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MEASUREMENT SYSTEMS ANALYSIS VFP COLLOQUIUM

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JUNE 29, 2015

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Outline

1. VFP Overview, 2011-2015
2. The Statapult and Scientific Process
3. Measurement Systems Analysis
4. A Measurement Systems Experiment

Thanks to BNL, DOE and:

Tim Green, Environmental Protection Division
Jennifer Higbie, Environmental Protection Division
Noel Blackburn, Office of Educational Programs
Salvador Gonzalez, Office of Educational Programs
John Heiser, Environmental and climate Science Department

Dowling College

SULI/VFP Students
Suhua Zeng
Tom Fasano
Raffelle Vesia
Matt Bernard

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Overview of VFP Projects

1. **A Series of experiments to create models that predict toxicity %**

Objective Predict toxicity % when controlling pH, temp, aeration, and copper nanoparticles, The toxicity response is based on E.coli

Method A mixture experimental design was constructed to capture two-way interactions

Models Regression model with 15 predictor terms, Ternary Plots

Collaborator Vishal Shah, VFP 2010 to 2012

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Mixture Design Matrix

	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	x14	x15
1	0.125	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063
2	0.063	0.125	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063
3	0.063	0.063	0.125	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063
4	0.063	0.063	0.063	0.125	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063
26	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0	0.071	0.071	0.071	0.071
27	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0	0.071	0.071	0.071
28	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0	0.071	0.071
29	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0	0.071
30	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0
31	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067

Row sums = 1.000 in a mixture design

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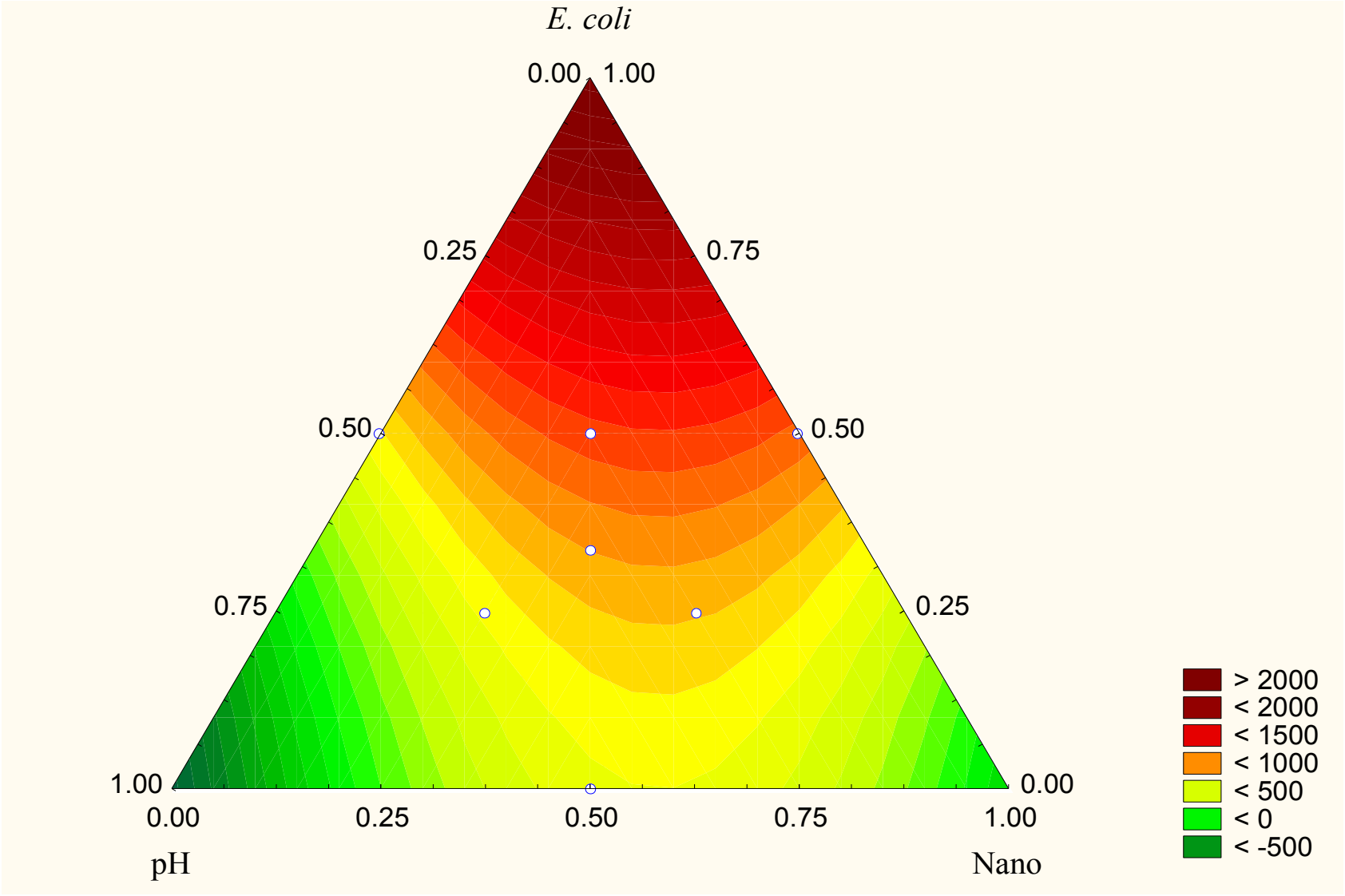
Ternary plots predicting toxicity



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Follow up experiment

Objective Predict toxicity % with 9 input variables: pH, Mg, K, Ca , nano-particles, RPM, E.coli, NOM, and Fructose, and 45 interaction terms

Method Augmented Factorial Design

Models Regression model with 54 terms, and a Polyline Visualization

Rispoli and Shah et. al, ***Journal of Hazardous Materials, 180, (2011)***
Rispoli and Shah et. al, ***PLOS One, (2012)***

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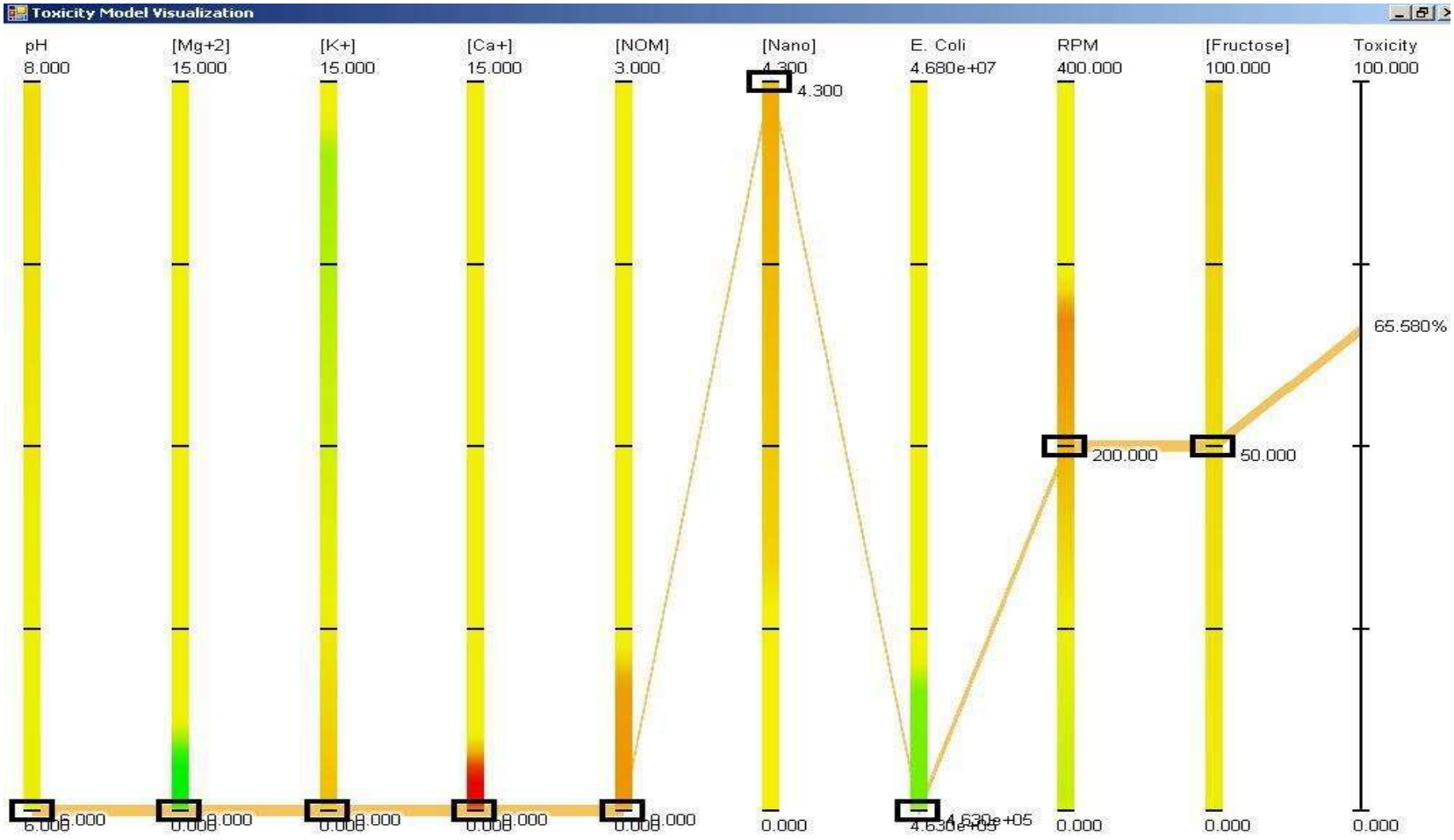
A “Polyline” Visualization for 9 inputs



VFP Projects Overview

2. Problem Because of soil contamination at BNL, some of the deer killed on the site roadways were found to have elevated levels of Cs-137. Since the site property is not fenced, this raised concern over the potential radiation doses
to those who eat venison from deer harvested on or near the BNL site.

BNL Host: **Dr. Tim Green**

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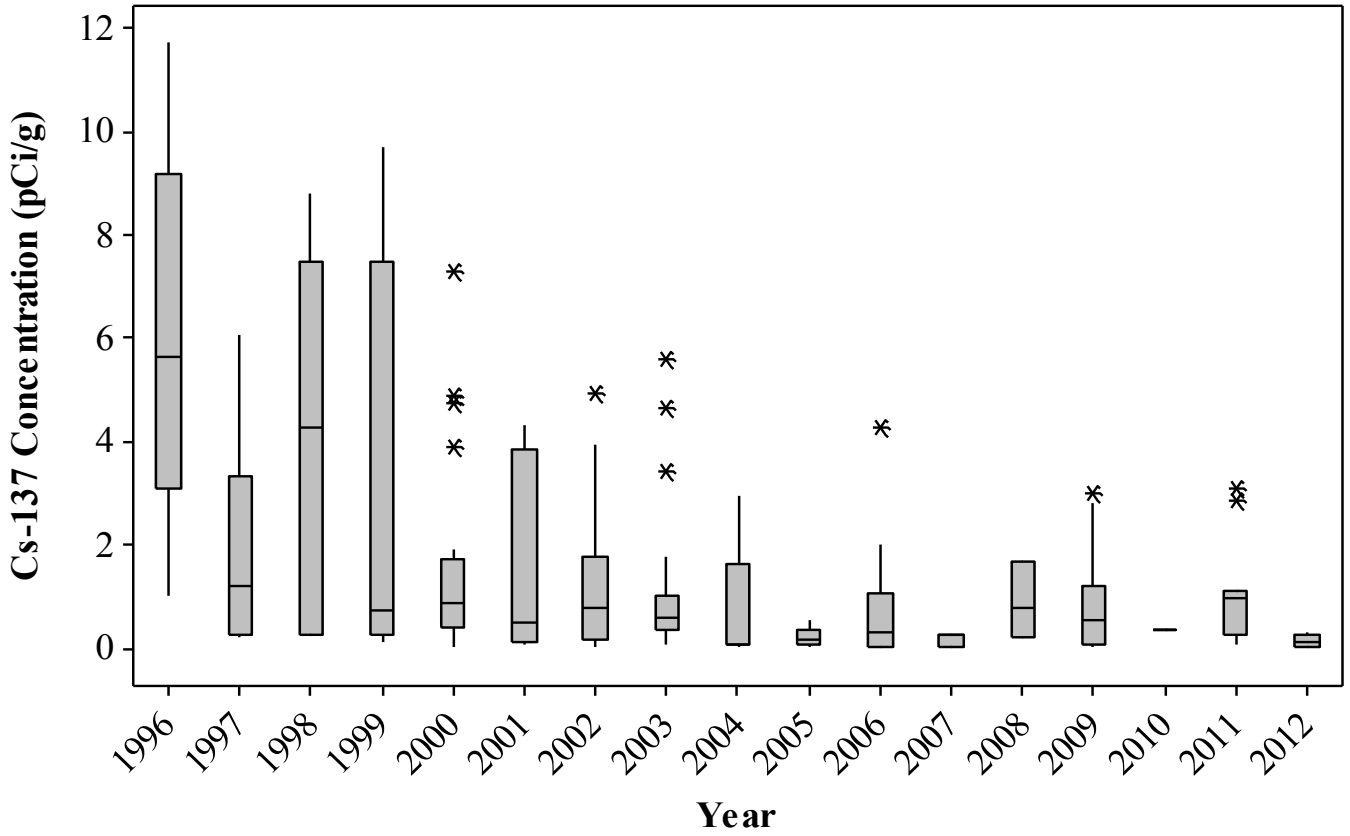
Data Collection and Analysis

Objective Determine if the BNL clean-up that took place from 2000 to 2005 was effective in significantly lowering Cs-137 levels

Data Collection Data was obtained from deer found dead on roads that are onsite (within 1 mile of BNL), and offsite, and
Data was obtained from hunters who allow BNL to remove 2 lbs of flesh of harvested deer to send to a laboratory to determine Cs-137 levels.

Statistics Bar Charts, box plots, time series graphs, non-parametric tests, ANOVA



Onsite, yearly box-plots of the Cesium-137 concentration distribution in the meat of white tailed deer.

Rispoli, Fasano, Green, *Environmental Science and Pollution Research (2014)*

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Formal Analysis

The distribution of Cesium Levels are not normal

Medians and sample size given in table below

	Onsite	Offsite
Pre Clean-up	2.04 pCi/g, 257	0.63 pCi/g, 93
Post Clean-up	1.22pCi/g, 92	0.65 pCi/g, 29

Mann Whitney Statistics Test for Medians:
The difference for Onsite is significant, p = 0.014

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VFP Projects Overview

3. Are Environmental Scientists Using Statistics Correctly? (Tim Green, and Huan Feng, VFP)

Observations of Some Common Flaws

- OFAT (One Factor At a Time) Experiments are not efficient and do not capture interactions, Use Statistical DOE such as Factorial Designs
- Primary outcome measures are not clearly defined or reliable, Use Measurement Systems Analysis, Study Variation Statistically
- Data collection methods are not clear or not reliable, Test methods for consistency, test for correct sample size
- Statistical assumptions are not met, Test for normality, use non-parametric tests
- Models are too sensitive to inputs (not robust), Use simulation to test reliability of models (*Energy and Environment Research*, Vol 5, 2015)

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Current VFP Projects

4. Measuring the effects of environmental changes

a) Has the solar farm effected bird diversity? (Tim Green)

b) How has an overabundant deer population effected bird diversity and vegetation at the BNL Site? (Tim Green)

c) Is a Wind Farm feasible? If so, how does this effect the environment? (John Heiser)

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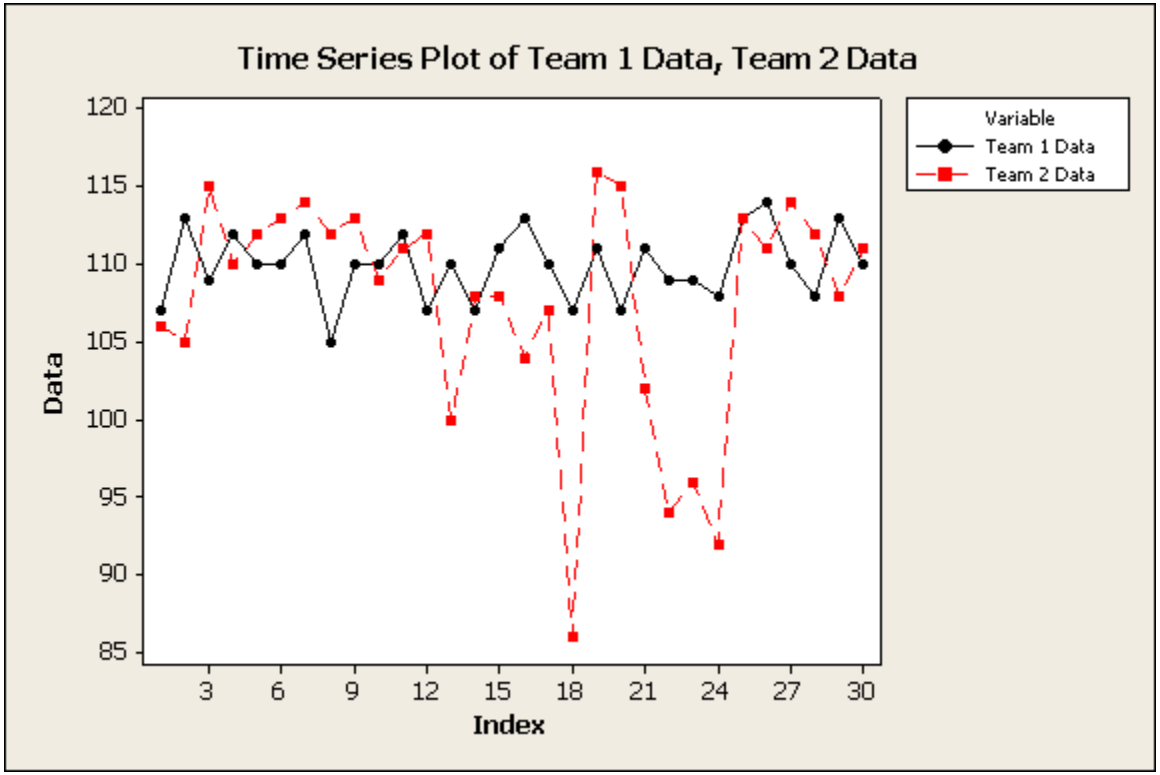
Using the Statapult to Improve/Teach the Scientific Process

- Design, Perform and Multi Factor Experiments
- Minimizing Process Variation and Stability
- Measurement Systems Analysis



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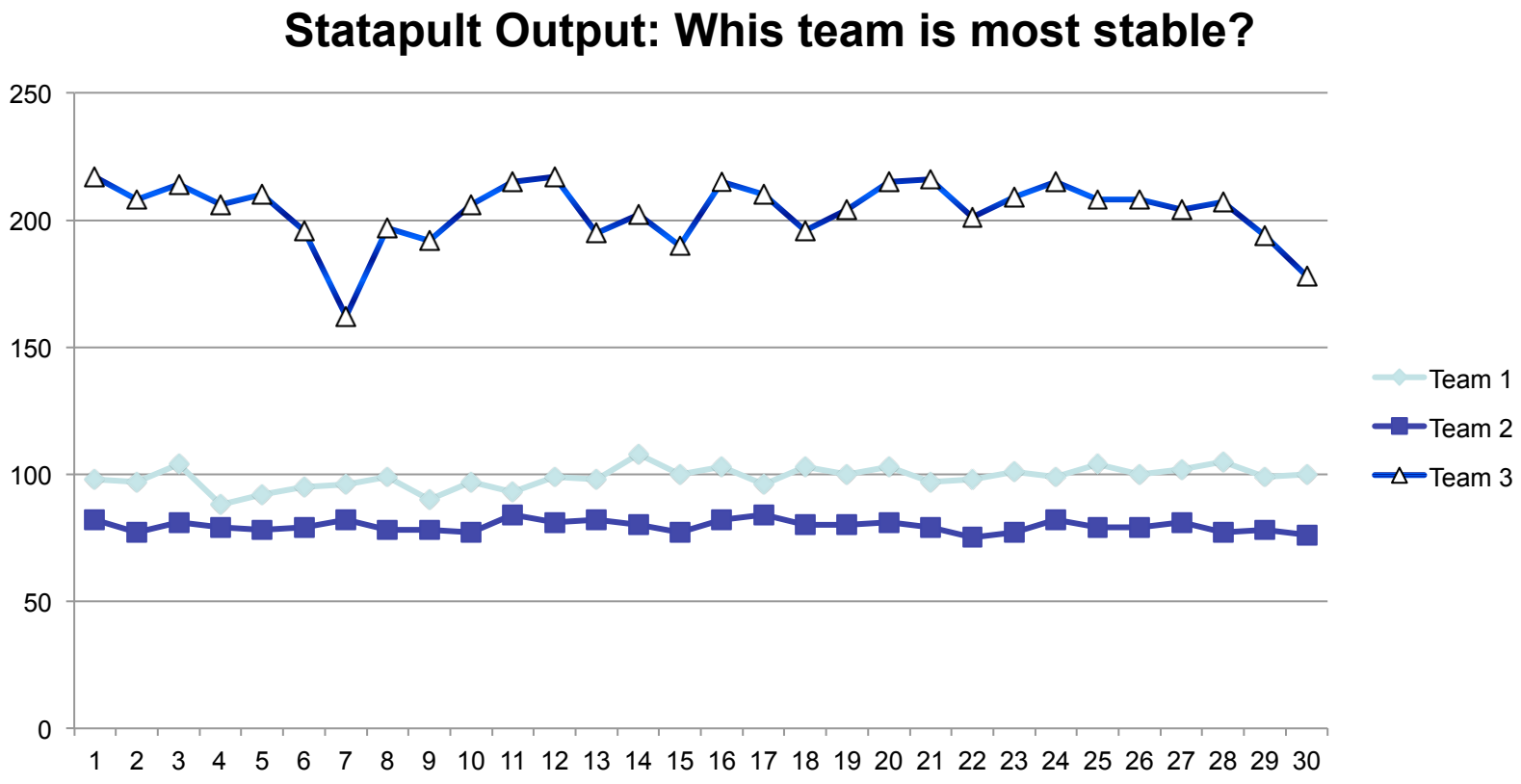
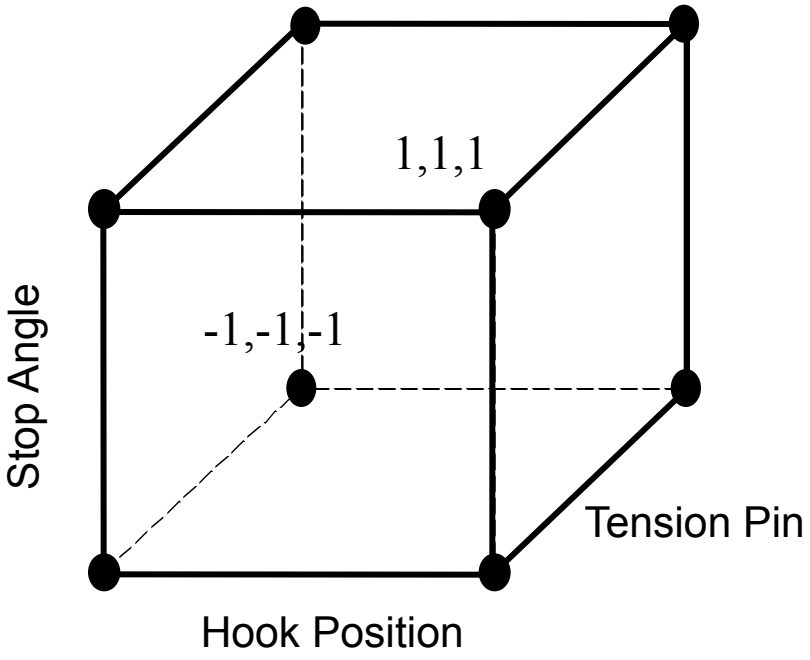
Minimizing Process Variation



A Factorial Design Example

What factor settings make the ball travel the farthest?

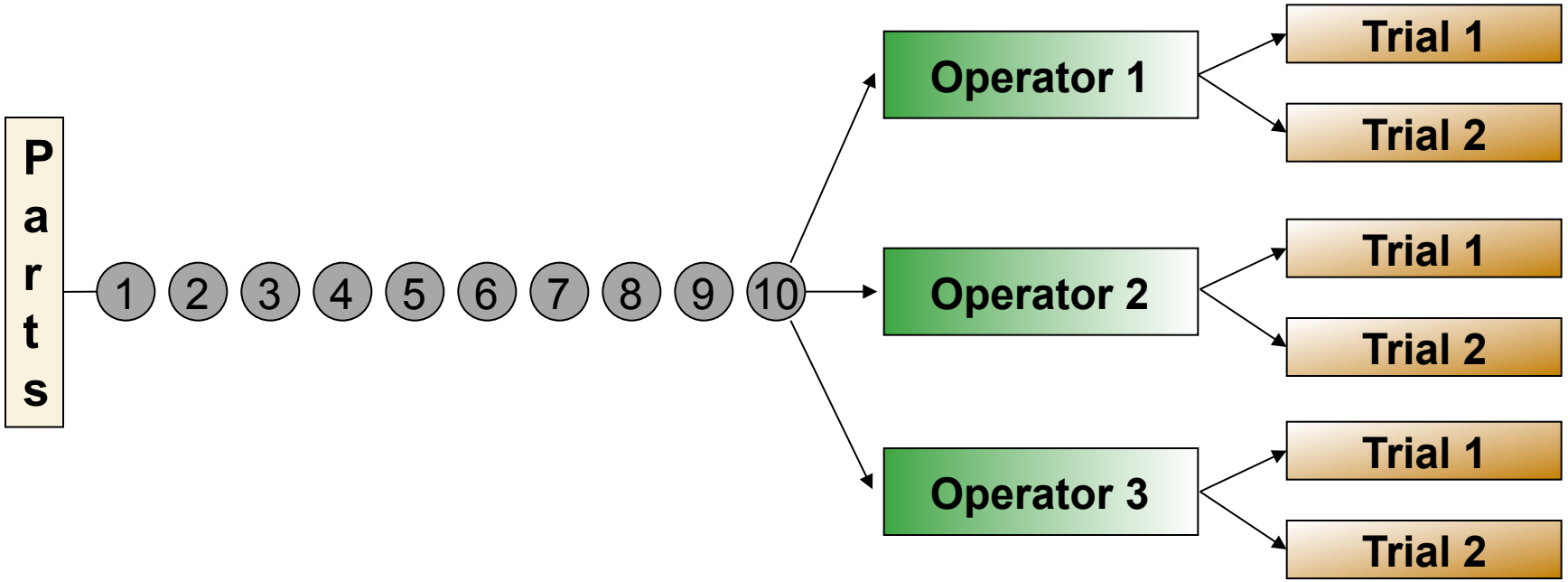


	A	B	C	Response
Run Number	Hook Position	Tension Pin	Stop Angle	Inches Traveled
1	-1	-1	-1	78
2	1	-1	-1	90
3	-1	1	-1	79
4	1	1	-1	85
5	-1	-1	1	92
6	1	-1	1	65
7	-1	1	1	82
8	1	1	1	45

Factorial designs are efficient and allow one to study interactions

Measurement System Analysis, A Typical Study

Measurement Systems Analysis is an experimental study designed to determine how much of the variation in measurements is due to the measurement system, and how much is due to the items being measured.



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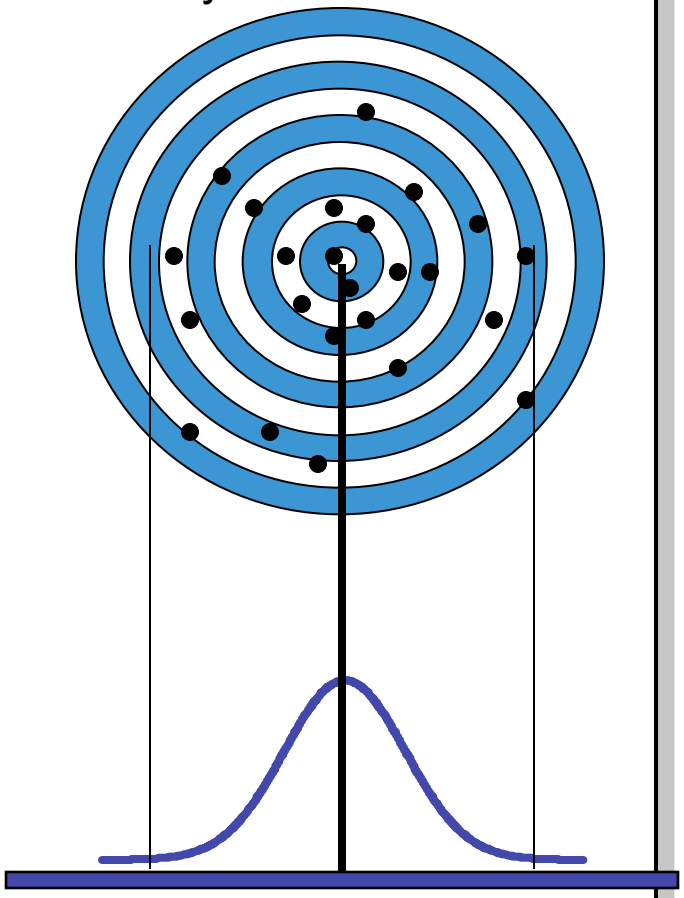
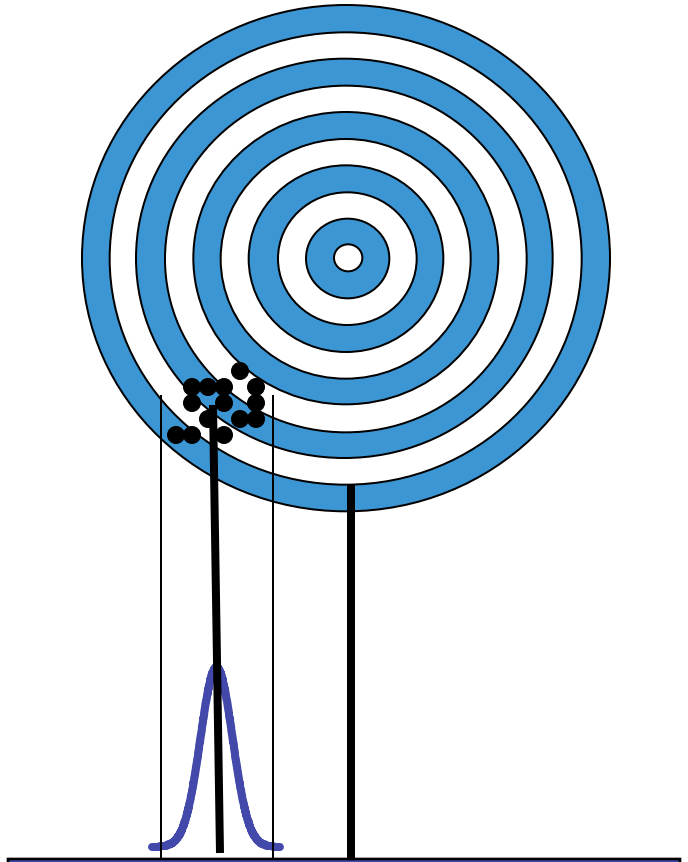
Accuracy vs. Precision

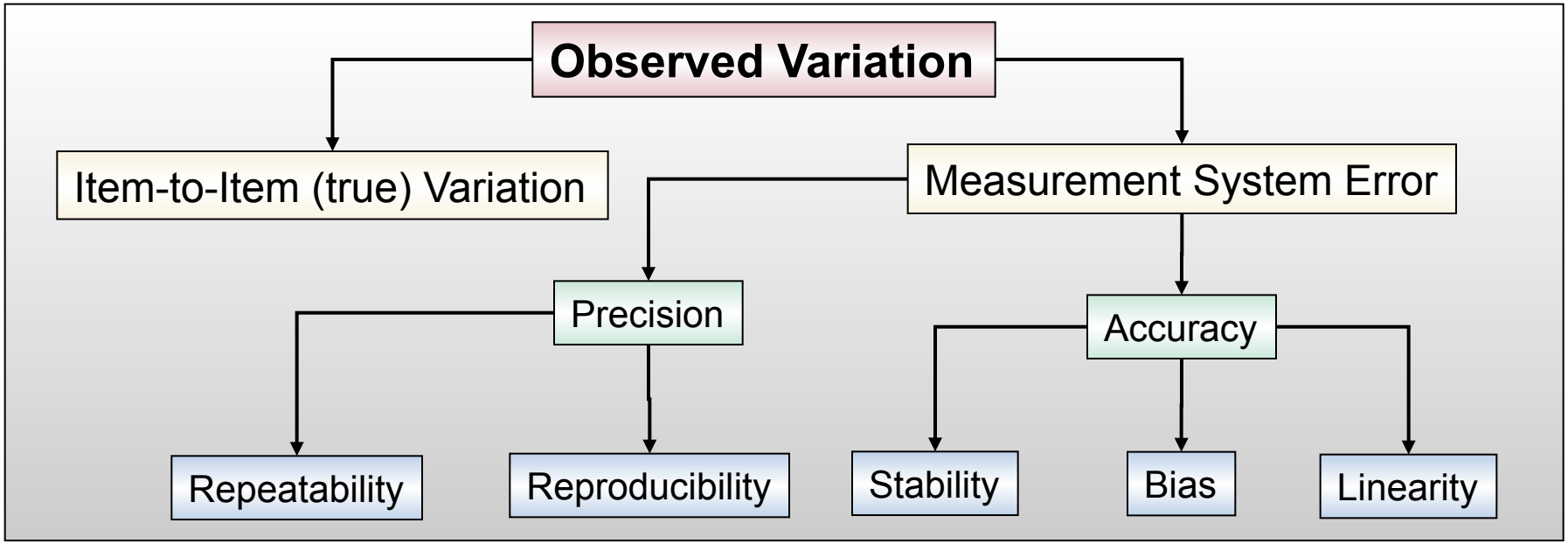
Accurate but not precise - On average, the shots are in the center of the target but there is a lot of variability



Precise but not accurate - The average is not on the center, but the variability is small



Components of Measurement Variation



All measurement systems have error. If you don't know how much of the variation you observe is contributed by your measurement system, you can not reach reliable conclusions.

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Measurement Systems Experiment

1. Organize into teams of 5 or 6 people. For each of the Statapult hook positions (1, 2, 3, 4, 5) launch the Statapult twice. Different hook positions correspond to different items to be measured. Identify 2 or 3 inspectors and have each inspector determine the measure and record the distance. Record the data on the data sheet.

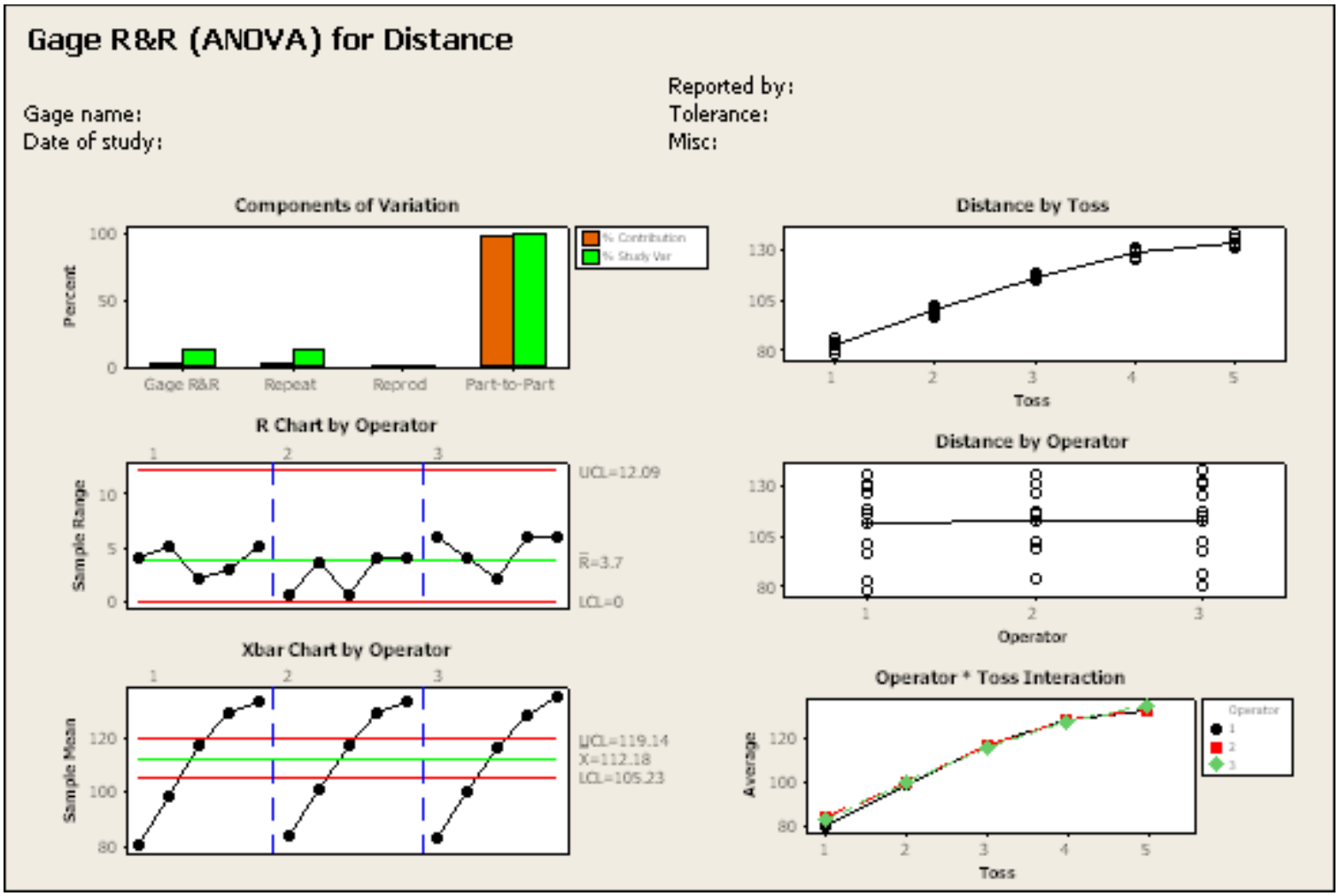
2. Perform a variable Gage R&R study using Minitab. Observe that now,
   - Number of items to measure: 5 (Hook positions correspond to items)
   - Number of inspectors: 2
   - Number of trials: 2

   This is a 5 x 2 x 2 test with 2 inspectors

Minitab Output, Team A

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	6.216	1.35
Repeatability	6.216	1.35
Reproducibility	0.000	0.00
Operator	0.000	0.00
Part-To-Part	453.045	98.65
Total Variation	459.262	100.00

Minitab Output, Team A



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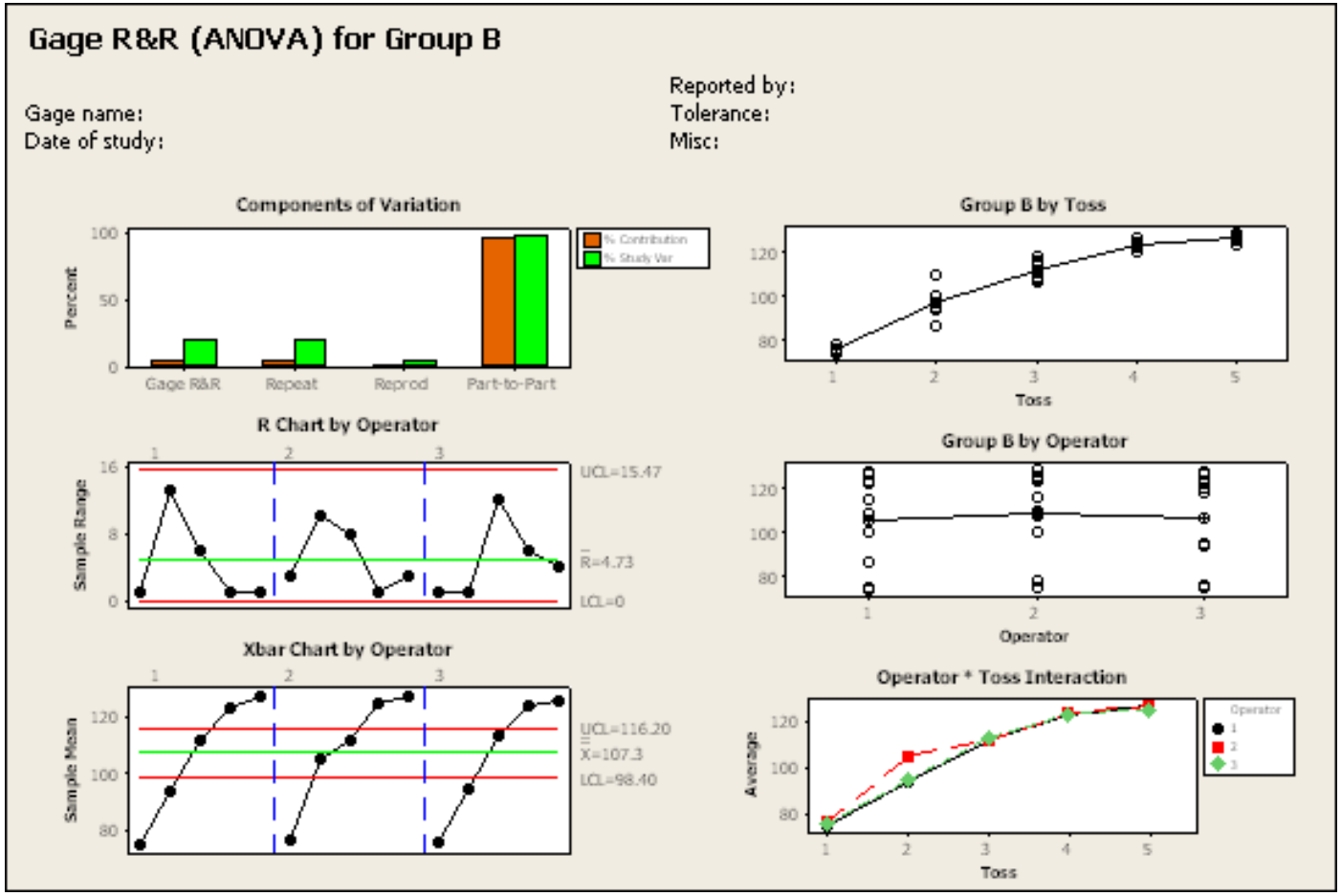
Sample Minitab Output, Team B

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	18.778	4.04
Repeatability	18.120	3.90
Reproducibility	0.658	0.14
Operator	0.658	0.14
Part-To-Part	446.069	95.96
Total Variation	464.847	100.00

Is this acceptable? Which team is better?

Minitab Output, Team B



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VFP carrying out a Measurement Systems Analysis Experiment

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Team A vs. Team B in the MSA Experiment