A Probabilistic Method for Predicting Code Growth - 2018 Update

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Outline

- Software Cost Estimating Process
- What is code growth?
- Existing Methodology - DSLOC Estimate Growth Model v7 (DEGM7)
- New Methodology - DSLOC Estimate Growth Model v8 (DEGM8)
  - Equations and Explanations
    - Technical Baseline Estimates (TBE)
    - Baseline Growth Amounts
      - Orthogonal Distance Regression (ODR)
    - Maturity
  - SRDR Filtering
  - Outputs
- Conclusion
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  - Variable Definition
  - Methodology Based on Specific Operating Environments

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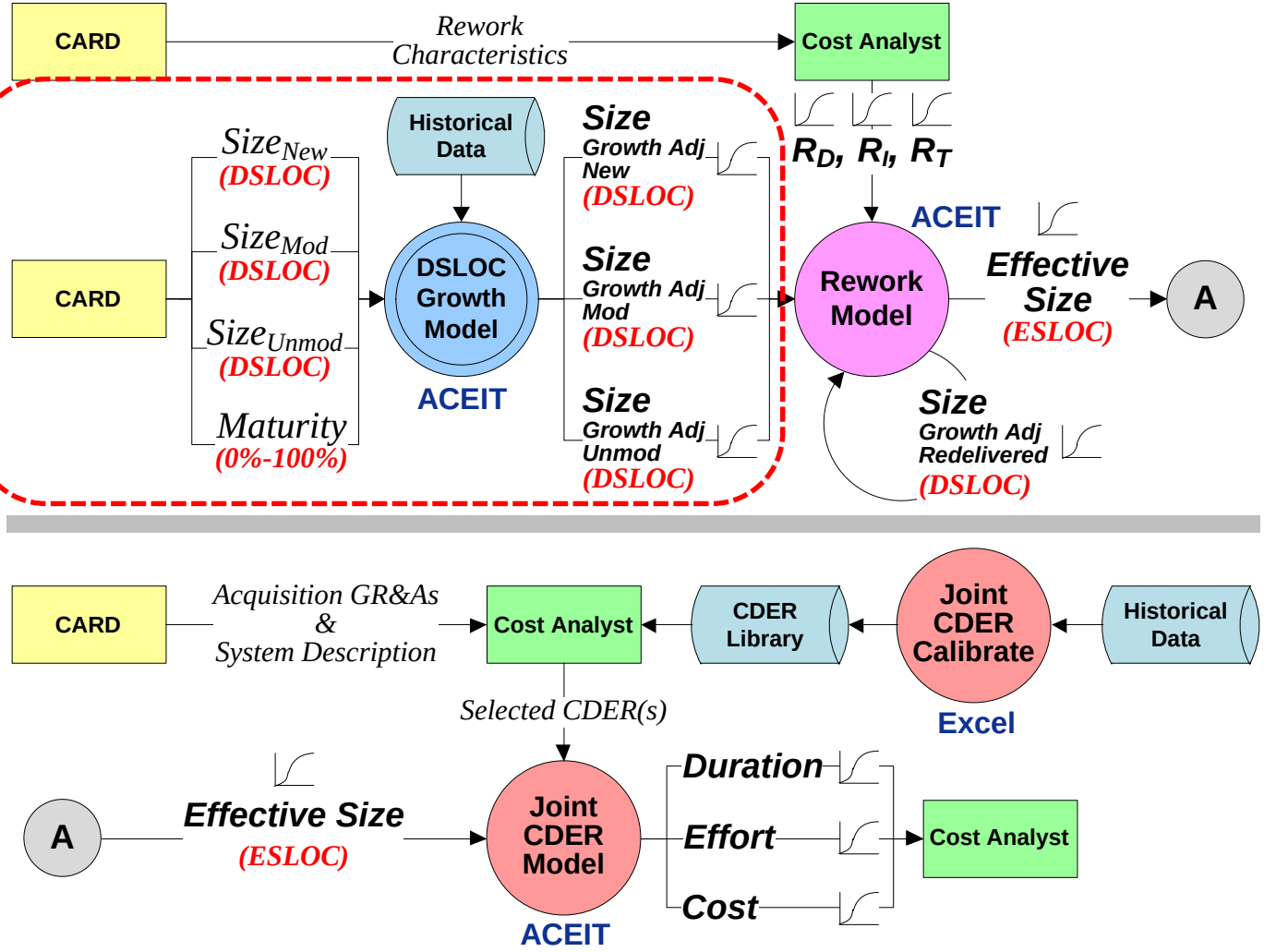
r2-v2 SEF Process Flow: Creating New CDERs for the Library



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What is code growth?

- Code growth is the difference between actual Delivered Source Lines of Code (DSLOC) of a completed software development project and its previously estimated DSLOC amount.

  Actual DSLOC > Estimated DSLOC → Growth
  Actual DSLOC < Estimated DSLOC → Growth (Shrink)

- Reasons for Code Growth:
  - The customers didn't know what they wanted at the start of the program
  - The mission/requirements (REQTS) changed (requirements volatility)
  - The vendor finished early so the customer thought up a few things to add
  - Software regulations have changed
  - Optimistic (e.g. overestimate of unmodified DSLOC)
  - Poor DSLOC TBE

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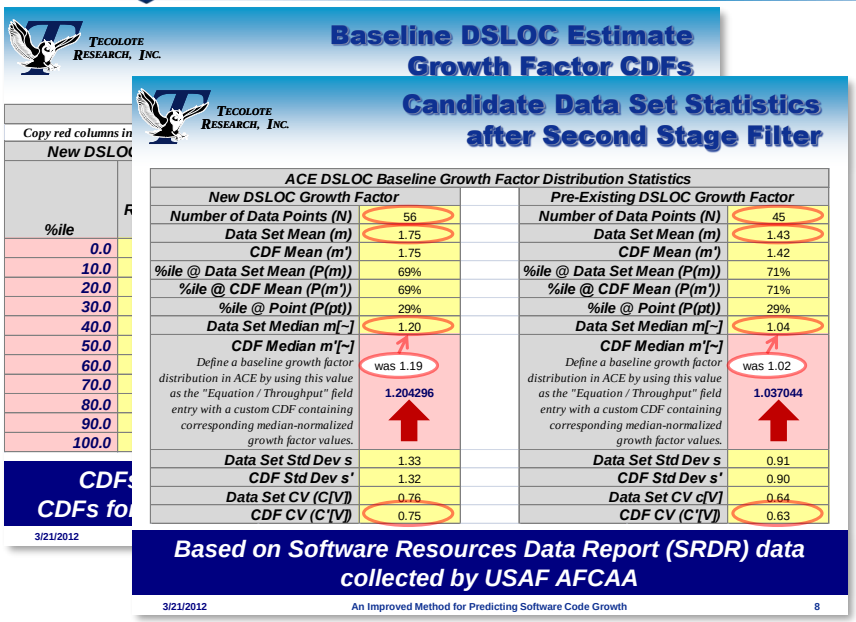
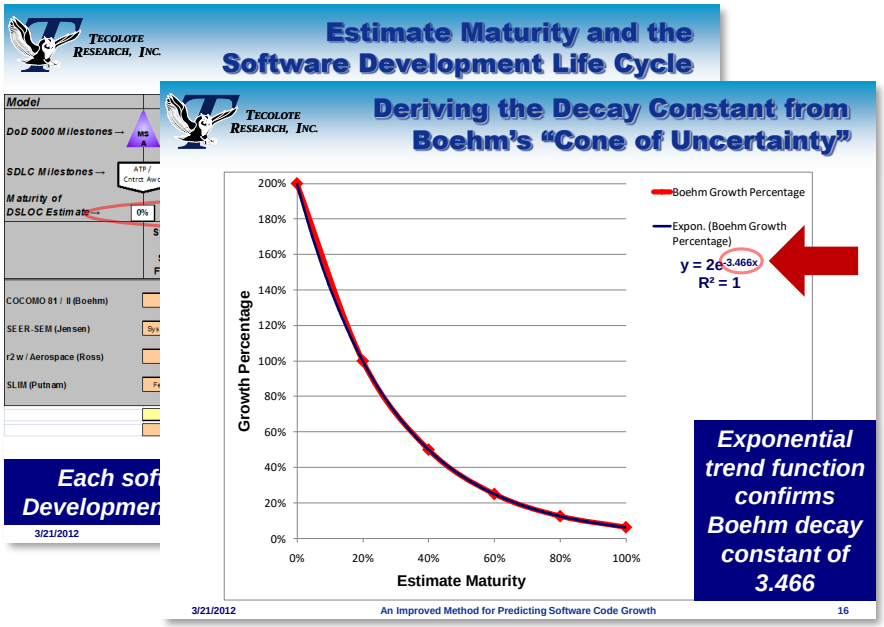
Existing Growth Methodology
DSLOC Estimate Growth Model v7 (DEGM7)





- What we are currently using:
  - Step 1: Baseline Growth (w/ uncertainty) applied to Technical Baseline
    - Based on DSLOC Estimate Growth Methodology (Ross, v07) using 2011 SRDR data
    - Factored Based Model
  - Step 2: Total growth discounted based on maturity
    - Barry Boehm's "Cone of Uncertainty"
    - Unchanged for DEGM8

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New Growth Methodology
DSLOC Estimate Growth Model v8 (DEGM8)

- This model represents a significant update and modernization of the DSLOC Estimate Growth Model version 7 (DEGM7) (Ross, 2011) in that:
  - It is based on additional data from the 2015 SRDR database.
  - It is based on a better method of regressing the historical data.
  - It recognizes non-linear relationships between size and growth.
  - It introduces error on the independent variable (DSLOC)
  - It decomposes the version 7 notion of Pre-existing reused software into Modified software and Unmodified software.
  - It recognizes correlation between New, Modified, and Unmodified growth.

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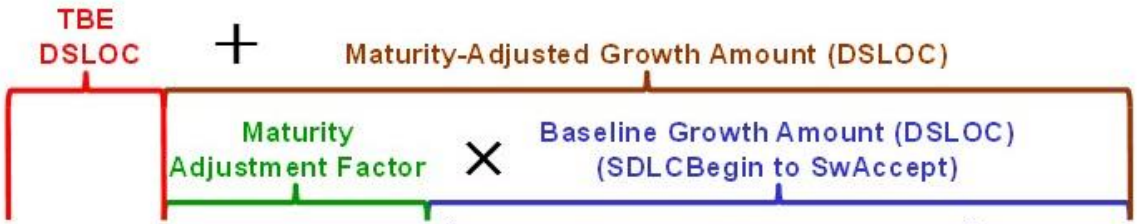
DSLOC Estimate Growth Model v8 (DEGM8) Growth Equations

- The DEGM8 equations for applying growth and uncertainty to TBE New, Modified, and Unmodified DSLOC are shown in Figure 1



$$S_{DGANew} \triangleq S_{DNew} + e^{-(Decay)(Maturity)} \left(\tilde{b}_{GN} \varepsilon_{GN} \left(\frac{S_{DNew}}{K_N} \right)^{a_{GN}} K_N - S_{DNew} \right)$$

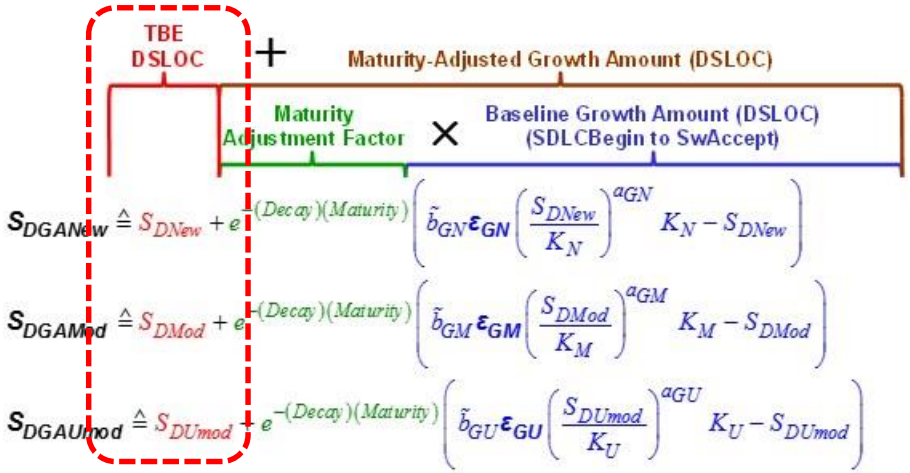
$$S_{DGAMod} \triangleq S_{DMod} + e^{-(Decay)(Maturity)} \left(\tilde{b}_{GM} \varepsilon_{GM} \left(\frac{S_{DMod}}{K_M} \right)^{a_{GM}} K_M - S_{DMod} \right)$$

$$S_{DGAUmod} \triangleq S_{DUmod} + e^{-(Decay)(Maturity)} \left(\tilde{b}_{GU} \varepsilon_{GU} \left(\frac{S_{DUmod}}{K_U} \right)^{a_{GU}} K_U - S_{DUmod} \right)$$

Figure 1 *DEGM8 equations yield the sum of the appropriate TBE DSLOC value and its calculated DSLOC growth amount. The calculated DSLOC Growth amount is the product of the baseline DSLOC growth amount (zero maturity) and the calculated estimate maturity adjustment factor.*

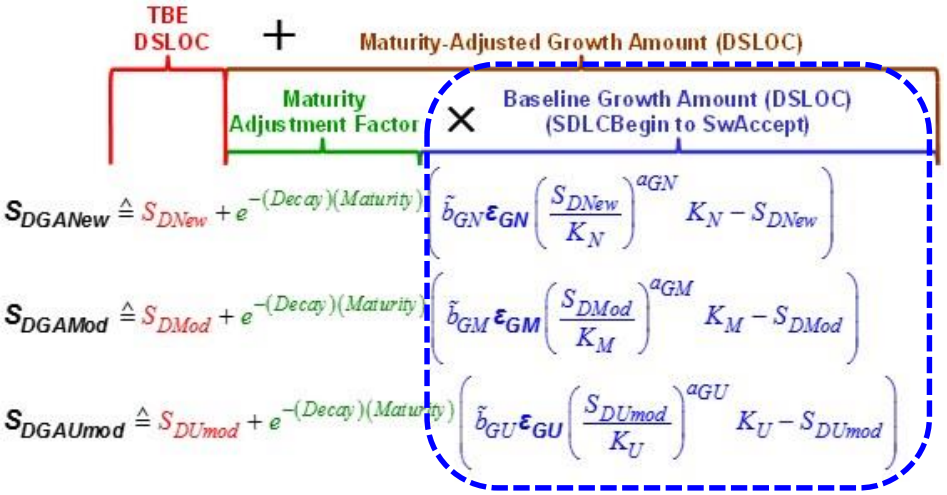
Variable Definition in backup

DEGM8 Growth Equations
TBE DSLOC



- The DEGM8 accepts, as input, Technical Baseline Estimate (TBE) amounts for New (S_{DNew}), Modified (S_{DMod}), and Unmodified DSLOC (S_{DUmod}).
  - They are rendered at various times during the program; Based on some combination of engineering analysis, relevant past program experience, and expert judgment
- These estimates represent the technical team's best guess as to what the final outcome New, Modified, and Unmodified DSLOC values will be when the system is delivered and accepted.

DEGM8 Growth Equations
Baseline Growth Amounts (DSLOC)



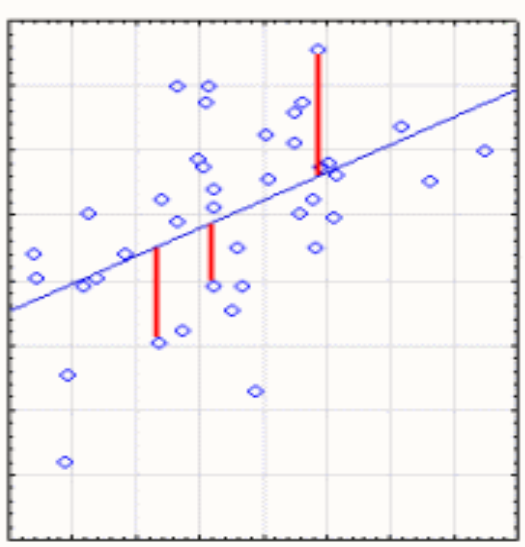
- DEGM8 introduces a new regression technique (ODR)
  - Baseline Growth Equation is now a power function rather than a factor
  - Historically, DoD SW intensive programs experience significant growth; this technique allows us to model error on the initial SLOC input
- $\tilde{b}_{G\_}, a_{G\_}, \varepsilon_{G\_} \rightarrow$ calculated as part of the regression technique
- $S_{D\_}, K_{\_} \rightarrow$ Inputs into Baseline Growth Equation

DEGM8
Orthogonal Distance Regression (ODR)

- What is ODR?
  - A process for finding a “best fit” line (an estimator) through a multi-dimension set of data points (observations) by minimizing the sum of the squared orthogonal (shortest) distances between each data point and that line

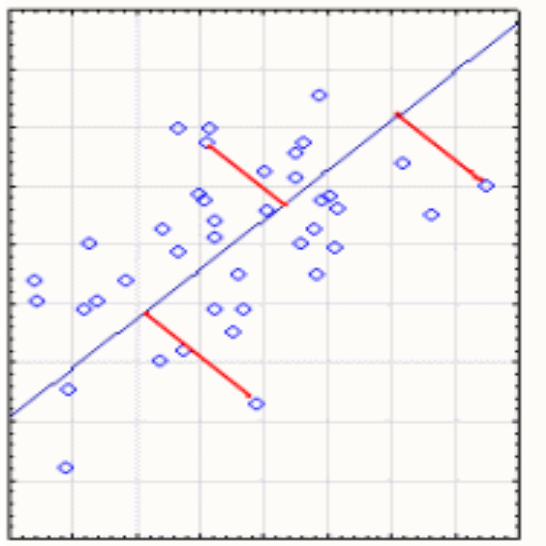
Ordinary Least Squares (OLS)

Minimizes the ***vertical*** distance between each data point and the regression line.



Orthogonal Distance Regression (ODR)

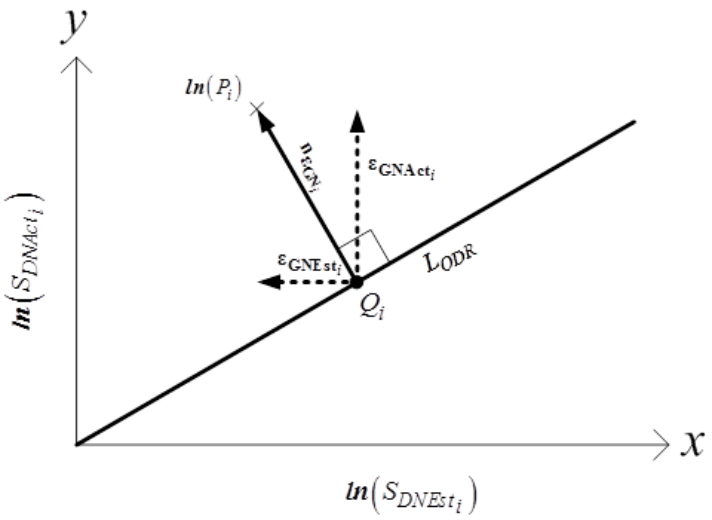
Minimizes the ***Orthogonal*** distance between each data point and the regression line.



DEGM8
OLS vs. ODR

Why is ODR better than Ordinary Least Squares (OLS) regression and its variants?

- Works in situations where there are more than two dimensions (measures) without making assumptions about which measure is dependent and which are independent (example: Space Flight Software)
- Accounts the existence of measurement error in all dimensions; not just in the "dependent" variable



Singular Value Decomposition (SVD) for DEGM8 Equation Coefficients

- To find the system of equations that define an ODR best fit line we center the data set by using the data set centroid and then applying the SVD

Transform & center the data

$$\mathbf{M} \equiv \begin{bmatrix} ln\left(S_{DNEst_1}\right) - C_{ln(\mathbf{P})S_{DNEst}} & ln\left(S_{DNAct_1}\right) - C_{ln(\mathbf{P})S_{DNAct}} \\ ln\left(S_{DNEst_2}\right) - C_{ln(\mathbf{P})S_{DNEst}} & ln\left(S_{DNAct_2}\right) - C_{ln(\mathbf{P})S_{DNAct}} \\ \mathrm{M} & \mathrm{M} \\ ln\left(S_{DNEst_N}\right) - C_{ln(\mathbf{P})S_{DNEst}} & ln\left(S_{DNAct_N}\right) - C_{ln(\mathbf{P})S_{DNAct}} \end{bmatrix}$$

Perform SVD

$$SVD(\mathbf{M}) \equiv \left\{\mathbf{U}, \mathbf{\Sigma}, \mathbf{V}^{\mathsf{T}}\right\} \mid \mathbf{M} = \mathbf{U}\mathbf{\Sigma}\mathbf{V}^{\mathsf{T}}$$

Define ODR coefficients using Direction Vector, *a*

$$\mathbf{M} = \mathbf{U}\begin{bmatrix} \Sigma_{1,1} & 0 \\ 0 & \Sigma_{2,2} \end{bmatrix}\begin{bmatrix} V_{1,1} & V_{1,2} \\ V_{2,1} & V_{2,2} \end{bmatrix}^{\mathsf{T}}$$

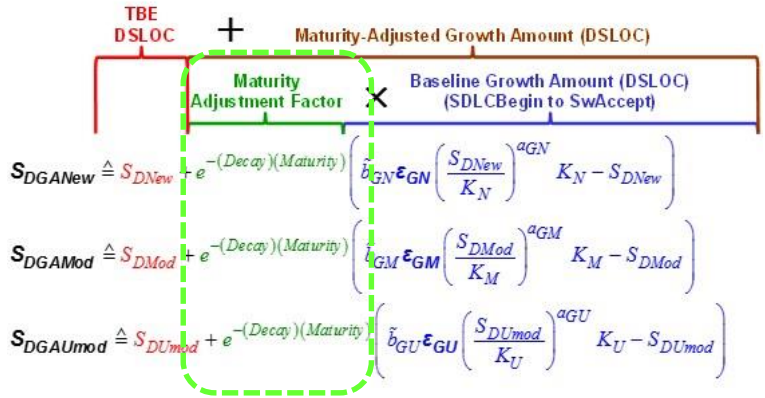
$$= \mathbf{U}\begin{bmatrix} \Sigma_{1,1} & 0 \\ 0 & \Sigma_{2,2} \end{bmatrix}\begin{bmatrix} a_{S_{DNEst}} & V_{1,2} \\ a_{S_{DNAct}} & V_{2,2} \end{bmatrix}^{\mathsf{T}}$$

- The resulting ODR best fit line is specified by a known point on the line (the data set centroid) and a direction vector (the column of the singular vector matrix that is associated with the largest singular value in the singular value matrix).

$$S_{DGANewBL} = b_{GN} S_{DNew}^{\ a_{GN}}$$

Note: Please see paper for details on SVD and transformation of SVD results to ODR line

DEGM8 Growth Equations
Maturity Adjustment Factor



Estimate Maturity Scale	
Maturity = 0%	Authorization to Proceed, SDLC Begin (ATP)
Maturity = 10%	System Specification/Requirements Review (SyRR)
Maturity = 20%	System Design Review / Software Specification/Requirements Review (SwRR)
Maturity = 40%	Software Preliminary (Top Level Architecture) Design Review (SwPDR)
Maturity = 60%	Software Critical (Detail) Design Review (SwCDR)
Maturity = 80%	Software Test Readiness Review (SwTRR)
Maturity = 100%	Software Acceptance / Final Qualification Test Compplete (SwAccept) (DD250)

- Maturity Adjustment Factor = $e^{-(Decay)(Maturity)} = e^{-(3.466)(Maturity)}$
- **Growth Decay:** Based on Boehm's (1981 pp. 310-311) Cone of Uncertainty. Given the limited amount of granular, periodic, and relevant historical DSLOC estimate data available, we used Boehm's (1981 pp. 310-311) Cone of Uncertainty as the DEGM8's default position.

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DEGM8
SRDR Filtering

- The baseline (default) instance of the DEGM8 equation parameter values for New, Modified, and Unmodified DSLOC is based on a subset of 2015 Software Resources Data Report (SRDR) data collected and archived by the U.S. Department of Defense's Defense Cost and Resource Center (DCARC)
- Filter criteria:
  - SI: TRUE – the observation must represent a Computer Software Configuration Item (CSCI)-like Software Item (SI) (i.e.., not a collection, summary, or roll-up of multiple CSCIs)
  - Nonphysical: TRUE – the observation's DSLOC values must not be measured in units of straight physical lines of code (i.e., they must be measured in logical lines of code (language statements) or non-comment physical lines of code)
  - GFValid: TRUE – the observation must contain DSLOC values to calculate New, Modified, and/or Unmodified DSLOC growth factors that are all inside three geometric standard deviations from their respective population (entire database) geometric mean (see Table 2 on the next slide)
- Database exhibit some CSCI's with unrealistic growth; they are obvious outliers in the database
  - 1 Example showed a CSCI with >100x's growth
  - Filtering out data at +/- 3 Geometric SD's is an attempt to unbiasedly remove those outliers

DEGM8 SRDR Filtering

Table 2 Statistical outlier filtering comparison; regression JCDER349 with 3 geometric standard deviation statistical outlier filtering was chosen as the basis for the DEGM8

	New DSLOC			Modified DSLOC			Unmodified DSLOC		
	JCDER345	JCDER349	JCDER346	JCDER345	JCDER349	JCDER346	JCDER345	JCDER349	JCDER346
Statistical Outlier Filtering:	None	3 GeoSigma	2 GeoSigma	None	3 GeoSigma	2 GeoSigma	None	3 GeoSigma	2 GeoSigma
Number of Data Points (observations):	302	225	213	169	136	125	190	142	132
Geometric (log space) mean of b:	0.7947	1.2084	1.1137	1.4203	2.6508	1.9364	0.3723	0.6199	0.5499
Arithmetic (unit space) mean of b:	3.4927	1.7360	1.4867	4.9077	4.0600	2.6865	0.9409	0.7510	0.6345
Standard deviation b:	19.1832	1.8493	1.3418	18.4790	4.5566	2.3590	3.1087	0.6566	0.4408
Coefficient of Variation (CV) b:	5.49	1.07	0.90	3.77	1.12	0.88	3.30	0.87	0.69
Arithmetic (unit space) mean of ε:	1.9368	1.3665	1.2819	2.2755	1.5105	1.4362	1.5683	1.1911	1.1280
Standard deviation of ε:	3.2795	1.2238	0.9590	4.0775	1.6230	1.4924	1.9782	0.9296	0.6398
Coefficient of Variation (CV) of ε:	1.69	0.90	0.75	1.79	1.07	1.04	1.26	0.78	0.57
Mean Magnitude of the Relative Error:	61%	44%	39%	67%	50%	44%	43%	24%	22%
Implied Growth Factor at data set arithmetic mean baseline DSLOC:	96% at 74,958 DSLOC	53% at 59,443 DSLOC	49% at 60,213 DSLOC	31% at 45,547 DSLOC	11% at 22,934 DSLOC	10% at 23,216 DSLOC	34% at 365,311 DSLOC	7% at 251,323 DSLOC	11% at 266,322 DSLOC
Implied Growth Factor at data set geometric mean baseline DSLOC:	80% at 25,635 DSLOC	50% at 23,035 DSLOC	45% at 23,672 DSLOC	33% at 9,161 DSLOC	22% at 7,756 DSLOC	17% at 7,808 DSLOC	14% at 72,523 DSLOC	1% at 70,790 DSLOC	3% at 75,292 DSLOC

Default Method based on filtering out +/- 3 Geometric SD

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Output (Default: All Paired Data – Filtered) ODR Equation

Coefficient	New	Modified	Unmodified
$a_{G\_}$	1.021	0.913	1.044
$b_{G\_}$	1.208	2.651	0.6199

Baseline Growth (New DSLOC)

- $b_{GN}\varepsilon_{GN}\left(\frac{S_{DNew}}{K_N}\right)^{a_{GN}} K_N - S_{DNew} \rightarrow 1.208\varepsilon_{GN}\left(\frac{S_{DNew}}{K_N}\right)^{1.021} K_N - S_{DNew}$

Baseline Growth (Mod DSLOC)

- $b_{GM}\varepsilon_{GM}\left(\frac{S_{DMod}}{K_M}\right)^{a_{GM}} K_M - S_{DMod} \rightarrow 2.651\varepsilon_{GM}\left(\frac{S_{DMod}}{K_M}\right)^{0.913} K_M - S_{DMod}$

Baseline Growth (Unmod DSLOC)

- $b_{GU}\varepsilon_{GU}\left(\frac{S_{DUmod}}{K_U}\right)^{a_{GU}} K_U - S_{DUmod} \rightarrow 0.6199\varepsilon_{GU}\left(\frac{S_{DUmod}}{K_U}\right)^{1.044} K_U - S_{DUmod}$

Output (Default: All Paired Data – Filtered) Cumulative Distribution Function (CDF)

- $\varepsilon_{GN}, \varepsilon_{GM} \varepsilon_{GU}$

JCDER349 (Custom Growth CDFs)			
Percentile	JCDER349_e_GN_CDF	JCDER349_e_GM_CDF	JCDER349_e_GU_CDF
5	0.22780002	0.19797695	0.31476088
10	0.29379456	0.26905482	0.52151790
15	0.42005378	0.37202772	0.69719375
20	0.51067177	0.44448984	0.80244290
25	0.58960123	0.58049465	0.87663594
30	0.72495221	0.74853580	0.93359197
35	0.86357696	0.88755418	0.95855498
40	0.94805461	0.96684746	0.97517640
45	1.07607675	1.04115081	0.99675890
50	1.13572756	1.12987711	1.01372680
55	1.21842846	1.17893913	1.02592816
60	1.33350780	1.20158562	1.04526460
65	1.44006179	1.29116776	1.09504214
70	1.48139681	1.37838414	1.13383614
75	1.51552892	1.51895071	1.16555251
80	1.63383151	1.67307957	1.26139028
85	1.86949605	2.17763327	1.39181571
90	2.68118931	4.02790186	1.77923586
95	3.85981488	5.56055883	2.52099764
100	8.80095370	8.68058303	6.98289033

CDFs above are abbreviated for this presentation

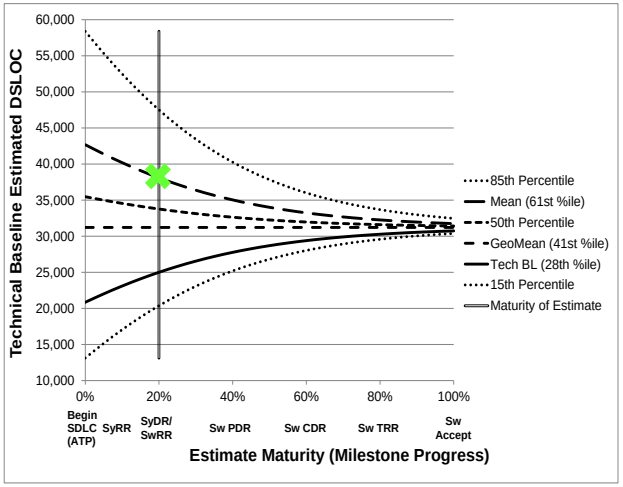
Output (Default: All Paired Data – Filtered) Correlation

Correlation Matrix			
	New DSLOC	Modified DSLOC	Unmodified DSLOC
New DSLOC	1		
Modified DSLOC	2.569663E-03	1	
Unmodified DSLOC	3.024662E-01	7.466961E-02	1

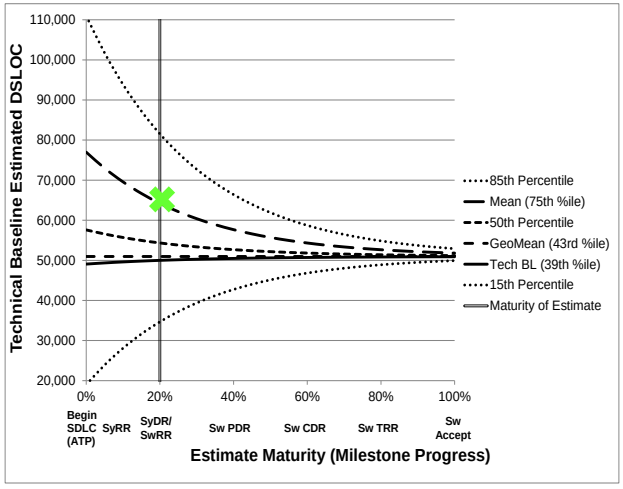
- Correlation between DSLOC type
  - New & Modified: 0.00257
  - New & Unmodified: 0.302
  - Modified & Unmodified: 0.0745
- For this particular subset, correlation between growth is weak and will have little impact on result
- When we start to investigate growth by operating environment, there is evidence of stronger correlations
- Interesting to note that negativity correlation may exists

Output (Default: All Paired Data – Filtered) Notional Example

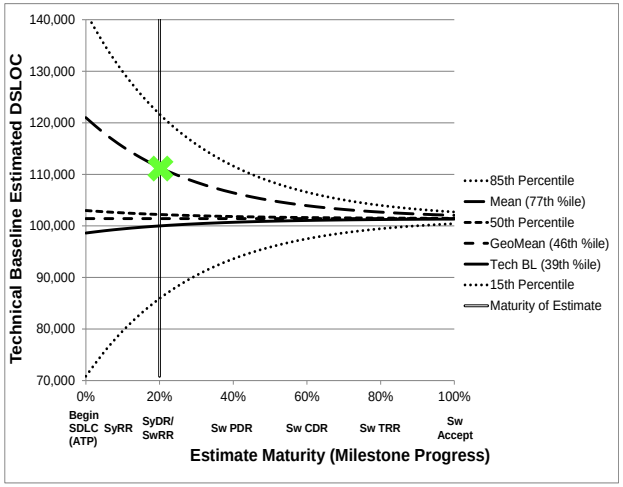
New DSLOC Growth



Modified DSLOC Growth



Unmodified DSLOC Growth



- Assume estimating NAV CSCI for Ground System
  - TBEs for New, Modified, and Unmodified software size are 25,000 DSLOC, 50,000 DSLOC, and 100,000 DSLOC respectively
  - 1 CSCI (normalization of the TBEs to the historical data is unnecessary)
  - Assume SLOC estimate rendered at SwRR (20% maturity)
  - Assume based on Boehm's (1981 pp. 310-311) Cone of Uncertainty
  - Assume methodology based on Default Methodology (All Paired Filtered Data)

✖ Represents mean growth at SwRR for Notional Program

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Conclusions/Way Ahead

- Our latest methodology (DEGM8) is based on a better method of regressing the historical data.
  - It recognizes non-linear relationships between size and growth.
  - Decomposes modified and unmodified software growth methodologies
  - It accounts for correlation between New, Modified, and Unmodified growth.

- Way Ahead
  - Update database with 2017 SRDR
  - Continue Flight Software data collection efforts
  - Rerun the data analysis for additional software operating environments, application domains, and other characteristics of interest.
  - Create a specific growth model for each Joint Cost and Duration Estimating Relationship (JCDER)

Contact Information

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BACKUP

DEGM8 Growth Equations
Baseline Growth Amounts (DSLOC)

$$S_{DGANew} \triangleq S_{DNew} + e^{-(Decay)(Maturity)}\left(\tilde{b}_{GN}\varepsilon_{GN}\left(\frac{S_{DNew}}{K_N}\right)^{a_{GN}} K_N - S_{DNew}\right)$$

$$S_{DGAMod} \triangleq S_{DMod} + e^{-(Decay)(Maturity)}\left(\tilde{b}_{GM}\varepsilon_{GM}\left(\frac{S_{DMod}}{K_M}\right)^{a_{GM}} K_M - S_{DMod}\right)$$

$$S_{DGAUmod} \triangleq S_{DUmod} + e^{-(Decay)(Maturity)}\left(\tilde{b}_{GU}\varepsilon_{GU}\left(\frac{S_{DUmod}}{K_U}\right)^{a_{GU}} K_U - S_{DUmod}\right)$$

S_{DGANew} ≡ ***Output*** – growth-adjusted New DSLOC distribution of outcomes with associated attainment probability[3]

S_{DGAMod} ≡ ***Output*** – growth-adjusted Modified DSLOC estimate distribution of outcomes with associated attainment probability

$S_{DGAUmod}$ ≡ ***Output*** – growth-adjusted Unmodified DSLOC estimate distribution of outcomes with associated attainment probability

$\triangleq$ ≡ Estimator equality symbol; the left expression estimates the right expression

S_{DNew} ≡ ***Input*** – Technical Baseline Estimate (TBE) of New DSLOC

S_{DMod} ≡ ***Input*** – Technical Baseline Estimate (TBE) of Modified DSLOC

S_{DUnmod} ≡ ***Input*** – Technical Baseline Estimate (TBE) of Unmodified DSLOC

$Decay$ ≡ ***Model*** – Decay constant; default is 3.466 based on Boehm's (1981 pp. 310-311) *Cone of Uncertainty*

$Maturity$ ≡ ***Input*** – Estimate Maturity Parameter: (SDLCBegin (ATP, Contract Award) = 0%; SyRR = 10%; SwRR = 20%; SwPDR = 40%; SwCDR = 60%; SwTRR = 80%; SwAccept = 100%)[4,5]

ε_{GN} ≡ ***Model*** – Baseline (SDLCBegin[6]) New DSLOC growth error factor distribution of outcomes with associated attainment probability; approximated by Custom CDF in Appendix A

ε_{GM} ≡ ***Model*** – Baseline (SDLCBegin) Modified DSLOC growth error factor distribution of outcomes with associated attainment probability; approximated by Custom CDF in Appendix A

ε_{GU} ≡ ***Model*** – Baseline (SDLCBegin) Unmodified DSLOC growth error factor distribution of outcomes with associated attainment probability; approximated by Custom CDF in Appendix A

a_{GN}, a_{GM}, a_{GU} ≡ ***Model*** – Exponent parameters for New, Modified, and Unmodified DSLOC growth estimating relationships that are calculated by the regression process

$\tilde{b}_{GN}, \tilde{b}_{GM}, \tilde{b}_{GU}$ ≡ ***Model*** – Geometric mean (arithmetic mean in log space) scale factor parameters for New, Modified, and Unmodified DSLOC growth estimating relationships that are calculated by the regression process

K_N, K_M, K_U ≡ ***Input*** – Software Item (SI) to Computer Software Configuration Item (CSCI) normalization factors for New, Modified, and Unmodified DSLOC

Output (Default: All Pair Data – Filtered) ODR Equation

DSLOC Estimate Growth Model Version:	Version 8
Version 8 DSLOC Estimate Growth Model Regression Method:	ODR

DSLOC Estimate Growth Model Equations and Variables

New DSLOC Growth Equation:	***S[DGANew]*** ≙ ***exp***(−(*Decay*Maturity*))*(*b̃[GM]**** **ε[GN]***(*S[DNew]/K[N]*)^*a[GN]*K[N]−S[DNew]*)+*S[DNew]*
Modified DSLOC Growth Equation:	***S[DGAMod]*** ≙ ***exp***(−(*Decay*Maturity*))*(*b̃[GM]**** **ε[GM]***(*S[DMod]/K[M]*)^*a[GM]*K[M]−S[DMod]*)+*S[DMod]*
Unmodified DSLOC Growth Equation:	***S[DGAUmod]*** ≙ ***exp***(−(*Decay*Maturity*))*(*b̃[GU]**** **ε[GU]***(*S[DUmod]/K[U]*)^*a[GU]*K[U]−S[DUmod]*)+*S[DUmod]*

where:

$a_{G\_}$	*a[GN]* = 1.021	*a[GM]* = 0.913	*a[GU]* = 1.044		
	e ≡ 2.7183	*Decay* ≡ 3.466			

$b_{G\_}$

List Statistics	[GN]	[GM]	[GU]
Number of Data Points (observations):	225	136	142
Geometric (log space) mean of b:	1.208E+00	2.651E+00	6.199E-01
Arithmetic (unit space) mean of b:	1.736E+00	4.060E+00	7.510E-01
Standard deviation of b:	1.849E+00	4.557E+00	6.566E-01
Coefficient of Variation (CV) b:	1.07	1.12	0.87
Arithmetic (unit space) mean of ε:	1.366E+00	1.510E+00	1.191E+00
Standard deviation of ε:	1.224E+00	1.623E+00	9.296E-01
Coefficient of Variation (CV) of ε:	0.90	1.07	0.78
Mean Magnitude of the Relative Error:	44%	50%	24%

Correlation

New to Modified DSLOC Correlation:	2.570E-03
New to Unmodified DSLOC Growth Correlation:	3.025E-01

Growth Factor Estimating Relationships Behavior	*New DSLOC Growth*	*Modified DSLOC Growth*	*Unmodified DSLOC Growth*
Implied Growth Factor at data set mean baseline DSLOC:	53% at 59,443 DSLOC	11% at 22,934 DSLOC	7% at 251,323 DSLOC
Implied Growth Factor at data set geometric mean baseline DSLOC:	50% at 23,035 DSLOC	22% at 7,756 DSLOC	1% at 70,790 DSLOC

$\varepsilon_{G\_}$

JCDER349 (Custom Growth CDFs)			
Percentile	*JCDER349_e_GN_CDF*	*JCDER349_e_GM_CDF*	*JCDER349_e_GU_CDF*
5	0.22780002	0.19797695	0.31476088
10	0.29379456	0.26905482	0.52151790
15	0.42005378	0.37202772	0.69719375
20	0.51067177	0.44448984	0.80244290
25	0.58960123	0.58049465	0.87663594
30	0.72495221	0.74853580	0.93359197
35	0.86357696	0.88755418	0.95855498
40	0.94805461	0.96684746	0.97517640
45	1.07607675	1.04115081	0.99675890
50	1.13572756	1.12987711	1.01372680
55	1.21842846	1.17893913	1.02592816
60	1.33350780	1.20158562	1.04526460
65	1.44006179	1.29116776	1.09504214
70	1.48139681	1.37838414	1.13383614
75	1.51552892	1.51895071	1.16555251
80	1.63383151	1.67307957	1.26139028
85	1.86949605	2.17763327	1.39181571
90	2.68118931	4.02790186	1.77923586
95	3.85981488	5.56055883	2.52099764
100	8.80095370	8.68058303	6.98289033

Operating Environment: Fixed Ground

SPACE AND MISSILE SYSTEMS CENTER

r2 Software Estimating Framework (r2SEF)			
Joint Cost and Duration Estimating Relationship (JCDER) Data Sheet (continued)			
ER351: Version 8 DSLOC Growth Model Baseline w/ GF3 Valid Filtering Only: Fixed Ground Logi			
DSLOC Estimate Growth Model Version:	Version 8		
Version 8 DSLOC Estimate Growth Model Regression Method:	ODR		
DSLOC Estimate Growth Model Equations and Variables			
New DSLOC Growth Equation:	**S[DGANew]** ≜ exp(−(Decay*Maturity))*(b̃[GN]*ε[GN]* (S[DNew]/K[N])^a[GN]*K[N]−S[DNew])+ S[DNew]		
Modified DSLOC Growth Equation:	**S[DGAMod]** ≜ exp(−(Decay*Maturity))*(b̃[GM]*ε[GM]* (S[DMod]/K[M])^a[GM]*K[M]−S[DMod])+ S[DMod]		
nmodified DSLOC Growth Equation:	**S[DGAUmod]** ≜ exp(−(Decay*Maturity))*(b̃[GU]*ε[GU]* (S[DUmod]/K[U])^a[GU]*K[U]−S[DUmod])+ S[DUMod]		
where:			
a[GN] = 1.050	a[GM] = 0.743	a[GU] = 1.275	
e ≡ 2.7183	Decay ≡ 3.466		

List Statistics	[GN]	[GM]	[GU]
umber of Data Points (observations):	48	23	27
Geometric (log space) mean of b:	1.001E+00	1.373E+01	4.149E-02
Arithmetic (unit space) mean of b:	1.537E+00	1.844E+01	5.440E-02
Standard deviation of b:	1.742E+00	1.332E+01	5.191E-02
Coefficient of Variation (CV) b:	1.13	0.72	0.95
Arithmetic (unit space) mean of ε:	1.474E+00	1.489E+00	1.189E+00
Standard deviation of ε:	1.524E+00	1.591E+00	7.854E-01
Coefficient of Variation (CV) of ε:	1.03	1.07	0.66
lean Magnitude of the Relative Error:	48%	53%	29%

New to Modified DSLOC Correlation:	1.399E-01
New to Unmodified DSLOC Growth Correlation:	-2.361E-01

JCDER351 (Custom Growth CDFs)			
Percentile	JCDER351_e_GN_CDF	JCDER351_e_GM_CDF	JCDER351_e_GU_CDF
5	0.22762555	0.28879716	0.20892398
10	0.29074110	0.37224510	0.34600877
15	0.32450063	0.50217307	0.52600805
20	0.49757245	0.53306236	0.68244218
25	0.56743434	0.56872118	0.70682042
30	0.65072762	0.58978237	0.86921910
35	0.75314420	0.59989374	0.95937548
40	0.89216252	0.60525967	1.07448472
45	0.92656909	0.73663852	1.08934477
50	1.00538050	0.81376043	1.10352074
55	1.19923930	1.08173528	1.11561548
60	1.28910046	1.19985968	1.14117023
65	1.59952201	1.34534346	1.16954904
70	1.71706921	1.50988568	1.31184404
75	1.76029032	1.57758170	1.45401684
80	1.86695537	1.76417333	1.49489554
85	2.23053443	2.45455265	1.64792676
90	2.86419186	4.20737863	1.74796409
95	4.32474823	5.51392208	2.87021541
100	8.46006991	6.46463042	4.08600963

Operating Environment: Mobile Ground

r2 Software Estimating Framework (r2SEF)			
Joint Cost and Duration Estimating Relationship (JCDER) Data Sheet (continued)			
R354: Version 8 DSLOC Growth Model Baseline w/ GF3 Valid Filtering Only: Mobile Ground Log			
DSLOC Estimate Growth Model Version:	Version 8		
Version 8 DSLOC Estimate Growth Model Regression Method:	ODR		
DSLOC Estimate Growth Model Equations and Variables			
New DSLOC Growth Equation:	***S[DGANew]*** ≜ ***exp***(−(*Decay*Maturity*))*(***b̃***[*GN*]****ε*[GN]*** (*S[DNew]/K[N]*)^*a[GN]*K[N]*−*S[DNew]*)+ *S[DNew]*		
Modified DSLOC Growth Equation:	***S[DGAMod]*** ≜ ***exp***(−(*Decay*Maturity*))*(***b̃***[*GM*]****ε*[GM]*** (*S[DMod]/K[M]*)^*a[GM]*K[M]*−*S[DMod]*)+ *S[DMod]*		
nmodified DSLOC Growth Equation:	***S[DGAUmod]*** ≜ ***exp***(−(*Decay*Maturity*))*(***b̃***[*GU*]****ε*[GU]*** (*S[DUmod]/K[U]*)^*a[GU]*K[U]*−*S[DUmod]*)+ *S[DUMod]*		
where:			
a[GN] = 0.965	*a[GM]* = 1.023	*a[GU]* = 1.039	
e ≡ 2.7183	*Decay* ≡ 3.466		

List Statistics	[GN]	[GM]	[GU]
umber of Data Points (observations):	24	18	13
Geometric (log space) mean of b:	2.483E+00	1.548E+00	6.739E-01
Arithmetic (unit space) mean of b:	3.692E+00	2.727E+00	7.831E-01
Standard deviation of b:	3.937E+00	3.605E+00	4.552E-01
Coefficient of Variation (CV) b:	1.07	1.32	0.58
Arithmetic (unit space) mean of ε:	1.402E+00	1.443E+00	1.237E+00
Standard deviation of ε:	1.238E+00	9.067E-01	1.097E+00
Coefficient of Variation (CV) of ε:	0.88	0.63	0.89
lean Magnitude of the Relative Error:	47%	55%	22%

New to Modified DSLOC Correlation:	3.601E-02
New to Unmodified DSLOC Growth Correlation:	5.369E-02

Percentile	*JCDER501_e_GN_CDF*	*JCDER501_e_GM_CDF*	*JCDER501_e_GU_CDF*
5	0.45013479	0.14330357	0.14007886
10	0.49553145	0.27018380	0.15824144
15	0.58140578	0.30099591	0.21667083
20	0.63885153	0.51185844	0.46130186
25	0.79090244	0.53448611	0.47783022
30	0.90596191	0.56632174	0.51610214
35	1.00962111	0.57671453	0.62626453
40	1.05811515	0.60395873	0.68075791
45	1.08394523	1.02760795	0.71319113
50	1.12029311	1.12965659	0.77768603
55	1.13898871	1.28950264	1.04813803
60	1.15677483	1.46473355	1.30497673
65	1.17698810	1.57600172	1.42833668
70	1.22701029	1.63317056	1.63640911
75	1.24858575	1.69296394	2.11570968
80	1.32829118	1.77517725	2.77989412
85	1.38402221	2.06913012	4.41452196
90	1.51039009	6.37208295	6.97308778
95	1.61373561	7.53914949	10.00927893
96	3.56984543	7.64541359	10.62341473

Operating Environment: Unmanned Space

SPACE AND MISSILE SYSTEMS CENTER

JCDER501: All Growth Eligible			
DSLOC Estimate Growth Model Version:	Version 8		
Version 8 DSLOC Estimate Growth Model Regression Method:	ODR		
DSLOC Estimate Growth Model Equations and Variables			
New DSLOC Growth Equation:	$S[DGANew] \triangleq exp(-(Decay*Maturity))*(\tilde{b}[GN]*\varepsilon[GN]*S[DNew]/K[N])^{a[GN]}*K[N]$		
Modified DSLOC Growth Equation:	$S[DGAMod] \triangleq exp(-(Decay*Maturity))*(\tilde{b}[GM]*\varepsilon[GM]*S[DMod]/K[M])^{a[GM]}*K[M]$		
Unmodified DSLOC Growth Equation:	$S[DGAUmod] \triangleq exp(-(Decay*Maturity))*(\tilde{b}[GU]*\varepsilon[GU]*S[DUmod]/K[U])^{a[GU]}*K[U]$		
where:			
$a[GN]$ = 1.074	$a[GM]$ = 0.709	$a[GU]$ = 1.265	
$Decay[GN]$ = 0.088	$Decay[GM]$ = 0.333	$Decay[GU]$ = 2.336	

List Statistics	[GN]	[GM]	[GU]
Number of Data Points (observations):	35	26	33
Geometric (log space) mean of b:	5.187E-01	1.421E+01	5.016E-02
Arithmetic (unit space) mean of b:	5.656E-01	2.296E+01	6.070E-02
Standard deviation of b:	2.510E-01	2.959E+01	3.430E-02
Coefficient of Variation (CV) b:	0.44	1.29	0.57
Arithmetic (unit space) mean of ε:	1.101E+00	1.769E+00	2.152E+00
Standard deviation of ε:	5.436E-01	2.205E+00	3.060E+00
Coefficient of Variation (CV) of ε:	0.49	1.25	1.42
Mean Magnitude of the Relative Error:	110%	177%	215%

New to Modified DSLOC Correlation:	5.868E-01
New to Unmodified DSLOC Growth Correlation:	-8.293E-02

Growth Factor Estimating Relationships Behavior	New DSLOC Growth	Modified DSLOC Growth	Unmodified DSLOC Growth
Implied Growth Factor at data set mean baseline DSLOC:	23% at 119,750 DSLOC	-37% at 45,778 DSLOC	-3% at 70,527 DSLOC
Implied Growth Factor at data set geometric mean baseline DSLOC:	16% at 55,026 DSLOC	-10% at 13,140 DSLOC	-10% at 52,272 DSLOC

Percentile	JCDER501_e_GN_CDF	JCDER501_e_GM_CDF	JCDER501_e_GU_CDF
5	0.45013479	0.14330357	0.14007886
10	0.49553145	0.27018380	0.15824144
15	0.58140578	0.30099591	0.21667083
20	0.63885153	0.51185844	0.46130186
25	0.79090244	0.53448611	0.47783022
30	0.90596191	0.56632174	0.51610214
35	1.00962111	0.57671453	0.62626453
40	1.05811515	0.60395873	0.68075791
45	1.08394523	1.02760795	0.71319113
50	1.12029311	1.12965659	0.77768603
55	1.13898871	1.28950264	1.04813803
60	1.15677483	1.46473355	1.30497673
65	1.17698810	1.57600172	1.42833668
70	1.22701029	1.63317056	1.63640911
75	1.24858575	1.69296394	2.11570968
80	1.32829118	1.77517725	2.77989412
85	1.38402221	2.06913012	4.41452196
90	1.51039009	6.37208295	6.97308778
95	1.61373561	7.53914949	10.00927893
96	3.56984543	7.64541359	10.62341473

- DEGM8SV (Space Vehicle)
  - Lack of Flight Software data in SRDR database
  - Performed data collection
    - Insufficient ATP DSLOC estimates
    - Modified DEGM8 to account insufficient data