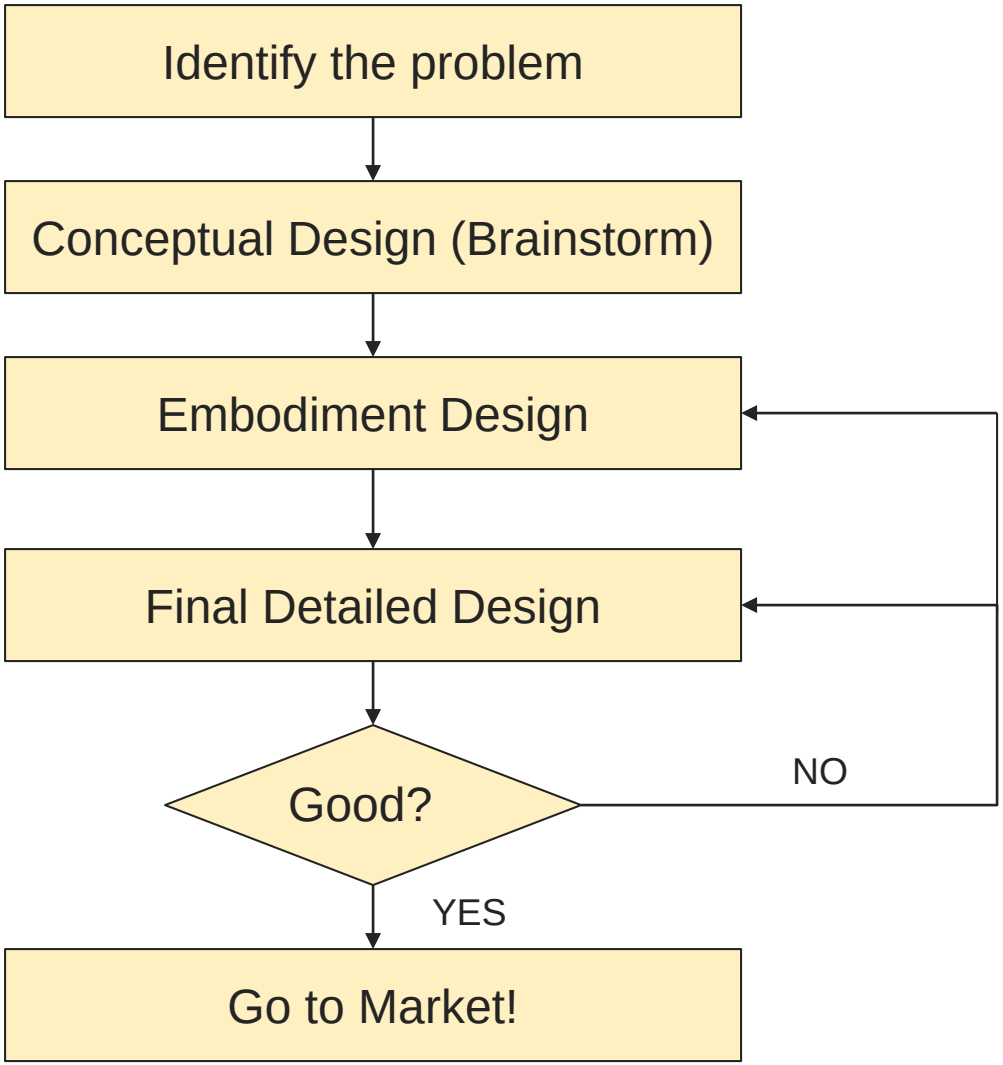
Ideas for Solutions to Local Problems

Steps for Project-based Problem Solving

Generate many ideas, >10 ideas

Reduce to ~5 ideas

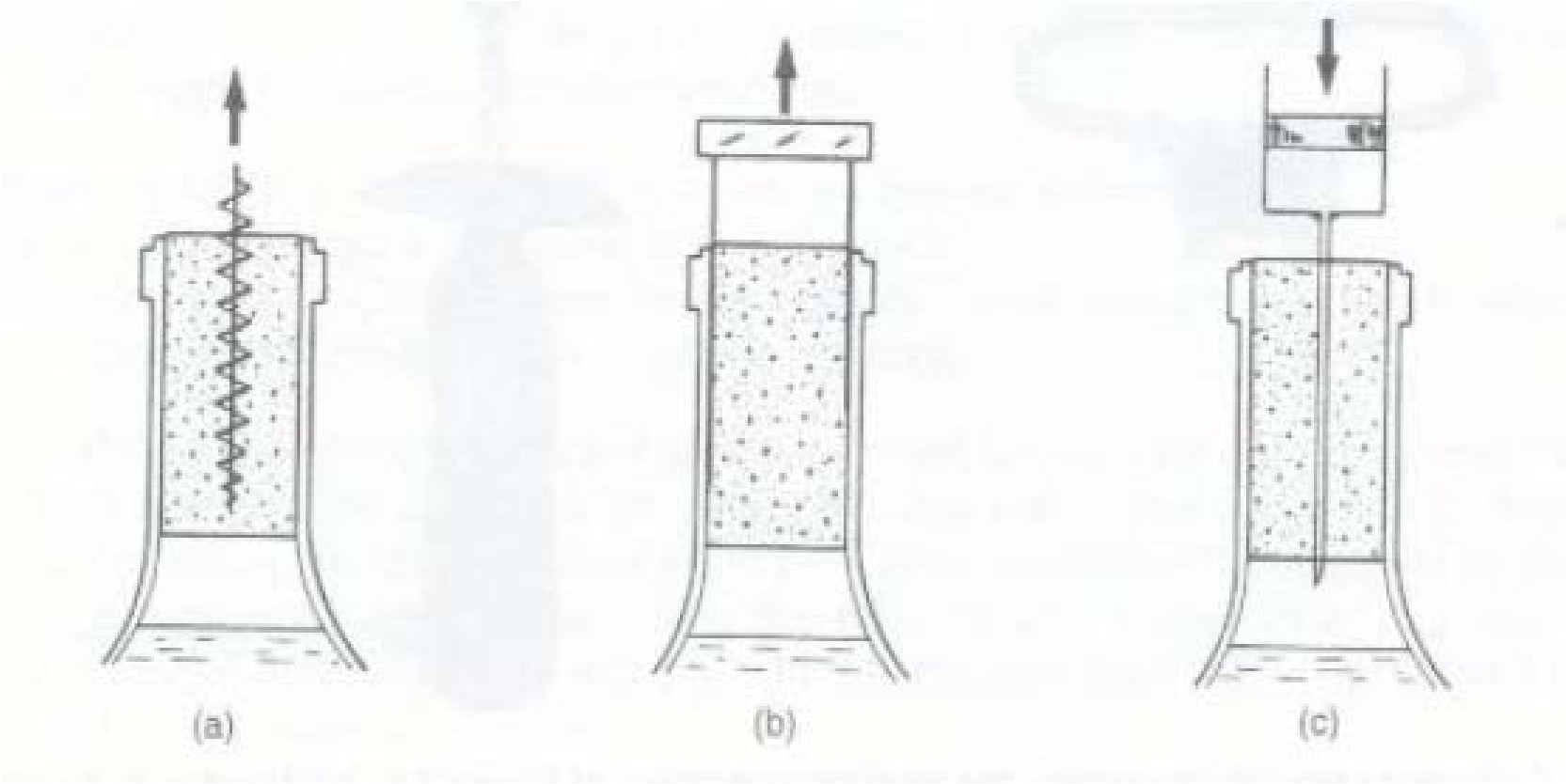
Reduce to 1 or 2 ideas



Devices to Open Corked Bottles

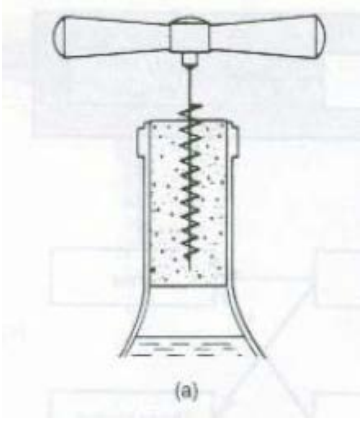
- Wine is really one of the special things we like to keep safely sealed in flasks and bottles
- This is often achieved by corking the bottle or flasks
- Corking the wine creates a market need i.e. a need to gain access to the wine in the bottle
- A device is therefore needed to pull corks from wine bottle
- Other design considerations include: modest cost without contamination of content

Working Principles for The First Three Schemes

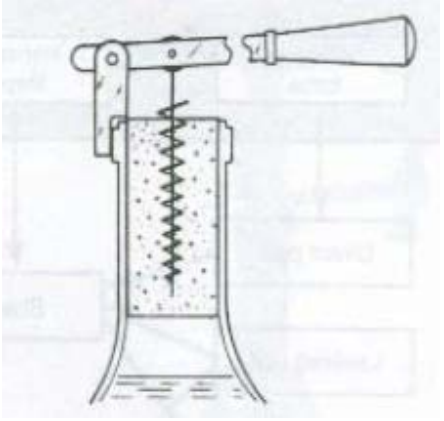


Embodiment Sketches Based on One Concept (Axial Traction)

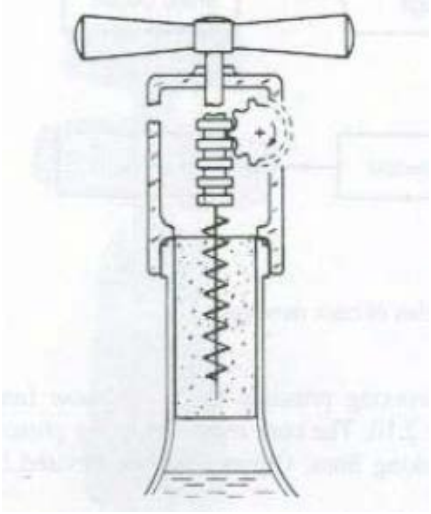
Direct Pull



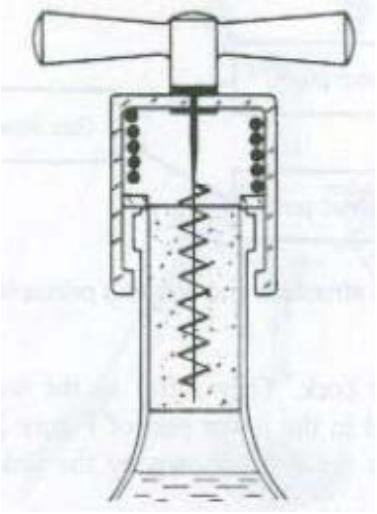
Levered Pull



Spring-Assisted Pull



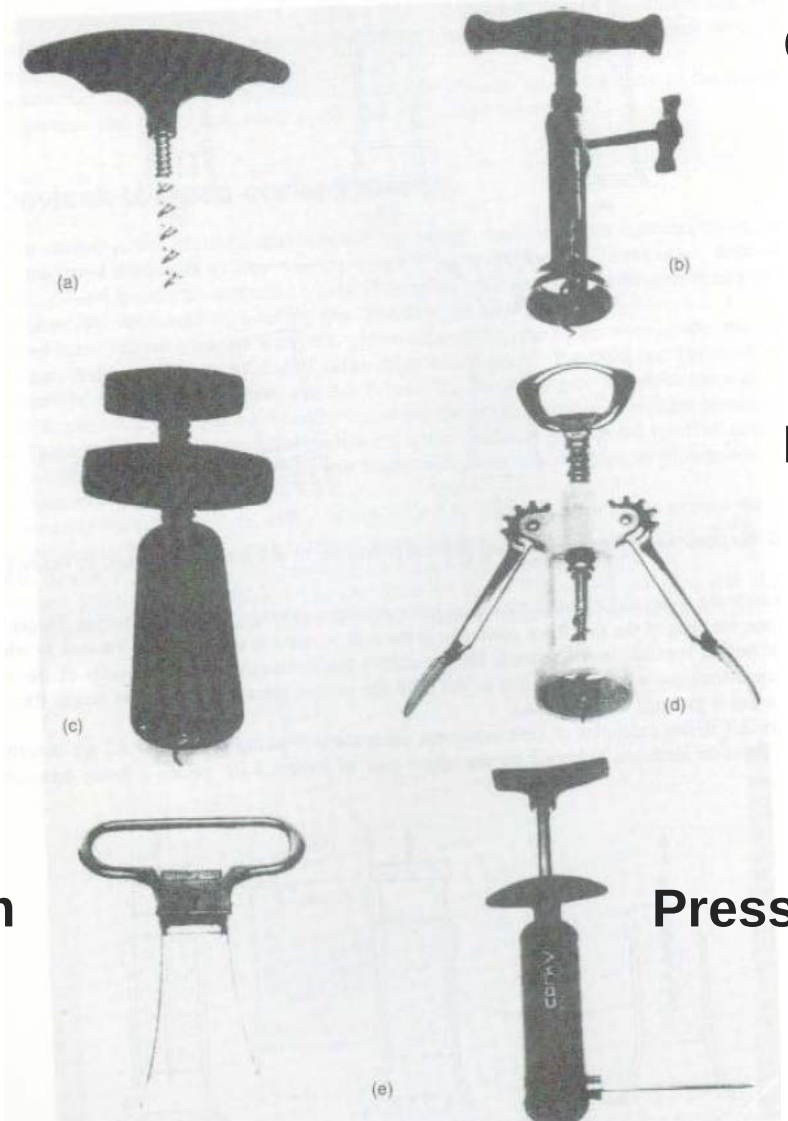
Spring-Assisted Pull



Examples of Cork Screw Removers

Direct Pull

Gear Level Screw



Lever-Assisted Screw

Spring Assisted

Shear Blade System

Pressure Induced Removal

Problem Statement

- Local transportation is expensive
- Traditional Bicycles are too expensive

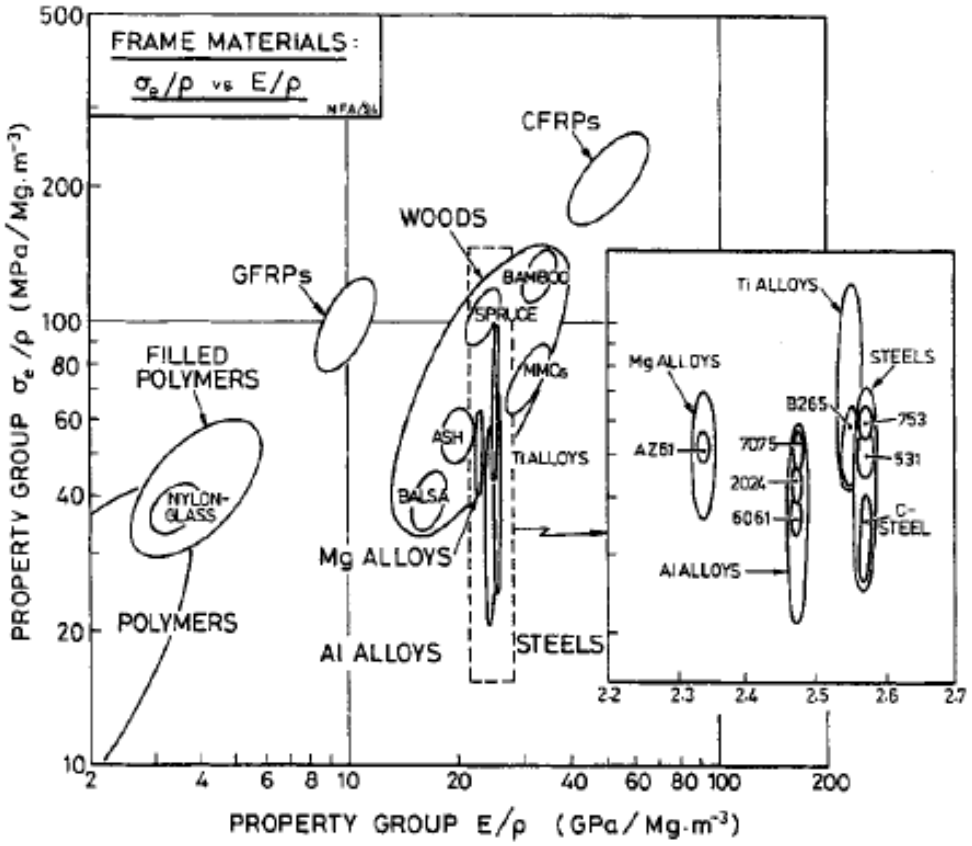
What can we do to solve this?

Design Objective

- The objective of this project was to make a **bamboo fixed gear bicycle** at low cost that would be strong and durable while providing a comfortable ride.

The frame must be light, stiff, and comfortable. The optimization of these three variables is crucial for the design of a successful racing bike or a comfortable road machine.

Background



The chart shows that bamboo, which is a very cheap and fast growing material, is the closest material to carbon fiber reinforced plastic in performance for bike frames.

With this information, we felt we could build a high performance bicycle without paying the large expense of having a carbon fiber frame.

The chart expresses the desire for materials with high Young's modulus and critical stress while having a low density, since in bicycling, light weight is extremely important for high velocity

Gathering & Treating the Bamboo

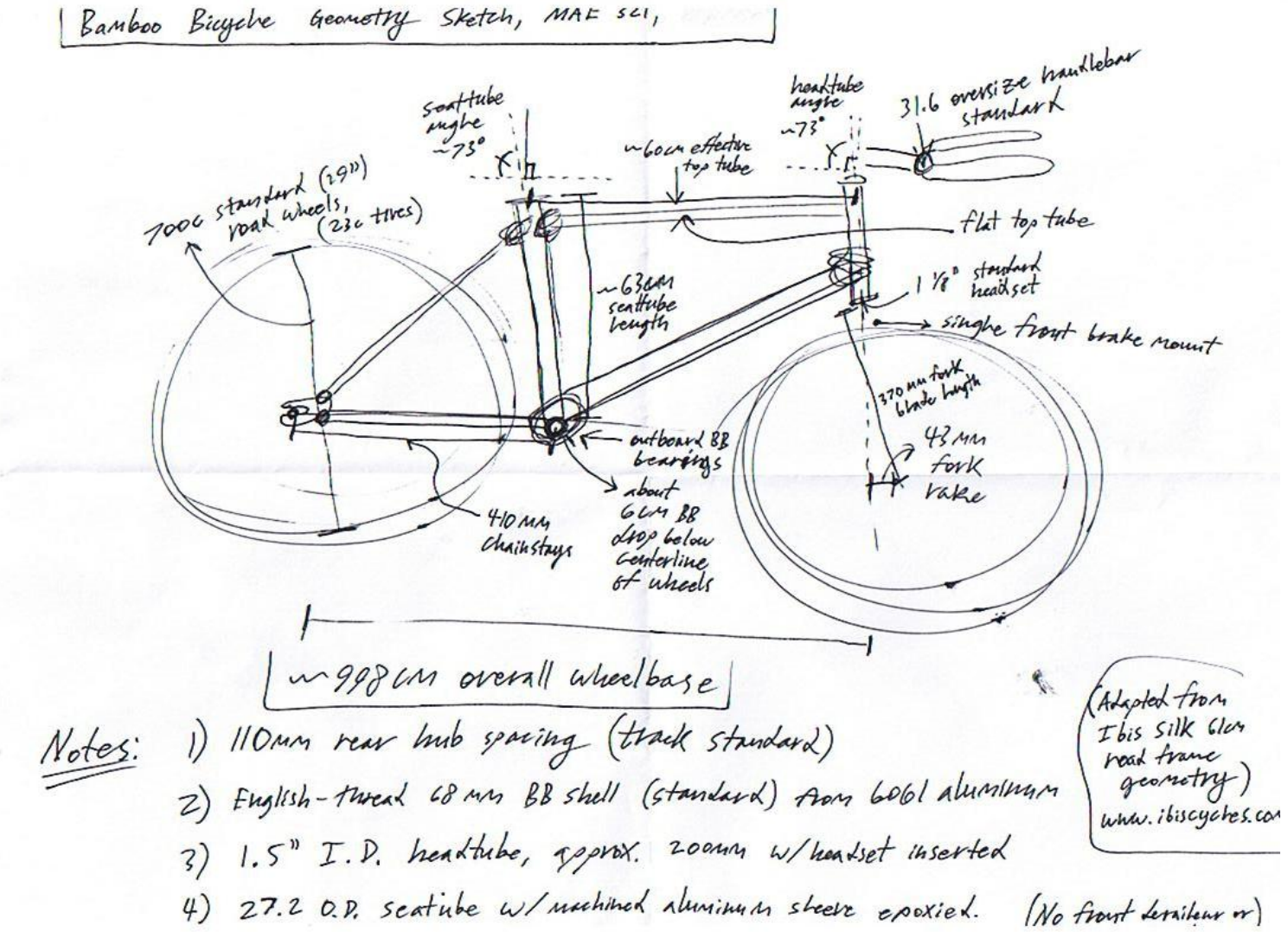
- Bamboo was collected from Pennsylvania along the Delaware River
- When cut down, the bamboo is full of water so experimentation was necessary to determine the best drying technique

Treating the Bamboo

- Baking the bamboo in an oven helped to remove water but caused cracking at the nodes
- After trying many techniques, we found the most effective approach was to first use a blow torch on the bamboo to seal the nodes and then bake it in an oven.

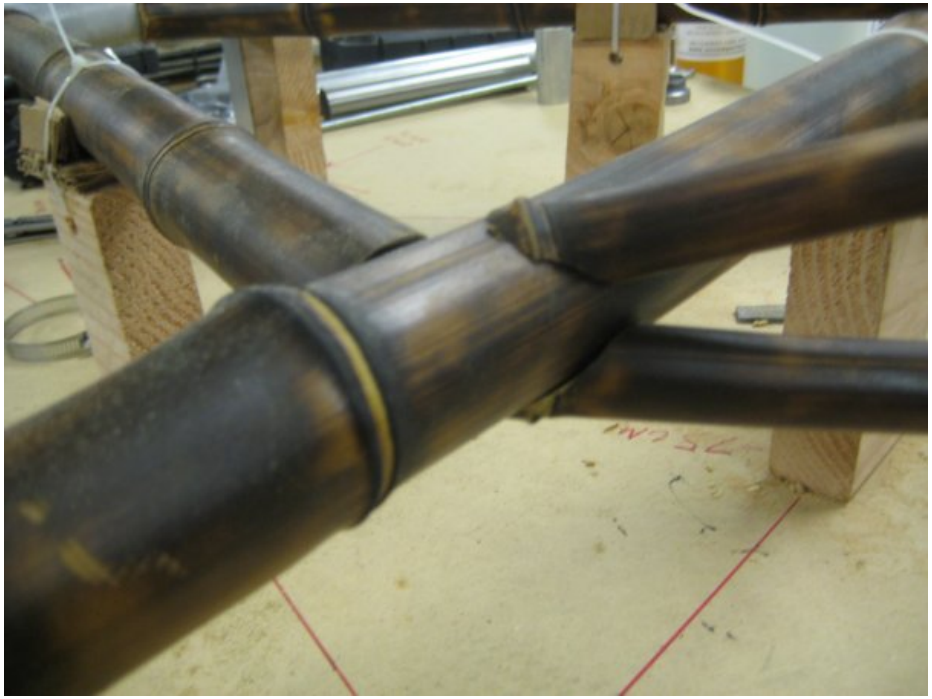
Testing the baking of bamboo with a fresh piece, a piece that was previously blowtorched, and a fresh piece wrapped in aluminum foil.

Frame Geometry



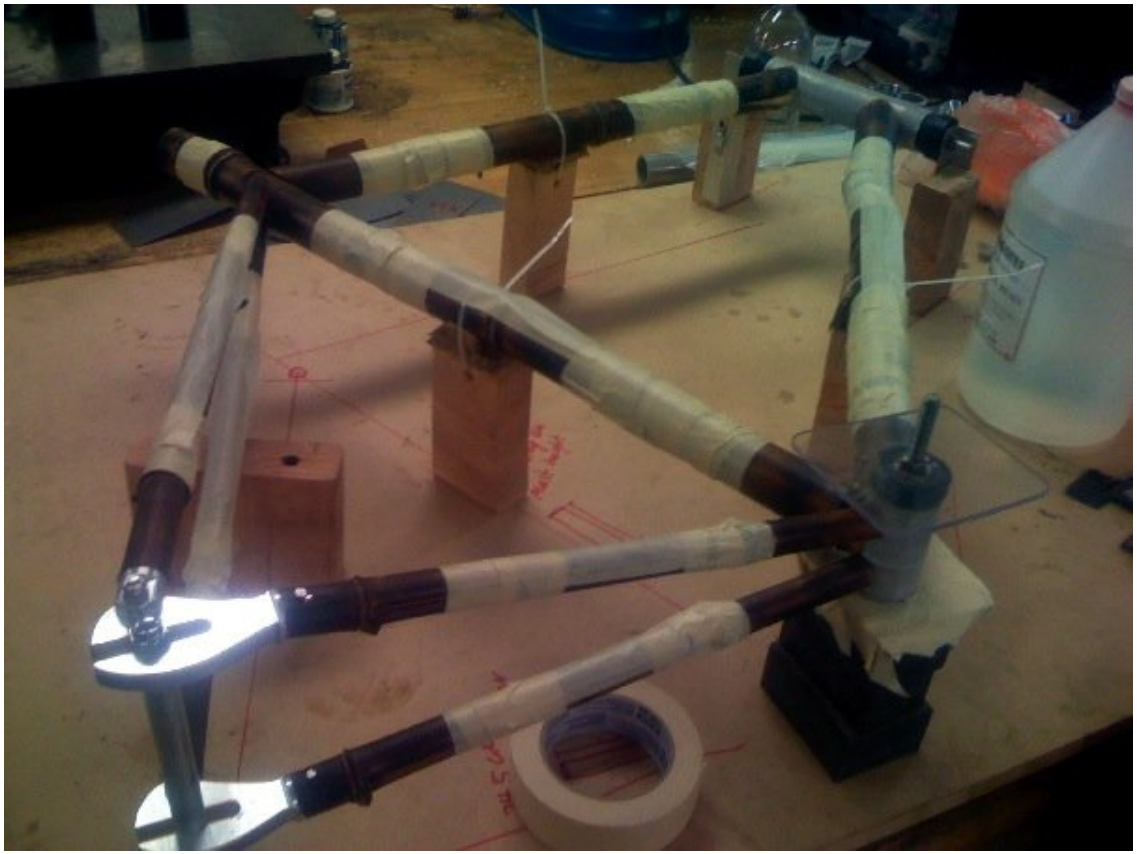
Cutting The Bamboo

- The first step was to cut the tubes to a ballpark length to fit the jig
- The tubes were then mitered with a large end mill, roughly the size of the head tube and BB shell to which they mate
- A Dremel was then used to miter the small diameter chainstays and seatstays as well as perfect the miters of the larger tubes



The Jig

- A key piece to putting the frame together was first building a jig
- The jig keeps the tubes together in a specific geometry while being wrapped with carbon tape and epoxy before curing



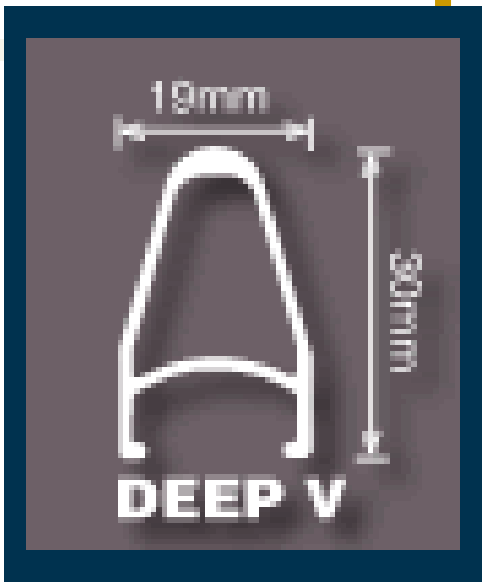
Wrapping the Tubes

- To connect the tubes together, we used unidirectional carbon fiber tape.
- The tape was dipped in an epoxy and wrapped around each joint.
- After curing, the joints were extremely sturdy
- Special attention was paid to area going to experience higher stresses, applying extra wrapping.

Components

Velocity Deep-V rim

Vittoria Evo-CX tires



Deep-V cross-section

Surly flip-flop rear hub

Components
Fork/Stem/Headset

Alpha-Q uni-direcitonal carbon fork

Chris King sealed headset bearings

Thomson CNC-machined stem

Components Drivetrain

Shimano Dura-Ace integrated-axle crankset

Shimano external bottom-bracket

KMC Z-chain Gold

Market and Prototype Cost

- In 2006 Bicycle industry was a 5.8 billion dollar industry with 18.2 million bicycles sold
- Carbon fiber frames of comparable durability cost in the $1000-$3000 range.

Cost analysis for initial prototype frame:
Bamboo – free
Carbon Fiber tape - $30
Stock Aluminum (dropouts) - $80
Epoxy and hardener - $5
Head tube - $7
Bottom bracket shell $8

Total - $130

- Bamboo bikes appeal to people supporting the “green revolution” who are trying to use more natural and environmentally friendly materials

Bamboo Frame Bicycle (Sol Cycles)

Nick Frey, Will Watts, Douglas Wolf, Tom Yersak

Design for Developing Countries

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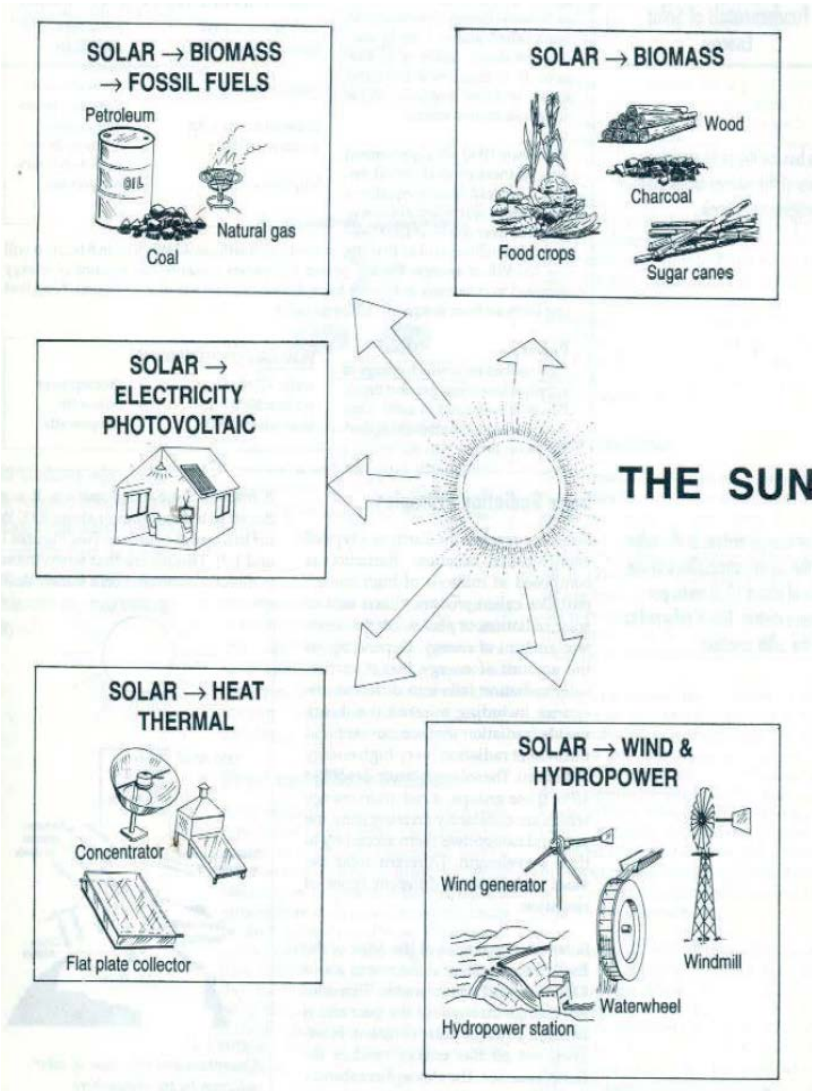
  - Water
  - Housing
  - Cooking
- Can you think of some concepts to provide solutions to these problems?
- How could you make the best use of local materials?
- What are the life cycle costs and how do we address issues to sustainability?

Potential Solutions to Energy Problems



Summary and Concluding Remarks

- Design is an iterative process
- The starting point is a market need captured in a need statement
- A concept is then devised for a product to meet this need
- If initial concepts and exploration suggest that the process is viable then design proceed to embodiment stage
  - Working principles selected & sized lay-out decided & initial cost/performance estimates
- If outcomes are successful - designer proceeds to the detailed design stage
  - Optimization of performance & full analysis (including computer methods if needed) & detailed drawings & specifications of tolerances, precision, joining, finishing, etc.
- Materials selection at each stage with different levels of breadth and precision
- There are basically two approaches to engineering design
  - Forward and reverse engineering (developing & developed countries)

Final Statements

- The design process is clearly a systematic process that calls for creativity
- However, creativity also involves risk
- So why not just opt for the safe bet
  - Stick to what you and others used before
- Many have chosen this option
- Few are still in business today