The Xpult

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The Xpult

Key Concepts

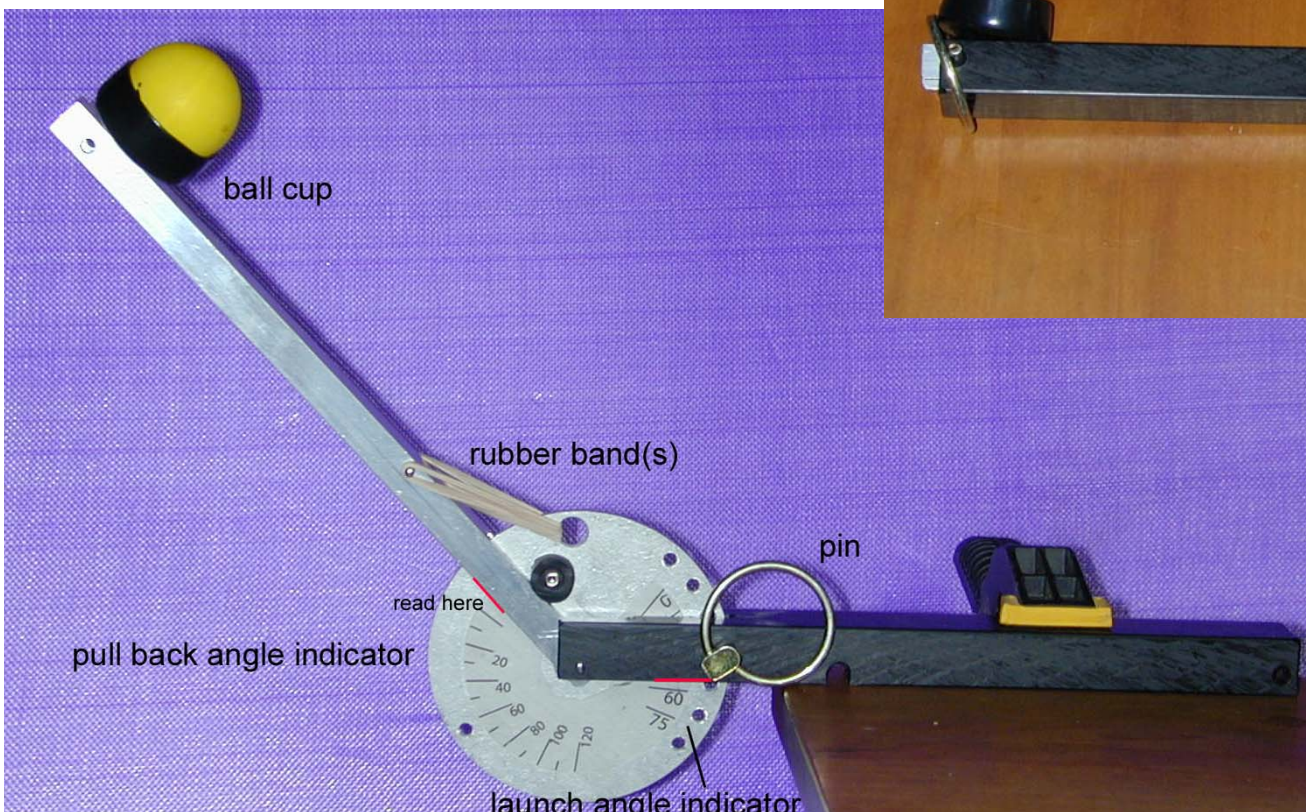
- Process capability
- Reduction of variability
- Design of experiments

Existing Devices

- We did not invent the idea of a catapult for teaching process control.
- Several existing devices.
- Big, heavy, expensive. (e.g., 5kg, $400)

Goal: A catapult for every student (or student team)

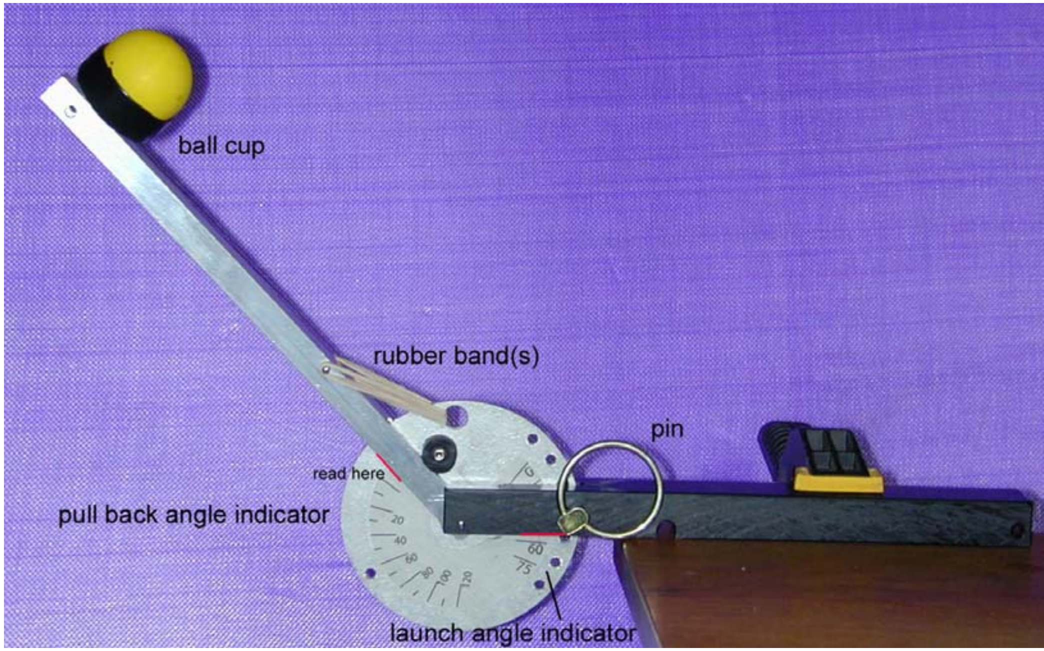
- Target price <$25/kit.
- Small enough to fit in book bag.
- Eliminate obvious coupling of variables.



Basic Operation

- Performance measures
  - Distance launched
  - Percentage of “baskets” made
  - Variance in distance
  - etc.

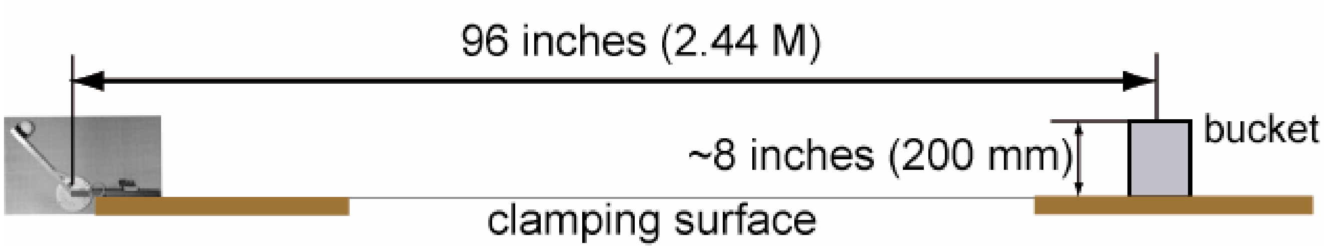
- Independent variables
  - Ball type: perforated or smooth
  - Number of rubber bands: 1, 2, 3
  - Launch angle: 0, 15, 30, 45, 60, 75, 90 degrees
  - Pull-back angle 0-120 degrees



Homework Exercise

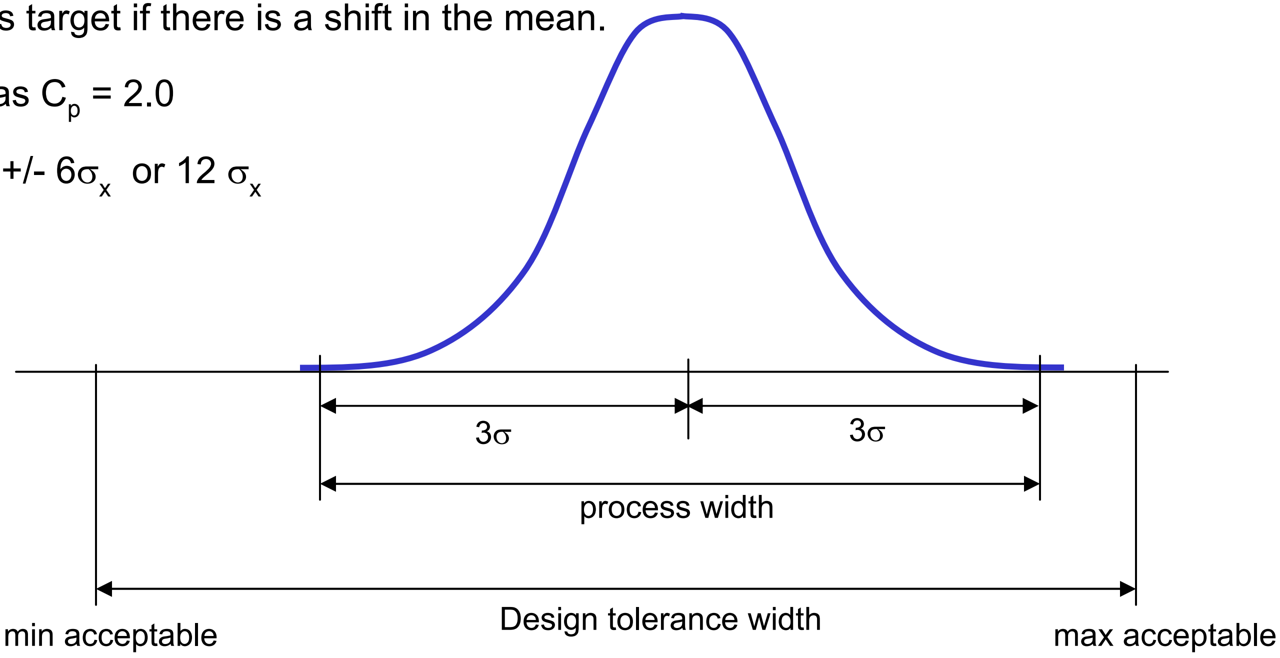
1. Holding everything else constant, how do you expect the variables to influence distance?
   a) When I increase the number of rubber bands, the launch distance _______________.
   b) When I increase the launch angle, the launch distance_________________________.
   c) When I increase the pull back angle, the launch distance_______________________.
   d) I expect the table tennis ball to go ____________ than the perforated plastic ball.
2. Is there exactly one set of values that will result in launching a ball 96 inches?
3. If more than one set of values will work, why might you prefer one set to another?
4. For the ambitious, you might try plotting launch distance as a function of each of the four variables. If you do this, you probably want to hold the other three variables constant at "reasonable" values.

Objective:
Launch the ball into a bucket 96 inches from the catapult pivot, with the bucket opening 8 inches above the clamping surface.



Process Capability

- C_p = (design tolerance width)/(process width) = (max-spec – min-spec)/ /6σ_x
- Example:
  - Plane is “on time” if it arrives between T – 15min and T + 15min.
  - Design tolerance width is therefore 30 minutes
  - σ_x of arrival time is 12 min
  - C_p = 30/6*12 = 30/72 = 0.42
- A “capable” process can still miss target if there is a shift in the mean.
- Motorola “Six Sigma” is defined as C_p = 2.0
  - I.e., design tolerance width is +/- 6σ_x or 12 σ_x



In Class

- Put team settings on screen/board.
- Pick team to demo their settings.
- What are the possible causes of variability in launch distance?
- Define process capability (using different size targets)
- How can capability be increased?
- Basic idea of robustness.
- How might robust settings be found.

Primary School Science and Math Education

- Catapult is popular with 6-12 year olds.
- Can be used to teach graphs, experimentation, scientific method, basic physics.
- Plan to “seed” several hundred units with math and science teachers.

Further Information

Instructions can be downloaded at http://opim.wharton.upenn.edu/~ulrich

XPULT™

EXERCISE AND INSTRUCTIONS

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Abstract
This document provides instructions for use of the Penn Catapult, an instructional aid we have developed for use in teaching experimental design and problem solving. In the ideal situation, individual students or student teams are provided with access to the physical hardware at least one week in advance of the class session in which the exercise will be discussed.

Key words: design of experiments, parameter design, product design, product development, quality management, six sigma, process capability, Taguchi methods, problem solving, process improvement.

New chapter in Ulrich and Eppinger *Product Design and Development* 3rd Edition on "Robust Design."

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