The Physics of Threshing Pearl Millet: Finding a Revolutionary* Solution to an Ancient Problem

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* literally

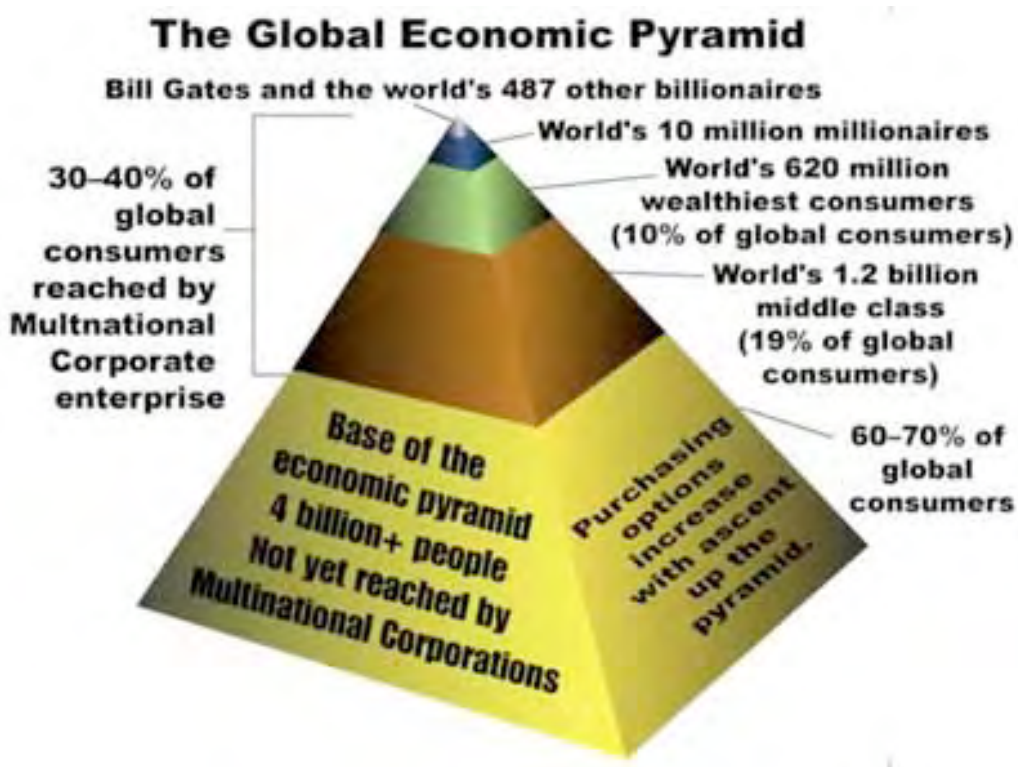
The Meta-challenge:

International Development

Applying science, technology, engineering, math, business, and economics to helping people in different economies and cultures

BoP

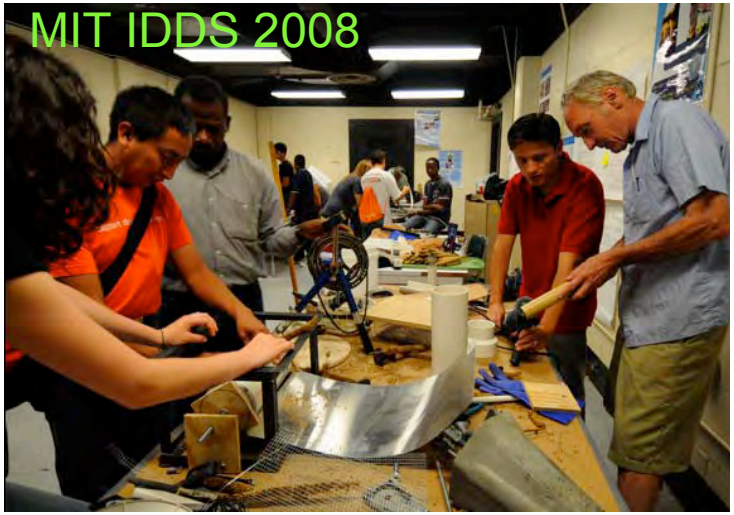
- The distribution of wealth is approximately pyramidal
- The base of the economic pyramid ("BoP") consists of ~4 billion people earning <$2/day*
- The BoP is the largest emerging market
- Growing numbers of students are eager to learn about and work in this sector



* http://en.wikipedia.org/wiki/Bottom_of_the_Pyramid

Educating for Development

- The “Professional pyramid” is inverted:
  - 90% of professionals work for the top 10% of the economic pyramid (“ToP”)
- Education focuses on the ToP
  - The BoP has many different problems, resources, constraints, methods, challenges, and contexts
- A few new university programs focus on the BoP



International Development Design Summit

MIT video:

http://features.csmonitor.com/innovation/2008/08/21/designs-for-a-better-world-emerge-from-mit-summit/

MIT

18 July - 9 Aug 2008

Our challenge

- Pearl Millet is a staple grain for millions of African and Indian families
- 75% of the pearl millet grown in Namibia is threshed manually by mortar and pestle or beating
- A faster, affordable threshing device could improve the health and economics of millions of poor families relying on millet for food or sale.

The process:

Defining and selecting projects

- A key problem is often defining “what is the problem?”
  - Language and framing can strongly constrain the solution path
  - Different stakeholders frame the problem differently
  - Limited intuition about different cultures, economies, geographies, etc.
- If framed too abstractly, its hard to find solutions. If framed to concretely, potential solutions maybe excluded.
- Formal and structured methods, like “progressive abstraction” can help
- Paul Polak’s “Out of Poverty” gives additional guidelines

The “Mahangurinas”

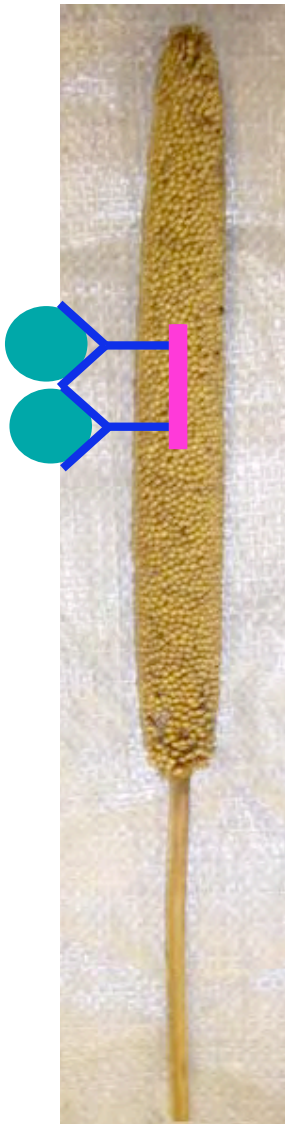
Michelle Marincel (USA), George Yaw Obeng (Ghana), Thalia Konaris (Cyprus), Francisco Rodriguez (Mexico), Brian Rasnow (USA), and mentor Donna Cohn (USA, not shown)

Structure of millet

- Millet grows on a **panicle** consisting of:
  a **stalk**, **florets**, and **grain**



- The panicle has complex physical properties, e.g.,
  - Panicles vary in size over a factor of 2
  - Grinding damages the grain
  - Twisting breaks the stalk
  - Rubbing removes florets from stalk
  - Etc.



panicle

Our Problem Statement

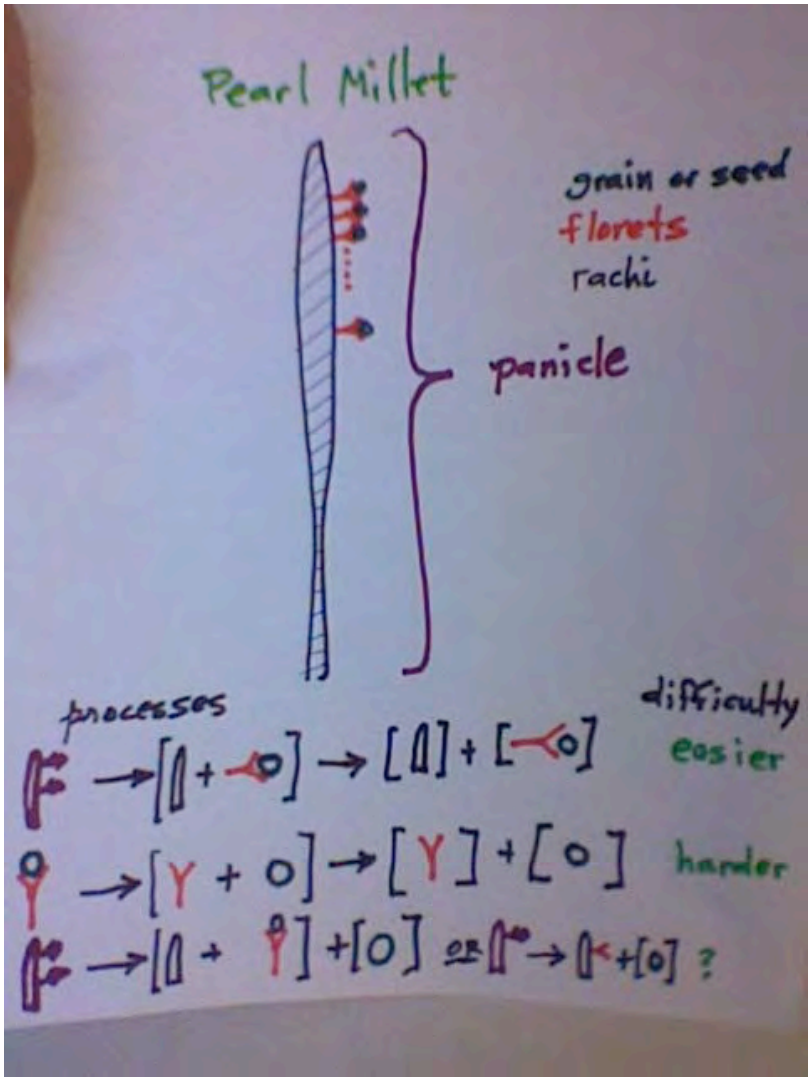
- What are the constraints?
  - Economic, materials, technological, social
- What scale of solution should we consider?
  - ~$1000 “community” thresher
  - ~$20 “personal” thresher
- What existing or competing solutions are there?
- Who will be affected by our solution, and how?
- How reliable is our information?
  - What happens if it is wrong?

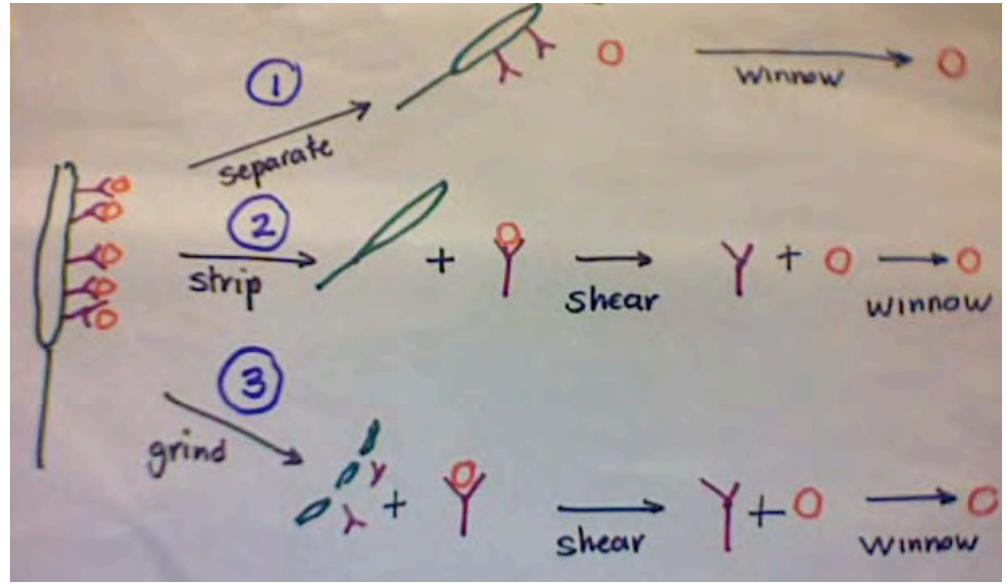
How to design a $20, 10kg/hr pearl millet thresher suitable for manufacture and sale in Africa and India?

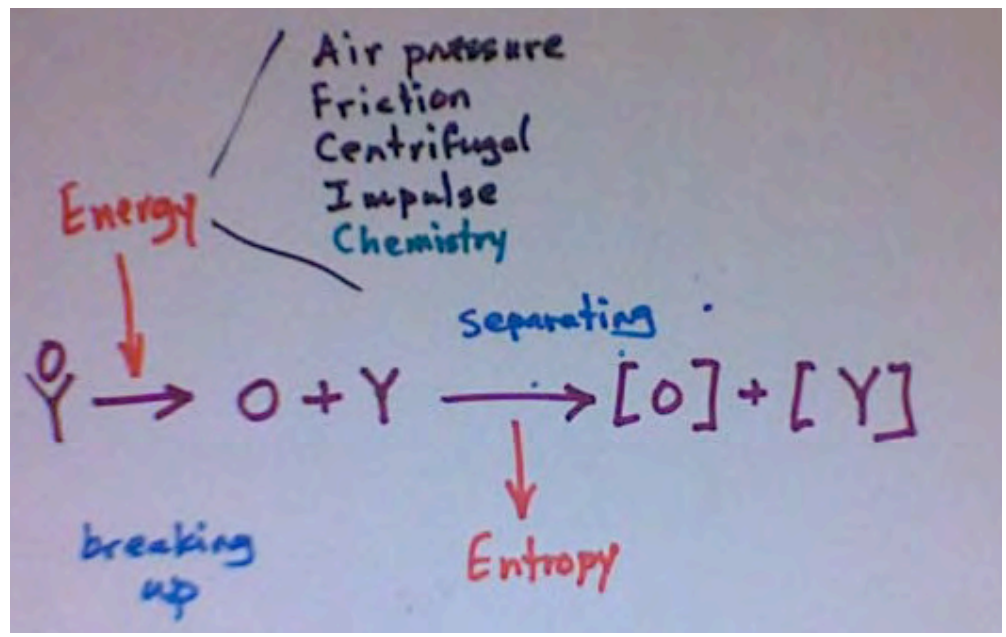
www.milllet.wetpaint.com

Representation and reduction

Millet mathematics







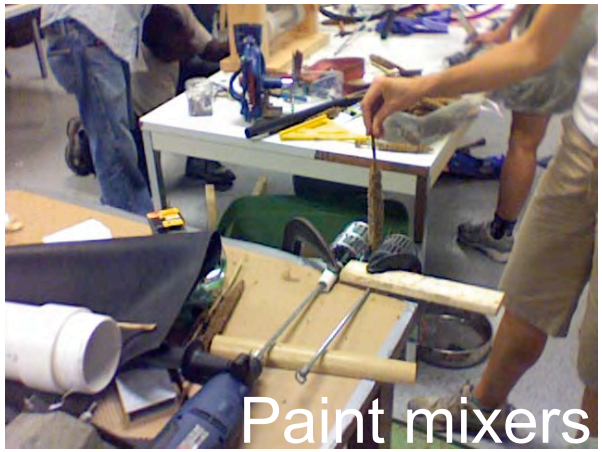
The process:

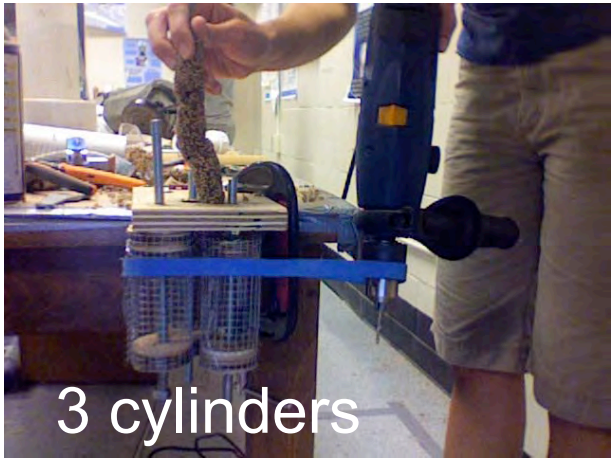
Exploring solution space

- Solution “spaces” are dimensionally huge with many local optima
- Bayesian methods
  - Include heuristics and prior knowledge
  - Increase your “degree of belief”
- Monte Carlo methods, e.g., simulated annealing
  - Sample diverse regions of solution space
  - Don’t converge too quickly on a solution class
- Noise can be helpful, e.g., stochastic resonance
  - Don’t spend too much effort trying to eliminate uncertainty
  - Seek robust, stiff solutions
- Balance risks between conventional & unconventional approaches
  - If conventional approaches to old problems have been tried and failed then *unconventional approaches may be less risky*

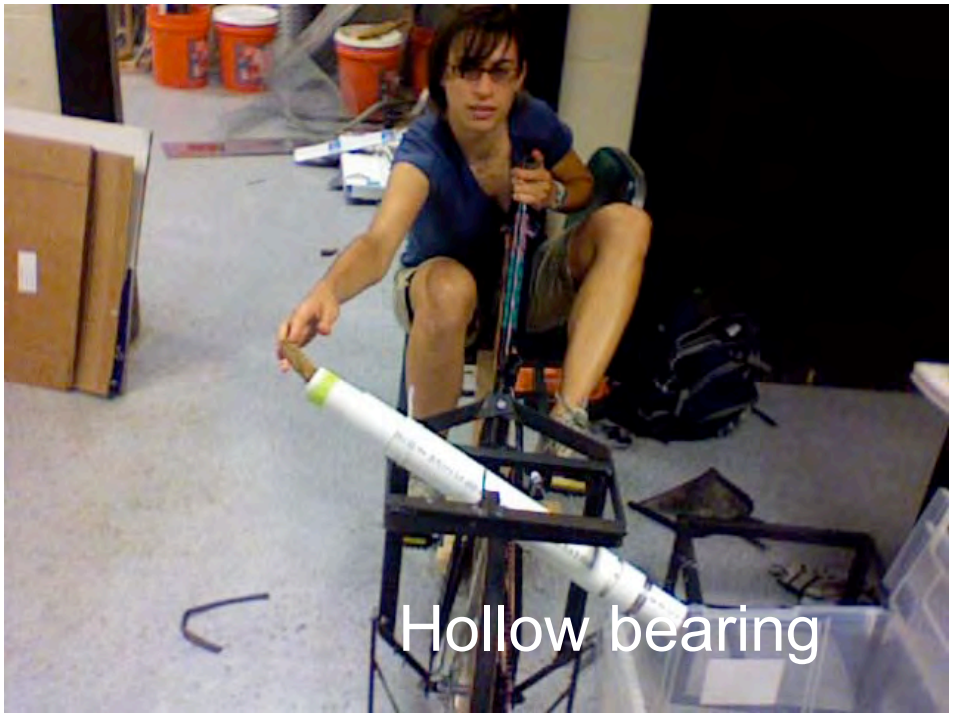
What didn't work

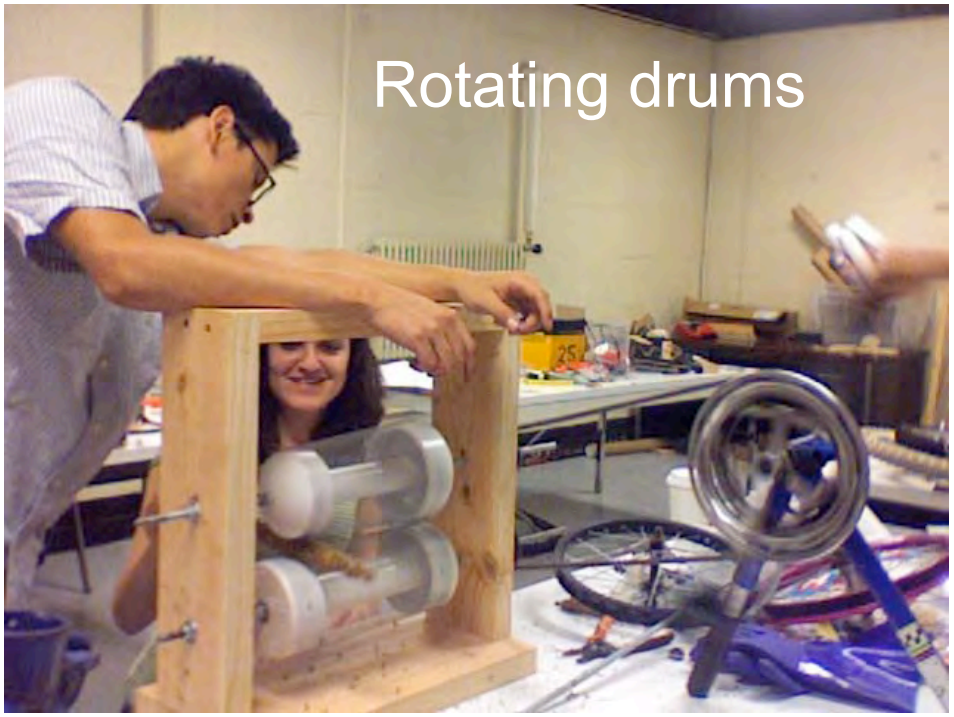
Knowing what doesn't work can be as valuable as knowing what does.





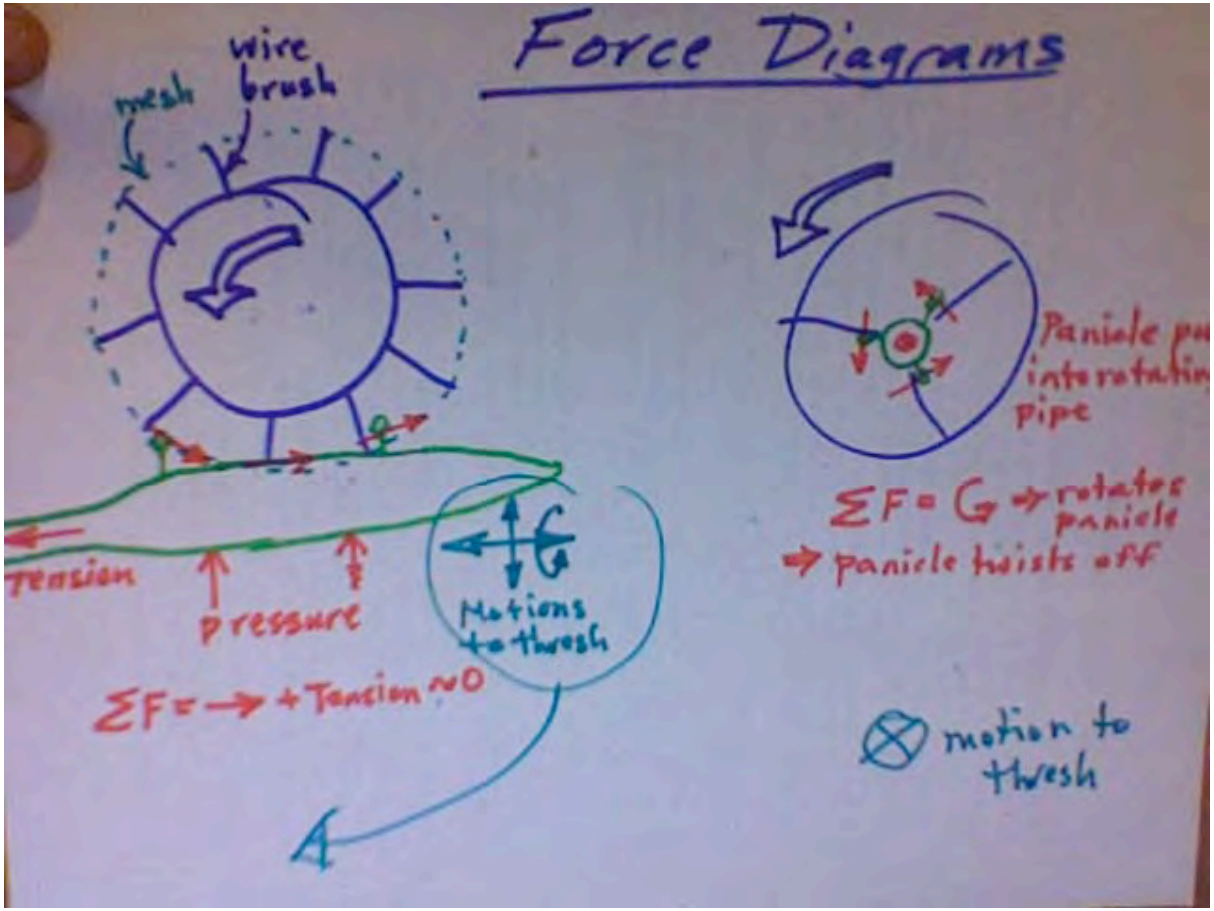
Two promising solutions





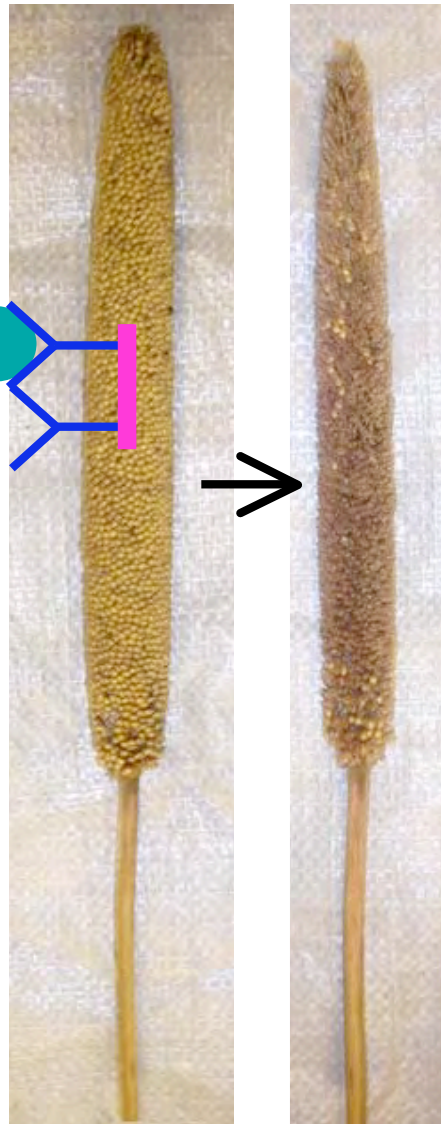
Analysis and synthesis

- The rotating drum is too conventional ⇒ probably won't work
- The hollow bearing torques the panicle and breaks it ⇒ won't work
- Analysis of forces led to a breakthrough



The breakthrough

We discovered that
~1 m/s impact on the grains,
directed toward the panicle tip,
knock off grains,
and leave the florets on the stalk.



(Impacts from other directions break the florets or the stalk)

Same panicle, before and after ~5 seconds of threshing

The IDDS Thresher

- Spoke nuts protruding through the rotating rim on an inverted bike efficiently thresh millet
- A metal plate bent as a spring presses the millet against the rim
- A grain sack collects the grain

http://features.csmonitor.com/innovation/2008/08/21/designs-for-a-better-world-emerge-from-mit-summit/

General lessons

- Do lots of experiments
  - Try to frame the problem in multiple ways
  - Reduce key ambiguity and uncertainty
  - Build empirical toolsets and conceptual frameworks
- Don’t plan too far ahead
  - Use today’s results to drive tomorrow’s exploration
- Avoid getting vested too early in specific solutions
  - Minimize investment in specific experiments or apparatus
- Seek emergence of more abstract understanding
  - As empirical puzzle pieces connect, try to interpret the pattern at higher levels
- Seek simple, cheap, quick paths to your goal
  - E.g., discovering the anisotropy of millet was key, but we did it without directly measuring tensile strength, density, etc.

Acknowledgements

- Several world-class bike experts guided us:
  - Amy Smith (McArthur fellow & IDDS organizer)
  - Gwyn Jones (co-founder, Merlin Bicycle Co.)
  - Carlos Marroquin (inventor, MayaPedal)
  - Carl Kurz (founder, Bikes Not Bombs)
  - Jock Brandis (inventor, peanut sheller)
  - Kurt Kornbluth (wheelchair design expert)

After three intense weeks doing precision engineering in MIT labs…

Our invention was completed!

Next steps: Gathering ground truth.
Optimizing ergonomics.

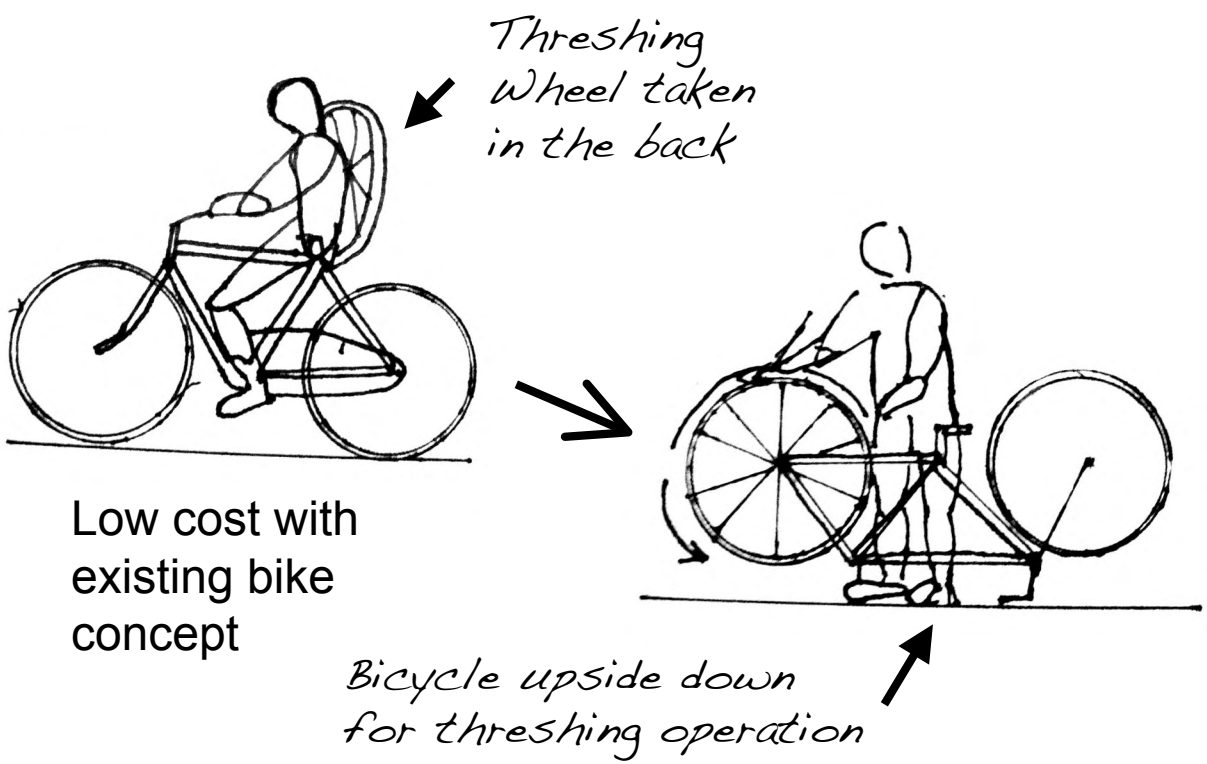
Future Directions

- Conduct market research and field trials in Mali, Ghana, and Namibia
- Validate value proposition
- Develop business/enterprise model

- A major challenge now is adding diverse social science skills to the team
  - Technical diversity was a big contributor to our technical success
  - Social engineering diversity will likely be key for dissemination

Future Technical Studies

- Optimize mechanical design
  - Optimize ergonomics, safety, portability, cost, and other important factors determined in the field
  - Winnow to produce clean grain ready for milling or sale
  - Multi-user design



Low cost with existing bike concept

Modifying spokes as winnowing fan

Thank you!

Questions?

More info at www.milllet.wetpaint.com