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DEFINING THE FUTURE

Ending the EAC Tail Chase:

An Unbiased EAC Predictor using Progress Metrics

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SCEA

The Society of Cost Estimating and Analysis

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Motivation

- **Northrop Grumman was approached by a customer to help develop new estimates for several units that were in construction when a major event happened at the facility**
- **Several traditional methods of trying to produce new-estimates had been only marginally successful**
  - The event that occurred represented a paradigm shift at the facility for which there was no historical comparison
- **This method arose from noticing a pattern occurring on a graph that was normally not created for this type of analysis**

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Progress-Based EACs

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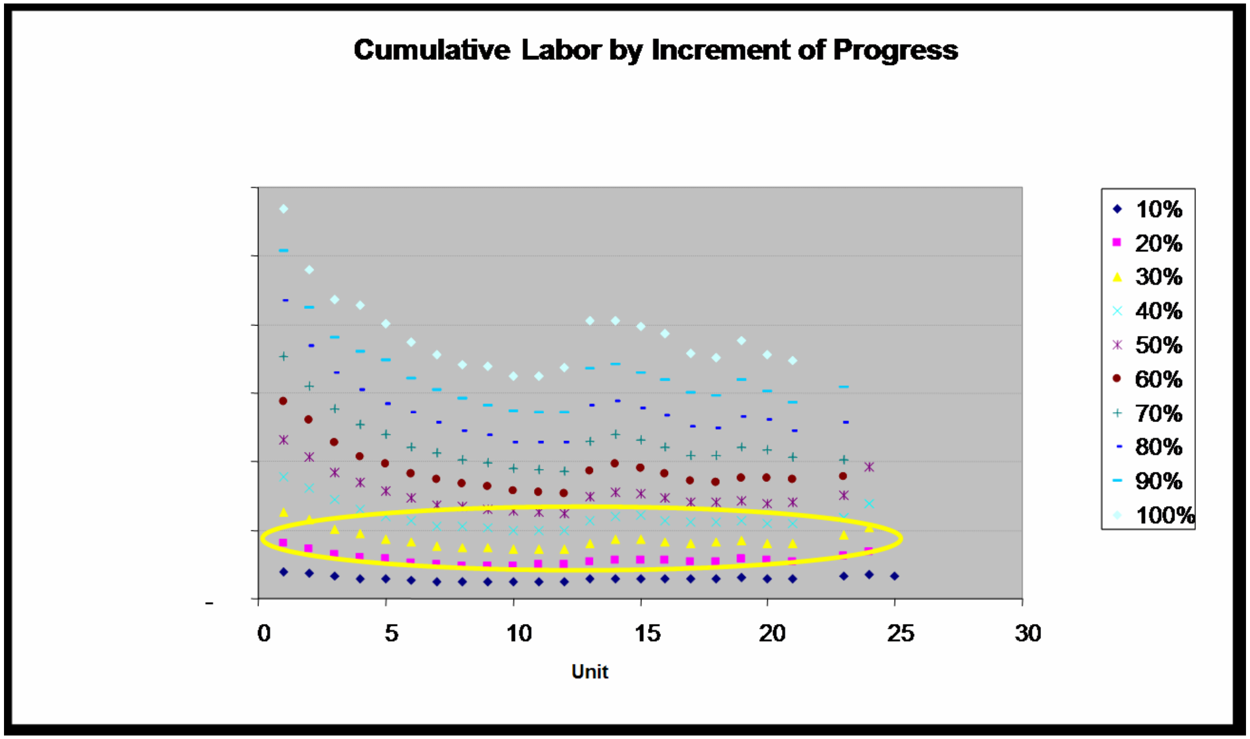
EAC Prediction – Step 1



- **Analysis started by looking at cumulative labor at different percent completes for each unit**
  - It quickly became apparent that a strong pattern at 100% begins to show up at ~ 30%

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Progress Based EACs – Step 2

- **In an attempt to verify the pattern seen on the previous slide, regression analysis was performed on two types of units at the same facility**
  - CERs were found mapping each 10% ACWP to the final cost
  - The CERs were found to be significant beginning at 20% with a CV of 4%

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.956210345
R Square	0.914338224
Adjusted R Square	0.90982971
Standard Error	
Observations	21

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	6.13857E+12	6.139E+12	202.80255	1.36728E-11
Residual	19	5.75105E+11	3.027E+10		
Total	20	6.71368E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept			0.5815324	0.5677177				
20%			14.240876	1.367E-11				

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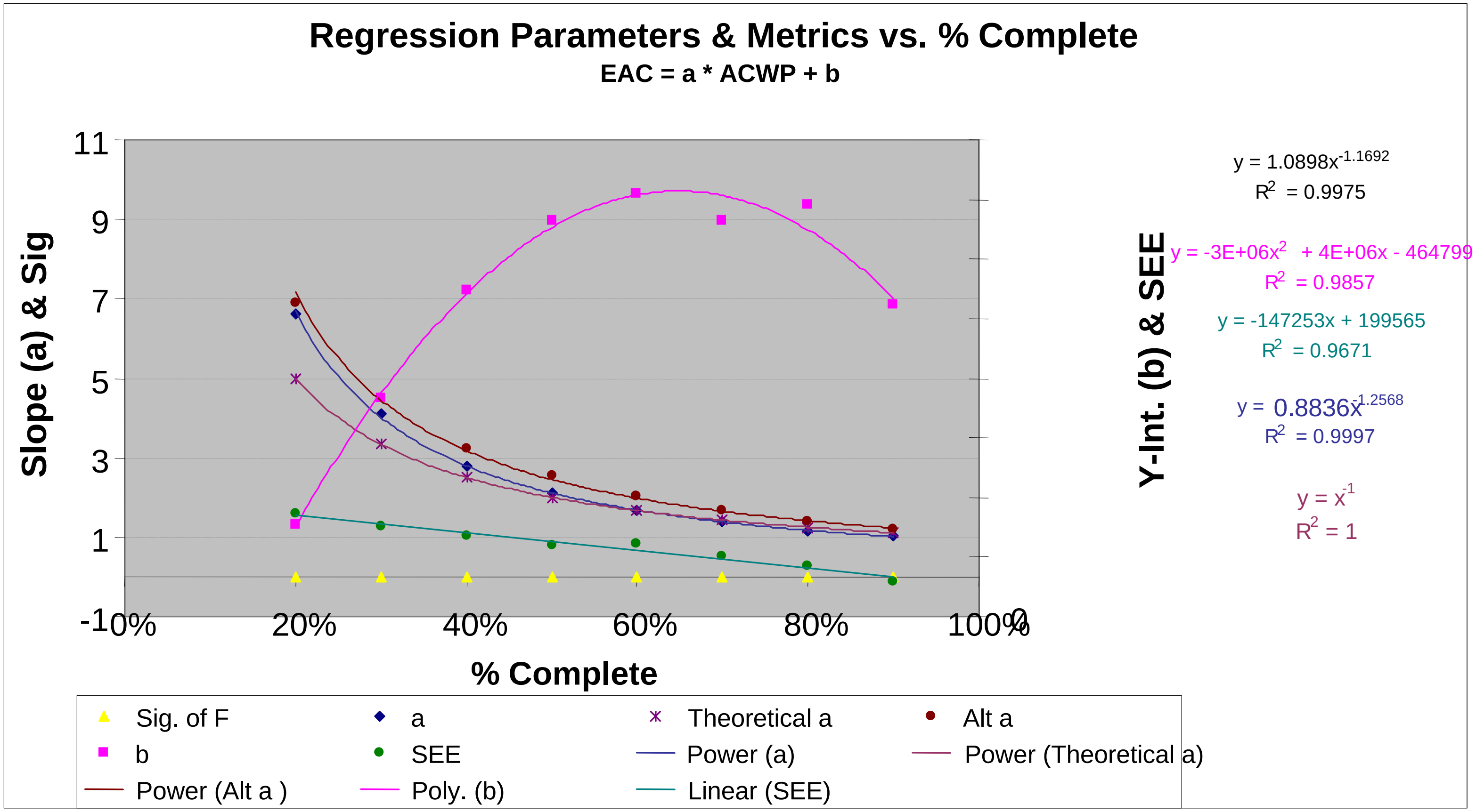
EAC Prediction – Step 3



- **The regression parameters were then graphed**
  - The *Y*-intercept seemed to be clouding understanding of the "*a*" coefficient

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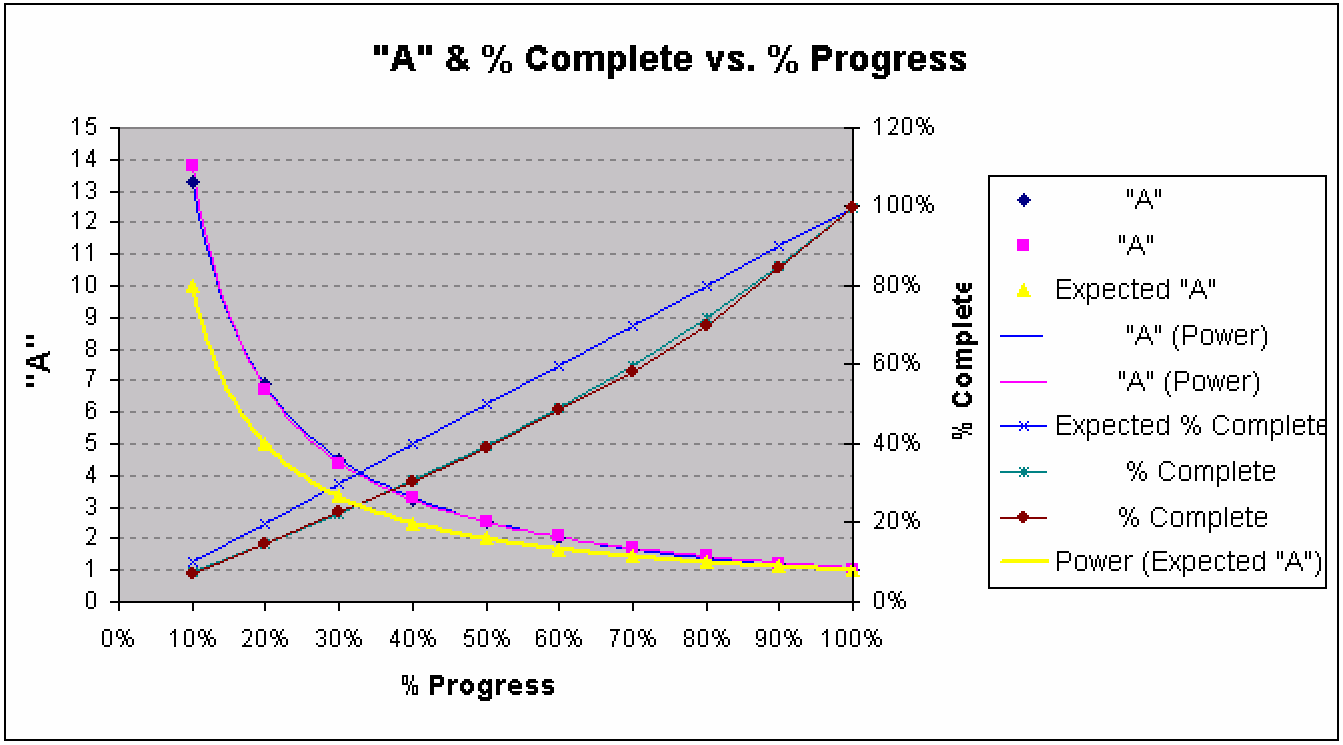
EAC Prediction – Step 4



- **Removing the Y-intercept revealed an almost perfect power curve that is essentially the same between the two types of units**
  - This showed that the facility's progress % points are <u>standard across unit types</u> and <u>directly related to cost</u>

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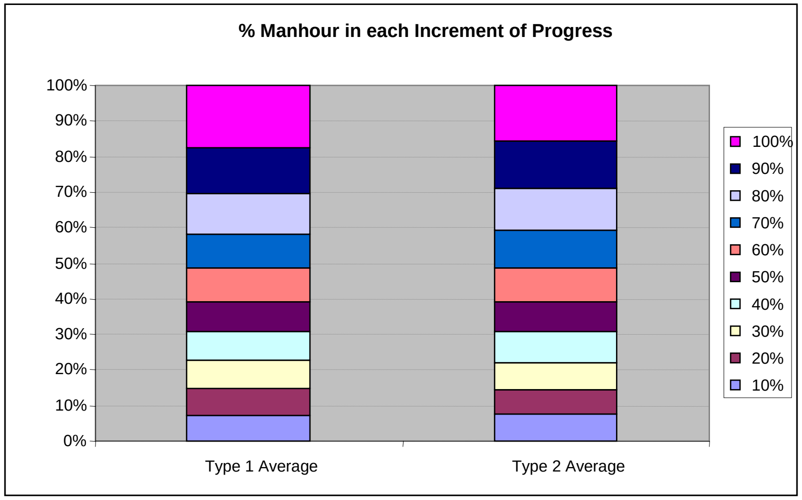
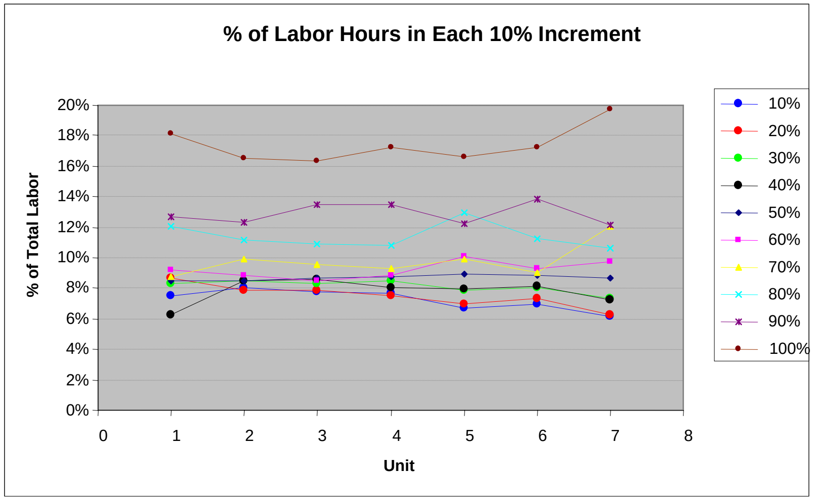
Incremental and Comparative Modes





- **MH % in any increment are well understood which should allow projection from any 20% segment**
- **Short Term Effects … model can show what was-to-be, so:**
  - Comparing this to Actuals will isolate an effect like a fire
  - Comparing a segment w/o a “fire effect” to a segment with a “fire effect” can show fire cost
- **Long Term Effects:**
  - Model can also test for any paradigm shift by comparing predictions from two windows of progress of 20% or longer
  - Model can show was-to-be and is-to-be (e.g., Katrina trends) by predicting the ETC after 20% of new-paradigm progress and adding it to ACWP for before the event

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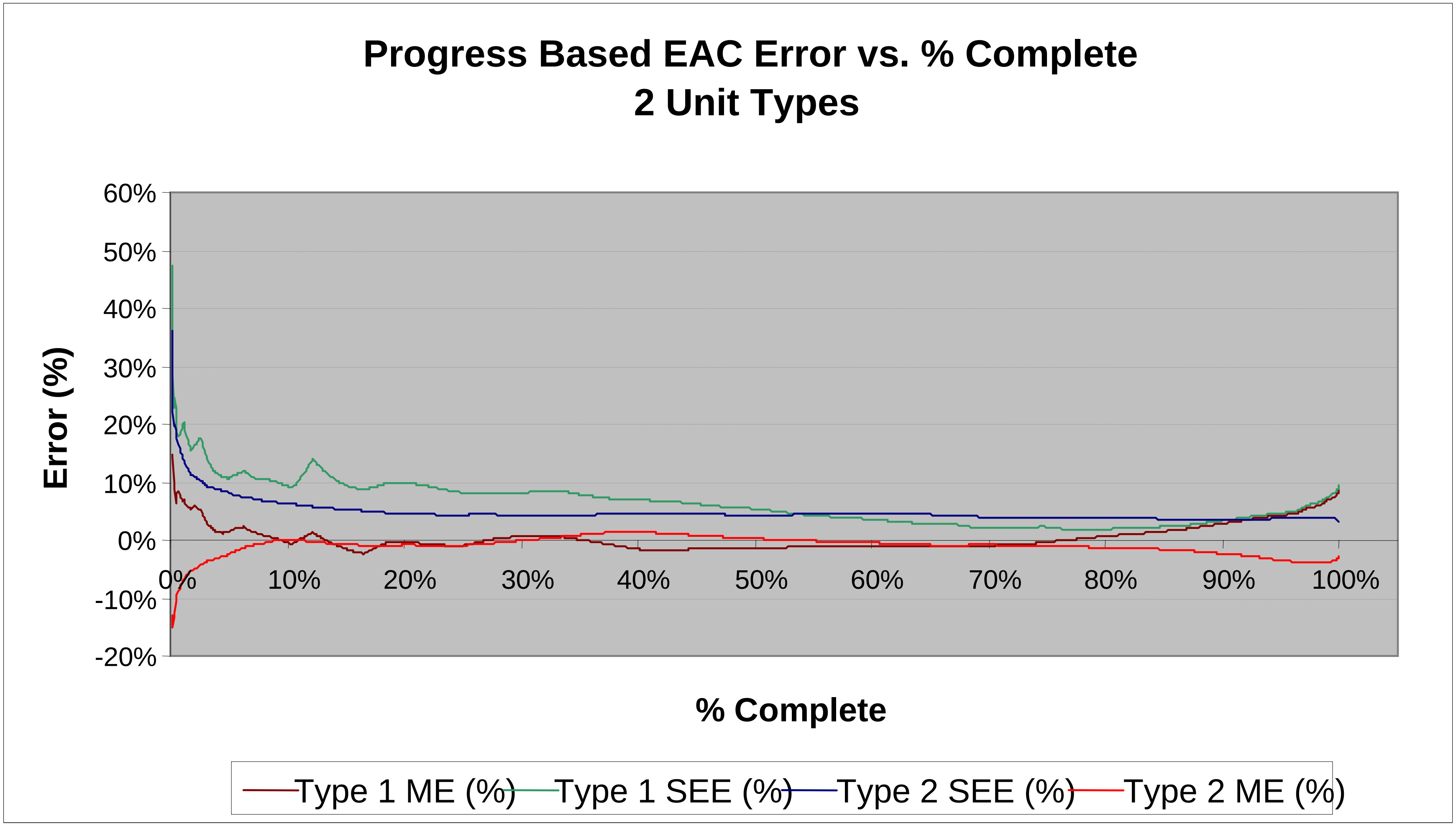
Error Track Record - Percent



This is *a posteriori* error not *a priori* error

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Implications

- **The study shows that if a production curve can be found for a commodity we have three new ways of performing certain analysis**
  - Final Cost Predicting
  - Productivity Monitoring
  - Productivity Shifts

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Implications – Final Cost Predicting

- **The most obvious implication of this method is that final cost can be estimated with minimal and non-biased error after a small amount of production**
    - The nature of this analysis allows prediction intervals to be included with the estimate
- **Using this as a tool, contracts can be structured to be CP up until the final cost is known, and FP after**
    - This allows the government to have realistic costs in their contract
    - It also requires the contractor to remain diligent in maintaining productivity
        - Fortunately, this method also allows a way of monitoring productivity!

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Implications – Productivity Monitoring

- **Because the production curve is known (and the same) for all units, final cost can be extrapolated from any interval of progress**
  - For example:

	ACWP	Derived Final Cost
30%	2,218	10,000
40%	3,233	10,670
30%-40% Interval	1,016	12,500

  - The data up to 30% shows a final cost of 10,000
  - At 40%, the data is predicting a higher final cost
  - Examining the 10% interval occurring between 30% and 40%, unveils a productivity shift equivalent to 2,500 additional hours per whole unit
  - Equation for extracting final cost from interval:

$$\frac{\mu(\%_1)\times\mu(\%_2)\times(ACWP_2-ACWP_1)}{[\mu(\%_1)-\mu(\%_2)]}$$

Where: $\mu(x)=ax^b+c$ at % progress

- **This leads to a major implication:**
  - Because cost per unit progress is not constant across production, the true measure of productivity is the final cost
  - This one number implies a productivity (cost per unit progress) for the unit and defines its entire curve
  - The exception of this is when a productivity shift occurs during construction
    - Luckily, this method is built to handle that as well!

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Implications – Dealing with Productivity Shifts

- **The detection of a shift in productivity in this model could signal several different things**
  - A specific event causing an increase in ACWP
    - In this event, the hours attributable to that event can be isolated
    - Example

	ACWP	Derived Final Cost
30%	2,218	10,000
40%	3,233	10,670
Interval	1,016	12,500
Predicted Interval	812	10,000
Cost of Event	203	

    - By subtracting the expected interval from the actual interval, we have isolated the true cost of our event!
      - This is extremely useful for insurance purposes
  - A work stoppage (if time is used as the progress variable)
    - In this event, the progress % is just adjusted accordingly to normalize the data
  - An actual change in productivity
    - This is a much more interesting situation!

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Implications – Productivity Shifts

- **There are a couple ways this method can handle changes in productivity**
  - The simple way
    - Take the productivity occurring in the interval, and use it for the remainder of the project
    - This involves the piecewise addition of production intervals
    - Useful when a specific event causes changes in productivity attributable to a specific point
      - Examples: New processes, destruction of equipment
  - The fun way
    - Monitor productivity as closely as possible, and phase productivity changes over the interval they occur in
    - Useful when productivity is expected to be dynamic
      - Examples: New hire learning, recovering from natural disaster

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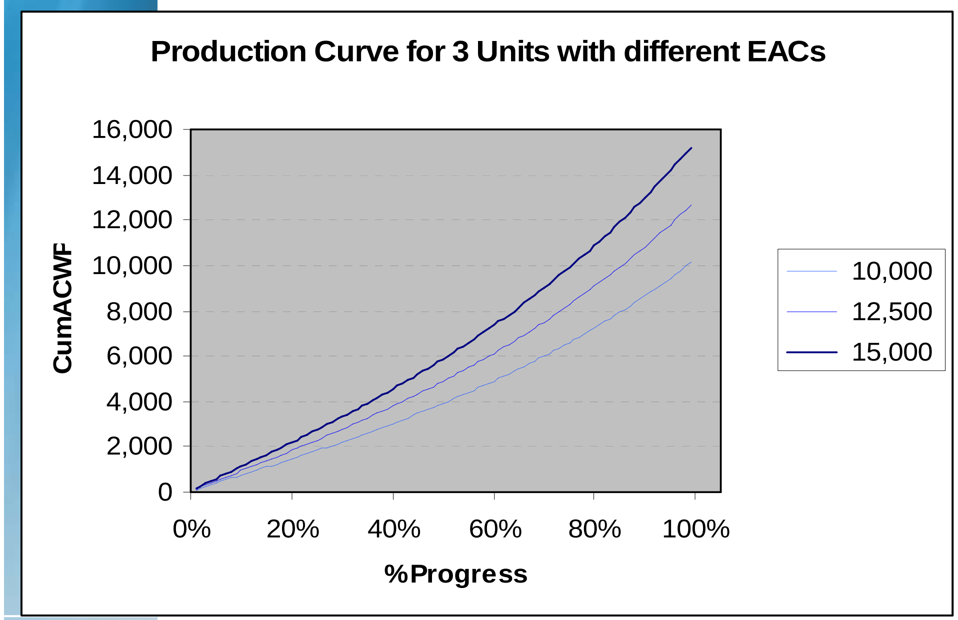
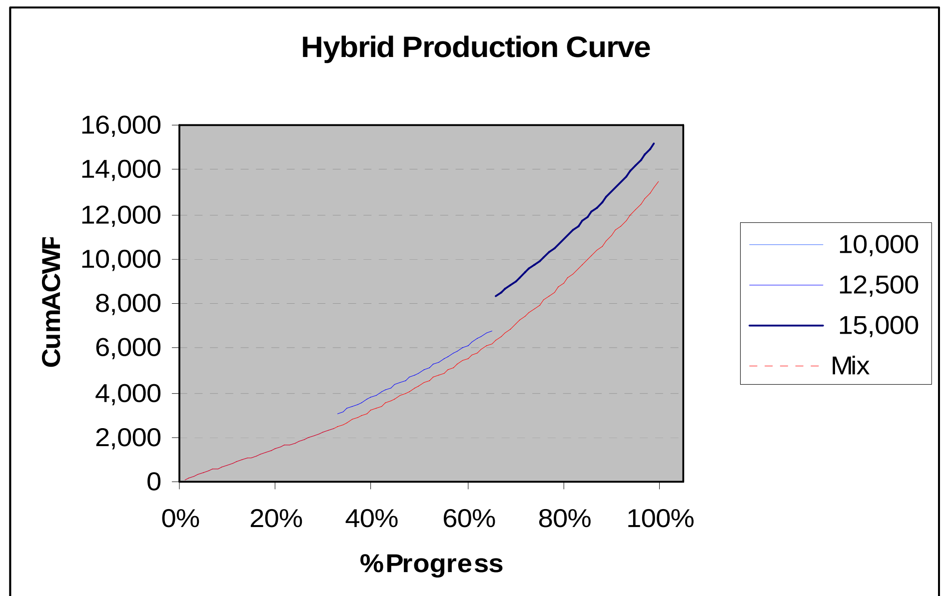
Implications – Productivity Shifts The Simple Way

- Because all curves have the same equation and are wholly defined by their final cost, pieces of different curves can be added together to create one conflated production curve
- Below we have taken three separate production curves (all defined by their final cost) and added their pieces together to create one curve





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Implications – Productivity Shifts The Fun Way

- **If productivity changes show a trend, or a trend is expected, the final EAC can be adjusted more accurately**
  - This requires productivity monitoring that, using this method, is not difficult
- **This equation allows you to produce the ACWP for an interval where productivity improves linearly from one %Complete to another %Complete**
  - SEAC = Hypothetical final cost of starting productivity
  - FEAC = Hypothetical final cost of ending productivity
  - SR = %Complete that improvement begins
  - FR = %Complete that improvement ends
  - μ = Production Curve function

$$\lim_{d \to 0} \sum_{i=1}^{\frac{FR-SR}{d}} \frac{SEAC - \left[\frac{(SEAC-FEAC)*d}{(FR-SR)}\right]*i}{\mu(SR+(i*d))} - \frac{SEAC - \left[\frac{(SEAC-FEAC)*d}{(FR-SR)}\right]*(i-1)}{\mu(SR+[(i-1)*d])}$$

Where: $\mu(x) = ax^b + c$

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Implications – Productivity Shifts The Fun Way (Example)

- **Let's make some assumptions**
  - An earthquake hit our facility, and our productivity has dropped to 50% its original value
  - At the point the earthquake occurred, our unit was at 50% progress
  - We expect our productivity to improve linearly to its previous value over the next several months
  - We expect that our unit will be 80% complete at the end of productivity improvement
    - Due to the fact that the % complete at end of productivity improvement could depend on the output of the model, the results might have to be iterated a few times until they level off

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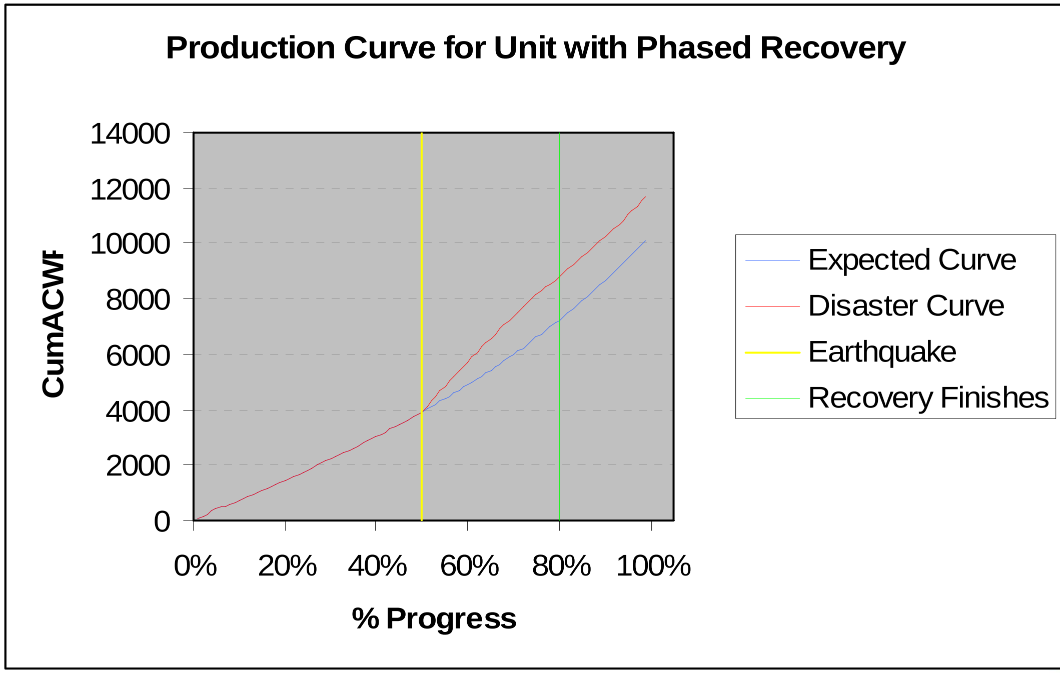
Implications – Productivity Shifts The Fun Way (Example Cont.)

- **Using the method discussed on the previous page, we have phased the recovery to give a more reliable estimate of final cost**
  - We were also able to isolate the cost of the earthquake to this unit

	Final Cost
Expected	10,000
Actual	11,861
Cost of Event	1,861



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Implications - Summary

- We have developed a wholly-data-based method of EAC projection that relies upon Progress-and-MH data alone. The below points are somewhat speculative but seem eminently achievable. The model is
  - Able to project EACs for two different unit types within about 2% - 5% after about the 20% progress point
  - Probably also able to work incrementally projecting work remaining given MH
  - Able to predict any unit type with as much accuracy at the 20% point
  - Unbiased – the error is symmetric … specifically, it does not result in a tail chase
- In the case of <u>short term effects</u>, the model, because it is progress based, appears able to separate out specific effects such as additional costs due to a fire or a lesser hurricane for ships that were at least 20% complete before an event
  - This "effect cost" will be obtained by subtracting the as-would-have-been cost from the actual end cost
- In the case of <u>long-term effects</u>, because of its incremental ability, the model appears able to add actuals up to an event, and, since it can predict <u>ETC after any post-event increment of about 20% of progress</u> has occurred, can predict ETCs after the event.
- This methodology, being virtually free of expert adjustment, seems to be ideal for our customer

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