Measuring Schedule Uncertainty

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Objectives

- Target Audience
  - Schedule Analysts with an interest in broadening their understanding of Schedule Analytics
  - PMs with an interest in broadening their understanding of Schedule Analytics
  - PMs struggling with inadequate and useless schedule analytics
- Purpose
  - Educate the audience on Schedule Risk Assessments (SRA), their value and how they are conducted
  - Promote improvement and innovation within the schedule analytics industry

My Journey to Analysis of Schedule Uncertainty

- Air Force Minuteman III Program (2002 – 2007)
  - Cost Analytics
- NASA Constellation Program (2007 – 2011)
  - My first introduction to Schedule Risk Analysis and Joint Cost/Schedule Risk Analysis
- Navy SSP Program (2011 – 2016)
  - Cost Analytics
- Air Force Minuteman III Program (2016 – 2018)
  - Joint Cost and Schedule Analysis
- Air Force Sentinel Program (2018 – Present)
  - Schedule Risk Analysis (SRA) and general schedule analytics

Joint Cost & Schedule Analysis

- Requirements of a Joint Cost & Schedule Analysis
  - Cost Risk and Uncertainty Analysis
    - Quality cost estimates assess the uncertainty of cost as well as the impact of program risks on the cost
  - Schedule Risk and Uncertainty Analysis
    - Quality schedule estimates account for schedule uncertainties as well as the impact of program risks on the schedule
- Joint Cost & Schedule Analysis
  - Maps cost elements to schedule elements
  - Defines the relationship between cost and schedule
  - Simulates the impact of schedule uncertainty on cost

Traditional Techniques for Assessing Schedule Uncertainty

- Small Schedules
  - Analyze each task to determine the likely duration of the task as well as the duration given the best case and the worst case

Name	Duration	Start	Finish	JACS Duration Uncertainty
Spares Provisioning Conference - Conducted	**45 d**	**Fri 4/11/25**	**Mon 6/16/25**	
Submit CDRL to Govt: Spares Provisioning Conference Meeting Agenda [CDRL A001]	0 d	Fri 4/11/25	Fri 4/11/25	
Prepare Spares Provisioning Conference Meeting/Briefing Materials [CDRL A002]	30 d	Mon 4/14/25	Fri 5/23/25	Tri*(95,100,125,0,100)
Submit CDRL to Govt: Spares Provisioning Conference Meeting/Briefing Materials [CDRL A002]	0 d	Fri 5/23/25	Fri 5/23/25	
!SVT! Spares Provisioning Conference-7d lead time task	5 d	Tue 5/27/25	Mon 6/2/25	Tri*(95,100,125,0,100)
Conduct Spares Provisioning Conference	0 d	Mon 6/2/25	Mon 6/2/25	
Submit CDRL to Govt: Spares Provisioning Conference Meeting Minutes and Action Items [CDRL A003]	10 d	Tue 6/3/25	Mon 6/16/25	Tri*(90,105,150,0,100)
Spares and Repairs PHS&T Design - Completed	**150 d**	**Tue 6/17/25**	**Tue 1/27/26**	
Perform Spares and Repairs PHS&T Design	120 d	Tue 6/17/25	Fri 12/5/25	Tri*(90,105,150,0,100)
Review and Approve Spares and Repairs PHS&T Design	30 d	Mon 12/8/25	Tue 1/27/26	Tri*(90,110,225,0,100)
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- Not Applicable to GBSD
  - Schedule has more than 30,000 tasks

Traditional Techniques (continued)

- Large Schedules
  - Create an analysis schedule
    - Not feasible for GBSD
  - Employ binning structure
    - Binning structures have significant advantages (next slides)
    - Binning structures have significant problems (next slides)
    - Technology allows for large-scale Monte Carlo simulations
  - Create custom uncertainty distributions
    - Based on program history
    - Technology facilitates implementation

Traditional Techniques (continued)

- Large Schedules

Risk Level	Decision Rule Set	Low Bound	Most Likely	High Bound
Low	Known Technology/Known Process Frequently employed	95%	100%	125%
Medium	Known Technology / Some Organizational experience	90%	105%	150%
High	Known Technology / No organization knowledge	90%	105%	200%
Very High	Unknown Technology / No organizational knowledge	90%	110%	225%

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Assessment of Traditional Techniques

- Strengths:
  - Easy to employ
  - A well-developed ruleset allows for common understanding of the interpretation of the results
  - Most all team members can contribute to the assessment
- Weaknesses:
  - There is not an industry convention (best practice) for defining the Low and High bounds
  - Very little investment has been made to measure schedule task variance, so the fidelity of the assessments are questionable

Traditional Techniques (continued)

- Large Schedules

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Approach in the Sentinel Program

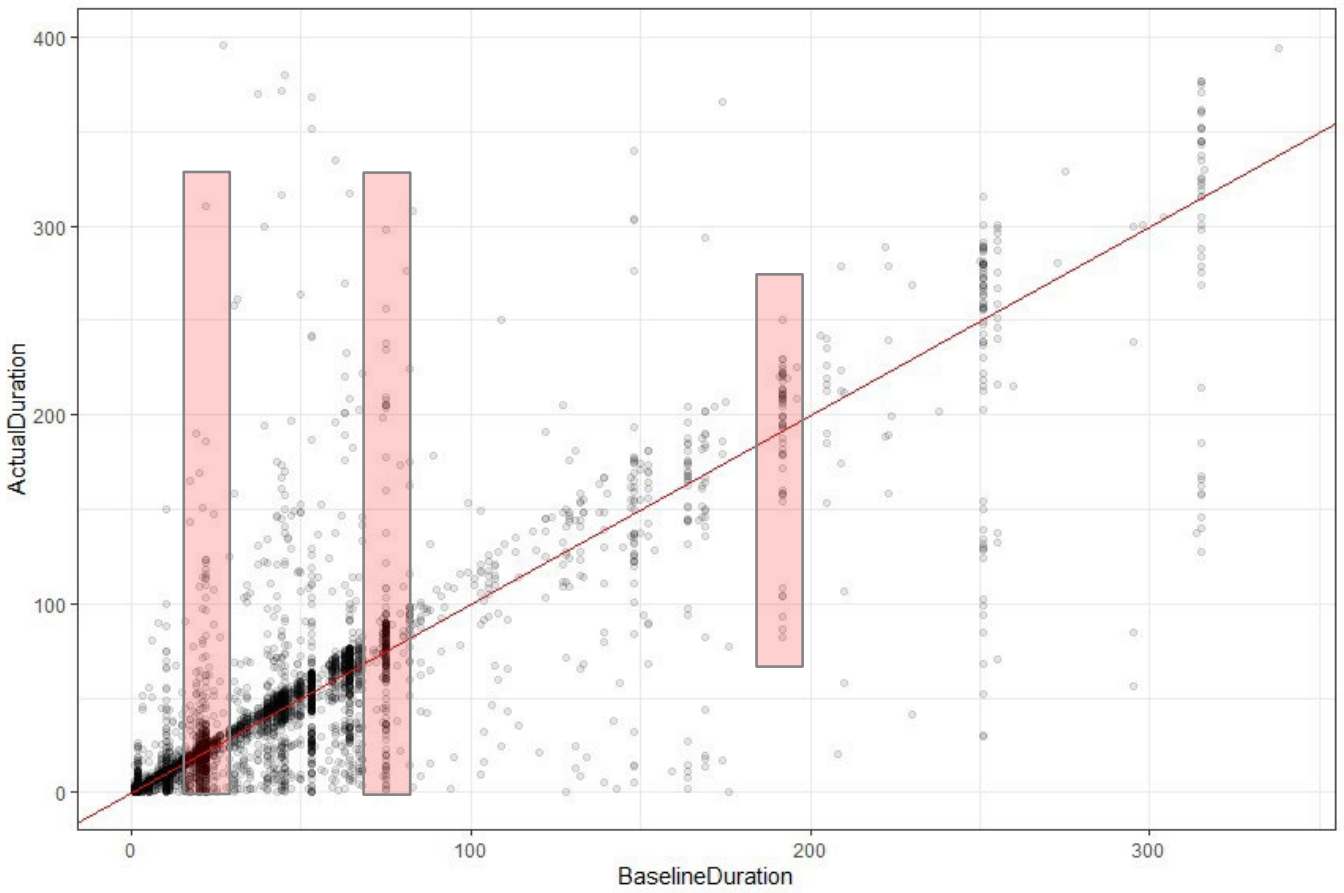
- Integrated Master Schedule (IMS) reporting requirement
  - Major fields of interest
    - Baseline Duration (Baseline Start & Finish Dates used for validation)
    - Actual Duration (Actual Start & Finish Dates used for validation)
    - Organization Breakdown Structure (OBS)
- Database development
  - Needed to capture each schedule delivery and allows us to track performance over time
  - Allows us to query the database for the fields of interest and filter to the tasks of interest (e.g. completed tasks, non-summary tasks)

Approach in the Sentinel Program

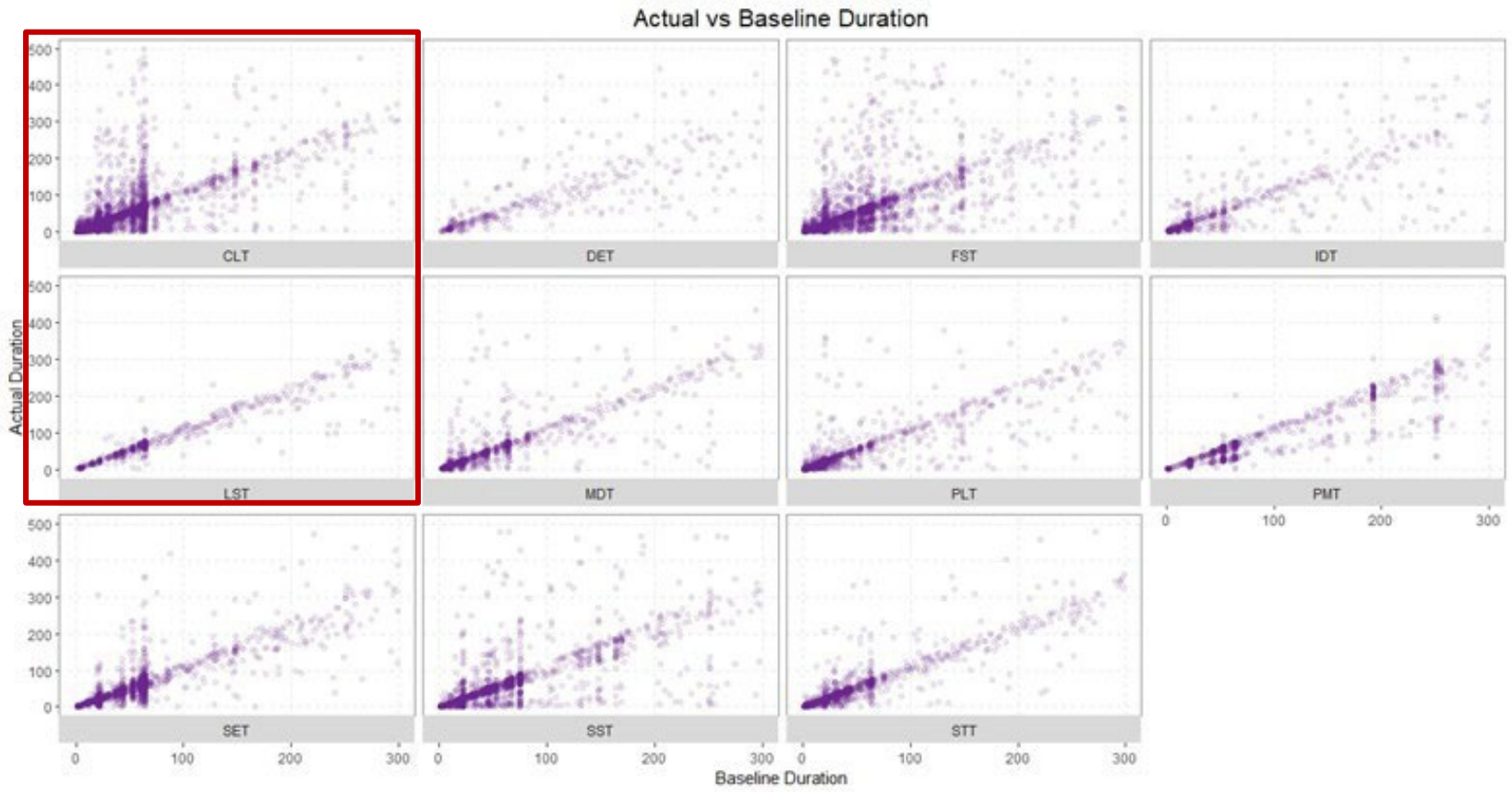
- Goal: Develop a ruleset for assigning uncertainty based on historical performance
- Process:
  - Measure the relationship between baseline duration and actual duration
  - Identify distributions by OBS
  - Employ more advanced clustering techniques
- Note: All data in this presentation has been simulated

Correlation Between Baseline & Actual Duration

- There is a strong correlation between baseline duration and actual duration
- There exists a lot of variability
- Some clustering based on baseline duration clearly exists

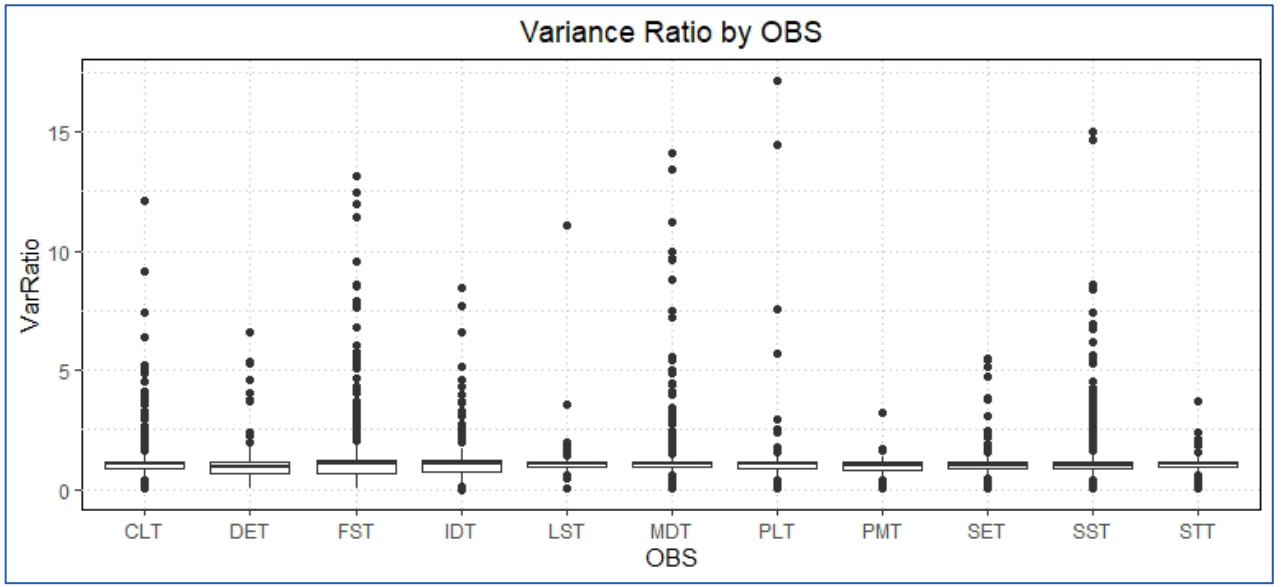


Correlation based on OBS



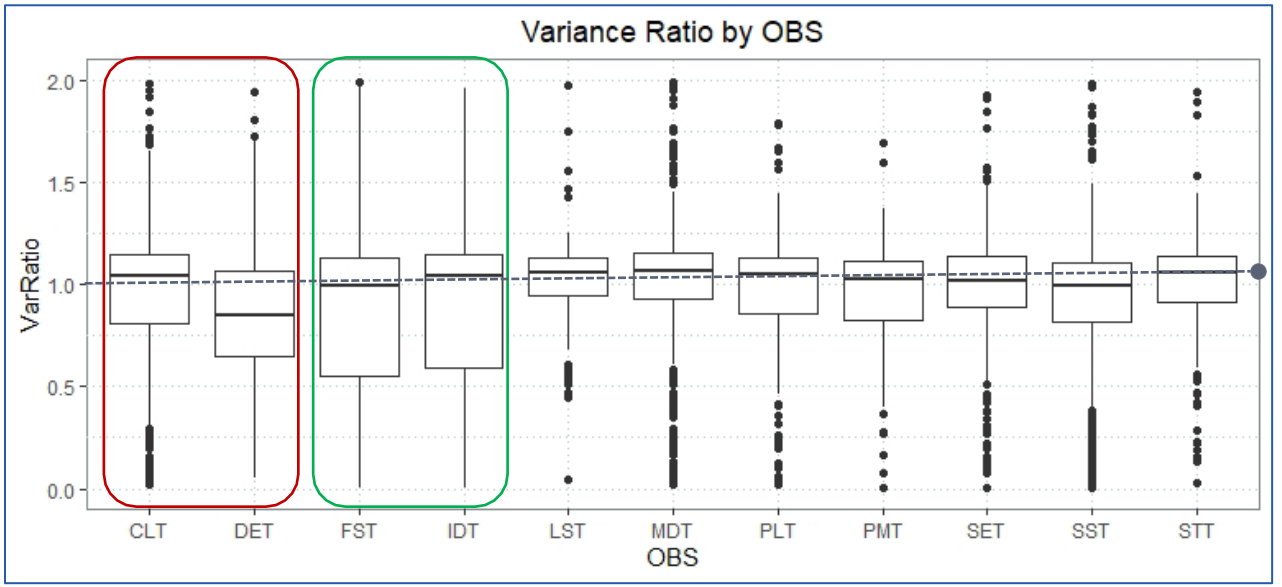
- Segregated by OBS, it seems clear that the different organizations perform differently (e.g. the variation within CLT seems to be significantly different from that of LST)

Uncertainty by OBS



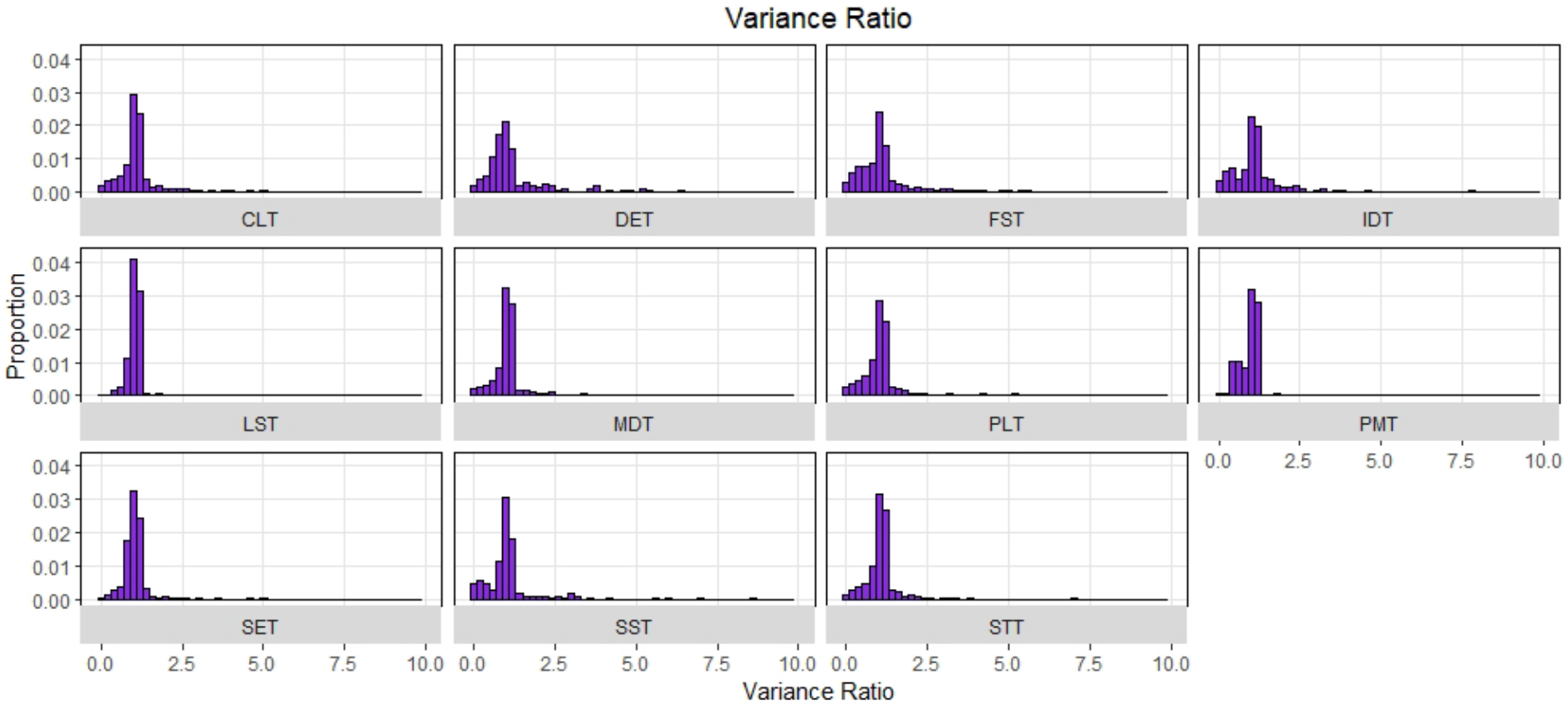
- Variance Ratio = ActualDuration / BaselineDuration
- Boxplots of the distributions illustrate the large amount of variability of thee data (some activities take 10 – 20 times longer than their baselined duration)
- The scale of the chart makes it difficult to analyze the distributions

Uncertainty by OBS (continued)



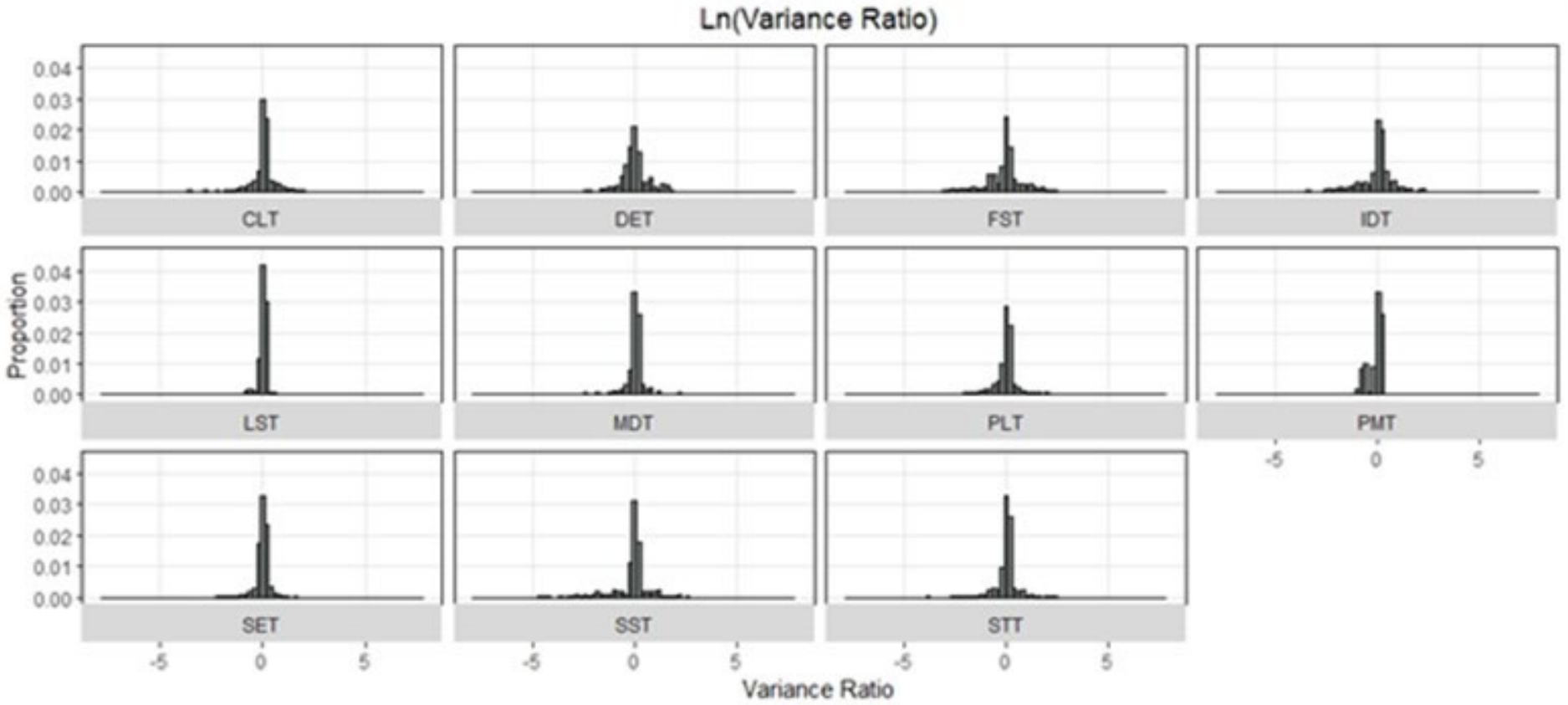
- The "zoomed-in" view allows us to identify some important attributes
  - Some of the distribution appear to be similar while others appear to be different
  - The median of several distributions appear to be slightly greater than 1 for half of the OBSs

Distributions by OBS



- Most (but not all) of the distribution have a peak around 1.0 and a tail to the right (i.e. LogNormal)

Transformed Variables



- Levene's Test
  - It will be noted that the distributions for LST and PMT may not be normal.
  - Instead of using the ANOVA test we will use the Levene's Test
  - Evaluate the equality of variances for a variable determined by two or more groups and is less sensitive to departures from normality than other tests.

Levene's Test Output

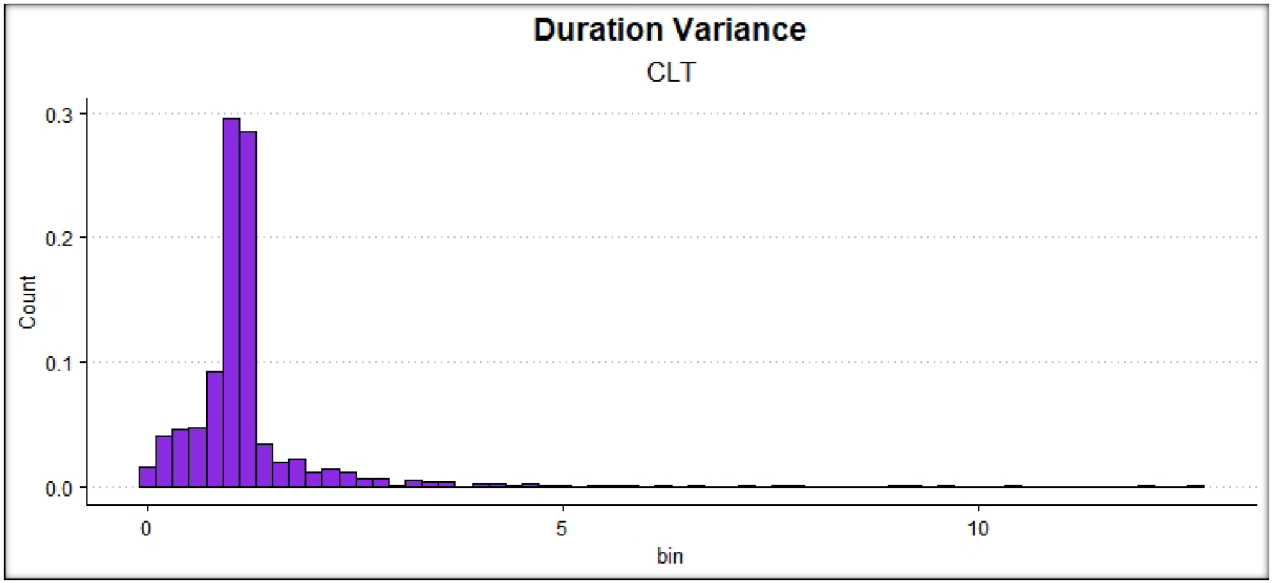
Levene's Test for Homogeneity of Variance			
	Df	F value	Pr(>F)
OBS	10	56.351	< 2.2e-16

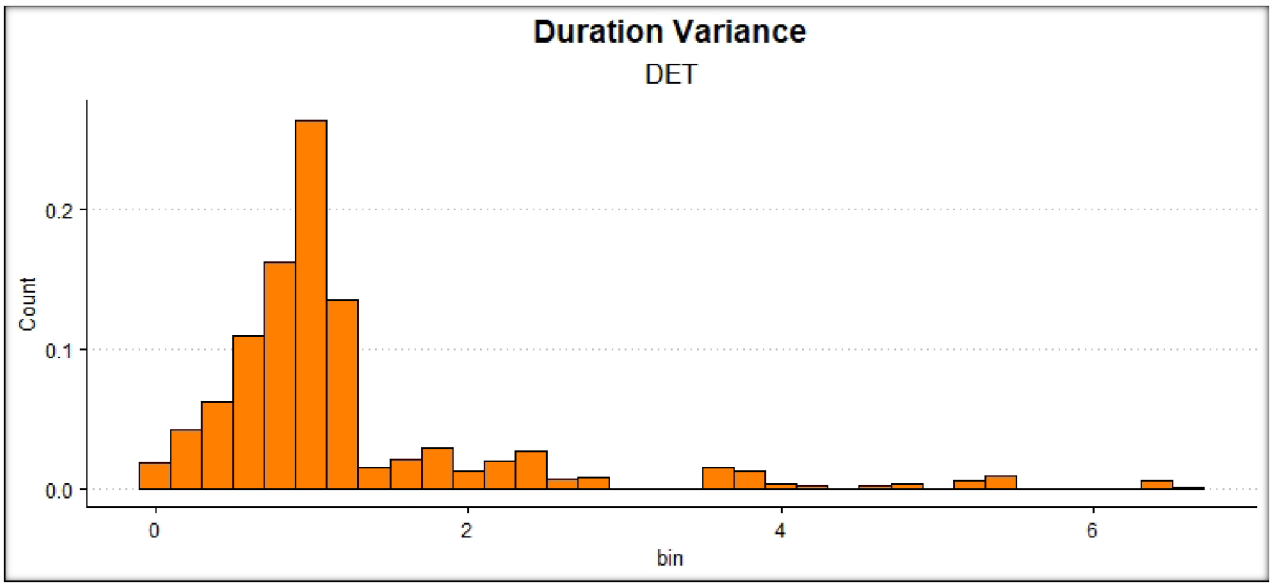
ANOVA for Pairwise Homogeneity										
	DET	FST	IDT	LST	MDT	PLT	PMT	SET	SST	STT
CLT	0.171	0.000	0.000	0.000	0.042	0.000	0.000	0.000	0.000	0.000
DET		0.000	0.000	0.000	0.503	0.000	0.000	0.000	0.000	0.000
FST			0.347	0.000	0.000	0.069	0.000	0.000	0.016	0.000
IDT				0.000	0.000	0.006	0.000	0.000	0.143	0.000
LST					0.000	0.000	0.000	0.000	0.000	0.000
MDT						0.000	0.000	0.000	0.000	0.000
PLT							0.000	0.000	0.000	0.000
PMT								0.040	0.000	0.000
SET									0.000	0.000
SST										0.000

- The p-value from Levene's test clearly suggests that we reject the hypothesis of homogeneity of variance between the OBS's
- To identify those distribution that are likely dissimilar from the other. We perform ANOVA on pairwise combinations.
  - Some, but relatively few combinations may share distribution

Correlation Between Baseline & Actual Duration

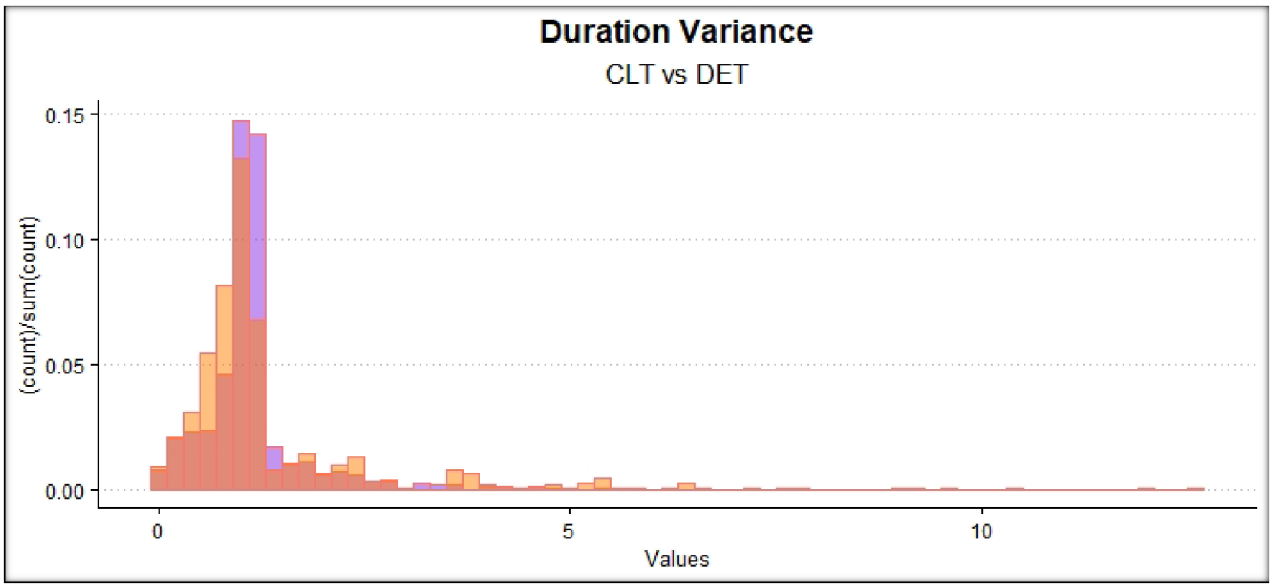
- CLT and DET distributions seem to be distinct
- Scales differences makes it difficult to evaluate with certainty





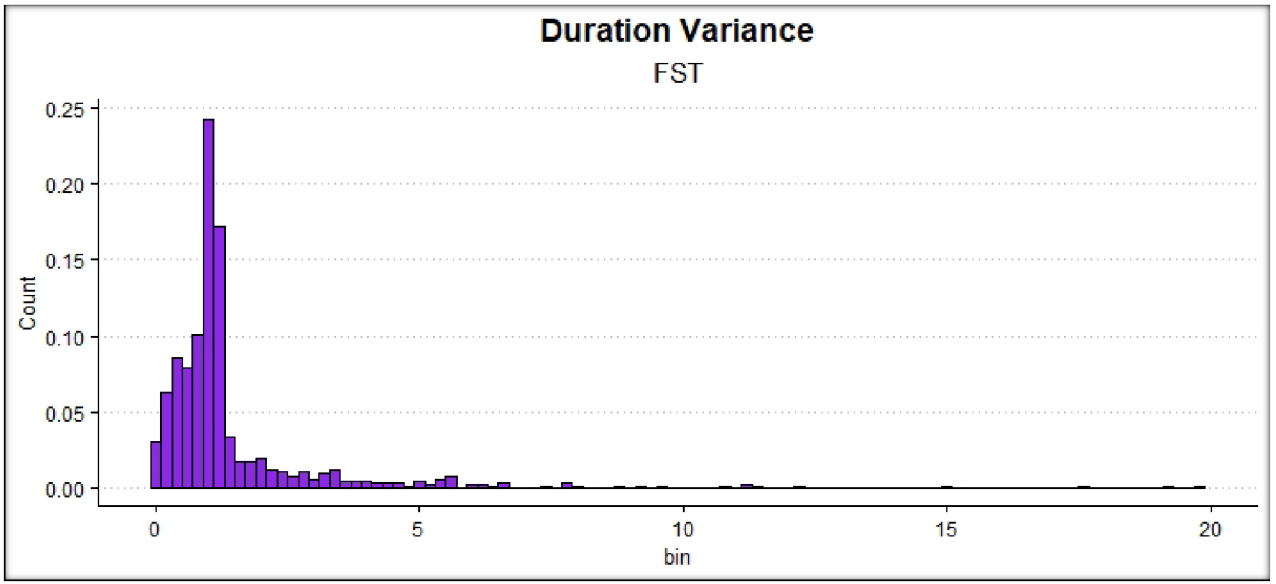
Correlation Between Baseline & Actual Duration

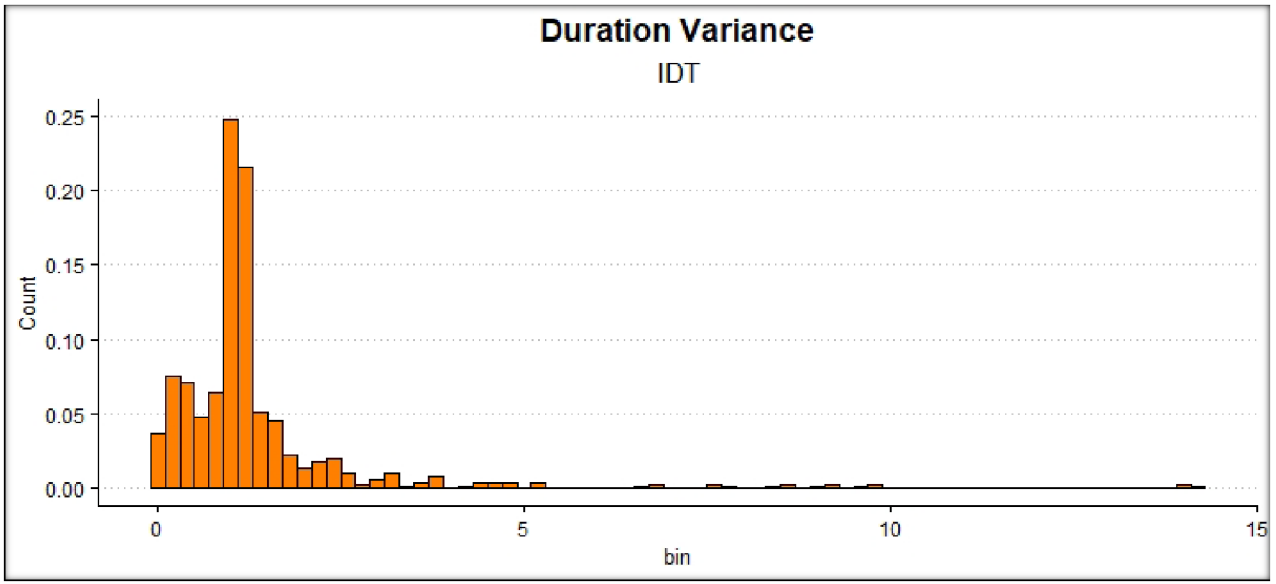
- Plotted on the same chart illustrates that the distributions are likely different
- The significance of the difference must be calculated statistically



Correlation Between Baseline & Actual Duration

- FST and IDT boxplots looked more similar than the side-by-side comparison
- Scales are different which could mask the similarities





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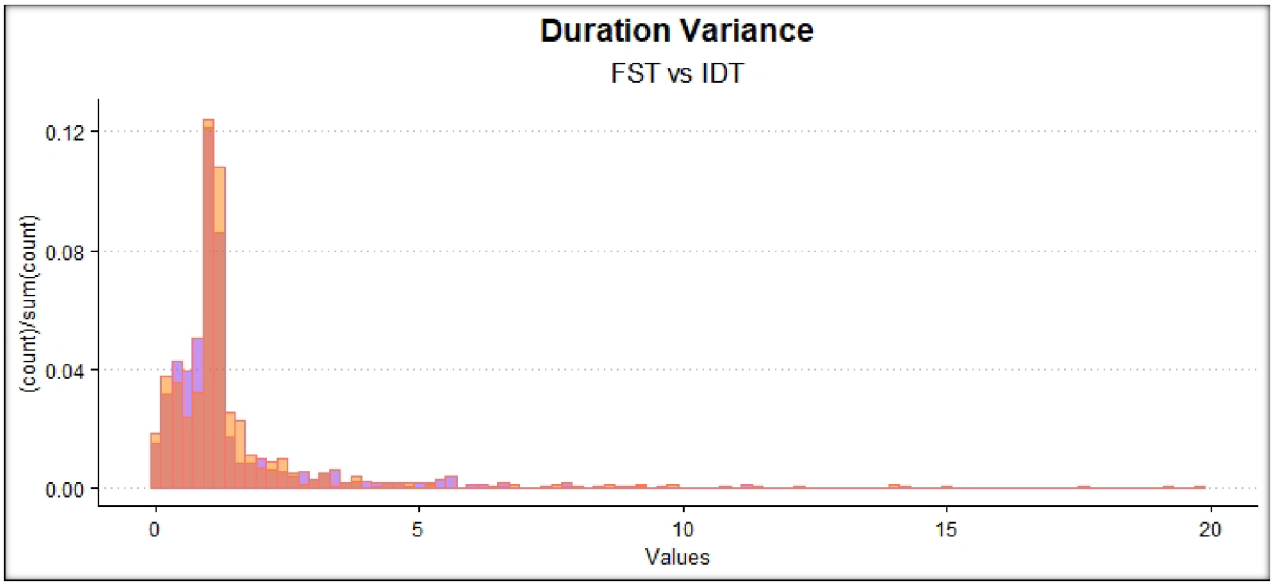
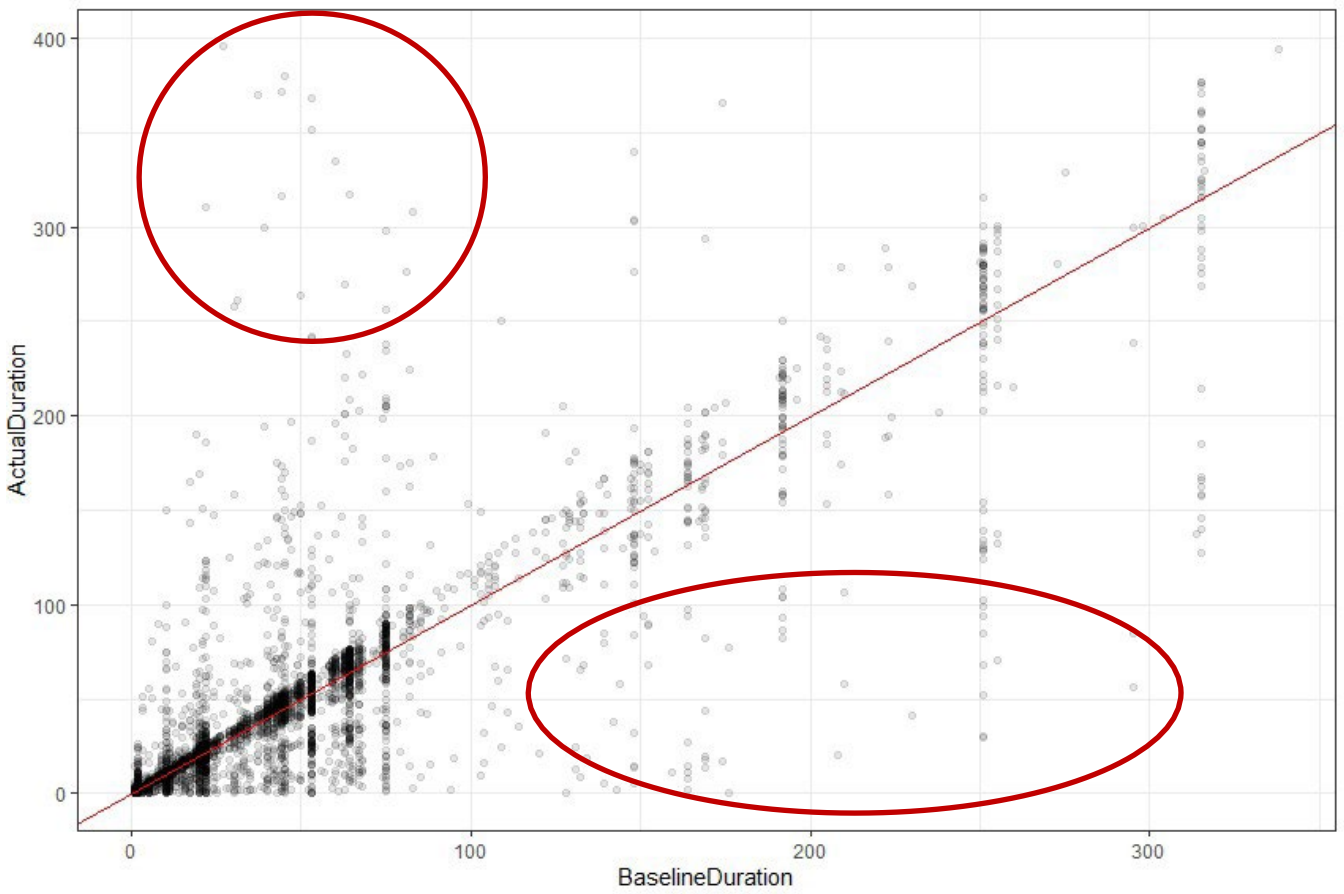


Conclusion

- Sentinel SRA was able to produce a ruleset that employed the Baseline Duration and the OBS to establish the pertinent distribution
- Strengths
  - The distribution were based on program data
  - The ruleset allowed for analysis of the IMS without having to produce an analysis schedule
- Weaknesses
  - Past performance may not be an indicator of future performance
    - Type of future work may be significantly different
    - The prime contractor experienced many startup challenges

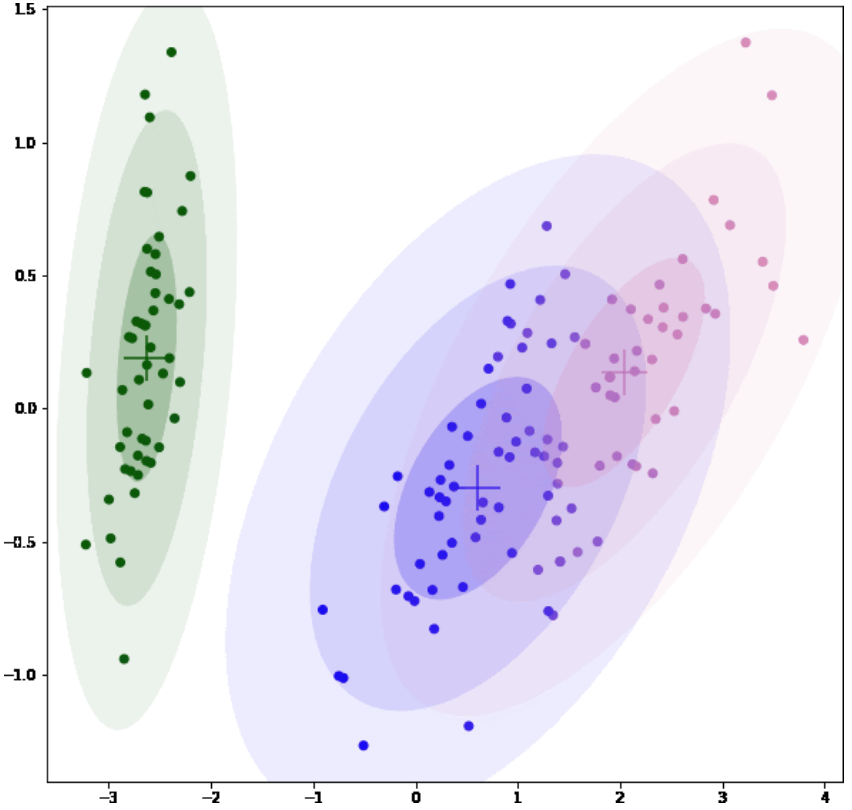
Path forward

- Understand the affect of outliers on the successor tasks and milestones of interest
- Understand the affect of a correlation that is slightly greater than one



Path Forward – Dimension Reduction

- OBS and duration are natural and intuitive ways to analyze the data, but there are other techniques that we can use understand natural but non-intuitive clustering.
- We intend to employ other machine learning techniques to find better ways to understand the variations and improve the accuracy of our forecasts.



Questions