



Big Data Meets Earned Value Management


We have lots data. How can we use it to make predictive and prescriptive forecasts of future performance to increase Probability of Program Success?

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+ The *Killer Question* For Every Manager Of A Complex, High Risk Program Is ...

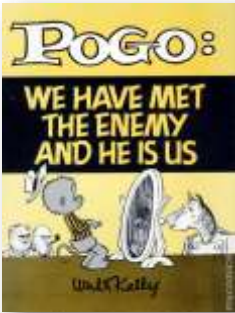


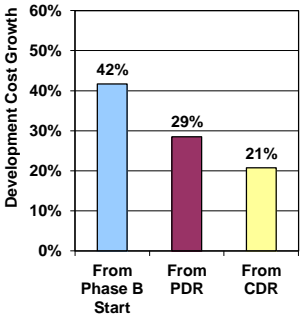
... How Can I See An Unanticipated Estimate At Completion (EAC) Coming Before It's Too Late?

"What's in Your Estimate at Completion?", Pat Barker and Roberta Tomasini, *Defense AT&L*, March-April, 2014

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+ Here's *WHY* We Need Better Ways To Forecast Estimate At Complete ...





From	Percentage
From Phase B Start	42%
From PDR	29%
From CDR	21%



From	Percentage
From Phase B Start	29%
From PDR	23%
From CDR	19%

... the root cause starts on day one,
with a less than credible PMB.

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+ Three Types Of Data Are Available In The Big Data Repositories

- **Descriptive** – looking in the past we can learn what happened, but it's too late to take corrective action.
- **Predictive** – using past performance we can answer the question what will happen if we do nothing but do the same as we've done in the past.
- **Prescriptive** – past performance data used to make predictions and suggest decision options to take advantage of the predictions

Prescriptive analytics not only *anticipates* what will happen and when it will happen, but ***why*** it will happen.

+ Descriptive Analytics

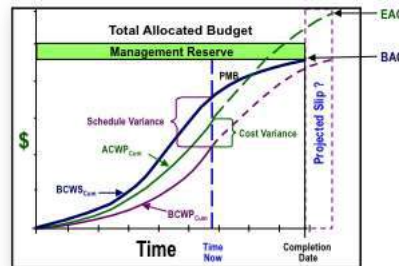
The EVM repositories provide the raw material for Descriptive Analytics through the IPMR (DI-MGMT-81861) submittals

- Descriptive Analytics – condensing big data into smaller, useful nuggets of information.
- Most raw Earned Value data is not suitable for human consumption since it is reported by WBS without the connectivity to the product or programmatic topology
- Descriptive data summarizes what happened in the past, many times 45 days in the past.
- Correlations between WBS elements not defined nor correlations between risk, technical performance or Systems Engineering attributes – MOE, MOP, KPP†

† The Defense Acquisition Guide defines how to apply Measures of Effectiveness, Measures of Performance, Technical Performance Measures, and Key Performance Parameters to assess program performance

+ DAU Gold Card's EAC Formula Uses Predictive Analytics, But ...

- Past variances are wiped out with “Cumulative to Date” data
- No adjustment for risk
- Not statistically corrected for past performance



ESTIMATE @ COMPLETION = ACTUALS TO DATE + [(REMAINING WORK) / (PERFORMANCE FACTOR)]

$$EAC_{CPI} = ACWP_{CUM} + [(BAC - BCWP_{CUM}) / CPI_{CUM}]$$

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

TO COMPLETE PERFORMANCE INDEX (TCPI) § #

$$TCPI_{Target} = \text{Work Remaining} / \text{Cost Remaining} = (BAC - BCWP_{CUM}) / (Target - ACWP_{CUM})$$

§ To Determine the TCPI_§ by BAC, LRE, or EAC Substitute TARGET with BAC, LRE, or EAC

To Determine the Contract Level TCPI for EAC, You May Replace BAC with TAB

+ Prescriptive Analytics

- Is a type of Predictive Analytics
- Used when we need to **prescribe** an action so leadership can take the data and act.
- Predictive analytics doesn't predict one future outcome – but Multiple outcomes based on the decision makers actions.
- Prescriptive analytics requires a predictive model with two additional components:
 - Actionable data.
 - Feedback system that tracks the outcome produced by the action taken..

+ Prescriptive Analytics Is The Foundation For Corrective Actions

- Prescriptive Analytics is about making decisions based on data.
- Prescriptive analytics requires a predictive model with two components:
 - Actionable data
 - Feedback from those actions
- Prescriptive models predict the possible consequences based on different choices of action.

Milestones are *rocks* on the side of the road. The Roman Milestone was a measure back to Rome. You only know that distance after you pass the milestone.



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+ There Is Untapped Value In An Earned Value Data Repository

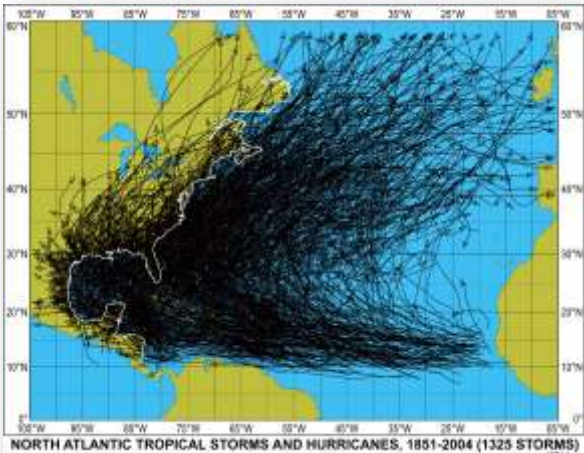
To extract this value we need to overcome some limitations in today's repositories

- Most data is of little value at the detail level since it is uncorrelated in the reporting process
 - Making correlations between cause and effect is difficult for humans, but statistical process algorithms can do this for us
- With correlated data in hand, we can start generating descriptive analytics
 - But drivers of variance are not visible in the repository
 - Variances from past can be calculated, but not used in future forecasts
- There is no built-in mechanism to see patterns in the data
 - Standard tools produce linear, non-statistical, non-risk adjusted forecasts

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+ All Programmatic Forecasting Is Probabilistic, Driven By Underlying Statistical Processes

If we make forecasts about program performance that are not statistically and risk adjusted – we're gonna get wet.



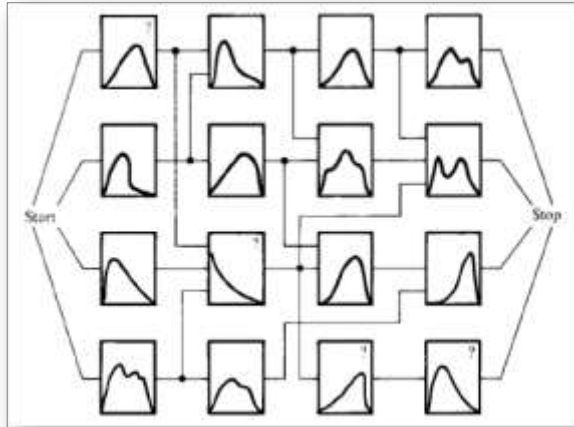
NORTH ATLANTIC TROPICAL STORMS AND HURRICANES, 1851-2004 (1325 STORMS)

The figure is a map of the North Atlantic region, showing the paths of 1325 tropical storms and hurricanes between 1851 and 2004. The map covers a latitude range from 0°N to 60°N and a longitude range from 100°W to 0°W. The landmasses of North America, South America, and Europe are shown in yellow. The ocean is blue. A dense network of black lines represents the tracks of individual storms, showing a clear seasonal migration pattern from the Caribbean and West Africa towards the North Atlantic and Europe. The tracks are most concentrated between 20°N and 40°N latitude.

+ Schedule, Related Cost And Technical Elements Are Probabilistic

The IMS doesn't help us much either, since the correlative drivers are themselves non-linear stochastic processes

A Stochastic process is a collection of random variables used to represent the evolution of some random value or system, over time.



+ The Ability To Forecast Future Performance Starts With A Tool That Provides...

- Forecasting of future performance, using time series of the past using Autoregressive Integrated Moving Average (ARIMA) algorithm
- Confidence intervals of these forecasts for past performance
- Correlation between the time series elements (CPI, SPI, WBS element)
- Deeper correlations between these Earned Value elements as risk retirement, increase effectiveness and performance and any other recorded measure of the program.



<http://cran.us.r-project.org/>

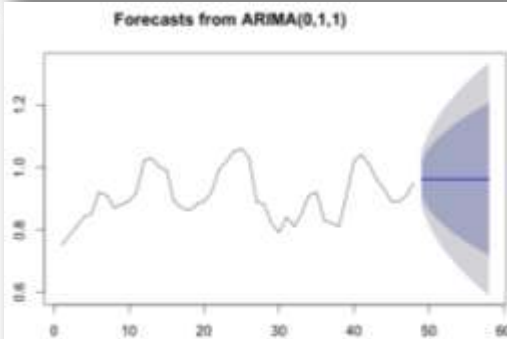
The combination of some data and an aching desire for an answer does not ensure that a reasonable answer can be extracted from a given body of data. - John Tukey

+ A Quick Look At Where We're Going Starting with Forecasting CPI/SPI

If we want to credibly forecast the future with the past, we'll need better tools. We've got the data, just need to use it

- We have a time series of CPI, SPI, in the repository
- What's possible behaviors in the future can we discover from the past behavior?
- The R code on the top answers that in 4 lines.

```
> CPITS=ts(CPI)
> CPITSARIMA=arima(CPITS, order=c(0,1,1))
> CPITSFORECAST=forecast(CPITSARIMA)
> plot(CPITSFORECAST)
```



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WE'VE GOT A DARK SECRET...

- The Units of Measures for Earned Value Management are Dollars
- Cumulative indices wipe out all the variances
- Forecasts of future performance are not statistically adjusted
- There is no correlative information drivers of variances
- None of these forecasts use the risk register to adjust their value

+ Since ARIMA Is A Well Traveled Path, We Need More and Better Tools

*To provide better forecasts of EAC, we need more data.
CPI/SPI needs to be augmented with technical program data*

- The Earned Value Management Performance measures need to be connected to:
 - Risk retirement and buy down status Technical Performance Measure compliance
 - Measures of Effectiveness and Measures of Performance
- Work Breakdown Structure correlations for each work activity
 - Correlations between performance and work performed is available in the repository
 - We're missing the tool to reveal these correlations, drivers, and corrective actions to keep the program GREEN

+ We Need More Power To See Into The Future And Take Corrective Actions



+ Principal Component Analysis (PCA) Gets *More Power* from our data

Principal component analysis (PCA) is a statistical procedure that uses orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components.

We want to convert a larger set of program performance variables – SPI, CPI, Risk Retirements, TPM, MOE, MOP, KPP, Staffing, and others, into a small set of *drivers of variance*.

PCA can provide visibility to *what are the connections between EAC growth and the source of that growth* in a statistically sound manner, not currently available with IPMR reporting using CPI/SPI

+ What Can PCA Tell Us?

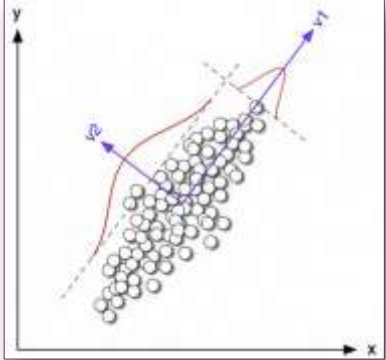
With “all” the data in a single place – which it is not – we need a way to reduce the dimensionality to provide analysis

- If data lies in high dimensional space (more than just CPI/SPI), then large amount of data is required to learn distributions or decision rules.
- For each WBS element 9 dimensions (CPI, SPI, WBS, TPM, MOE, MOP, KPP, Risk, Staffing Profiles).
- Each dimension has 36 levels (36 months of data).
- We could produce a 9 dimension scatter plot for the 36 months of data and it'd look like a *big blob*.
- We need to know *what are the drivers in this Blob of data?*

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+ From 2 Dimensions (SPI/CPI) to 8 Dimensions and Back Again

- Two components, for example – SPI and CPI
- Discover the correlation between these two data samples
- Locate in the individual samples the time the drivers started impacting the program
- Extend this to 8 dimensions
- Similar to Joint Confidence Level, but with actual data



$$PC_i = a_1X_1 + a_2X_2 + a_3X_3 + \dots + a_8K_8$$

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+ Program Performance Dimensions

PCA data can be simple 2 dimensional – CPI/SPI or more complex and represent other “attributes” driving EAC

Variable	Information that mat drive Unanticipated EAC
CPI/SPI	CPI for program, time phased by reporting period
TPM	Technical Performance Measures, with control bands as program moves left to right. These can be any measure technical compliance <ul style="list-style-type: none"> ■ Weight ■ Throughput ■ Information Assurance validation ■ Any of the JROC KPPs
Risk	Risk <ul style="list-style-type: none"> ■ Risk retirement buy down plan ■ Risk handling and planned reduction
Margin	Cost and schedule margin burn down to plan

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<p>+ Call to Action for increased visibility to Unanticipated EAC Growth using BIG Data</p>		
0	Normalize data in the Central Repository in preparation for analysis	EV, WBS, Timeline units normalized with No missing items
1	Apply ARIMA to normalized data to forecast CPI, SPI, and Calculated EAC	Product EAC now based on statistically sound forecast
2	Adjust ARIMA parameters using past performance compliance	Tune ARIMA for program phase sensitivity
3	Integrate external data with EV repository data to build correlations the EAC forecasts	Add risk register and SEMP measures to ARIMA
5	Apply Principal Component Analysis (PCA) to identify correlated <i>drivers</i> of EAC growth	Research the Use multivariate forecasting for EAC