Customer Success Is Our Mission

# Applying Development Cycle Electronics Hardware Sub-Product Cost Models to Project Execution

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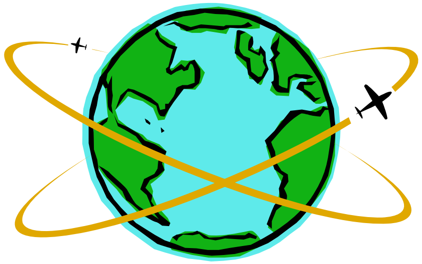
28 March 2011

# Outline

- Introduction
- Defining a Sub-Product
- Effective Size of a Sub-Product
- Effective Productivity of a Sub-Product
- Relationship Between Productivity and EVMS
- Leading and Lagging Indicators in Project Execution
- How Parametric Model Influences Effective Productivity
- Key Parametric Model Considerations
- Benefits of Model Based Productivity Tracking
- Summary

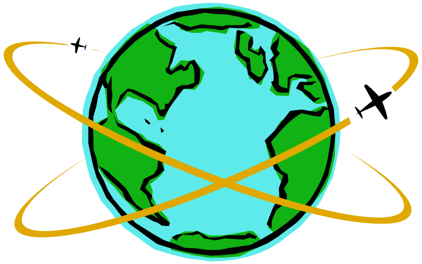
Cost Estimation



Parametric Models
CERs
OTS Bidding Tools

?

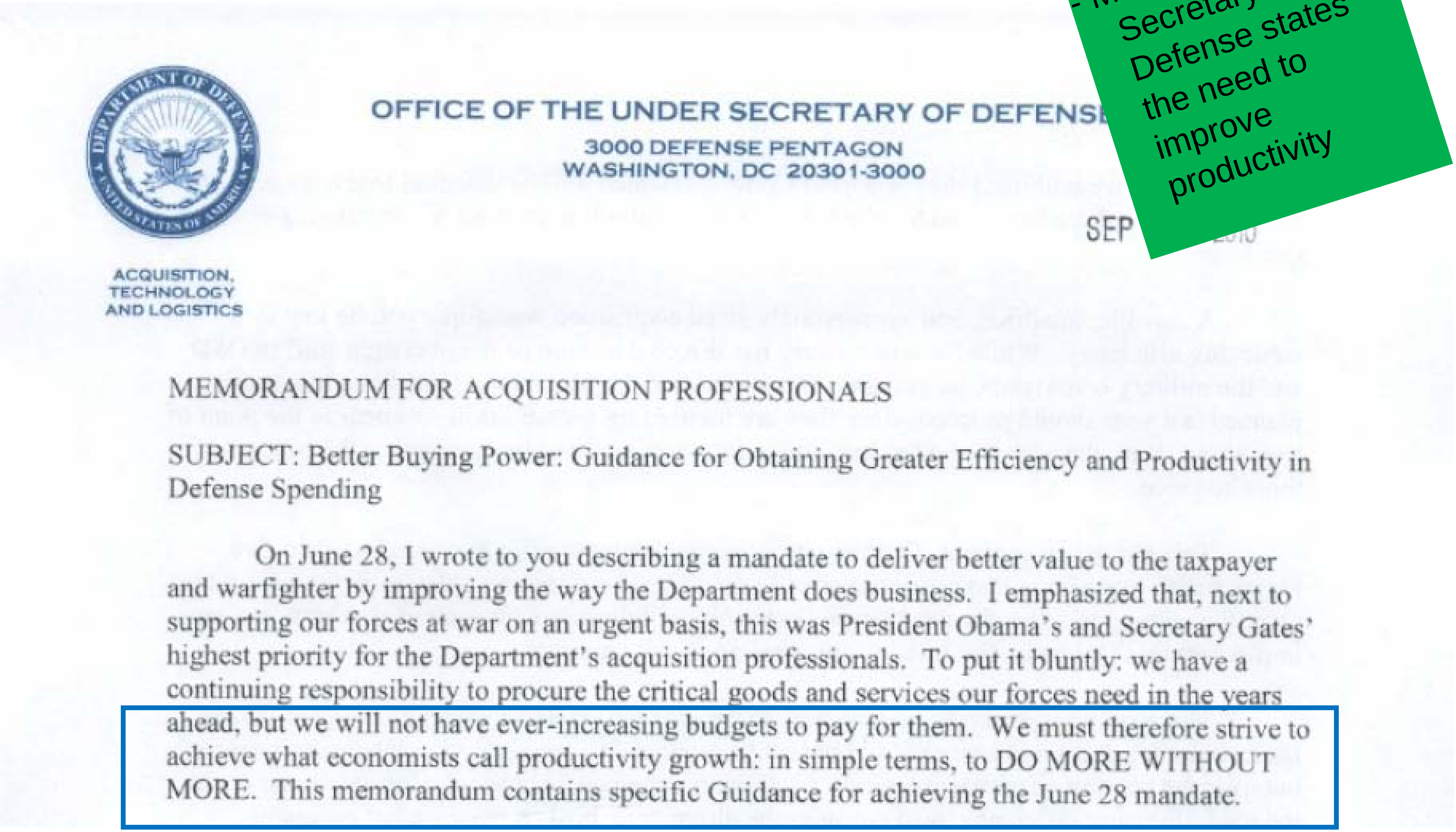
Execution



Productivity
EVMS
OTS Scheduling Tools

# 2010 Defense Memo - Productivity

- Memo from Under Secretary of Defense states the need to improve productivity



OFFICE OF THE UNDER SECRETARY OF DEFENS
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

SEP 2010

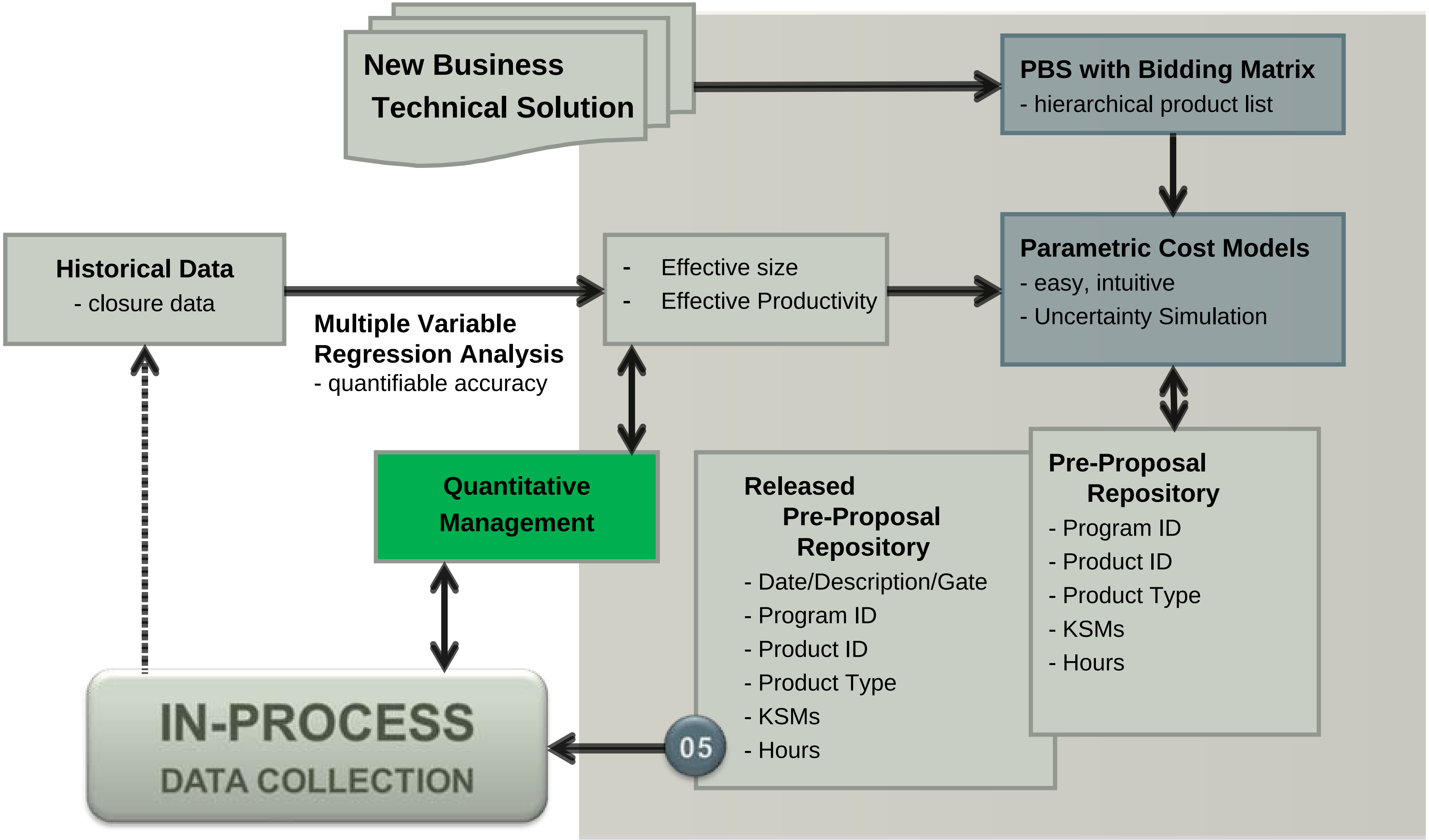
ACQUISITION,
TECHNOLOGY
AND LOGISTICS

MEMORANDUM FOR ACQUISITION PROFESSIONALS

SUBJECT: Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending

On June 28, I wrote to you describing a mandate to deliver better value to the taxpayer and warfighter by improving the way the Department does business. I emphasized that, next to supporting our forces at war on an urgent basis, this was President Obama's and Secretary Gates' highest priority for the Department's acquisition professionals. To put it bluntly: we have a continuing responsibility to procure the critical goods and services our forces need in the years ahead, but we will not have ever-increasing budgets to pay for them. We must therefore strive to achieve what economists call productivity growth: in simple terms, to DO MORE WITHOUT MORE. This memorandum contains specific Guidance for achieving the June 28 mandate.

# Bidding and Execution



**New Business Technical Solution**

**PBS with Bidding Matrix**
- hierarchical product list

**Historical Data**
- closure data

**Multiple Variable Regression Analysis**
- quantifiable accuracy

- Effective size
- Effective Productivity

**Parametric Cost Models**
- easy, intuitive
- Uncertainty Simulation

**Quantitative Management**

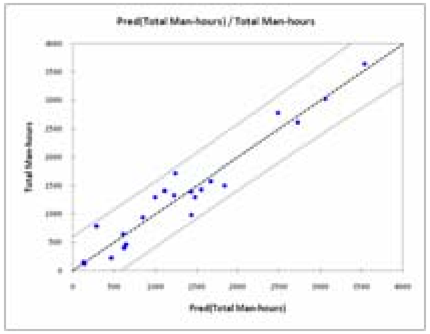
**Released Pre-Proposal Repository**
- Date/Description/Gate
- Program ID
- Product ID
- Product Type
- KSMs
- Hours

**Pre-Proposal Repository**
- Program ID
- Product ID
- Product Type
- KSMs
- Hours

**IN-PROCESS DATA COLLECTION**

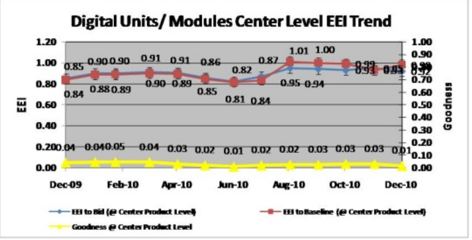
# Bidding / Execution / Bidding

***Completed projects used to update cost models***



**Updated Cost Models**

**Productivity trends are early indicators**



**Data:**
TDP EEI on Active development programs

**Source:** EEC Productivity Database in Marketplace

**Process Owner:**
Sam Estess

**Update Frequency:** Monthly

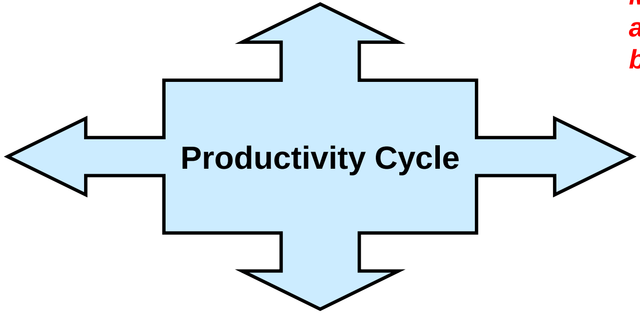
**Date:** December 2010

**Analysis & corrective actions:**

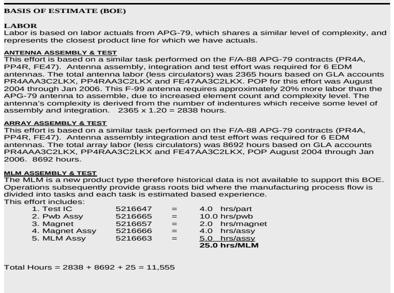
1. The Digital Unit/Module EEI to baseline improved in December from 0.93 to 0.98.
2. Corrected error in spreadsheet calculation of "Goodness" which reduced the value.

**Proposal / BOE**

***More accurate bids***



**Productivity Cycle**



**BASIS OF ESTIMATE (BOE)**

**LABOR**
Labor is based on labor actuals from APG-79, which shares a similar level of complexity, and represents the closest product line for which we have actuals.

**ANTENNA ASSEMBLY & TEST**
This effort is based on a similar task performed on the F/A-88 APG-79 contracts (PR4A, PP4R, FE47). Antenna assembly, integration and test effort was required for 6 EDM antennas. The total antenna labor (less circulators) was 2365 hours based on GLA accounts PR4AAA3C2LKX, PP4RAA3C2LKX and FE47AA3C2LKX. POP for this effort was August 2004 through Jan 2006. This F-99 antenna requires approximately 20% more labor than the APG-79 antenna to assemble, due to increased element count and complexity level. The antenna's complexity is derived from the number of indentures which receive some level of assembly and integration. 2365 x 1.20 = 2838 hours.

**ARRAY ASSEMBLY & TEST**
This effort is based on a similar task performed on the F/A-88 APG-79 contracts (PR4A, PP4R, FE47). Antenna assembly integration and test effort was required for 6 EDM antennas. The total array labor (less circulators) was 8692 hours based on GLA accounts PR4AAA3C2LKX, PP4RAA3C2LKX and FE47AA3C2LKX, POP August 2004 through Jan 2006. 8692 hours.

**MLM ASSEMBLY & TEST**
The MLM is a new product type therefore historical data is not available to support this BOE. Operations subsequently provide grass roots bid where the manufacturing process flow is divided into tasks and each task is estimated based experience.
This effort includes:

| | | | |
|---|---|---|---|
| 1. Test IC | 5216647 | = | 4.0 hrs/part |
| 2. Pwb Assy | 5216665 | = | 10.0 hrs/pwb |
| 3. Magnet | 5216657 | = | 2.0 hrs/magnet |
| 4. Magnet Assy | 5216666 | = | 4.0 hrs/assy |
| 5. MLM Assy | 5216663 | = | 5.0 hrs/assy |
| | | | **25.0 hrs/MLM** |

Total Hours = 2838 + 8692 + 25 = 11,555

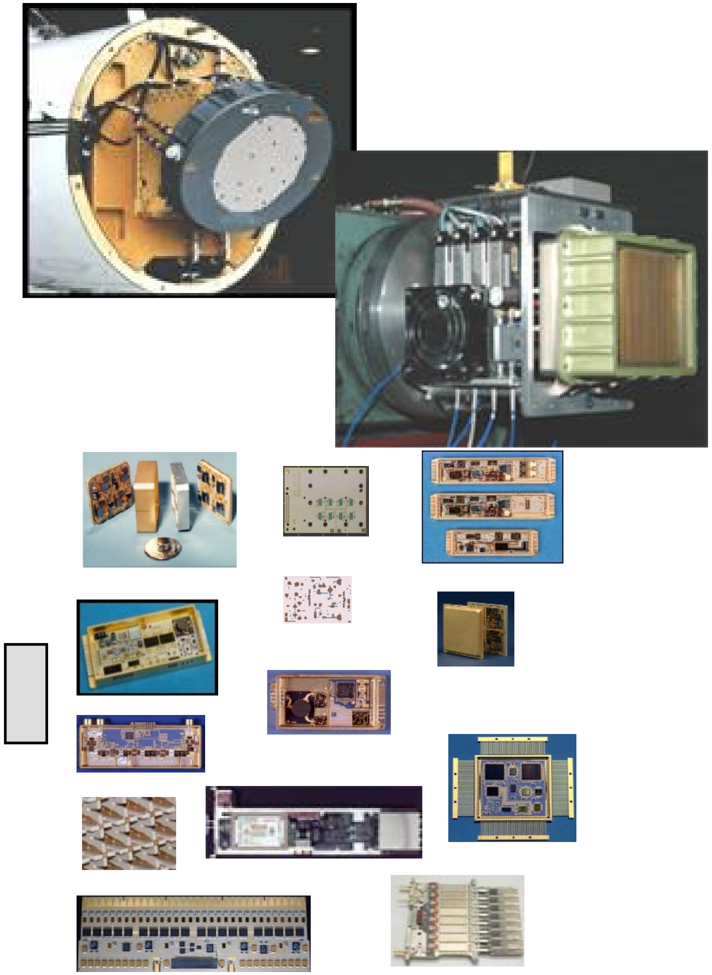
***Trends drive analysis & corrective actions***

***Predictable Execution***

***Collect Data analyze, and identify cause & corrective action***

# Defining a Sub-Product

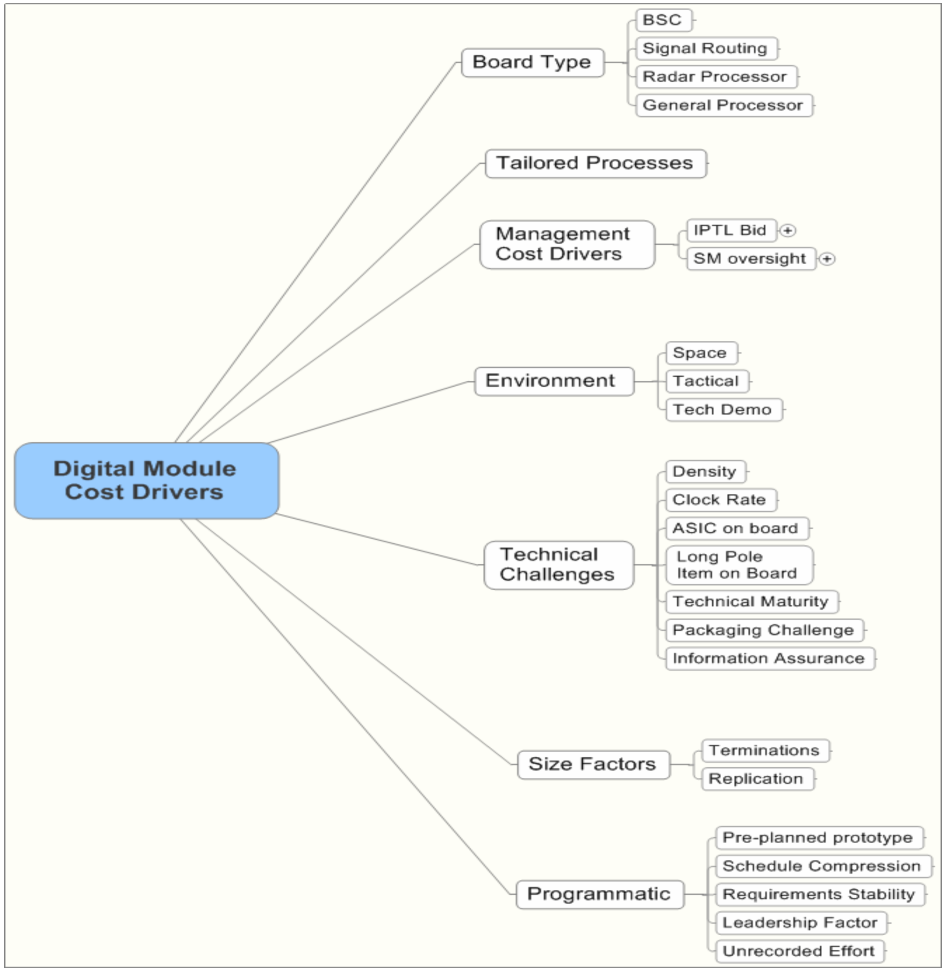
- Products are either systems or major components of systems
  - Radar
  - EO Sensor
  - STE
  - Etc
- Sub-Products are the items that make up the products
  - Radar
    - Receiver Units, Antennas, Digital Units, Power Supplies, etc
    - Digital Modules, Analog Modules, RF Modules, Power Modules, etc
    - FPGAs, ASICs, Analog ASICs etc
  - EO Sensors
    - Optical Assemblies, Driver CCAs, A/D Mixed Signal Modules etc



# Foundational Principles

- Execution of products depends on the execution of the sub-products
- Execution of electronics sub-products depends primarily on how big the sub-product is (size) and the rate at which it can be completed (productivity).
  - Examples
    - If I need to design an FPGA and I can write FPGA VHDL code at 5 LOC/hour, and the FPGA requires approximately 5000 LOC to accomplish its task, then I should be able to complete the FPGA design in 1000 hours.
  - Size and Productivity are complex parameters and therefore the terms “Effective Size” and “Effective Productivity” are used to establish cost driving relationships.
  - When tracked, effective size and effective productivity are leading indicators of execution performance

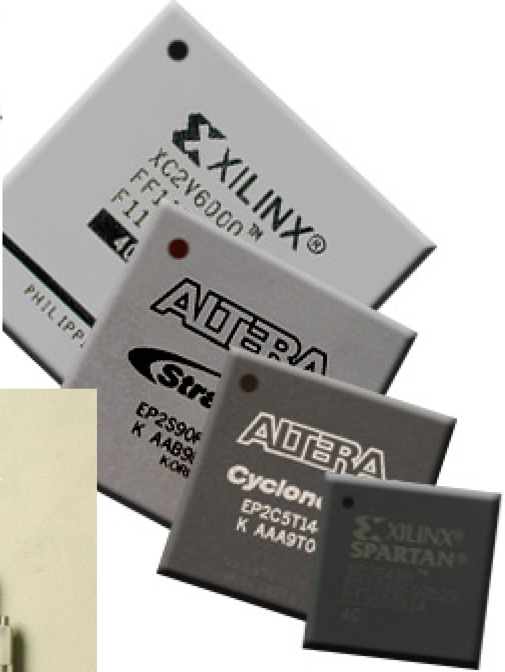
# Detailed Example

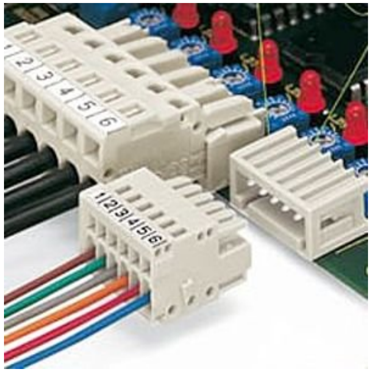


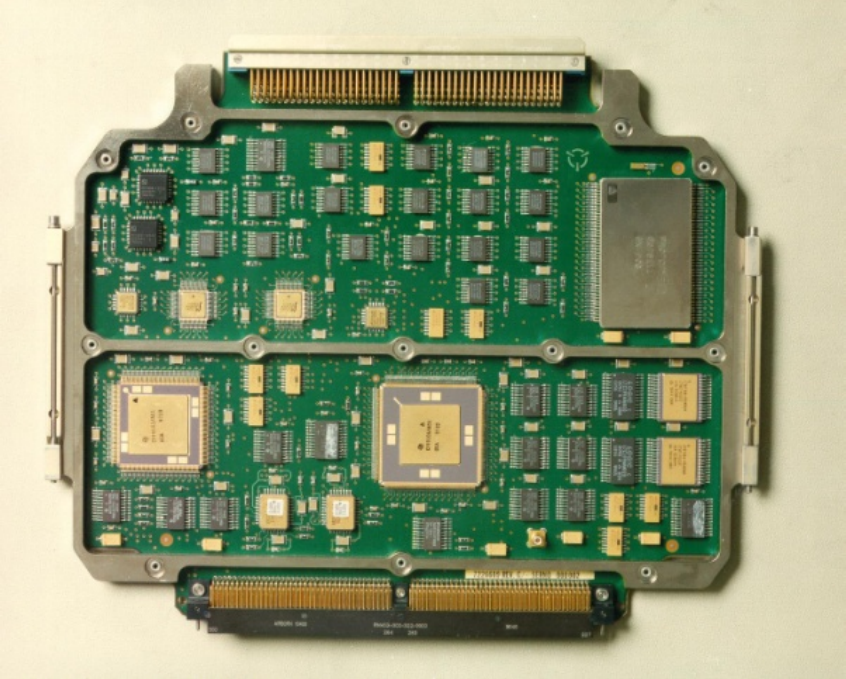
- **Digital Module Cost Drivers**
  - Board Type
    - BSC
    - Signal Routing
    - Radar Processor
    - General Processor
  - Tailored Processes
  - Management Cost Drivers
    - IPTL Bid
    - SM oversight
  - Environment
    - Space
    - Tactical
    - Tech Demo
  - Technical Challenges
    - Density
    - Clock Rate
    - ASIC on board
    - Long Pole Item on Board
    - Technical Maturity
    - Packaging Challenge
    - Information Assurance
  - Size Factors
    - Terminations
    - Replication
  - Programmatic
    - Pre-planned prototype
    - Schedule Compression
    - Requirements Stability
    - Leadership Factor
    - Unrecorded Effort

- Cost Drivers for a Digital Module:
  - Some drivers affect the “size” of the Module
  - Some drivers affect the productivity at which the design can be achieved
- Size Variables
  - Terminations
  - Replication
- Productivity Variables
  - Environment
  - Technical Challenges

# Counting Digital Module KSMs







# Defining the Effective Size

- KSM in the simplest form
  - Digital Modules: Terminations
  - RF Modules: Stages
  - FPGAs:(eLOCs)
- Effective size in simplest form
  - KSM*(SF1)*(SF2)
    - SF1 = % New
    - SF2 = (1 - % Repetition)
- Effective size less simple
  - Multivariable Sum Equation
    - Separate size factors from complexity factors
- Adjusting effective size with qualitative variables
  - Re-use

$$\underbrace{y}_{\textbf{Hours}} = \underbrace{b}_{\text{Constant Offset}} + \underbrace{m}_{\text{Productivity}} \cdot \underbrace{x}_{\textbf{KSM}}$$

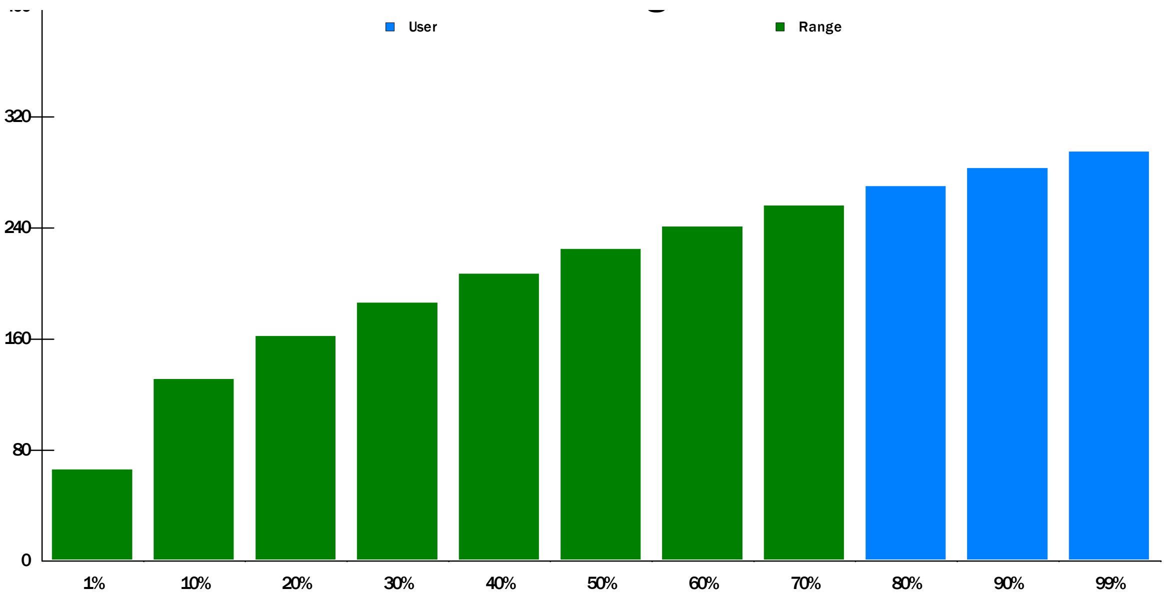
$$y = b + m_1 x_1 + m_2 x_2 \ldots + m_n x_n$$

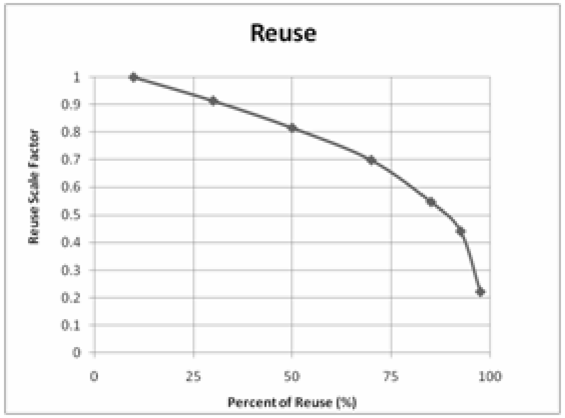
$$y = b + m_n x_1 (SF)_1 (SF)_2 \ldots (SF)_n$$

$$y = B\left(x_1 \ldots x_n\right)^A$$

# Effective Size: ReUse Example

Given enough historical data **SEER-H** can use Monte Carlo Simulations to predict the effect of well defined parameters.





| Amount of Re-use | Scaling factor |
|---|---|
| 0-20% | 1 |
| 20-40% | 0.914504 |
| 40-60% | 0.816298 |
| 60-80% | 0.699113 |
| 80-90% | 0.547398 |
| 90-95% | 0.442756 |
| 95-100% | 0.223067 |

# Defining Productivity

- Productivity in Simple Terms
  - Productivity is defined in the units of hours/KSM where KSM represents the Key Sizing Metric
  - Offset constant may or may not have an impact on the overall productivity
- KSM
  - Quantitative variable
  - Defined method for counting KSM
  - Repeatable by independent party

$$\underbrace{y}_{\textbf{Hours}} = \underbrace{b}_{\text{Constant Offset}} + \underbrace{m}_{\text{Productivity}} \cdot \underbrace{x}_{\textbf{KSM}}$$

# Defining Effective Productivity

- Effective Productivity
  - Productivity is defined in terms of hours/KSM and is scaled by a complexity factor and a scaling factor associated with reuse.
  - Offset constant may or may not have an impact on overall productivity

$$L = C \cdot P_{WP} \cdot (R) \cdot KSM + P_0$$

where

$P_{WP}$ = Productivity

$KSM$ = Key Size Metric

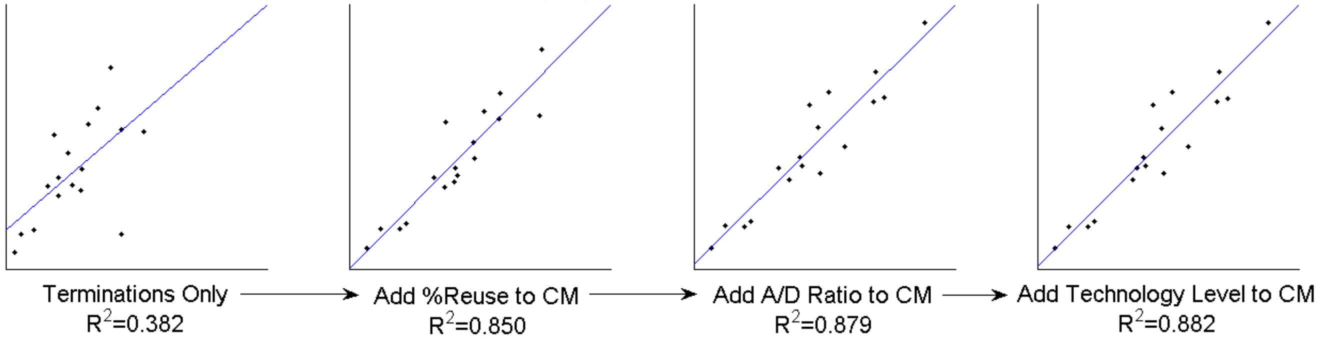
C = Complexity Scaling Factor

$L$ = Cost (Hours)

$R$ = Reuse Factor (less than 1)

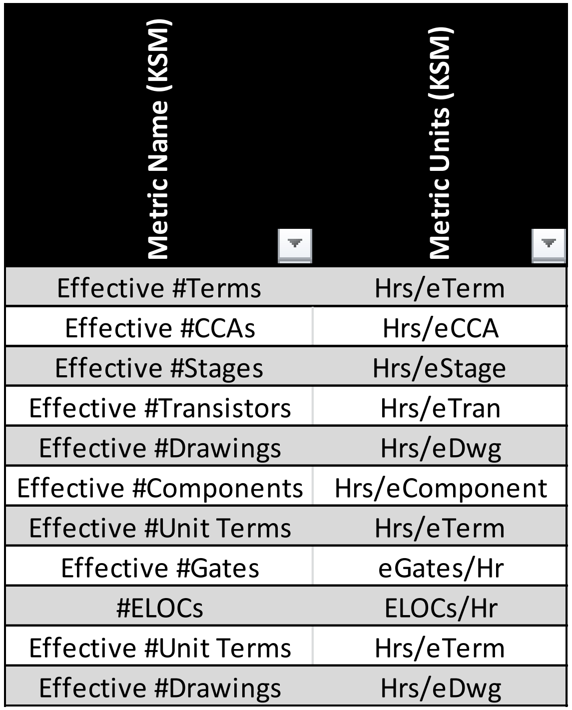
$P_0$ = Offset

Cost Model (CM) Fit as More Cost Drivers are Added



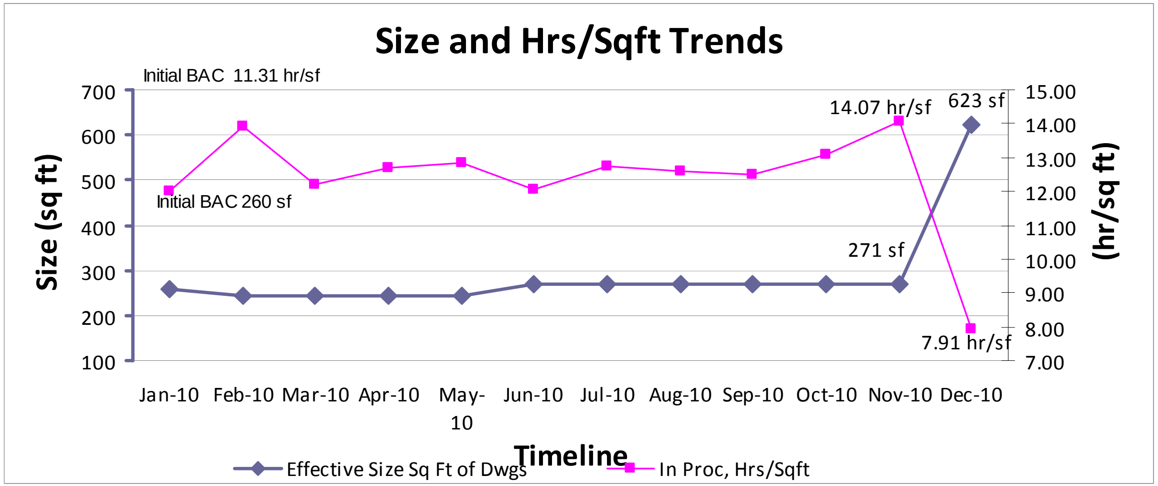
# eProductivity as a Performance Measure

- Related to EVMS
  - If CPI says a project is over-budget, this should show up in effective productivity
- Related to Process
  - Can be implemented in less than ideal circumstances
    - Not all jobs are cradle to grave developments.
    - Can be defined for any parameter
- Descriptive Performance Measure
  - Still not a leading indicator
  - Useful for “gauge level descriptions”



| Metric Name (KSM) | Metric Units (KSM) |
|---|---|
| Effective #Terms | Hrs/eTerm |
| Effective #CCAs | Hrs/eCCA |
| Effective #Stages | Hrs/eStage |
| Effective #Transistors | Hrs/eTran |
| Effective #Drawings | Hrs/eDwg |
| Effective #Components | Hrs/eComponent |
| Effective #Unit Terms | Hrs/eTerm |
| Effective #Gates | eGates/Hr |
| #ELOCs | ELOCs/Hr |
| Effective #Unit Terms | Hrs/eTerm |
| Effective #Drawings | Hrs/eDwg |

# In-Process Productivity



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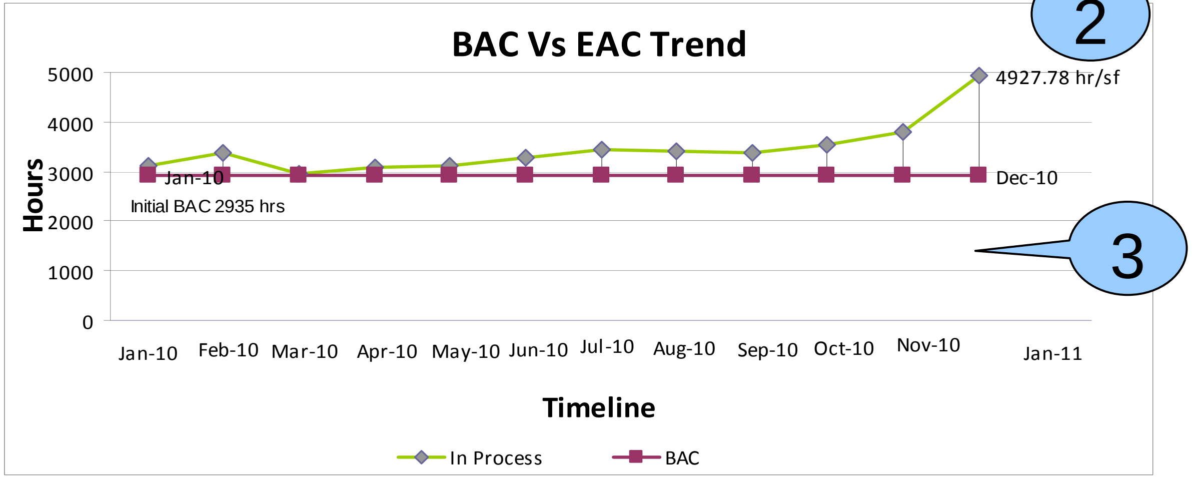

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In process = ACWP/ (% Complete x effective size SF)

-where Size increased and % Compl decreased

**Data:**
Productivity on Active Development Programs

**Source:** Productivity Database

**Process Owner:**

**Update Frequency:** Monthly

**Date:** Jan (Dec data)

**Analysis & corrective actions:**

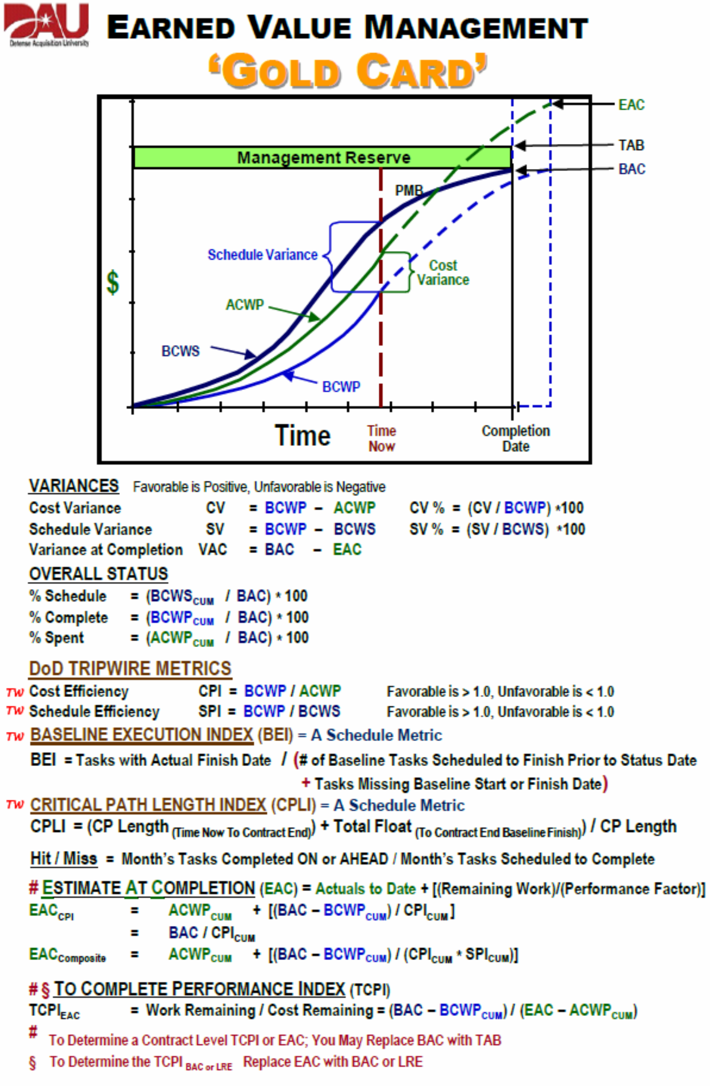
1. Significant increase in Size to meet design requirements
2. In-Process Hrs/SF drastically changed due to size increase (see formula)
3. In-Process EAC vs BAC gap driven by reduced % complete and increase in Effective size (BCR planned for part of the growth, but unlikely due to funding limitations)

# Relationship Between EVMS and eProductivity

- Clearly both EVMS and Productivity are numerical measures of in-process execution
- Fundamentally, in-process productivity could be reduced to:

$$P_{InProcess} = CPI * P_{BAC}$$

- Be sure to use "budgeted productivity" as opposed to "bid productivity"
- EVMS "to complete performance index" could also be applied to in-process productivity.
  - With statistical analysis, this "to complete performance index" could be associated to a probability of success



**EARNED VALUE MANAGEMENT 'GOLD CARD'**

**VARIANCES** Favorable is Positive, Unfavorable is Negative

| | | | |
|---|---|---|---|
| Cost Variance | CV | = BCWP – ACWP | CV % = (CV / BCWP) *100 |
| Schedule Variance | SV | = BCWP – BCWS | SV % = (SV / BCWS) *100 |
| Variance at Completion | VAC | = BAC – EAC | |

**OVERALL STATUS**

% Schedule = $(BCWS_{CUM} / BAC) * 100$
% Complete = $(BCWP_{CUM} / BAC) * 100$
% Spent = $(ACWP_{CUM} / BAC) * 100$

**DoD TRIPWIRE METRICS**

| | | | |
|---|---|---|---|
| TW | Cost Efficiency | CPI = BCWP / ACWP | Favorable is > 1.0, Unfavorable is < 1.0 |
| TW | Schedule Efficiency | SPI = BCWP / BCWS | Favorable is > 1.0, Unfavorable is < 1.0 |

TW **BASELINE EXECUTION INDEX** (BEI) = A Schedule Metric

BEI = Tasks with Actual Finish Date / (# of Baseline Tasks Scheduled to Finish Prior to Status Date + Tasks Missing Baseline Start or Finish Date)

TW **CRITICAL PATH LENGTH INDEX** (CPLI) = A Schedule Metric

CPLI = $(\text{CP Length}_{\text{(Time Now To Contract End)}} + \text{Total Float}_{\text{(To Contract End Baseline Finish)}}) / \text{CP Length}$

**Hit / Miss** = Month's Tasks Completed ON or AHEAD / Month's Tasks Scheduled to Complete

\# **ESTIMATE AT COMPLETION** (EAC) = Actuals to Date + [(Remaining Work)/(Performance Factor)]

$EAC_{CPI} = ACWP_{CUM} + [(BAC – BCWP_{CUM}) / CPI_{CUM}]$
$= BAC / CPI_{CUM}$
$EAC_{Composite} = ACWP_{CUM} + [(BAC – BCWP_{CUM}) / (CPI_{CUM} * SPI_{CUM})]$

\# § **TO COMPLETE PERFORMANCE INDEX** (TCPI)

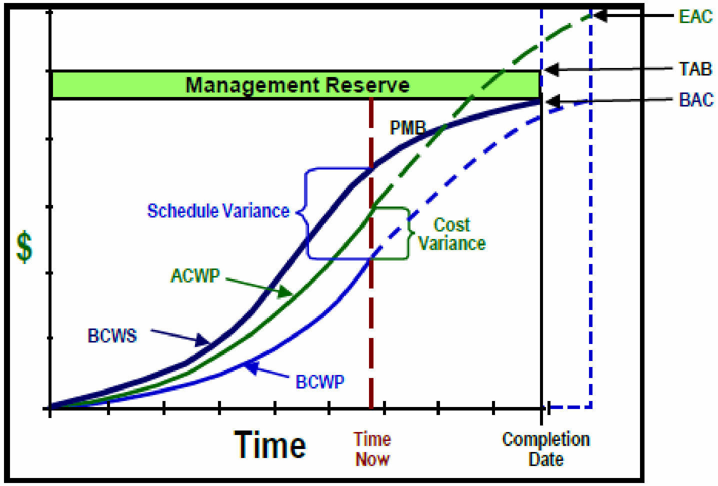
$TCPI_{EAC}$ = Work Remaining / Cost Remaining = $(BAC – BCWP_{CUM}) / (EAC – ACWP_{CUM})$

\# To Determine a Contract Level TCPI or EAC; You May Replace BAC with TAB

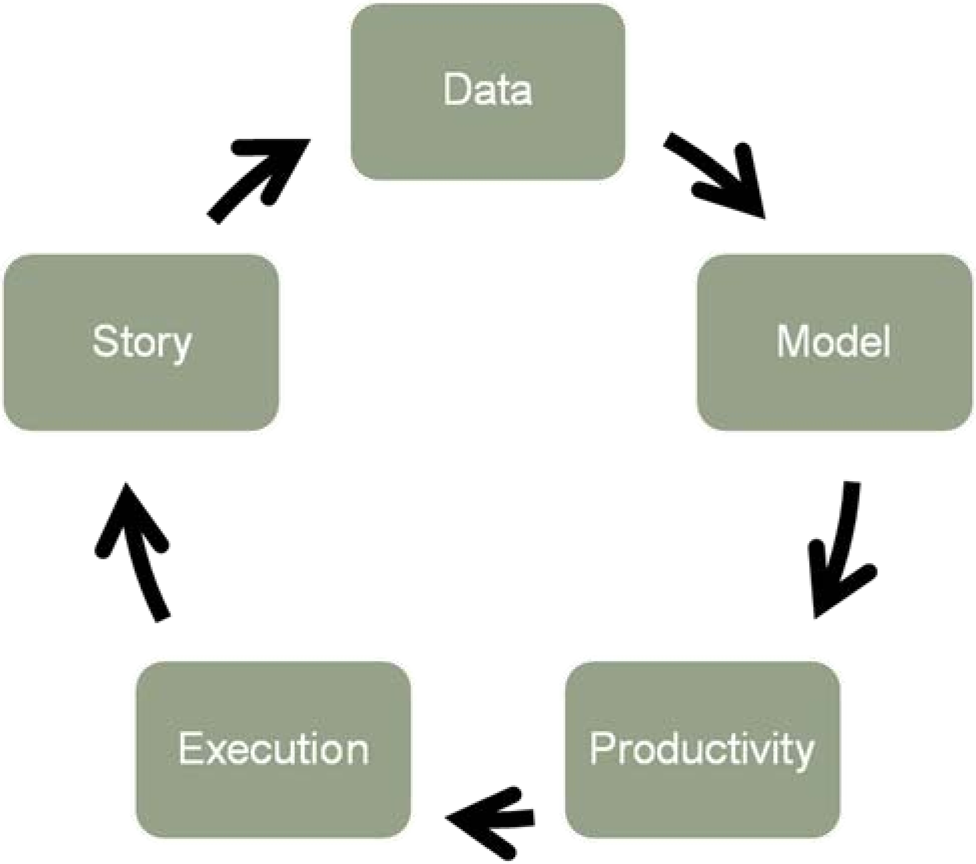
§ To Determine the $TCPI_{\text{BAC or LRE}}$ Replace EAC with BAC or LRE

# Leading Indicators in Project Execution

- The difference between a leading indicator and a predictive indicator
  - A leading indicator provides an indication that a project may or may not be in trouble with regard to cost
  - A predictive indicator provides numerical inference into the final cost of a project
- CPI
  - Clearly a leading indicator
    - Predictive interference not established
    - Extremely difficult to establish reliable spend profile
- Effective Productivity
  - Clearly a leading indicator
  - Effective size is clearly a predictive indicator through parametric models



# Parametric Models Influence Productivity



# Key Parametric Model Considerations

- Choosing the form of parametric model is key in being able to apply to productivity concepts
  - Implementing SF multiplier parametric models is easiest form to apply
  - Multiple linear regression is also possible, but in the end will lead to representing other variables in terms of KSM variable
    - For example, if parametric model for STE contains both drawings and # of bays, then generally productivity based model will represent bays in terms of drawings (e.g. 1 bay equals 5 drawings)
- All “effective” variables grouped under “Effective Size”

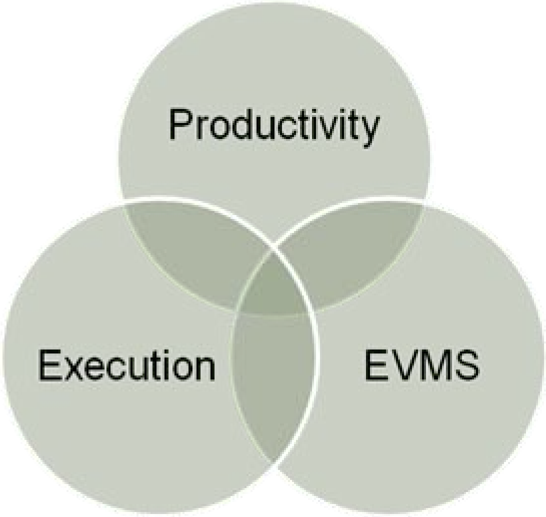
$$y = b + m_1 x_1 + m_2 x_2 \ldots + m_n x_n$$

$$y = b + m_n x_1 (SF)_1 (SF)_2 \ldots (SF)_n$$

$$y = B(x_1 \ldots x_n)^A$$

# Benefits of Model Based Productivity Tracking

- Productivity is a more visual execution language than EVMS
  - – Capable of being applied to organizational performance and performance improvement
  - – Productivity is the language of upper management
    - It is also the language of the government customer
- When paired with predictive parametric models, productivity tracking (through “effective size” becomes a predictive indicator
- More insight into the execution of each sub-product is gained by tracking productivity



# Summary

- Defining a Sub-Product
  - Organically defined by KSMs and integrated into products
- Effective Size of a Sub-Product
  - A predictive indicator of the cost of development of any sub-product
  - Includes CERs such as KSM, re-use and complexity
- Effective Productivity of a Sub-Product
  - A leading indicator closely associated to CPI
  - Takes into account effective size
- Relationship Between Productivity and EVMS
  - Productivity encompasses EVMS plus the ability to apply statistical inference
- Parametric Model Influences Effective Productivity