HMA Acceptance Specifications – Assessing Contractor Risk

Who Really Has Risk?

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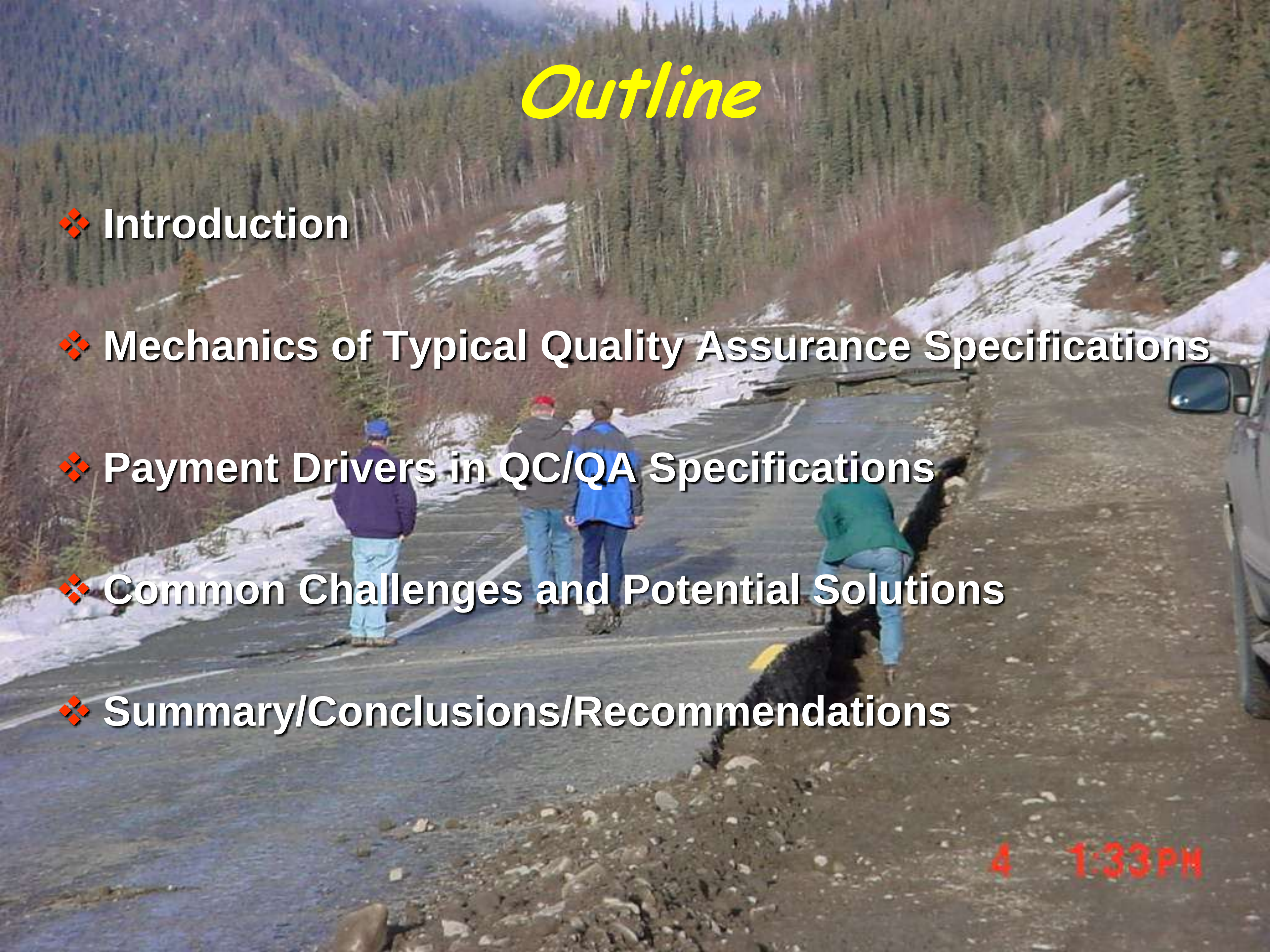
Outline

- Introduction
- Mechanics of Typical Quality Assurance Specifications
- Payment Drivers in QC/QA Specifications
- Common Challenges and Potential Solutions
- Summary/Conclusions/Recommendations



Introduction

- **Many States using Quality Assurance Specifications**

- **Quality Assurance Spec Objective:**
  - **To specify and measure quality related to pavement performance *and* pay for quality provided (Pay For Performance)**

- **Statistically Based**
  - **Acceptance Sampling and Testing**
  - **PWL used to Quantify Quality**
  - **Pay Factors = f(PWL)**

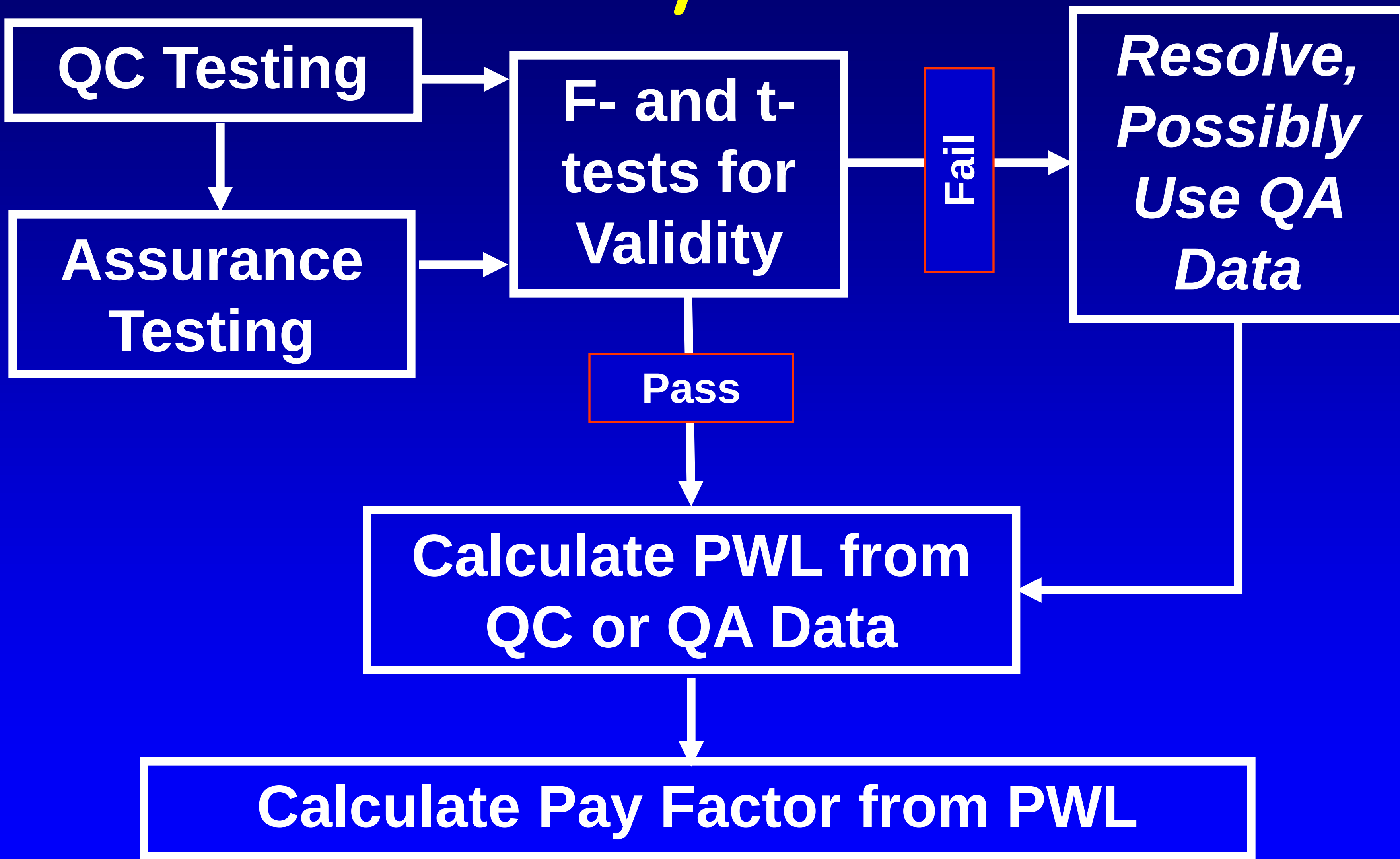
Introduction

- Many Specifications Seem Alike

- Engineering Judgment Used to Select Many Specification Parameters

- Specifications Sensitive to
  - Variability in Measured Quality Characteristics
    - Sampling, Testing, M/C
  - N and n
  - Specifications Limits

Macro View–Typical Quality Assurance Specs



Statistically Based Acceptance Plan

- **Components**
  - **Acceptance Sampling and Testing**
  - **Quality Characteristics**
  - **Specification Limits**
  - **Statistical Model**
  - **Quality Level Goals**
  - **Risk**
  - **Pay Factors**

Common Challenges

- Understanding Variability & Setting Specification Limits
- Understanding of Risk
- Impact of Small Changes (ie. Sampling location)
- Test Turn Around Time
- Dispute Resolution
  - No Outlier Definition, Detection, or Handling/Disposition
  - Independent Labs
- Serving Multiple Customers
  - Offset Between Labs

Statistically Based Acceptance Plan

- Acceptance Sampling and Testing
  - QC & PC – Acceptance –IA
  - Lot and Sublot Definitions
  - Sampling/Testing Frequencies
  - Sampling Methods/Locations
  - Test Methods
  - Basis: Engineering Judgment

- Quality Characteristics (What is Specified)

Determine the Composite Pay Factor (*CPF*) for each mixture. The *CPF* shall be rounded to 3 decimal places.

$$CPF = \left[f_{VMA}\left(TPF_{VMA}\right) + f_{voids}\left(TPF_{voids}\right) + f_{density}\left(TPF_{density}\right)\right] / 100$$

Substituting from Table 1:

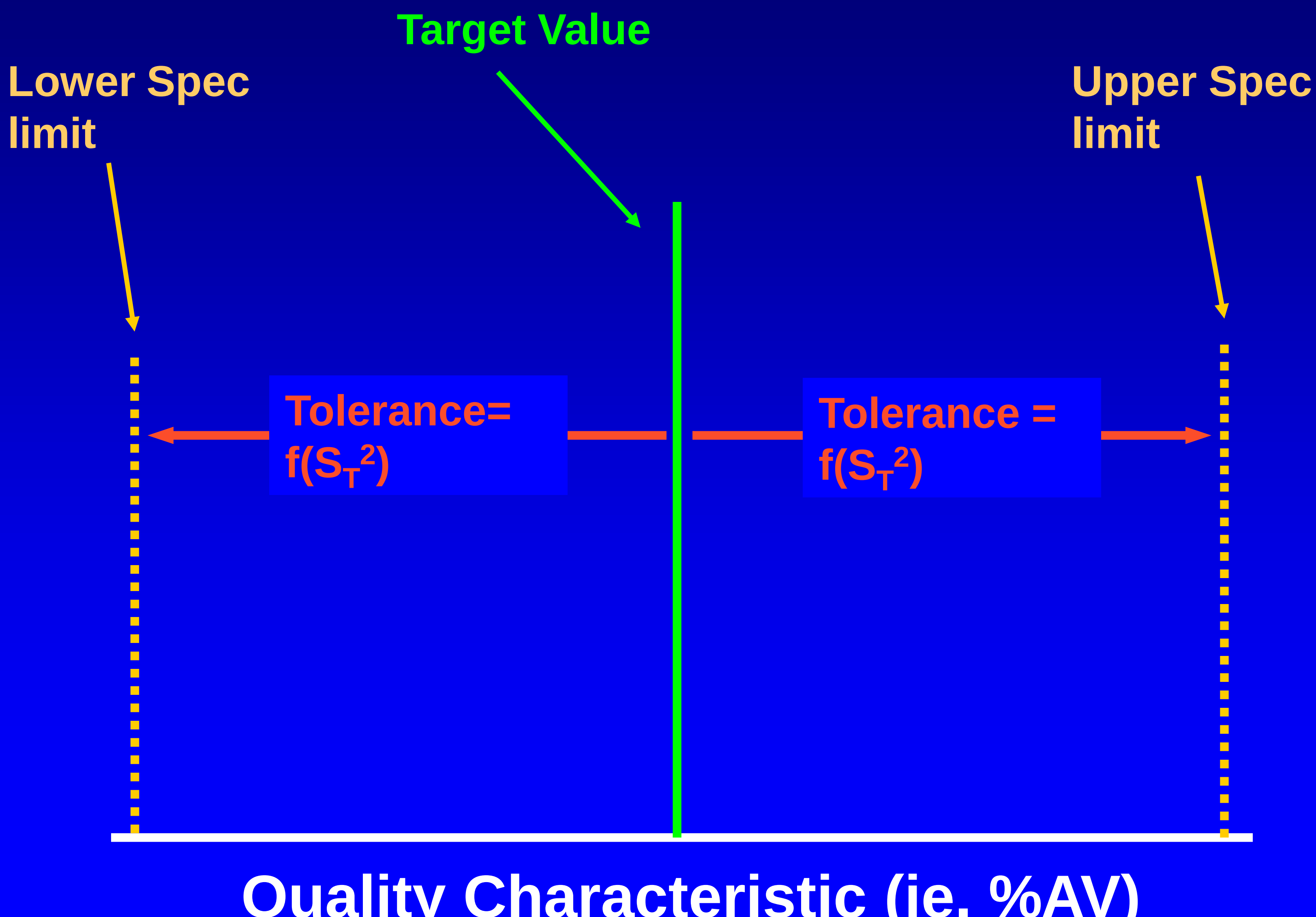
$$CPF = \left[0.3\left(TPF_{VMA}\right) + 0.3\left(TPF_{voids}\right) + 0.4\left(TPF_{density}\right)\right] / 100$$

Statistically Based Acceptance Plan

- **Specification Limits**
  - **Define *Acceptable and Unacceptable* Material Quality**
  - **Function of $(S^2_T) = S^2_s + S^2_t + S^2_{m/c}$**
  - **Basis: Engineering Judgment?**

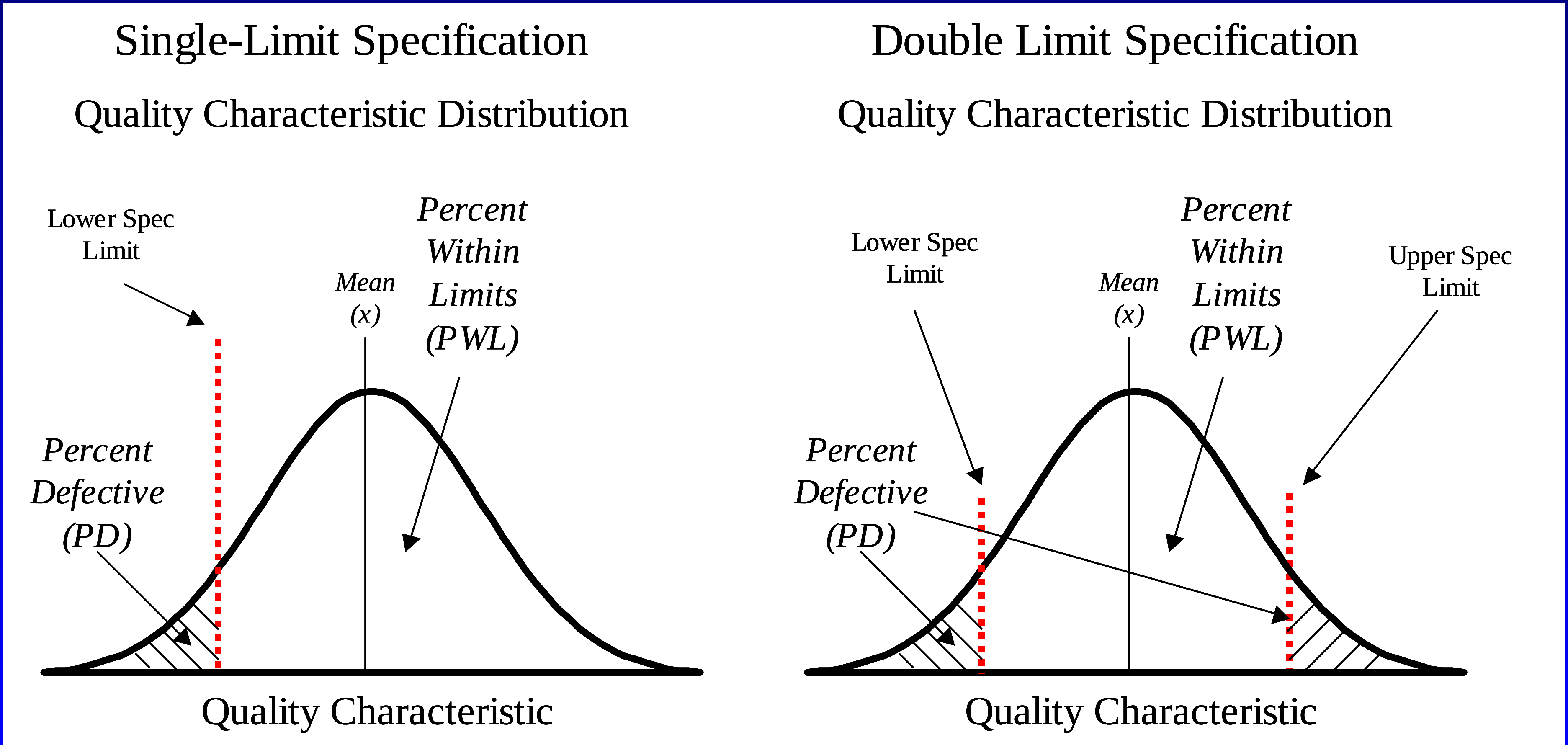
- **Statistical Model**
  - **Quality Defined as Percent of Quality Characteristic (ie. In-place Density) Within Spec Limits**
  - **PWL Method Normally used to Define Quality**
  - **Use QC, QA, QC+QA Data? – Engineering Judgment**

Establishing Specification Limits



Statistical Model = PWL

Single and Double Spec Limits



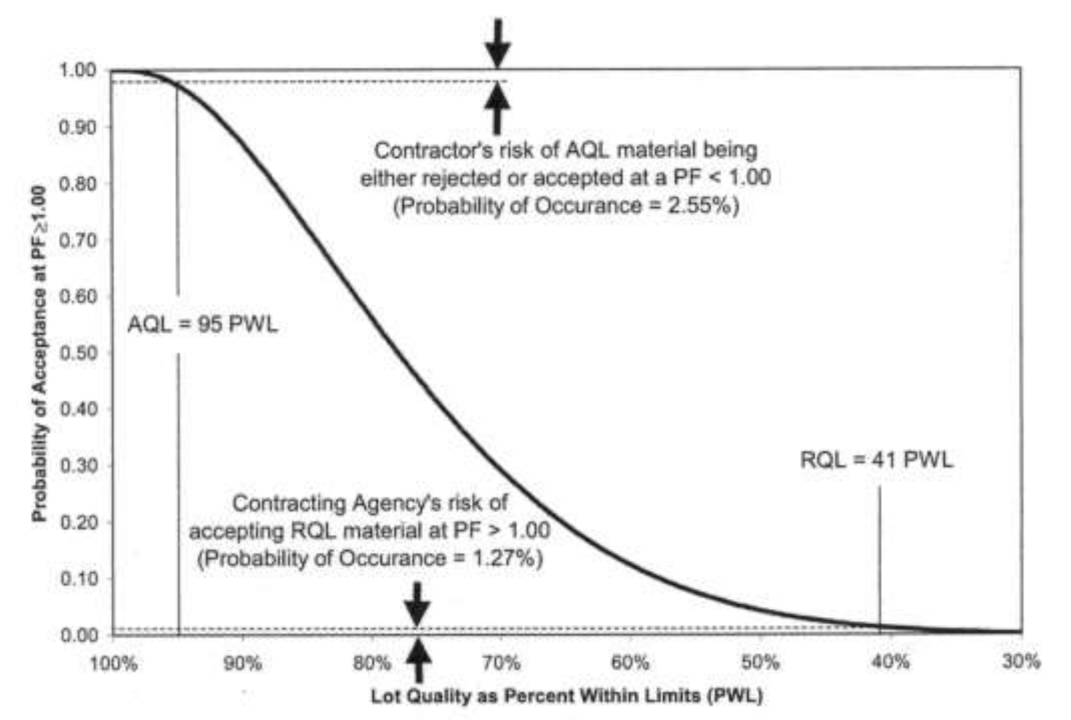
Statistically Based Acceptance Plan

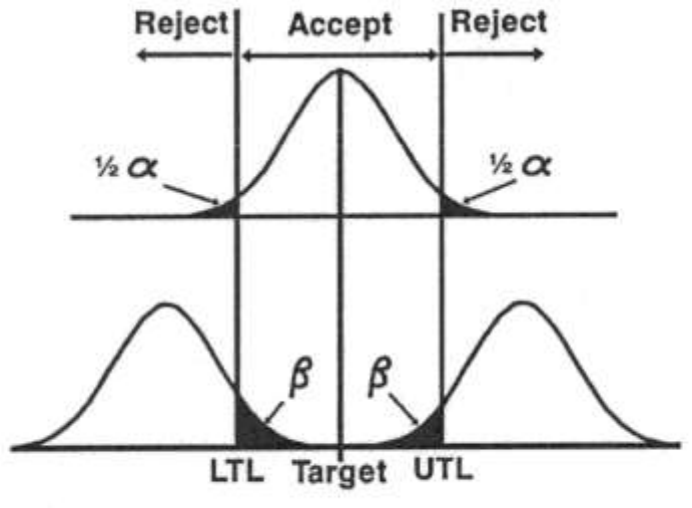
- Quality Level Goals
  - AQL=Min Quality (PWL) at Full Acceptance
    - 90 or 95
  - RQL=Max Quality (PWL) at Unacceptable
    - 60 to 75
  - Basis: Engineering Judgment

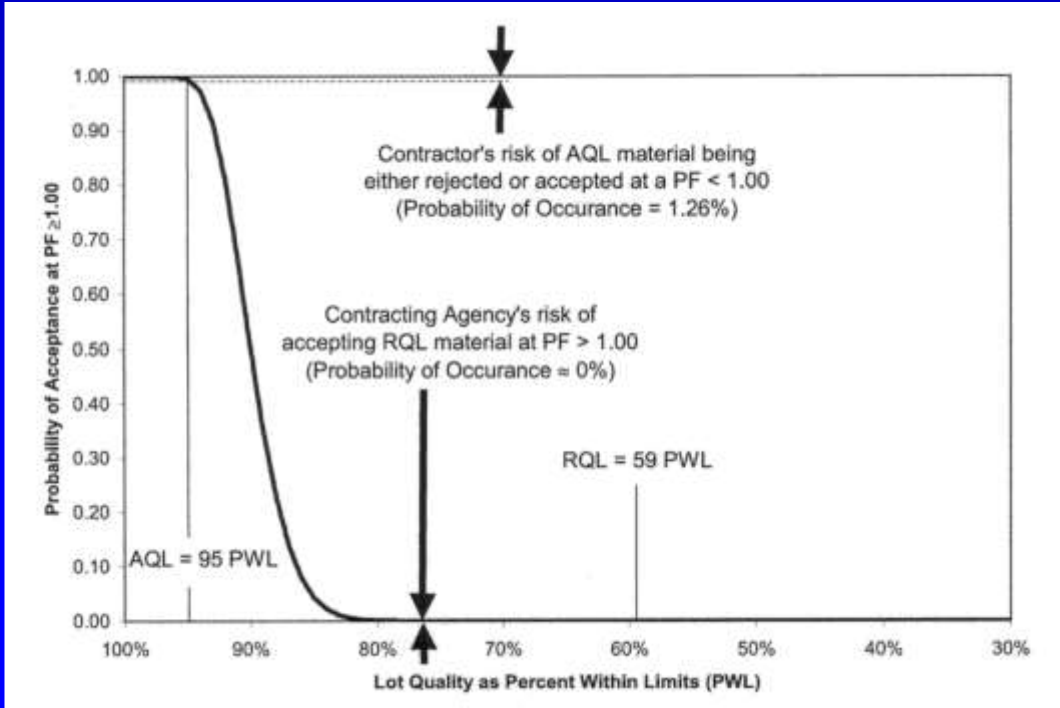
- Risk
  - Use Sample not Population, so Risk
  - Wrongful Acceptance or Rejections
  - Balance Seller and Buyer Risks with n
  - Basis: Engineering Judgment and Logistics

OC Curves

- Risk
- Sample/Test Frequency







Statistically Based Acceptance Plan

- Pay Factors
  - Quality (Defined by PWL) is Related to Payment by Pay Factor
    - Incentives (Bonuses) for
      - PWL > AQL
    - Disincentives (Penalties) for
      - AQL > PWL > RQL
- Composite Pay Factors

$$CompositePayFactor = \frac{\sum (PF_n x Wt_n)}{\sum Wt_n} x100$$

Advantages

- **PWL is Best Tool to Quantify Quality Relative to**
  - **TV, Spec Limits Mean, Variability**
- **QC/QA with PWL: Transfer of Responsibility from SHA to Material Producer/Contractor for Quality**
- **Opportunity for Producer/Contractor to Control Processes**
- **Opportunity to Be Compensated for Quality Provided**
- **Opportunity for Producer/Contractor to Refine Processes and Build Technical Competency**

Disadvantages

- Lack of Knowledge of Risk in Specifications
  - Risk and Payment Changes with:
    - Lot and Sublot Size
    - Samples and Tests per Lot and Sublot
    - Sampling Location
    - Test Methods and Test Method Options
    - Acceptance Limit Changes
    - Specification Limit Changes
    - Pay Factor Equations, Weights and Variables
    - …
  - Are tools are not perfect, so we can't eliminate risk

Specification Selection & Changes

- **Borrow Specification and Make "*Small Refinements*"**
  - **Tests per Sublot**
    - **5 vs. 10 for Density**
  - **Sample Location**
    - **Mat vs. Truck**
  - **Test Method Options**
  - **Specification Limits**
    - **Changes for Several Reasons**
  - **Pay Factor Equation**
    - **Continuous to Stepped Function**

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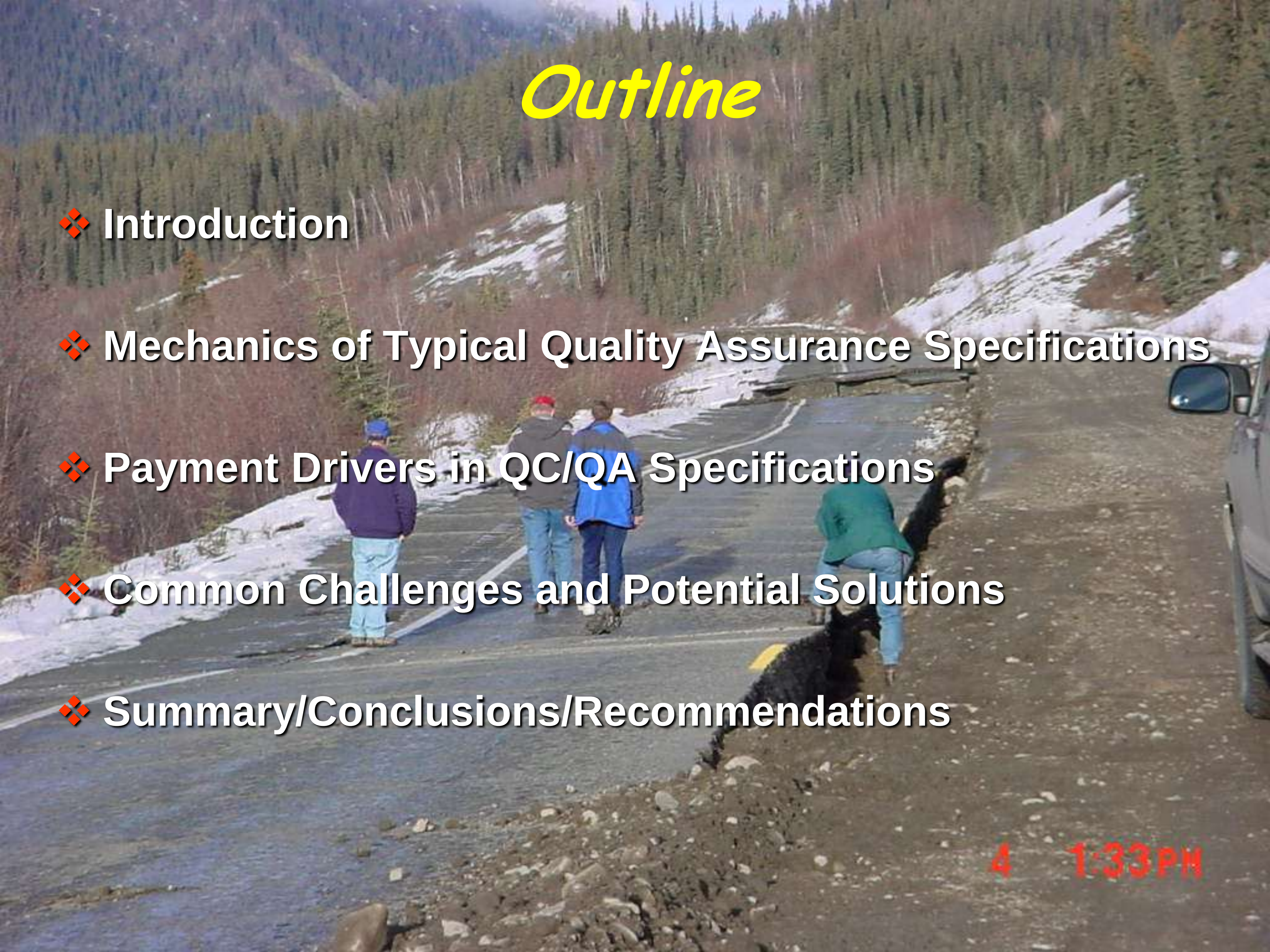
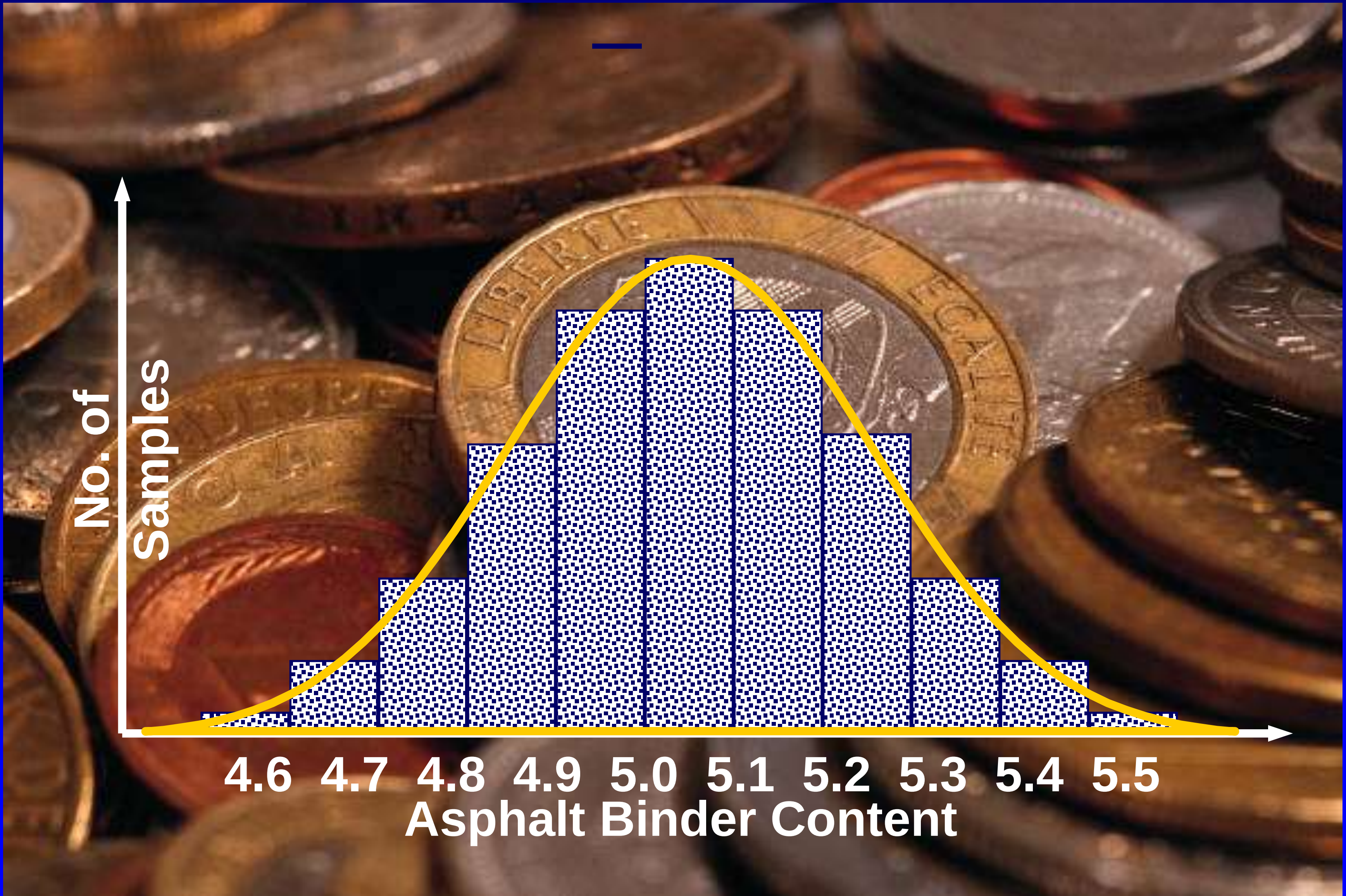


PWL and Pay Factor Theory
(It Doesn't Have to be a Gamble!)

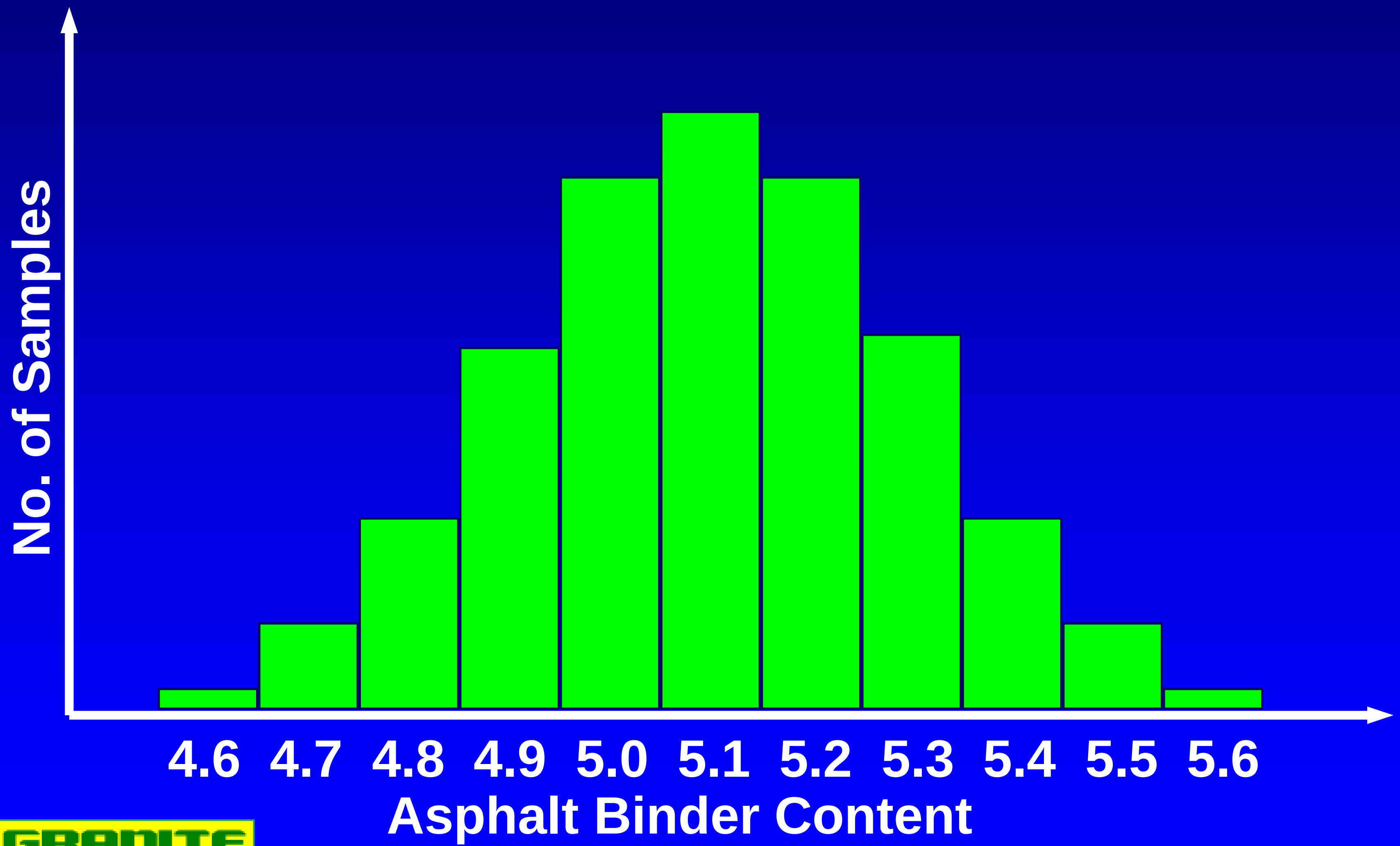


Percent Within Limits Concept

- **Percent Within Limits (PWL) methodology and Pay Factors**
  - **Small number of tests results outside the specification limits is normal and not necessarily detrimental to performance**
  - **Led to Acceptable Quality Level (AQL) definition**
  - **Thus Percent Deficient (PD) and Percent Within Limits (PWL) definitions**
  - **PWL = the percent of a lot falling within set specification limits**
  - **Payment is based on PWL and allows for both potential penalty or bonus**
  - **Idea is to tie Quality (& Payment) to Performance**

Histogram

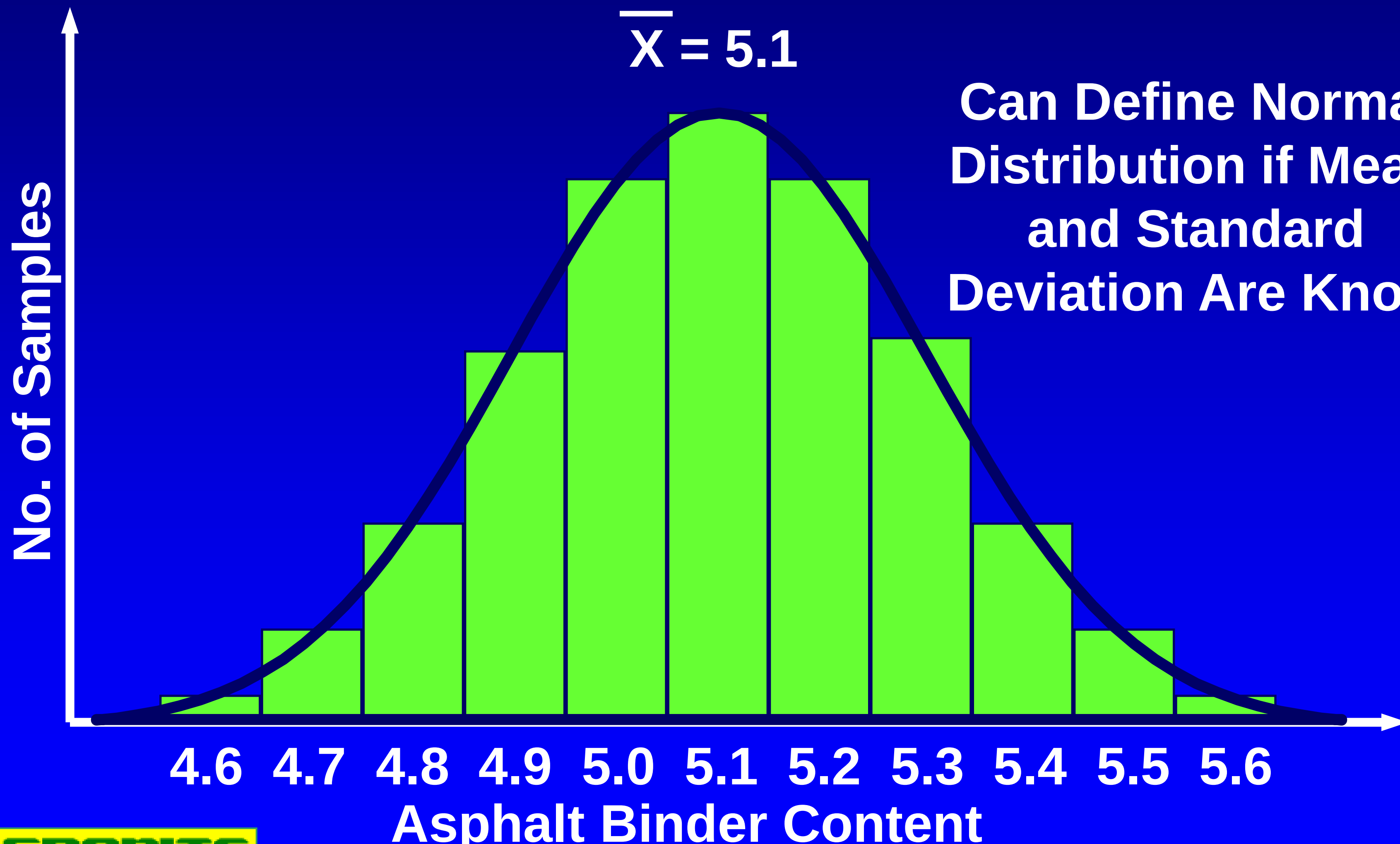
A Bar Chart of Test Result Frequency



GRANITE Engineering Services

Normal Distribution

A Bell Curve of the Histogram



Can Define Normal Distribution if Mean and Standard Deviation Are Know

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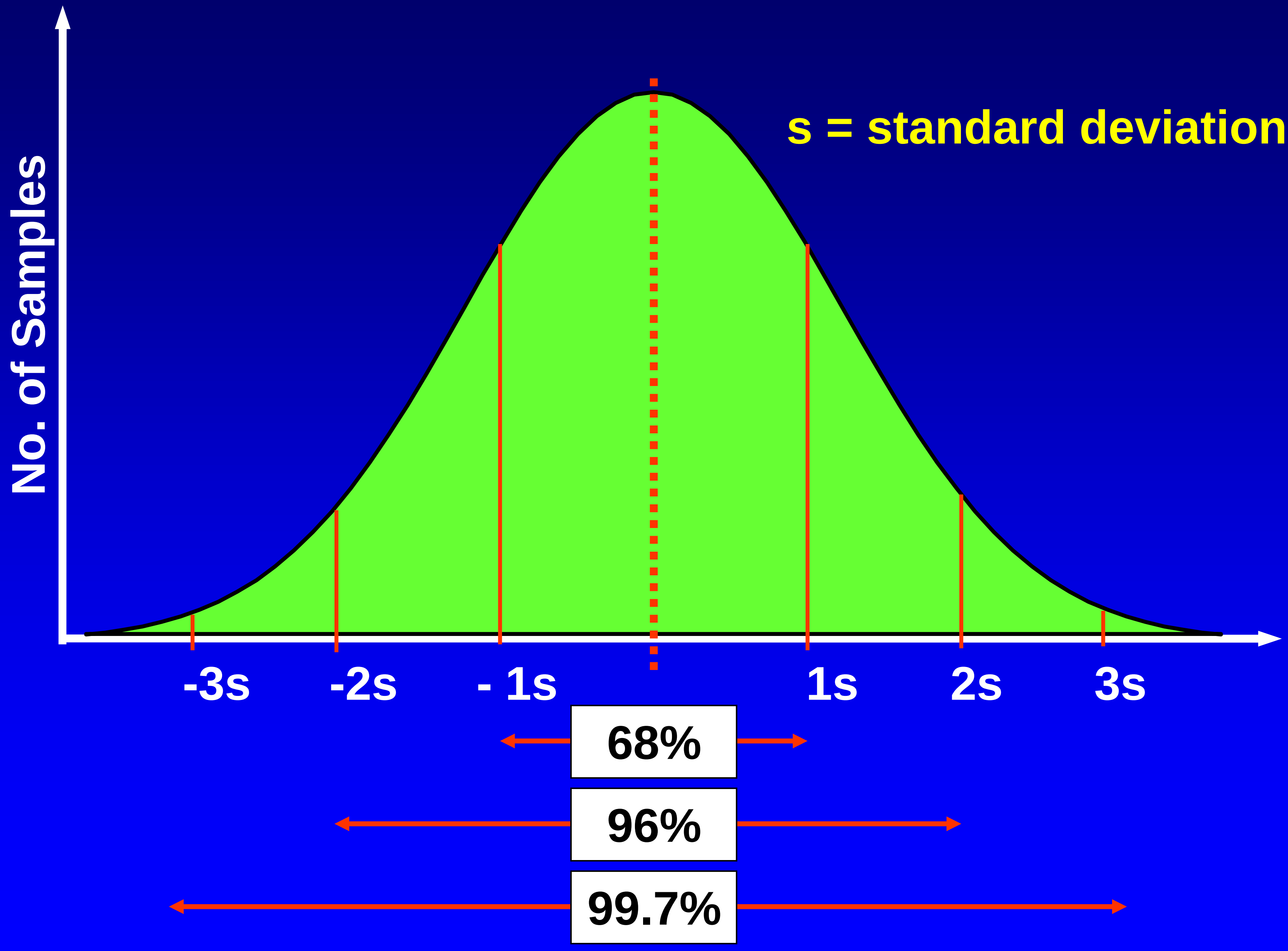
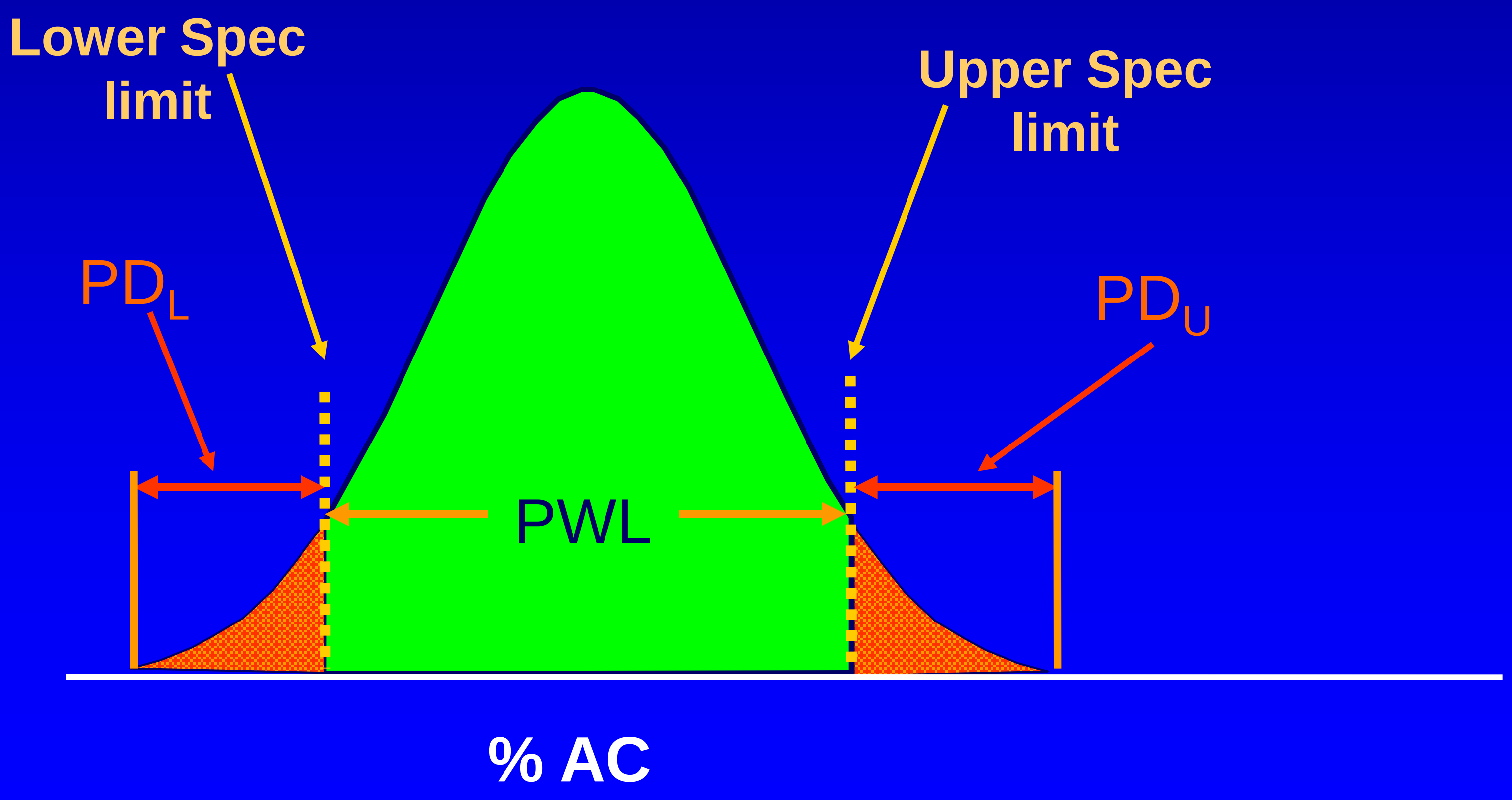
Normal Distribution and Standard Deviation



PWL and PD Concepts

PWL = Area of Distribution within Spec Limits

PWL = 100 - (PD_U + PD_L)



Mechanics of PWL

$$PWL = 100 - (PD_U + PD_L)$$

Where:

PD_U = Percent Defective (upper), obtained from PD table for calculated QI_U and given n

PD_L = Percent Defective (lower), obtained from PD table for calculated QI_L and given n

n = number of test results

Mechanics of PWL

$$QI_U = \frac{(UL - \bar{X})}{S} \qquad QI_L = \frac{(\bar{X} - LL)}{S}$$

Where:

QI_U = Upper Quality Index

QI_l = Lower Quality Index

$\bar{X}$ = mean of test results

S = standard deviation

UL = Upper specification Limit (target value + tolerance)

LL = Lower specification Limit (target value - tolerance)

Quality Level Analysis (PWL=f(n, spec limits)

Illinois Department of Transportation

PFP Quality Level Analysis
Appendix E.1
(continued)

Effective: December 12, 2003
Revised: January 1, 2017

TABLE 2: QUALITY LEVELS
QUALITY LEVEL ANALYSIS BY STANDARD DEVIATION METHOD

P_U OR P_L PERCENT	UPPER QUALITY INDEX Q_U OR LOWER QUALITY INDEX Q_L														
WITHIN LIMITS FOR POSITIVE VALUES OF Q_U OR Q_L	n=3	n=4	n=5	n=6	n=7	n=8	n=9	n=10 to n=11	n=12 to n=14	n=15 to n=18	n=19 to n=25	n=26 to n=37	n=38 to n=69	n=70 to n=200	n=201 to infinity
100	1.16	1.50	1.79	2.03	2.23	2.39	2.53	2.65	2.83	3.03	3.20	3.38	3.54	3.70	3.83
99		1.47	1.67	1.80	1.89	1.95	2.00	2.04	2.09	2.14	2.18	2.22	2.26	2.29	2.31
98	1.15	1.44	1.60	1.70	1.76	1.81	1.84	1.86	1.91	1.93	1.96	1.99	2.01	2.03	2.05
97		1.41	1.54	1.62	1.67	1.70	1.72	1.74	1.77	1.79	1.81	1.83	1.85	1.86	1.87
96	1.14	1.38	1.49	1.55	1.59	1.61	1.63	1.65	1.67	1.68	1.70	1.71	1.73	1.74	1.75
95		1.35	1.44	1.49	1.52	1.54	1.55	1.56	1.58	1.59	1.61	1.62	1.63	1.63	1.64
94	1.13	1.32	1.39	1.43	1.46	1.47	1.48	1.49	1.50	1.51	1.52	1.53	1.54	1.55	1.55
93		1.29	1.35	1.38	1.40	1.41	1.42	1.43	1.44	1.44	1.45	1.46	1.46	1.47	1.47
92	1.12	1.26	1.31	1.33	1.35	1.36	1.36	1.37	1.37	1.38	1.39	1.39	1.40	1.40	1.40
91	1.11	1.23	1.27	1.29	1.30	1.30	1.31	1.31	1.32	1.32	1.33	1.33	1.33	1.34	1.34
90	1.10	1.20	1.23	1.24	1.25	1.25	1.26	1.26	1.26	1.27	1.27	1.27	1.28	1.28	1.28
89	1.09	1.17	1.19	1.20	1.20	1.21	1.21	1.21	1.21	1.22	1.22	1.22	1.22	1.22	1.23
88	1.07	1.14	1.15	1.16	1.16	1.16	1.16	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
87	1.06	1.11	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.13	1.13
86	1.04	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08

Fron CPF)

- C
- P nit
  Pr

PFP Quality Level Analysis
Appendix E.1
(continued)

Effective: December 12, 2003
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(9) Once the project is complete determine the Total Pay Factor (*TPF*) for each parameter by using a weighted lot average by tons (mix) or distance (density) of all lots for a given parameter.

TPF = W1PFlot1 + W2PFlot(n+1) + etc.

Where:
W1,W2… = weighted percentage of material evaluated
PF = Pay factor for the various lots
TPF = Total pay factor for the given parameter

(10) Determine the Composite Pay Factor (*CPF*) for each mixture. The *CPF* shall be rounded to 3 decimal places.

$$CPF = \left[f_{VMA}\left(TPF_{VMA}\right)+f_{voids}\left(TPF_{voids}\right)+f_{density}\left(TPF_{density}\right)\right] / 100$$

Substituting from Table 1:

$$CPF = \left[0.3\left(TPF_{VMA}\right)+0.3\left(TPF_{voids}\right)+0.4\left(TPF_{density}\right)\right] / 100$$

Where:
f_{VMA}, f_{voids}, and $f_{density}$ = Price Adjustment Factor listed in Table 1

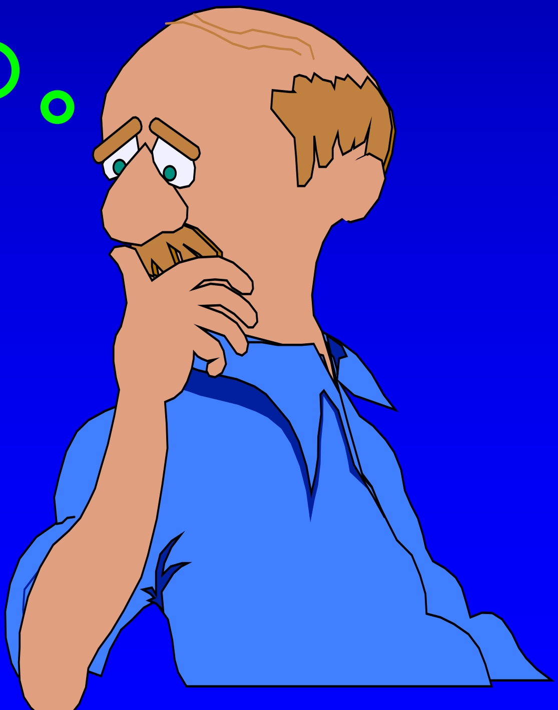
TPF_{VMA}, TPF_{voids}, and $TPF_{density}$ = *Total Pay Factor for the designated measured attribute from (9)*

(11) Determine the final pay for a given mixture.

*Final Pay = Mixture Unit Price * Quantity * CPF*

PWL, PF, and Specification Limits

Can We have a PF less than 1.0 even if all test results are in Spec?

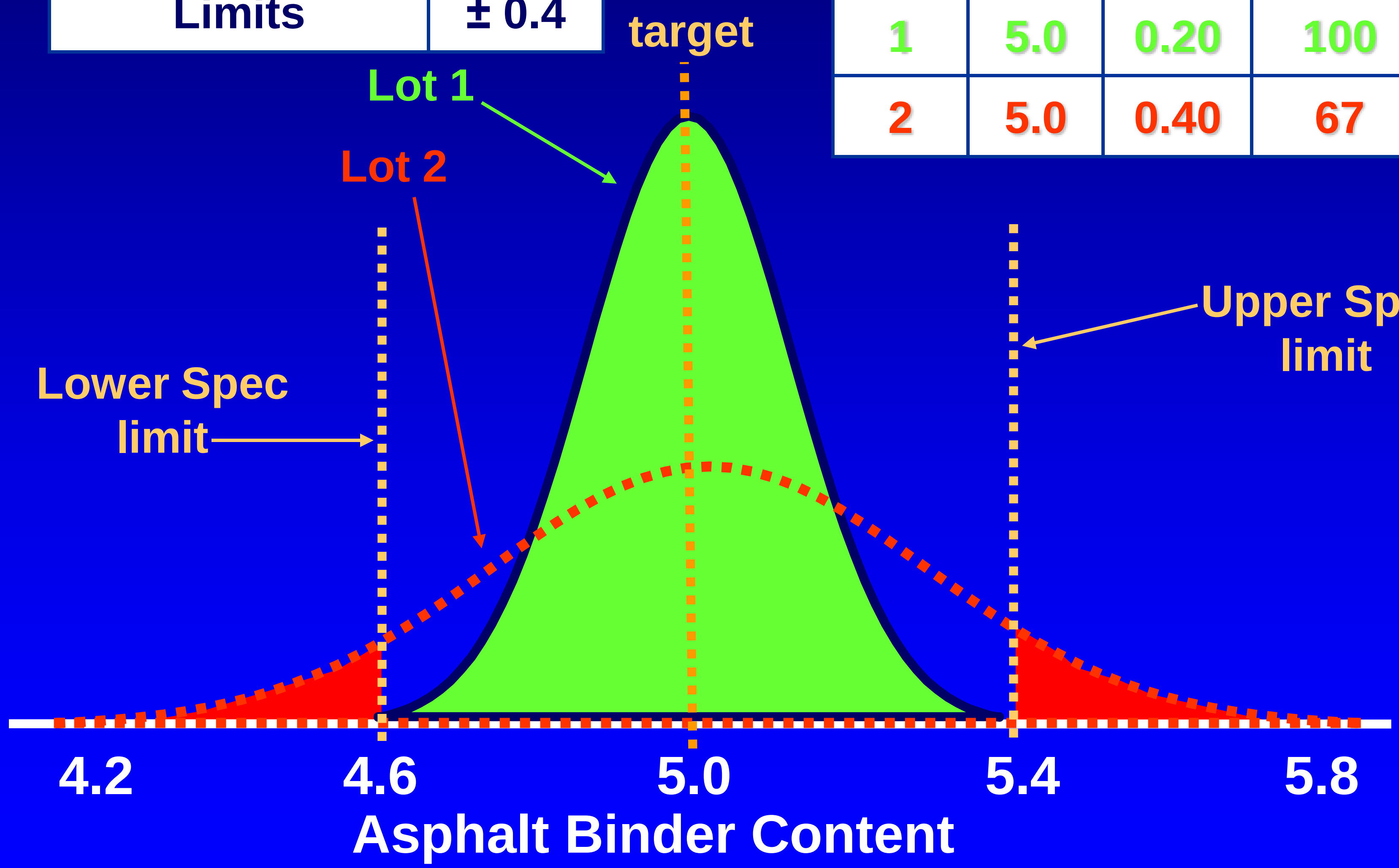


Effect on PWL's

(Equal Means but Different Standard Deviations)

Target Value	5.0
Limits	± 0.4

Lot	X	s	PWL	PF
1	5.0	0.20	100	105
2	5.0	0.40	67	89

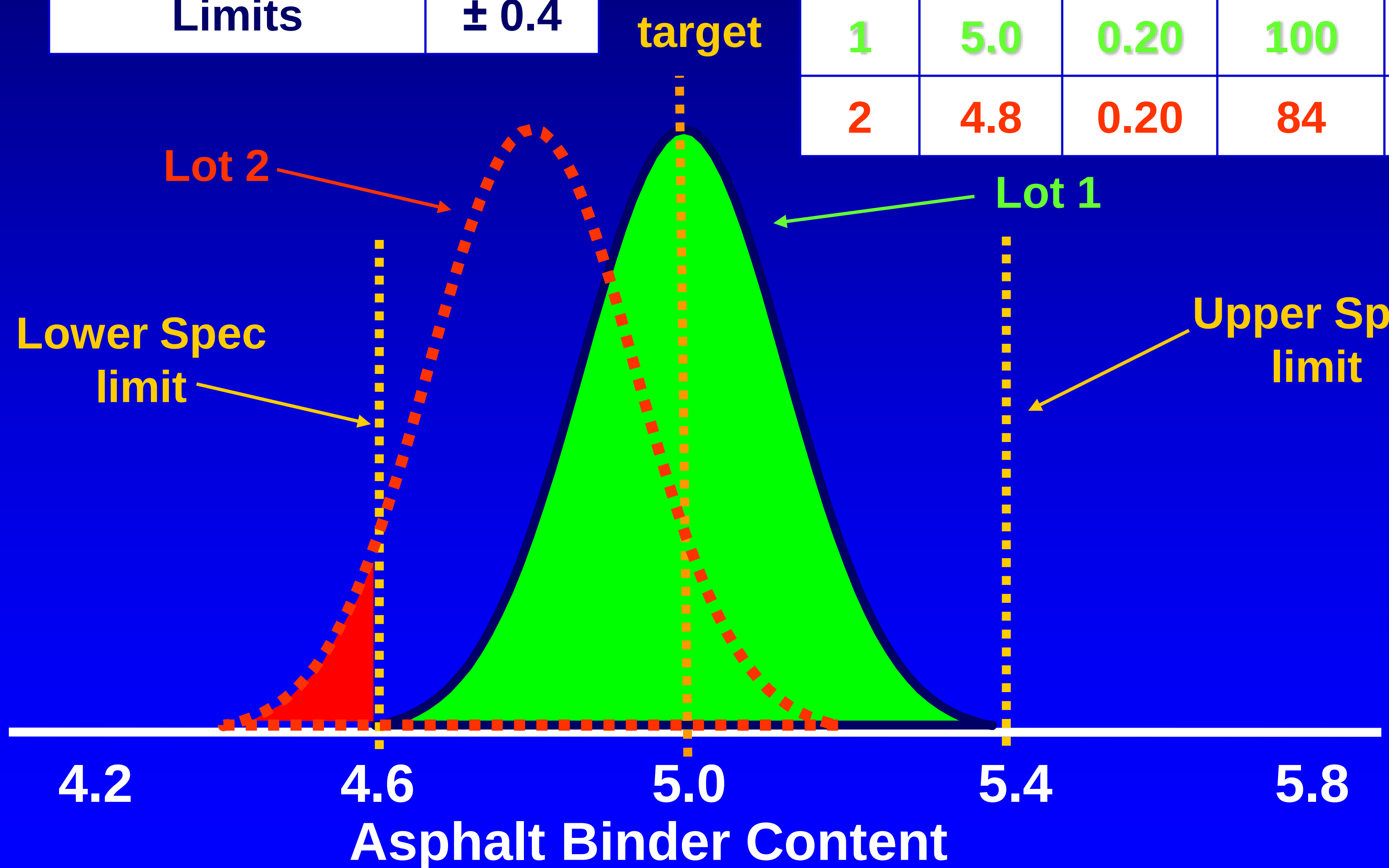


Effect on PWL's

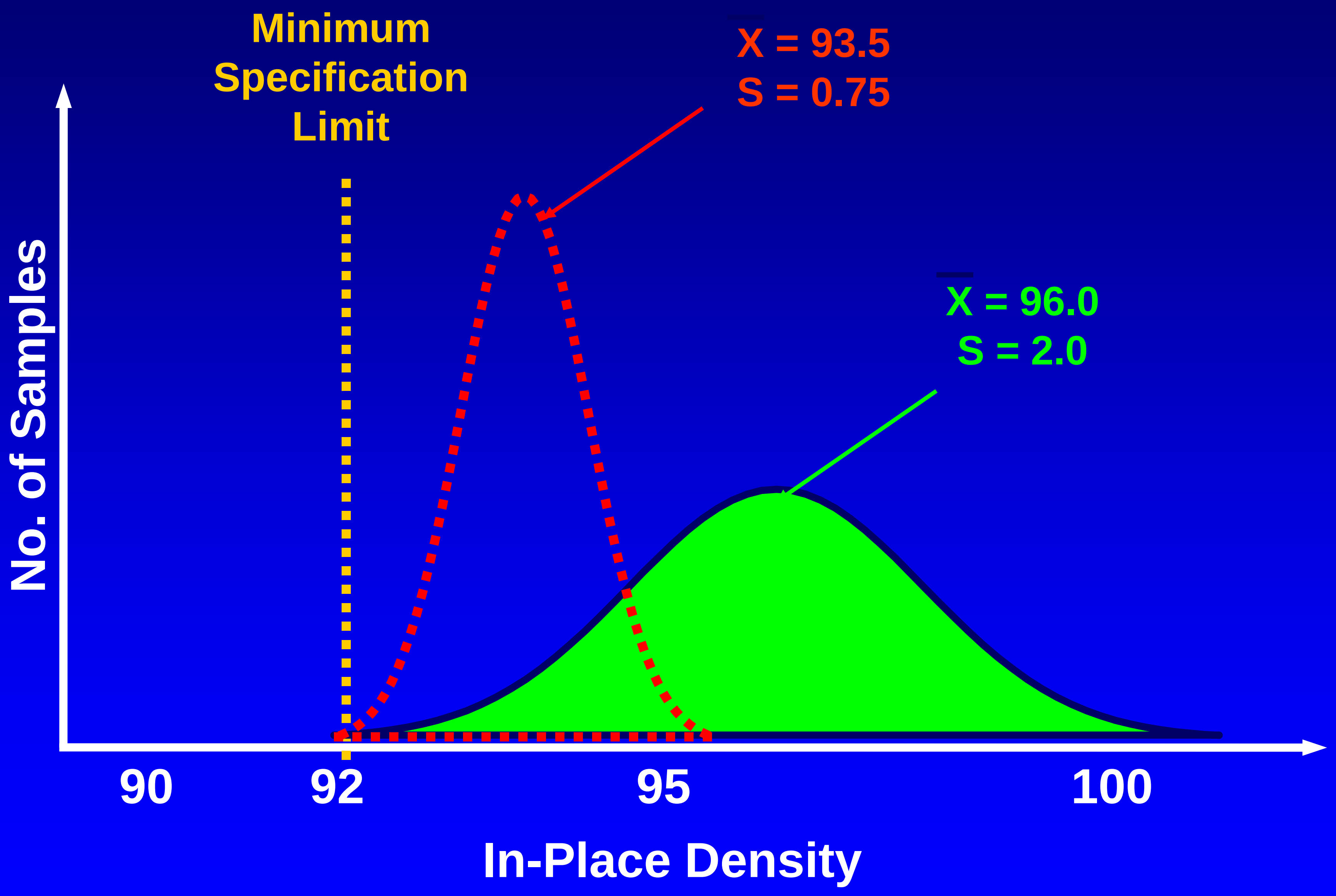
(Off Target Means and Same Standard Deviations)

Target Value	5.0
Limits	± 0.4

Lot	X	s	PWL	PF
1	5.0	0.20	100	105
2	4.8	0.20	84	96



Single Spec Limit PWL (Density)



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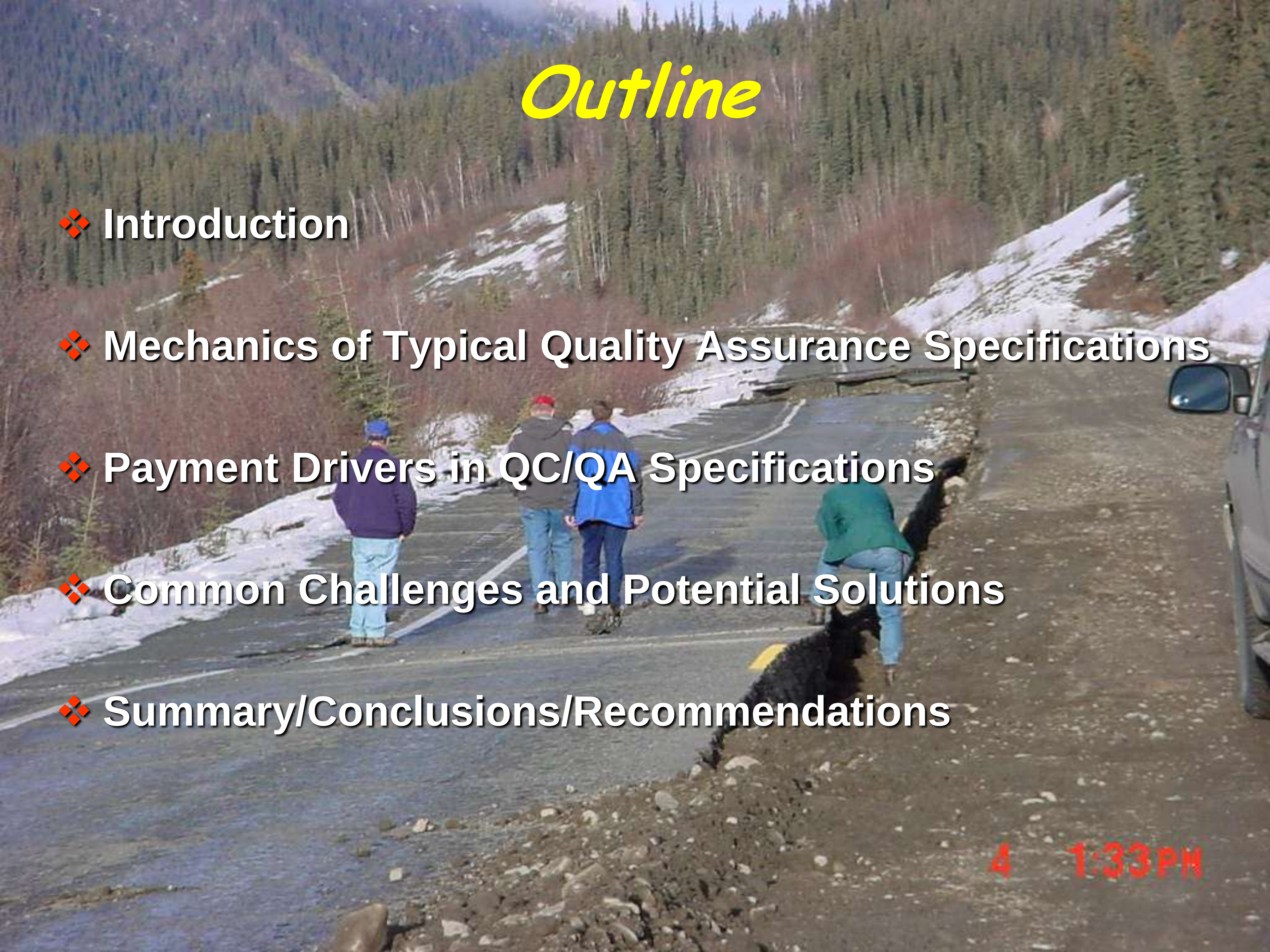

Acceptance & Payment Drivers in Assurance Specifications

- Variability (from Mechanics)
  - On Target and Standard Deviation
- Variability and Spec Limits
- Reducing Variability and Specification Limits
- Examples
  - Sample Location
  - Test Methods
  - Pooling QC & QA Data for Payment
  - Spec Limit Changes

Effect on PWL's

(Equal Means but Different Standard Deviations)

Target Value	5.0
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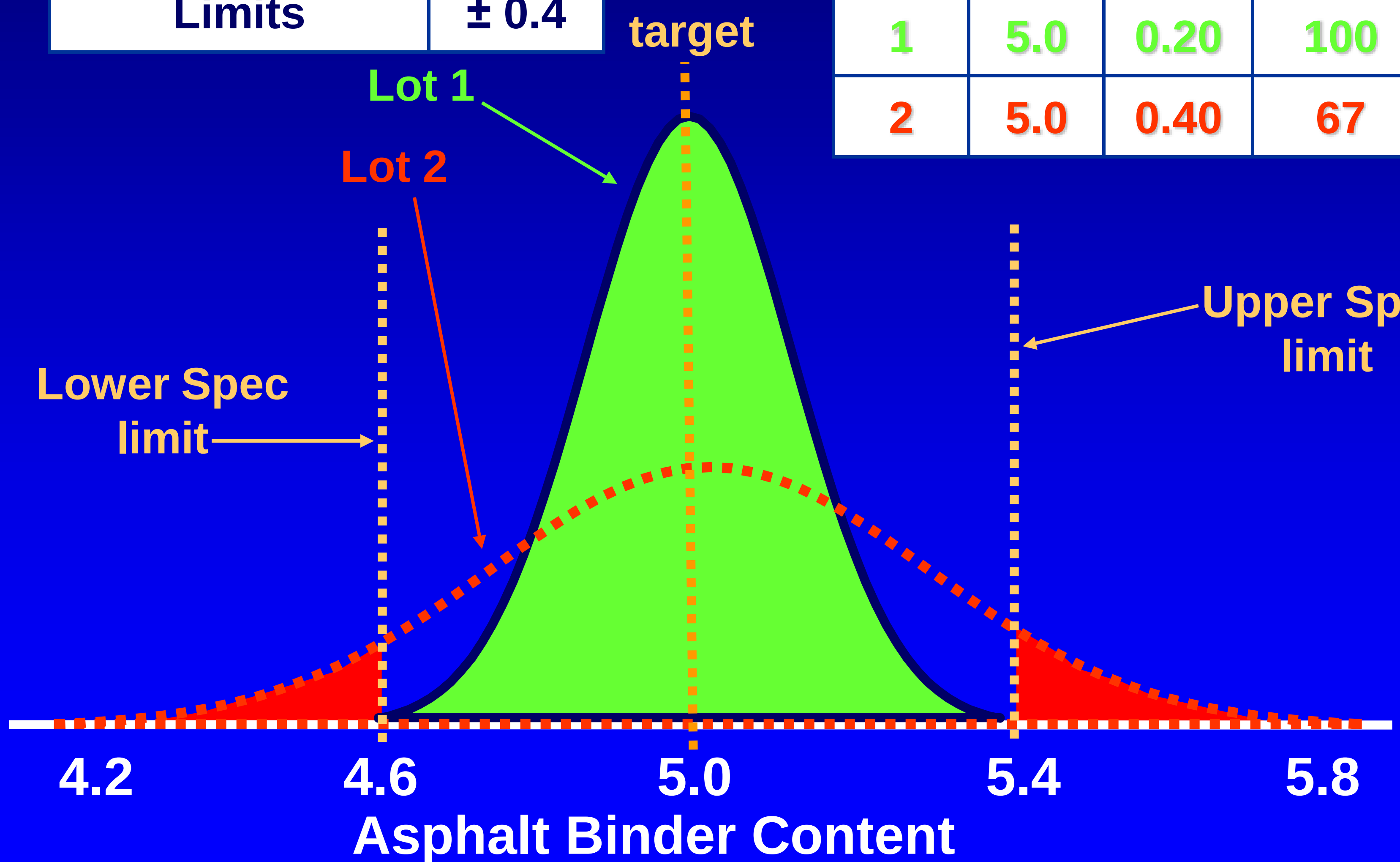
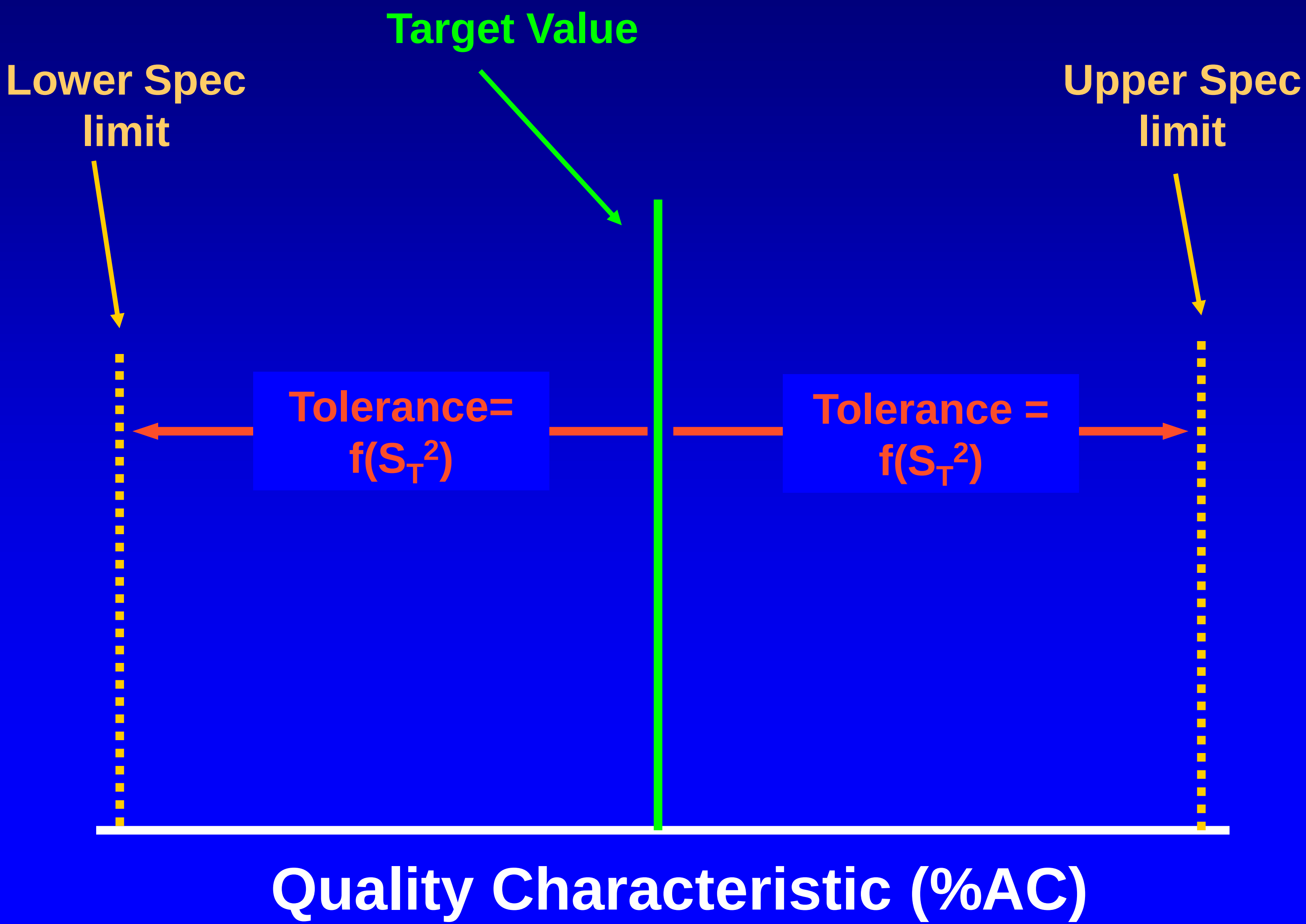


Establishing Specification Limits



Variability and Spec Limits

- Several Components of Total Variability
  - Little Work to Define Percent Distribution of Components for Most Quality Characteristics
  - Materials Supplier/Contractor only Controls One Component

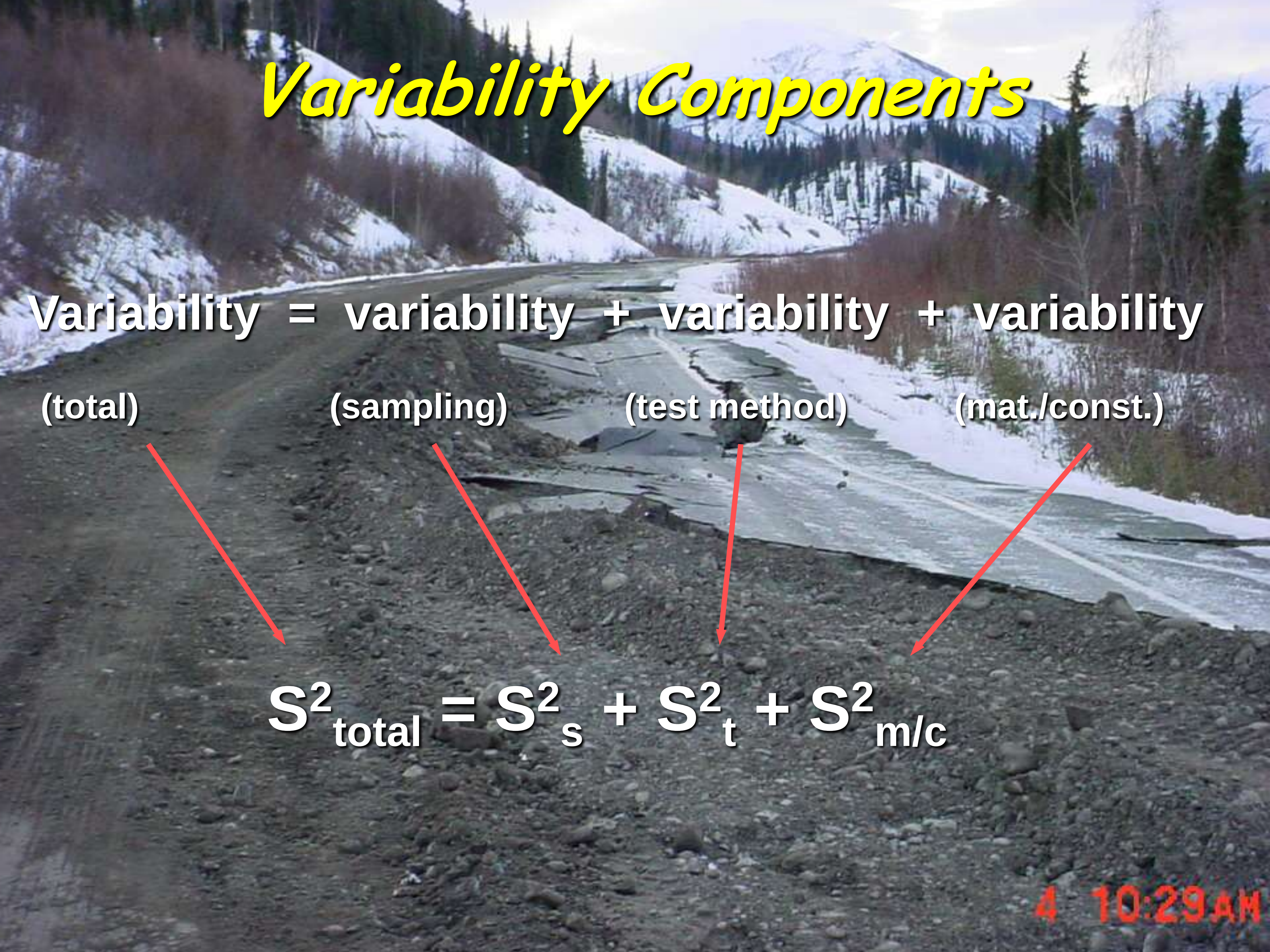
- Establishing Specification Limits
  - R9: 3 x S_T
  - Stroup-Gardner/Newcomb/Savage: 3 x S_t

Variability Components

Variability = variability + variability + variability

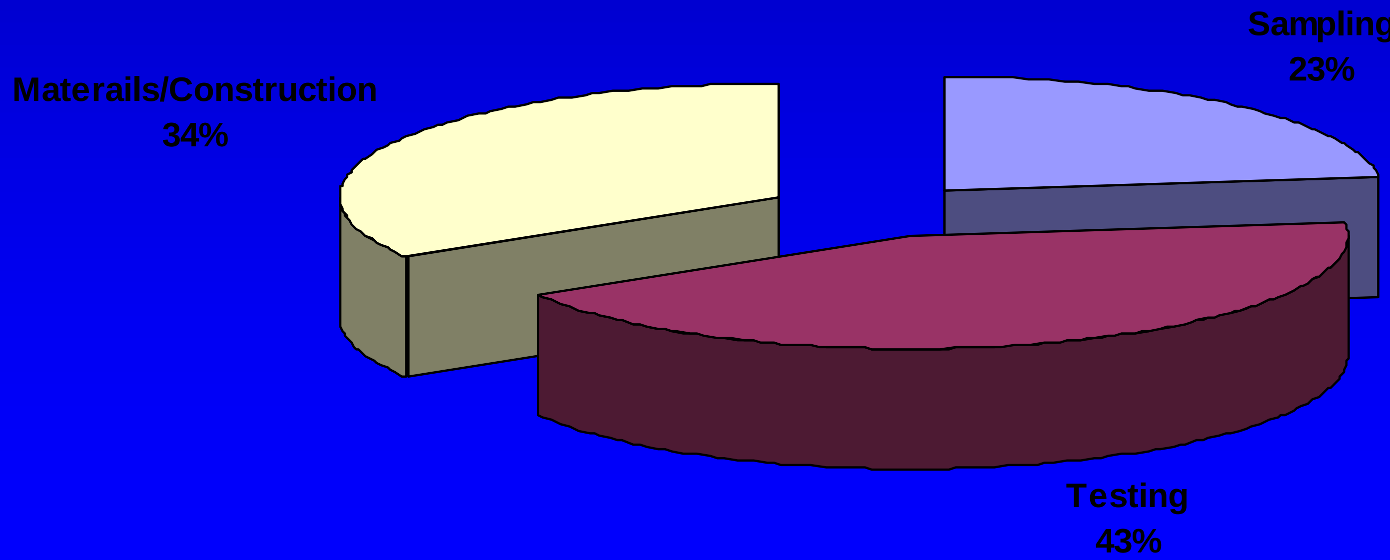
(total) (sampling) (test method) (mat./const.)

$$S^2_{total} = S^2_s + S^2_t + S^2_{m/c}$$



Sampling Variability (s^2_s)

- 10-30% of Total Variability
  - Sample Location
  - Sample Method
  - Sample Size
  - Sample Split

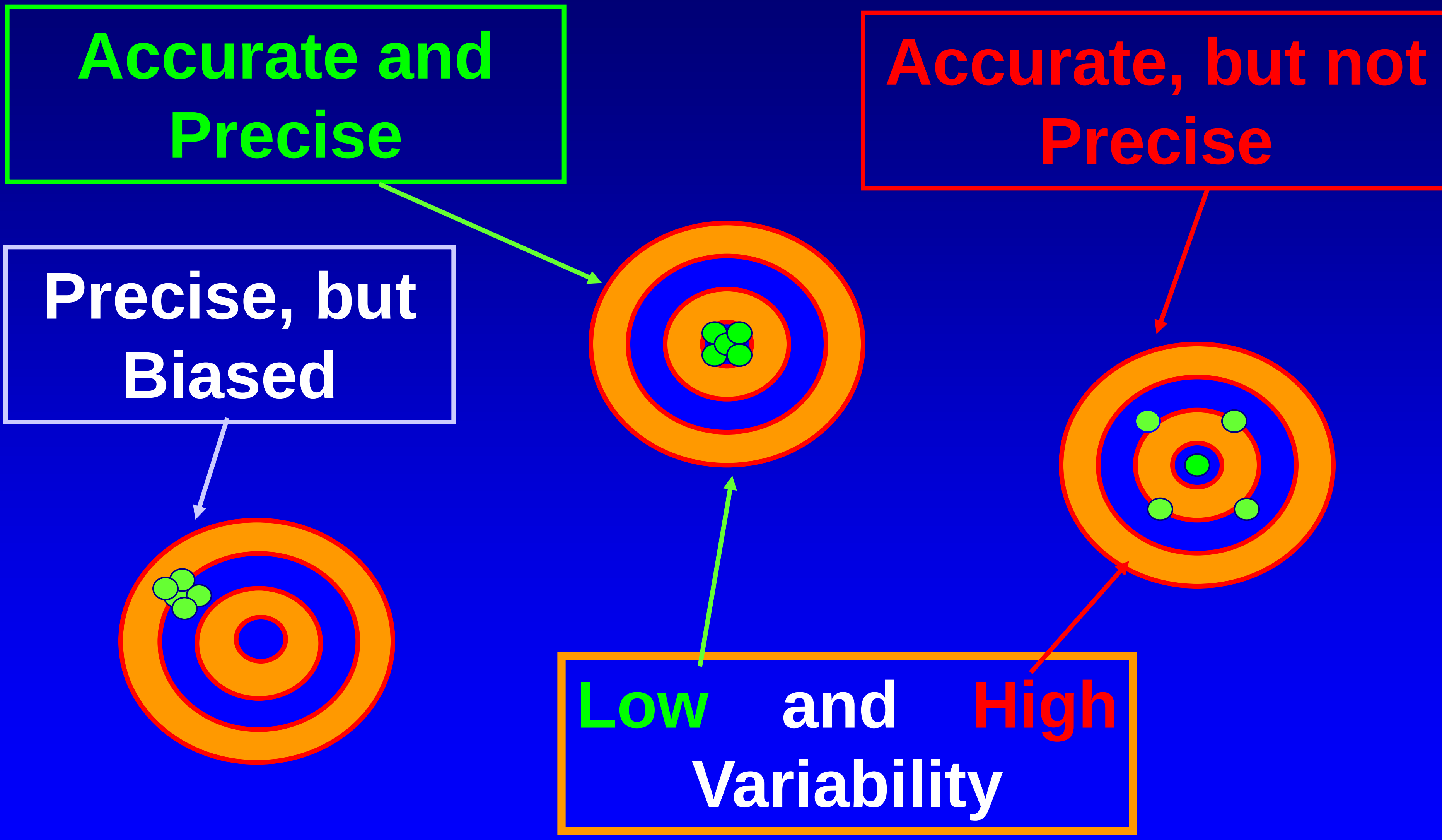


Test Method Variability (s^2_t)

- 30 to 50% of Total Variability
- Precision and Bias Statements
- Within vs. Between Lab Variability
  - Use of QC vs. QC+QA vs. QA data to calc PWL

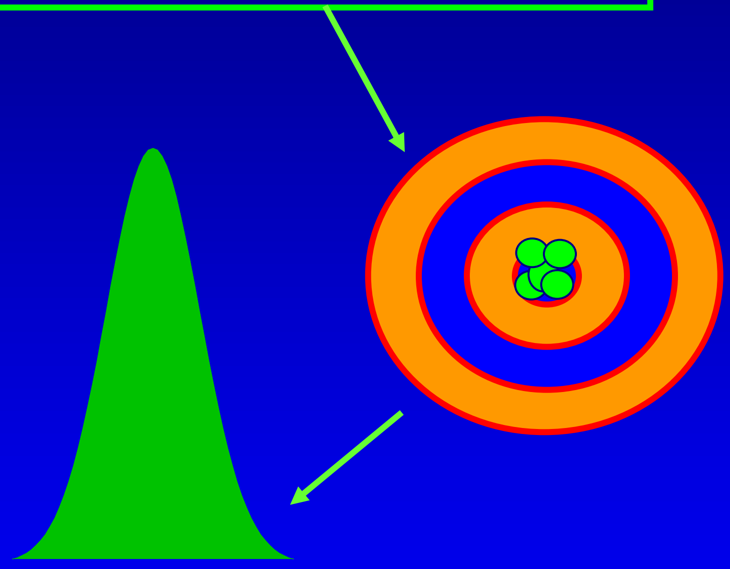
Designations		Description	Multilaboratory Precision			
AASHTO Method	ASTM Method		Standard Deviation (1S)		Acceptable Range of Two Results (D2S)	
			AASHTO	ASTM	AASHTO	ASTM
T228	D70	Asphalt Cement Specific Gravity	0.0024	0.0024	0.0068	0.0068
T85	C127	Coarse Aggregate Specific Gravity	0.013	0.013	0.038	0.038
T84	C128	Fine Aggregate Specific Gravity	0.023	0.023	0.066	0.066
T166	D2726	Bulk Specific Gravity of Compacted Bituminous Specimens	*	0.0269	*	0.076
T209	D2041	Theoretical Maximum Specific Gravity of Bituminous Mixture	0.0064 (0.0193)	0.0064 (0.0193)	0.019 (0.055)	0.019 (0.055)

Precision, Bias and Accuracy



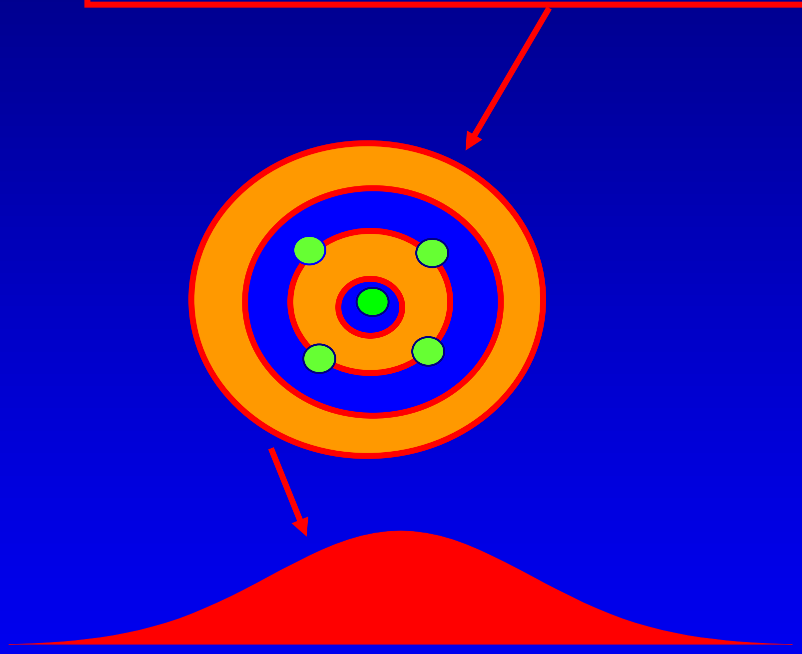
Precision, Bias and Accuracy

Accurate and Precise



Low Variability

Accurate, but not Precise



High Variability

Precision Statements are Based on Interlaboratory Studies (Round Robin)

ASTM Interlaboratory Studies

Material ID	Laboratory Number	Replicate Number	Within Lab Variance (σ^2)	Average Within Lab Variance ($\overline{\sigma^2}$)	Average Within Lab Std Dev (σ)
1	1	1, 2, 3	2	3	1.73
	2	1, 2, 3	4		
	.	1, 2, 3	.		
	.	1, 2, 3	.		
	.	1, 2, 3	.		
	10	1, 2, 3	3		
2	1	1, 2, 3	3	4	2.0
	2	1, 2, 3	4		
	.	1, 2, 3	.		
	.	1, 2, 3	.		
	.	1, 2, 3	.		
	10	1, 2, 3	5		
.	.	1, 2, 3	.	.	.
.	.	1, 2, 3	.	.	.
.	.	1, 2, 3	.	.	.
5	1	1, 2, 3	4	5	2.24
	2	1, 2, 3	5		
	.	1, 2, 3	.		
	.	1, 2, 3	.		
	10	1, 2, 3	5		
Average					1.99

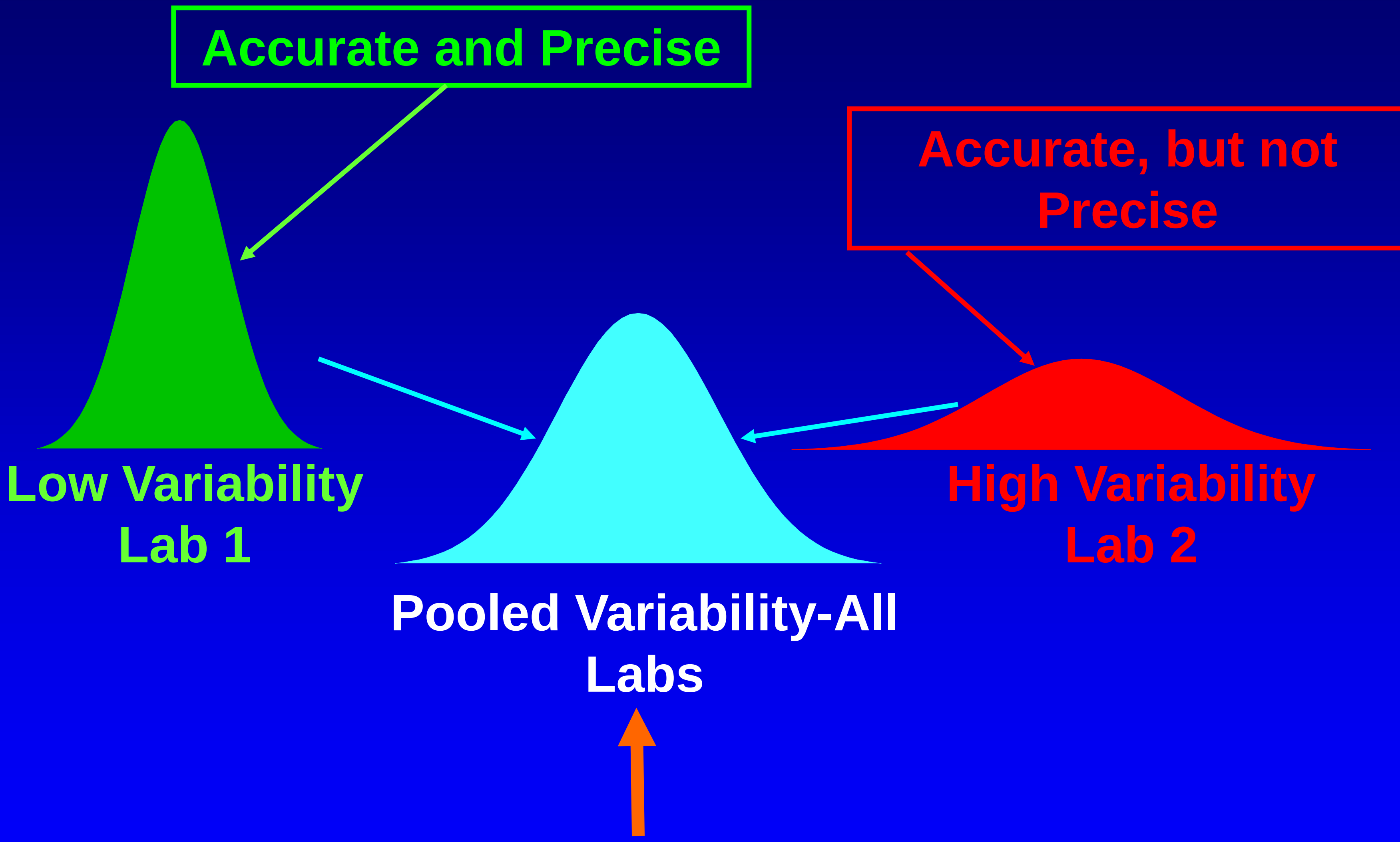
ASTM

1S

ASTM

D2S = 1S($2\sqrt{2}$)

ASTM Interlaboratory Studies



Precision Statements are Based on Pooled (all labs) Variance (σ_p)

Within Laboratory Precision

(Single Operator Precision)

Designations		Description	Single Operator Precision			
			Standard Deviation (1S)		Acceptable Range of Two Results (D2S)	
AASHTO Method	ASTM Method		AASHTO	ASTM	AASHTO	ASTM
T228	D70	Asphalt Cement Specific Gravity	0.0008	0.0008	0.0023	0.0023
T85	C127	Coarse Aggregate Specific Gravity	0.009	0.009	0.025	0.025
T84	C128	Fine Aggregate Specific Gravity	0.011	0.011	0.032	0.032
T166	D2726	Bulk Specific Gravity of Compacted Bituminous Specimens	*	0.0124	*	0.035
T209	D2041	Theoretical Maximum Specific Gravity of Bituminous Mixture	0.0040 (0.0064)	0.0040 (0.0064)	0.011 (0.018)	0.011 (0.018)

* - "Duplicate specific gravity results by the same operator should not be considered suspect unless they differ more than 0.02."

( ) - supplemental procedure for mixtures containing porous aggregate conditions ("dryback procedure").

Between Laboratory Precision

(Multilaboratory Precision)

Designations		Description	Multilaboratory Precision			
			Standard Deviation (1S)		Acceptable Range of Two Results (D2S)	
AASHTO Method	ASTM Method		AASHTO	ASTM	AASHTO	ASTM
T228	D70	Asphalt Cement Specific Gravity	0.0024	0.0024	0.0068	0.0068
T85	C127	Coarse Aggregate Specific Gravity	0.013	0.013	0.038	0.038
T84	C128	Fine Aggregate Specific Gravity	0.023	0.023	0.066	0.066
T166	D2726	Bulk Specific Gravity of Compacted Bituminous Specimens	*	0.0269	*	0.076
T209	D2041	Theoretical Maximum Specific Gravity of Bituminous Mixture	0.0064 (0.0193)	0.0064 (0.0193)	0.019 (0.055)	0.019 (0.055)

*** - "Duplicate specific gravity results by the same operator should not be considered suspect unless they differ more than 0.02."**

( ) - supplemental procedure for mixtures containing porous aggregate conditions ("dryback procedure").

Material/Construction Variability ($s^2_{m/c}$)

- 30 to 40% of Total Variability
- Asphalt Binder, Aggregate
- Production
- Placement

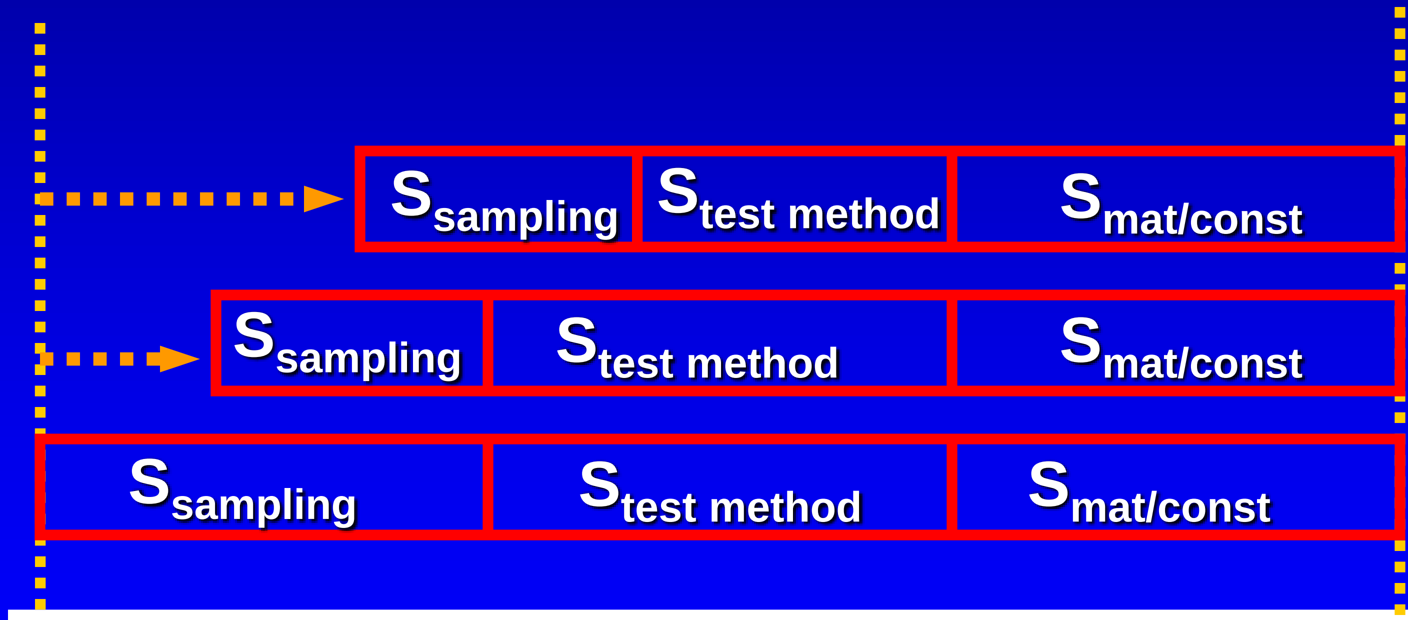
Fixed?

$$S_T^2 = S_s^2 + S_t^2 + S_{m/c}^2$$

What Payment Should Reflect!

Variability and Spec Limit Changes

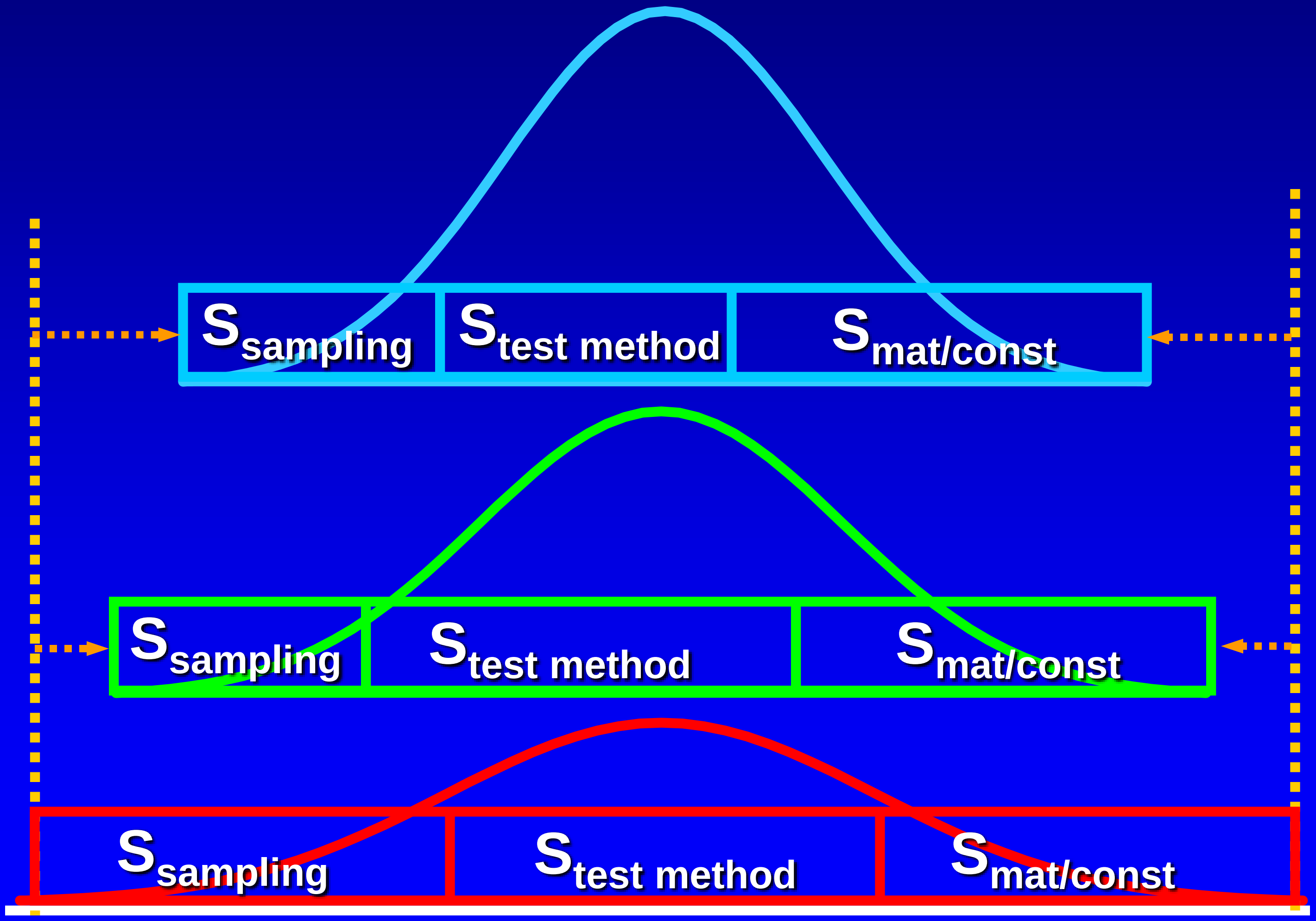
$$S^2_{total} = S^2_s + S^2_t + S^2_{m/c}$$



Total Variability in Quality Characteristic

Spec Limits and Variability

$$S^2_{QC/QA} = S^2_s + S^2_t + S^2_{m/c}$$

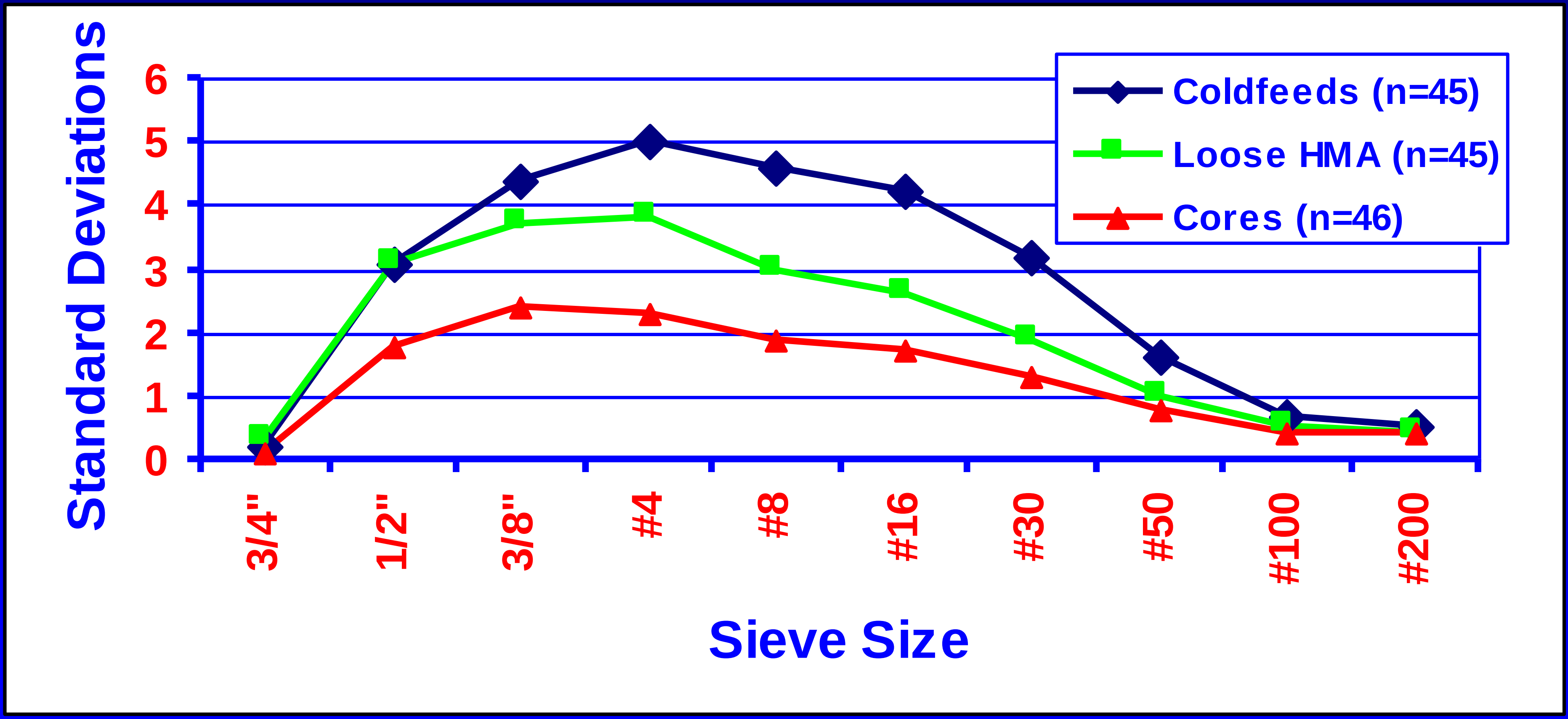


Example – Sampling Location

What is Influence of Sampling Location on Gradation PWLs

- ***Use Data as an Example***
  - **45 sublots**
  - **Loose = truck samples**
  - **Cores = 6” cores from mat**
    - **Note MTV used**

Effect of Sampling Location on Gradation Variability
(Fine Mixture)



Influence of Sampling Location on PWL

Sieve	Sample Location & Standard Deviations	
	Truck	Cores
#4	4.9	2.2
#8	3.1	1.8
#200	0.6	0.5
PWL[1]	98.4	99.9

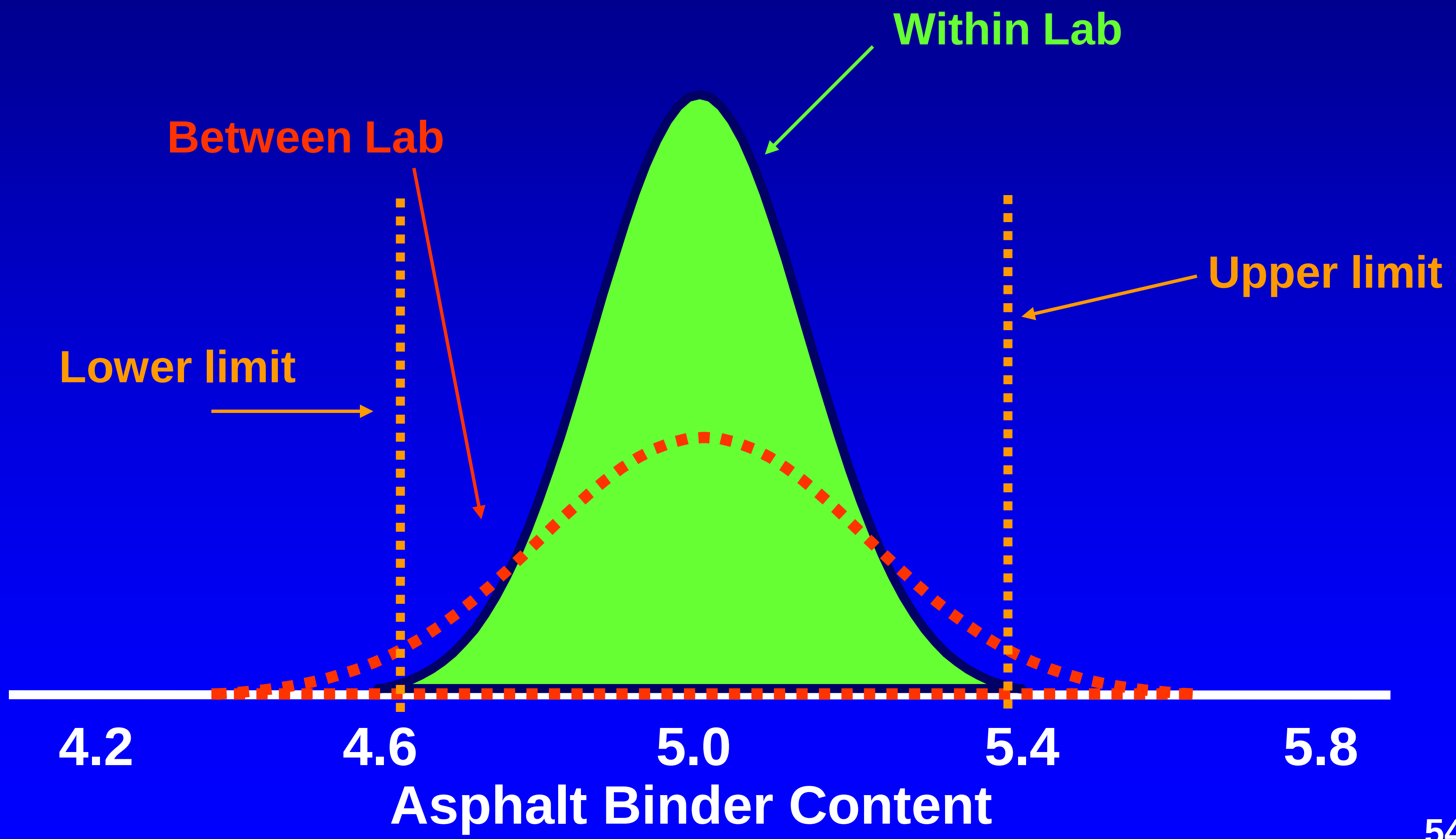
[1] Assumes that PWL for Asphalt Content and Voids in Total Mixture are 100

Example – Pooling QC&QA Data for Payment Determination

- Specification Developed Around Within Lab Testing Variability
- Pooling QC and QA Data Results in Between Lab Variability in PWL Determination
- Decreased PWL, Decreased Payment

- Two Examples
  - SHA Spec When t-test Significant, Pool QC and QA
  - Contract Administrator Dictates Post-Contract Award, Pre-Construction to Eliminate Potential for Dispute

Influence of Within and Between Lab Variability on PWL



Pooling QC and QA Data for Payment

- Used State DOT QC/QA Spec
- Assumed Means = Target Values
- Determined Standard Deviations to Get PF = 1.0
- Increased Standard Deviations by Difference in Within and Between Lab 1S
  - Holding Sampling and Materials Variability Constant
- Compared Composite Pay Factors

Increase in 1S from Within to Between Lab Case

Property	Test Method	Standard Deviations (1S)		
		Within Lab	Between Lab	Increase from Within to Between Lab
Asphalt Content	AASHTO T308	0.04	0.06	0.02
Density	AASHTO T166/T209/T269	0.51	1.09	0.58
Air Voids	AASHTO T166/T209/T269	0.51	1.09	0.58
19.0 mm	AASHTO T27	2.25	2.82	0.57
2.0 mm	AASHTO T27	0.83	1.41	0.58
0.425 mm	AASHTO T27	0.36	0.73	0.37
0.075mm	AASHTO T27	0.14	0.31	0.17

Reduction in PWL and PF from Within to Between Lab Case

Characteristic	Weighting Factor	Standard Deviation		Percent Within Limits (PWL)		Individual Pay Factor		Composite Pay Factor	
		Within Lab	Between Lab	Within Lab	Between Lab	Within Lab	Between Lab	Within Lab	Between Lab
Asphalt Content	50	0.19	0.21	90.0	86.0	1.000	0.980	1.00	0.94
Density	50	1.90	2.48	90.0	78.0	1.000	0.940		
Air Voids	50	0.82	1.40	90.0	64.0	1.000	0.870		
19.0 mm	10	3.10	3.67	90.0	82.0	1.000	0.960		
2.0 mm	15	2.53	3.11	90.0	80.0	1.000	0.950		
0.425 mm	15	2.53	2.90	90.0	84.0	1.000	0.970		
0.075mm	15	1.26	1.43	90.0	84.0	1.000	0.970		

Laboratory Accreditation

- Quality of Test Results in non-AASHTO Accredited labs
  - STD Labs and STD Qualified Labs (Via STD IA Program)
    - Mix Design Verification Problems
    - STD and Industry Round Robin
      - ”Blind” Study of Compacted Mix Gmb Variability

STD/Industry Round Robin

- 15 Participating Laboratories
  - STD, Consultants, and Contractors
  - All Labs STD IA Program Qualified
- 1 Material/Mixture
  - Rigorous QC in Sample Preparation
- 10 Specimens per Laboratory
  - Compact all 10
    - 5 - Gmb in Lab
    - 5 – Gmb by DOT Central Lab
- Compactor Calibration Performed/Verified Prior to Study

Participating Labs
(15 Total)

Participating Lab	STD IA Certified	AASHTO Accredited
STD Central Lab	Yes	Yes
STD District Lab 1	Yes	No
STD District Lab 2	Yes	No
STD District Lab 3	Yes	No
Industry Lab 1	Yes	No
Industry Lab 2	Yes	No
Industry Lab 3	Yes	Yes
Industry Lab 4	Yes	Yes
Industry Lab 5	Yes	No
Industry Lab 6	Yes	No
Industry Lab 7	Yes	Yes
Industry Lab 8	Yes	Yes
Industry Lab 9	Yes	Yes
Industry Lab 10	Yes	Yes
Industry Lab 11	Yes	No

Gmb & %AV Statistical Analysis

- ANOVA - STD Qualified vs. AASHTO Accredited
  - Lab Accreditation Significant? YES
    - Variability in STD Qualified ≈ Double AASHTO Accredited
    - All Extreme Data in STD Qualified Labs
- Paired t-Tests of Means (SPLIT SAMPLES)
  - 105 paired t-tests
  - 53 of 105 Significant (Over 50%)
- Air Void Differences (Same Gmm)
  - 57% of Between Lab Comparisons ≥ 1.0%
  - 27% of Between Lab Comparisons ≥ 2.0%
  - Mix Design Verification
- ALL Labs Should Be AASHTO Accredited!

Between Lab %AV Differences

- **Bold = >1.0%** Difference in Air Voids
- **Red = > 2.0%** Difference in Air Voids

		Laboratory Number														
Laboratory Number		*11*	*15*	*19*	*20*	*24*	*28*	*33*	*47*	*54*	*63*	*86*	*101*	*102*	*103*	*104*
	11		**1.1**	0.4	0.3	**1.8**	**1.7**	**1.0**	0.5	**1.0**	**1.5**	0.5	**1.6**	0.1	0.9	**1.8**
	15	1.1		0.7	**1.4**	0.7	**2.8**	0.1	0.0	**2.1**	**1.4**	0.6	**1.5**	**1.0**	0.2	0.7
	19	0.4	0.7		0.7	**1.4**	**2.1**	0.6	0.7	**1.4**	**2.1**	0.1	**2.2**	0.3	0.6	**1.4**
	20	0.3	1.4	0.7		**2.1**	**1.4**	**1.3**	**1.4**	0.7	**2.8**	0.8	**2.9**	0.4	**1.2**	**2.1**
	24	1.8	0.7	1.4	2.1		**3.5**	0.8	0.7	**2.8**	0.7	**1.3**	0.8	**1.7**	0.9	0.0
	28	1.7	2.8	2.1	1.4	**3.5**		**2.7**	**2.8**	0.7	**4.2**	**2.2**	**4.3**	**1.8**	**2.6**	**3.5**
	33	1.0	0.1	0.6	1.3	0.8	**2.7**		0.1	**2.0**	**1.5**	0.5	**1.6**	0.9	0.1	0.8
	47	0.5	0.0	0.7	1.4	0.7	**2.8**	0.1		**2.1**	**1.4**	0.6	**1.5**	**1.0**	0.2	0.7
	54	1.0	2.1	1.4	0.7	2.8	0.7	2.0	2.1		**2.5**	**1.5**	**3.6**	0.7	**1.9**	**2.8**
	63	1.5	1.4	2.1	2.8	0.7	4.2	1.5	1.4	2.5		**2.0**	0.1	**2.4**	**1.6**	0.7
	86	0.5	0.6	0.1	0.8	1.3	2.2	0.5	0.6	1.5	2.0		**2.1**	0.4	0.4	**1.3**
	101	1.6	1.5	2.2	2.9	0.8	4.3	1.6	1.5	3.6	0.1	2.1		**2.5**	**1.7**	0.8
	102	0.1	1.0	0.3	0.4	1.7	1.8	0.9	1.0	0.7	2.4	0.4	2.5		0.8	**1.7**
	103	0.9	0.2	0.6	1.2	0.9	2.6	0.1	0.2	1.9	1.6	0.4	1.7	0.8		0.9
	104	1.8	0.7	1.4	2.2	0.0	3.5	0.8	0.7	2.8	0.7	1.3	0.8	1.7	0.9	

Laboratory Accreditation

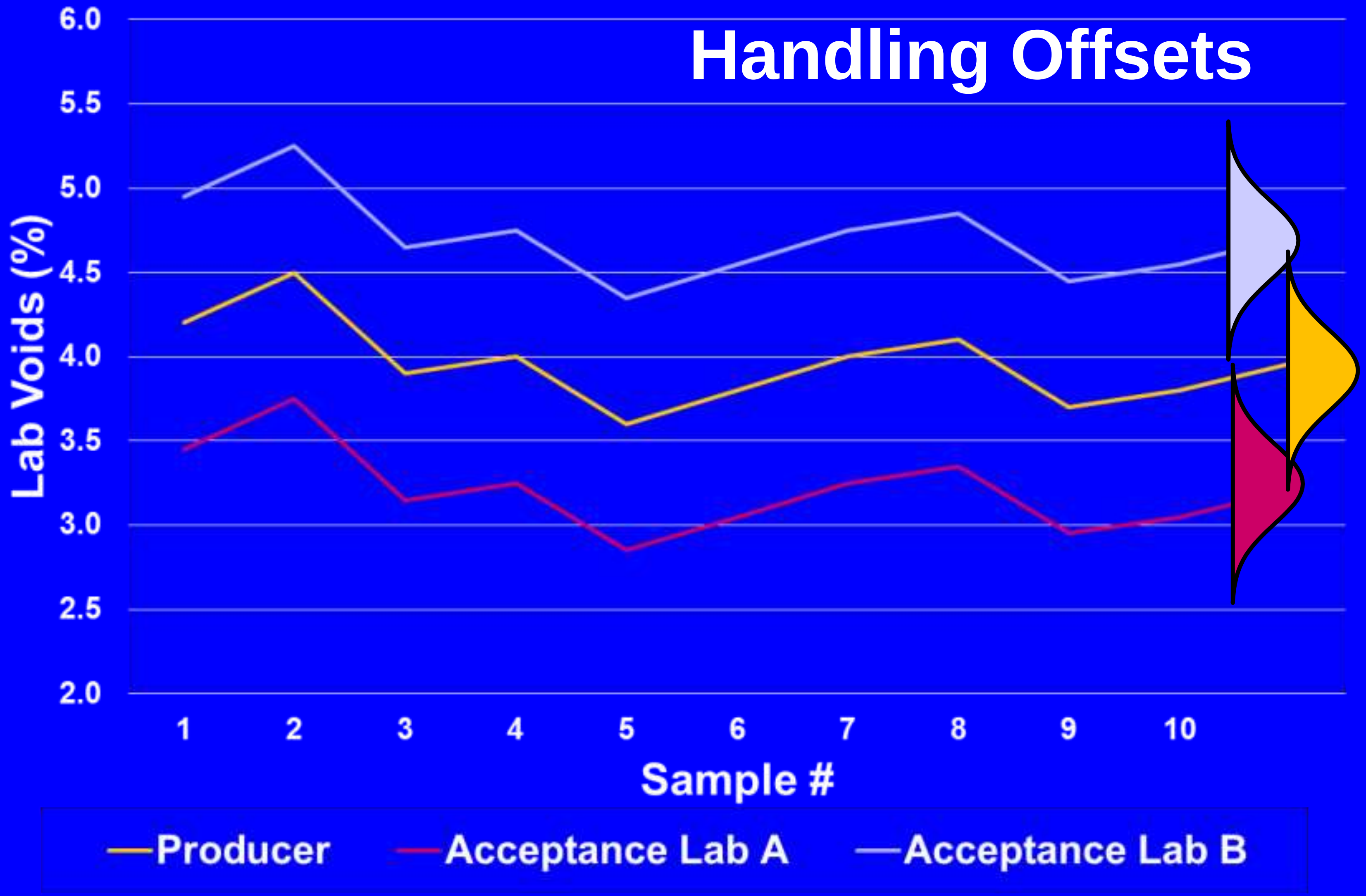
- It is a Priceless Investment
- State DOT vs. AMRL
- AMRL is Best
- Contractor or SHA Central Labs Only NOT Enough
- Internal Controls
- Proficiency Sample Programs

- Correct Between Lab Bias BEFORE Doing a Job!

Technician Qualification

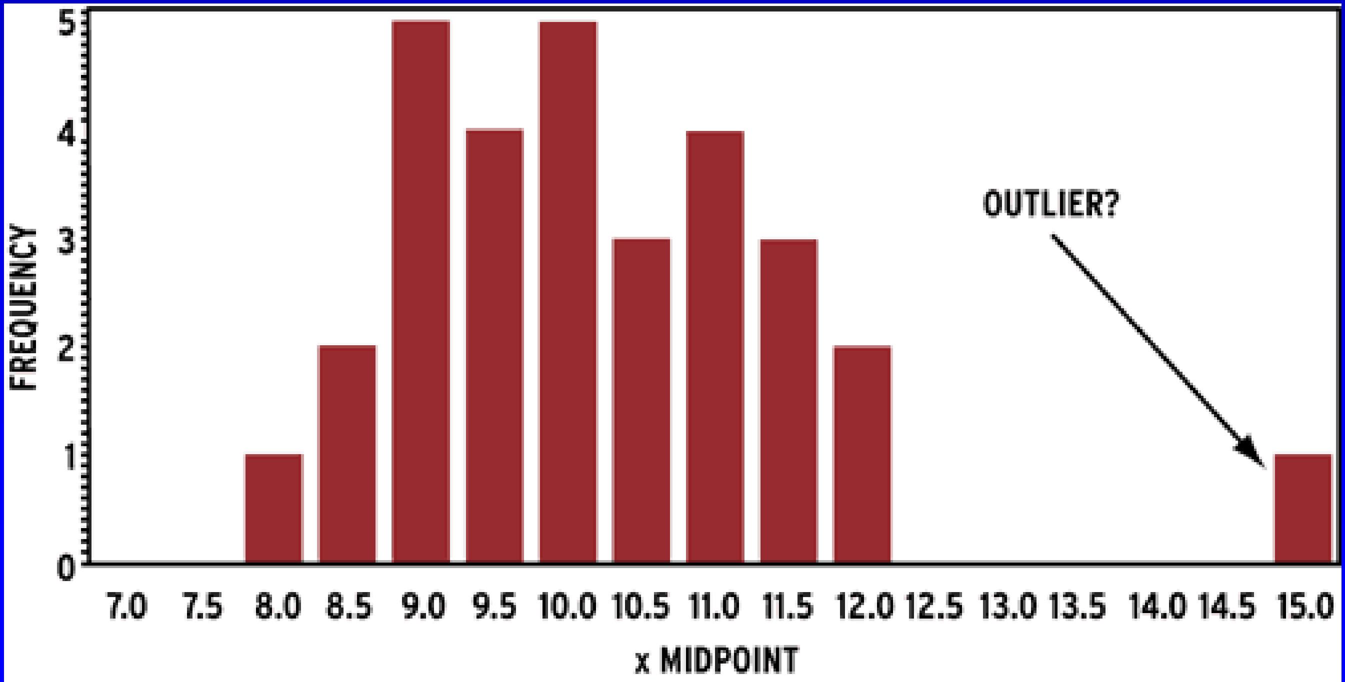
- Qualification Important
- Perceived Cost Significant
- Lack of Appreciation for Importance
  - Who Bears Risk With High Testing Variability?
    - Owner?
    - Consultant?
    - Material Producer/Contractor?
- Rigor of Processes
  - Good Examples
    - Texas, Colorado, and Arizona
- Another Priceless Investment

Producing for Multiple Customers



Dispute Resolution

- Need for Outlier Definition – "*Wacky or Flyer*"
- Need for Outlier Detection Tool
  - ASTM E178 or some other criteria
- Need for Re-test Provision – Test whole sample or individual test? Split or independent sample…



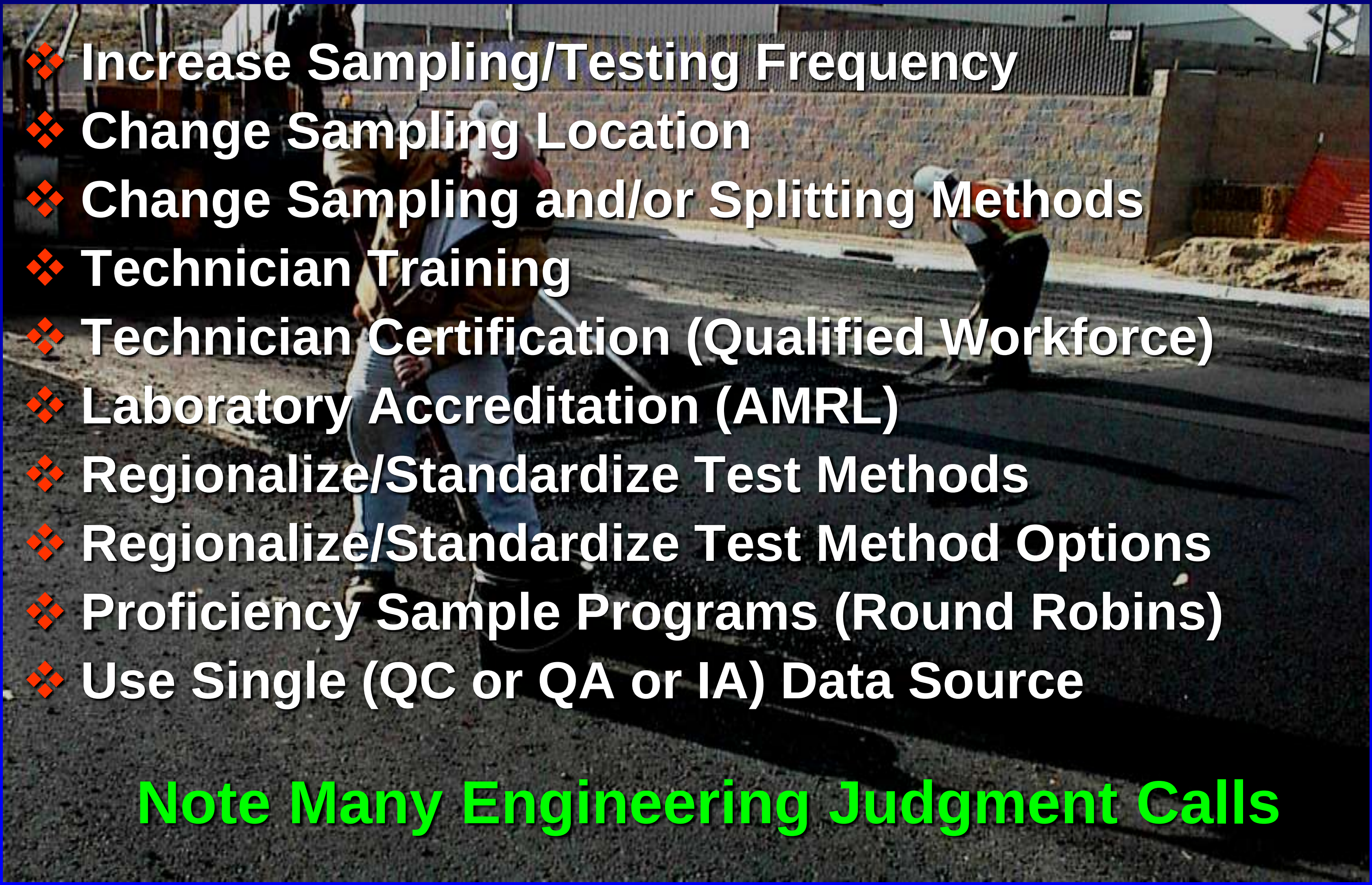
Fraud

- NCHRP Project
- ARI Postings
- Request Outlier/Re-Test Provisions
  - ASTM
  - Arizona
- WE are the Keepers of Industries Integrity Perception!
- Dispute Resolution Provisions Help US

Summary

- Many Agencies Using Stat Based Quality Assurance Specs with *Pay for Quality Objective*
- Increased Contractor Responsibility with Reduced Agency Demands
- Specs More Complicated than Meet the Eye due to
  - Lack of Relationships between Quality and Pavement Performance
  - Subjective Engineering Judgment in Selection of Many Specification Parameters
- Influence of Variability and Spec Limits Critically Important

Reducing Sampling & Testing Variability



- Increase Sampling/Testing Frequency
- Change Sampling Location
- Change Sampling and/or Splitting Methods
- Technician Training
- Technician Certification (Qualified Workforce)
- Laboratory Accreditation (AMRL)
- Regionalize/Standardize Test Methods
- Regionalize/Standardize Test Method Options
- Proficiency Sample Programs (Round Robins)
- Use Single (QC or QA or IA) Data Source

Note Many Engineering Judgment Calls

Suggestions

- Cooperative Spec Development & Refinement
- Knowledgeable Spec Developers - Use Shadow Approach
- Refine Specs Over Time
  - Knowledge/Experience/Equipment Improvements
  - Use Rational Analysis (Avoid Arbitrary Changes)
- Support Efforts to Minimize σ_s and σ_t
- Support Efforts to Develop Relationships between Quality and Pavement Performance
- Develop Databases as Basis for Future Changes
- Support Lab Accreditation
- Support Technician Certification

Thank You and Discussion

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