NATIONAL RECONNAISSANCE OFFICE

Impact of Full Funding on Cost Improvement Rate: A Parametric Assessment

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SUPRA ET ULTRA

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Full Funding

- DoD policy for most items funded by procurement appropriations
  - Air Force, Navy satellite production contracts
  - Funds for entire delivered end item (eg. Satellite) appropriated in one fiscal year
  - Some end items on contract remain unfunded until future acts of congress
- Several exceptions in space business
  - Many production contracts since 1982 use Multi-Year Procurement: Entire contract funded over several years
  - Development programs: Typically first two satellites in a new block are incrementally funded
  - One-of-a-kind/demonstration-type satellites
  - NASA & NRO Programs

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Cost Improvement

- Also known as "Production Cost Efficiencies"
- Decrease in recurring average unit cost when there are higher quantities on a contract
- Contributors include:
  - Touch-labor learning effects
  - Amortization of production set-up costs
  - Amortization of fixed costs
  - Quantity discounts on vendor items
  - Efficient use of staff – work on multiple units

Full funding can preclude some of these contributors & may inhibit cost improvement

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Cost Improvement Rate, *r*

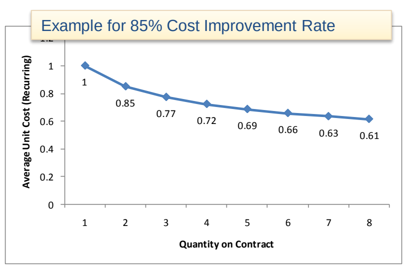
- Relative average unit cost (AUC) when quantity on contract doubles
- Standard "Wright" learning-curve form also used for cost improvement:

$$AUC = T1 \cdot Q^{B}$$

$$B = \frac{\ln(r)}{\ln(2)}$$

$$r = 2^{B}$$

Cost-improvement rate, ***r***, is the relative AUC when quantity is doubled



- NRO CAAG estimates cost improvement rate for space hardware boxes during CER development
  - Quantity is an independent variable in NRO CERs
  - Each equipment type may have a different result

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Cost Improvement in CERs

Quantity As an Independent Variable (QAIV)

- QAIV CERs estimate average unit cost (*AUC*) as a function of quantity (*Q*) and other technical variables such as weight (*w*)

$$\text{Example: } AUC = K \cdot w^A \cdot Q^B$$

- In this example, *Q* = 1 gives a CER that estimates AUC of 1 unit

$$T1 = K \cdot w^A$$

- This form of the QAIV CER therefore reduces to

$$AUC = T1 \cdot Q^B$$

- This is the standard “Wright” learning-curve form
  - Learning rate (or cost-improvement rate) = 2^*B*
  - 2^*B* = Relative *AUC* when *Q* is doubled

Cost-Improvement Rate is Relative Unit Cost When Quantity on Contract Doubles

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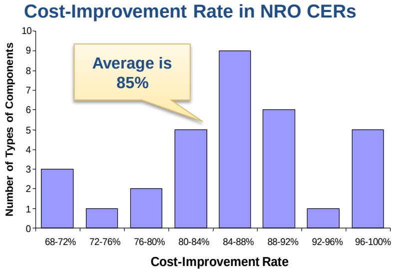
NRO CERs for Recurring Cost

79 Equipment Groups

Att. Control Elex (ACE)	Helix antenna	Solid Rocket Motors
Back-End RF Electronics	Dipole/Other antenna	Solid-State Transponders
Power Monitors	Nutation Dampers	Solid-State Transmitters
BAPTAs	Comm Data Processing Electronics	Star Trackers
Li batteries	SIG or EO Processing Electronics	Solar-Array Booms
NiCd batteries	Positioner assemblies	Other Deployable Structure
NiH batteries	Positioner motors	Secondary Structures
Booster Adapters	DC power converters	Trusses and Towers
Command Receivers	AC power converters	Equipment Compartments
GPS Digital	Power & Coax Harnesses	Optical Payload structures
Comm Front-End RF Electronics	Propulsion Plumbing	Analog sun sensors
Comm LNAs	Pressurant Tanks	Digital sun sensors
DC Power Harnesses	Propellant Tanks	Bus and RF Payload thermal H/W
Deployment Drives	Pyro Driver Electronics	EO Payload Thermal H/W
Driver Control & Data Rounting Elex	RF Coax Harnesses	Thermal Blankets
Earth Sensors	Shunts, Dissipators and Capcitors	Thermal Heaters and Sensors
EPS Electronics	Feed Equipment Groups	Thermal Heat Pipes & Radiators
Flight Computers	Feeds	Thermal Shields/Barriers/Louvers
IRUs	Front End RF Electronics	Thrusters
Accelerometers		Oscillators
Large Deployable Reflectors	Preamplifiers	Timers/Clocks
Magnetic Torquers	Small Parabolic Antennas	TT&C Digital Electronics
Magnetometers	GaAs, deployable arrays	TWTAs
Downlink MW Plumbing	GaAs, not deployable arrays	Waveguide Assemblies
TT&C MW Plumbing	Silicon, deployable arrays	Reaction Wheels
Horn antenna	Silicon, not deployable arrays	CMGs
Spiral antenna	Solar Array Drives	

Histogram: Cost-Improvement Rate in NRO CERs



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USCM Dataset: Funding Policies

CONTRACT	Full Funded?	Basis/Comment
ACTS	No	NASA
AE	No	NASA
AEHF 1-3	No	F3 added 4 years into contract.
AQUA/AURA	No	NASA
AXAF	No	NASA
Coriolis	No	Demo
CRRES	No	Demo
DMSP 5D1 (1-4)	**Yes**	**Contract 72-C-0221 had development and production.**
DMSP 5D2 (8-10)	**Yes**	**Prior to 1982 DoD Auth Act MYP not used for major acquisitions. (5d2-Improved S11-14 were MYP in 1983.)**
DMSP 5D3 (16-20)	No	MYP per 12/31/90 SAR.
DSCS IIIA (1&2)	No	RDT&E funded.
DSCS IIIB (4-7)	**Yes**	**B4/5 were approved in 1982, and B6/7 in 1983.**
DSCS IIIB (8-14)	No	MYP per 12/31/84 SAR.
DSP 14-17	**Yes**	**Prior to 1982 DoD Auth Act MYP not used for major acquisitions.**
DSP 18-22	No	MYP per 12/31/87 SAR
FLTSAT 1-5	**Yes**	**GAO LCD-79-108 describes a development contract (design and qual model) plus two production contracts, which would have been full funded.**
FLTSAT 6-8	**Yes**	**No mention of MYP in any document describing this acquisition. Long lead was awarded before the 1982 law changes. Overall very disjointed production program.**
Galileo	No	NASA
GeoLITE	No	NRO
GOES I-M	No	NASA
GPS II/IIA (13-40)	No	MYP per 12/31/85 SAR
GPS (1-8)	No	RDT&E funded.
GPS (9-11)	No	RDT&E funded.
GPS IIR (41-61)	No	MYP per 12/31/88 SAR
GRO	No	NASA
IKONOS	No	Commercial

CONTRACT	Full Funded?	Basis/Comment
Landsat 7	No	NASA
LCROSS	No	NASA
Mightysat II	No	Demo/RDT&E
Milstar I LDR Payload	No	RDT&E funded.
Milstar II Crosslink Payload	No	12/31/94 SAR has all MILSTAR RDT&E funded
Milstar II LDR Payload Flight 4	No	12/31/94 SAR has all MILSTAR RDT&E funded
Milstar II LDR Payload Flight 5 & 6	No	12/31/94 SAR has all MILSTAR RDT&E funded
Milstar II MDR Payload	No	12/31/94 SAR has all MILSTAR RDT&E funded
OSO	No	Demo/RDT&E
P72-2	No	Demo/RDT&E
P78-1	No	Demo/RDT&E
P78-2	No	Demo/RDT&E
Program 1	No	commercial
Program 2	No	commercial
Program 3	No	commercial
Program 4	No	commercial
Program 5	No	commercial
Program 6	No	commercial
Program 7	No	commercial
Program 8	No	commercial
Program 9	No	commercial
Radarsat I	No	Commercial
RHESSI	No	Demo/RDT&E
S3	No	Demo/RDT&E
SIRTF Bus	No	NASA
SMS	No	NASA
Spaceway	No	Commercial
SSM	No	NASA
Thuraya (1-2)	No	Commercial
Topex	No	NASA
UFO (1-10)	No	MYP per 12/31/93 SAR.
WGS (1-3)	**Yes**	**Interview w/ Boeing PM 2008. Parts bought for 1 sat at a time.**

NRO CERs include these contracts – We can evaluate differences

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NRO CERs for Recurring Cost

Att. Control Elex (ACE)	Helix antenna	Solid Rocket Motors
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1681 Total Data Points in 81 CERs

↓

567 from USCM

↓

122 from Full-Funded Contracts

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Analysis Process

Hypothesis: If full funding contracts truly have a higher (flatter) cost improvement rate, then:

- Residual errors will exhibit an upward trend vs. production quantity
- That trend will take an exponential form

$$AUC_i = X \cdot Q_i^B \cdot \left(1 + \%error_i\right)$$

Residual error for data-point *i*

Evaluation Steps:

1. Collect all residuals from existing NRO recurring-cost CERs
2. Identify data points as coming from a fully funded contract or not
3. Assess trends in residuals vs. quantity on contract by regression of residuals
   - All data
   - Full-funded points only
4. Test for significance (in LOLS case)

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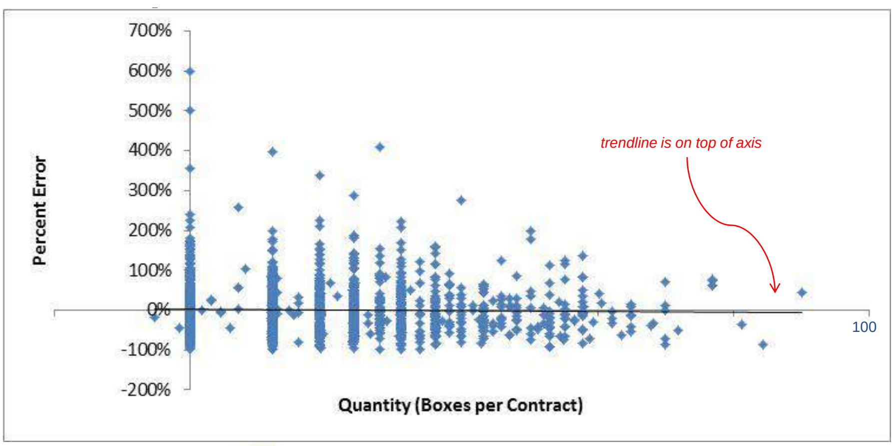
All Data



Average cost improvement rate of 85% is resulting in balanced error for quantities of 1 to 100 boxes per contract.

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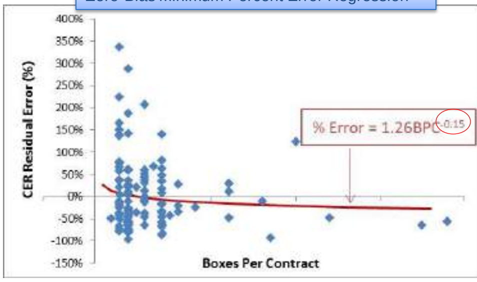
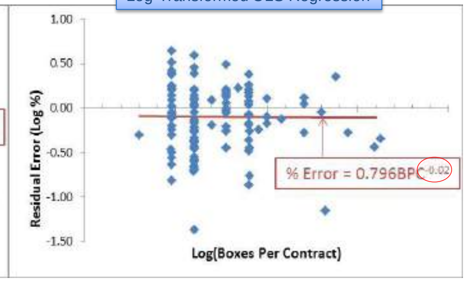
Full-Funded Data

- Two regression techniques used to assess trend in residuals

Zero-Bias Minimum Percent Error Regression



Log-Transformed OLS Regression



Note: Residuals are biased low in log space

Trends show cost-improvement rate possibly steeper for these programs (contradicts our hypothesis).

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Regression on % Error (Residuals)

- % Error = $x \cdot Q^{\Delta B}$
- ΔB = difference in quantity exponent from the CER average

	ΔB	**$2^{\Delta B}$**	**Difference in CIC Rate**
ZMPE	$\Delta B_{ZMPE} = -0.15$	$2^{-0.15} = 90\%$	-10% difference
LOLS	$\Delta B_{LOLS} = -0.02$	$2^{-0.02} = 98.6\%$	-1.4% difference

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Significance Test

- In a test for significance of a LOLS regression
  - Log(%Error +1) = log(B) + C*log(BPC)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.015
R Square	0.000
Adjusted R Square	-0.008
Standard Error	0.332
Observations	120

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.00	0.00	0.03	0.87
Residual	118	13.04	0.11		
Total	119	13.04			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-0.10	0.09	-1.10	0.27	-0.29	0.08	-0.29	0.08
log(BPC)	-0.02	0.12	-0.16	0.87	-0.27	0.23	-0.27	0.23

- The null hypothesis in this regression test is that the true slope equals zero
- P-value of 0.87 is high, indicating we cannot reject the hypothesis that the trend is flat

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Summary

- We cannot conclude that fully funded contracts have a higher cost improvement rate.
- Most programs in USCM database are not full funded.
- Cost efficiencies due to Multiyear Procurement or Incremental Funding are not evident at unit-level.

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