From Part B lite

- Include a cumulative measurement bias SOP.
- Detail how long overlapping measurements are to be made.
- Changes in personnel (at least 7).
- Changes in instrument (at least 30).
- Change in indicator or in estimator surrogate (at least 50).

- Record the following:
- Average % Bias as average of % difference.
- Statement of direction of Bias.
- 95% t-distribution CI about the mean average % bias.
- SD of mean % bias.
- Sample Size (7, 30, or 50?)
- Precision as Reproducibility Expanded Uncertainty.
- Measurement sensitivity as either MDL or AMS.
- Date measurements started and stopped.
- Date PD was calculated.
- Store paired values.

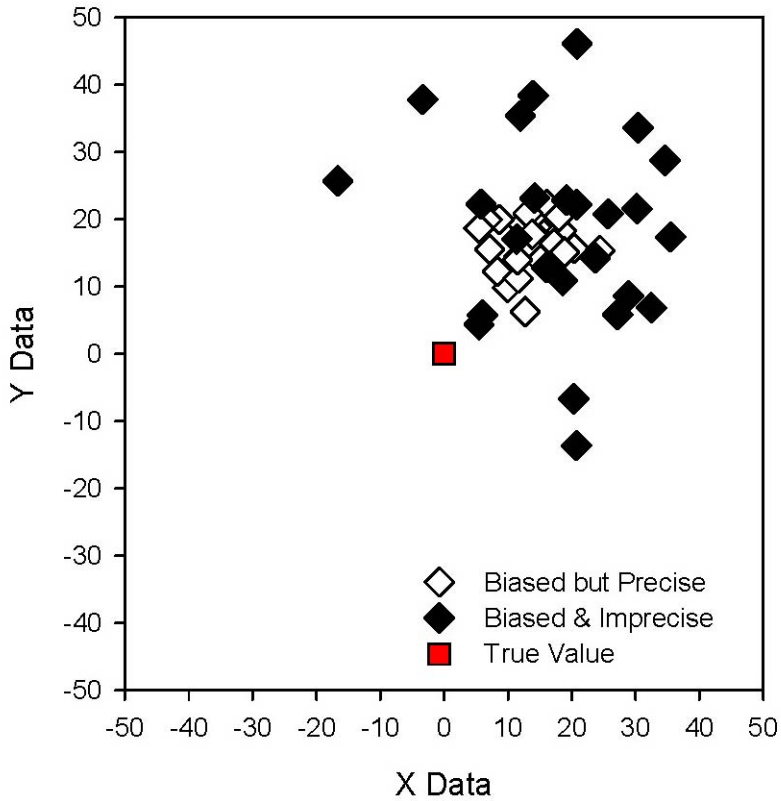
- If the half the 95%CI is greater than 20% of the mean of either value, increase the number of overlapping measurements.
- Normalize to original measurement.

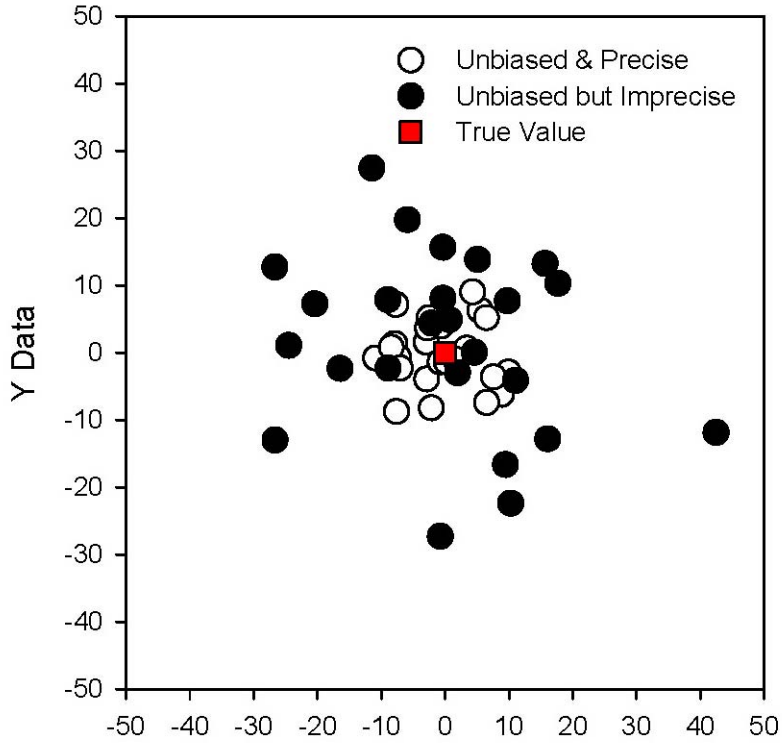
A Different Approach

- T-test: perform t-test or paired t-test as appropriate for data collected.
- If bias detected determine mean difference.
- We can also determine percent difference and then perform a t-test (Ho: mean of percent difference = 0)
- Estimate precision:
  - Variance ration test (Zarr, 1999)
  - Coefficient of variation
- Adjust data

Cumulative Bias

A Case Study


Y Data
X Data
Biased but Precise
Biased & Imprecise
True Value


Y Data
Unbiased & Precise
Unbiased but Imprecise
True Value

MEDN Buys a New pH Meter

- Old reliable Din-o-Sour 101 finally giving up the ghost.
- We purchase state-o-the-art digital, self-calibrating, data-logging, report-writing, self-transporting Hatchet pH meter with the attached cooling compartment for storing your lunch.

Lets Begin

- Following part b lite. We take 30 paired measurements from Always-flowing stream.
- Then perform a paired t-test.

Paired T-Test and CI: Dino, Hatch

```
Paired T for Dino - Hatch

             N     Mean   StDev  SE Mean
Dino        30   7.4488  0.2562   0.0468
Hatch       30   7.7397  0.2070   0.0378
Difference  30  -0.2910  0.2907   0.0531


95% CI for mean difference: (-0.3995, -0.1824)
T-Test of mean difference = 0 (vs not = 0): T-Value = -5.48  P-Value = 0.000
```

Power and Sample Size

```
1-Sample t Test

Testing mean = null (versus not = null)
Calculating power for mean = null + difference
Alpha = 0.05  Assumed standard deviation = 0.2907


Sample
  Size  Power  Difference
    30    0.4    0.093662
    30    0.6    0.121514
    30    0.8    0.153849
    30    0.9    0.178038
```

Variance Ratio Test

$$F = \frac{s^2_{large}}{s^2_{small}} = \frac{0.0656}{0.0428} = 1.533$$

Cumulative Distribution Function

```
F distribution with 29 DF in numerator and 29 DF in denominator

    x  P( X <= x )
1.533     0.872067

Probability that the variances are equal = 1 - 0.872067 = 0.127933
```

One-Sample T: H-D/D*100

```
Test of mu = 0 vs not = 0


Variable    N   Mean  StDev  SE Mean      95% CI         T      P
H-D/D*100  30  0.552  0.566    0.103  (0.341, 0.763)  5.34  0.000
```

Coefficient of Variation for pH data from the two instruments evaluated.

Din-o-sour 101	Hatchet 1000
3.43921	2.67397

Paired T-Test and CI: Dino(new), Hatch

```
Paired T for Dino(new) - Hatch

              N    Mean   StDev  SE Mean
Dino(new)    30  7.7431  0.0469   0.0086
Hatch        30  7.7397  0.2070   0.0378
Difference   30  0.0034  0.2016   0.0368


95% CI for mean difference: (-0.0719, 0.0787)
T-Test of mean difference = 0 (vs not = 0): T-Value = 0.09  P-Value = 0.927
```

Paired T-Test and CI: Dino, Hatch

```
Paired T for Dino - Hatch

             N     Mean   StDev  SE Mean
Dino        30   7.4488  0.2562   0.0468
Hatch       30   7.7397  0.2070   0.0378
Difference  30  -0.2910  0.2907   0.0531


95% CI for mean difference: (-0.3995, -0.1824)
T-Test of mean difference = 0 (vs not = 0): T-Value = -5.48  P-Value = 0.000
```

Power and Sample Size

```
1-Sample t Test

Testing mean = null (versus not = null)
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Sample
  Size   Power   Difference
    30     0.4     0.093662
    30     0.6     0.121514
    30     0.8     0.153849
    30     0.9     0.178038
```
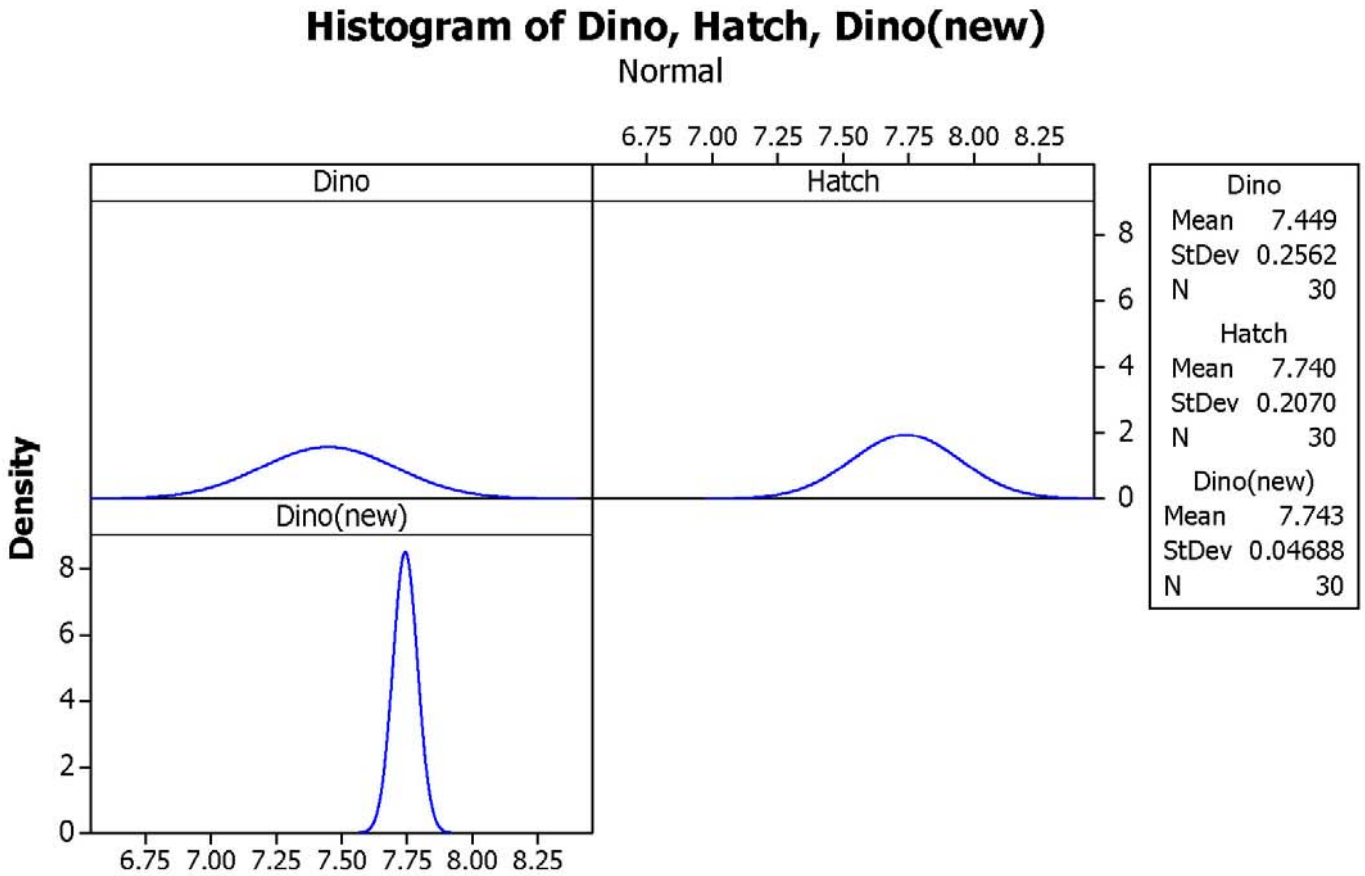

Power and Sample Size

1-Sample t Test

Testing mean = null (versus not = null)
Calculating power for mean = null + difference
Alpha = 0.05 Assumed standard deviation = 0.2907

Difference	Sample Size	Power
0.100	30	0.44509
0.150	30	0.77983
0.200	30	0.95360
0.250	30	0.99519
0.291	30	0.99957
0.300	30	0.99977
0.350	30	0.99999


Histogram of Dino, Hatch, Dino(new)
Normal
Dino
Hatch
Dino(new)
Density
6.75 7.00 7.25 7.50 7.75 8.00 8.25
0 2 4 6 8
Dino
Mean 7.449
StDev 0.2562
N 30
Hatch
Mean 7.740
StDev 0.2070
N 30
Dino(new)
Mean 7.743
StDev 0.04688
N 30