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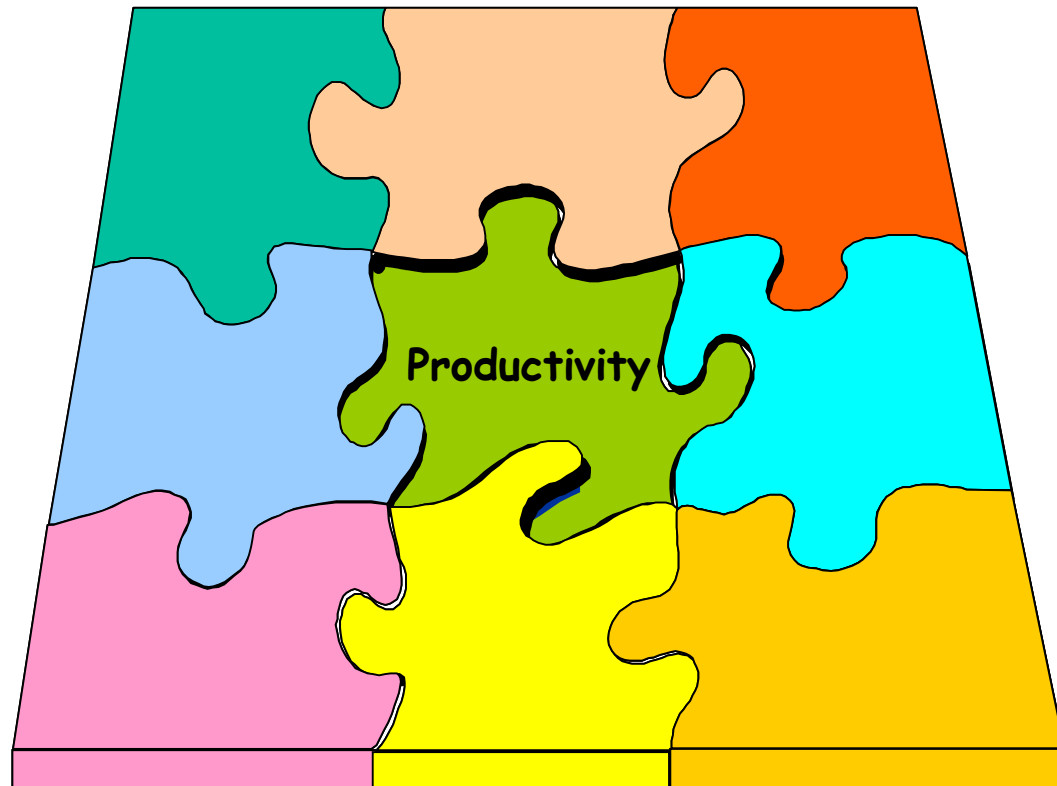
**Raytheon**

*Customer Success Is Our Mission*



# The Productivity Puzzle

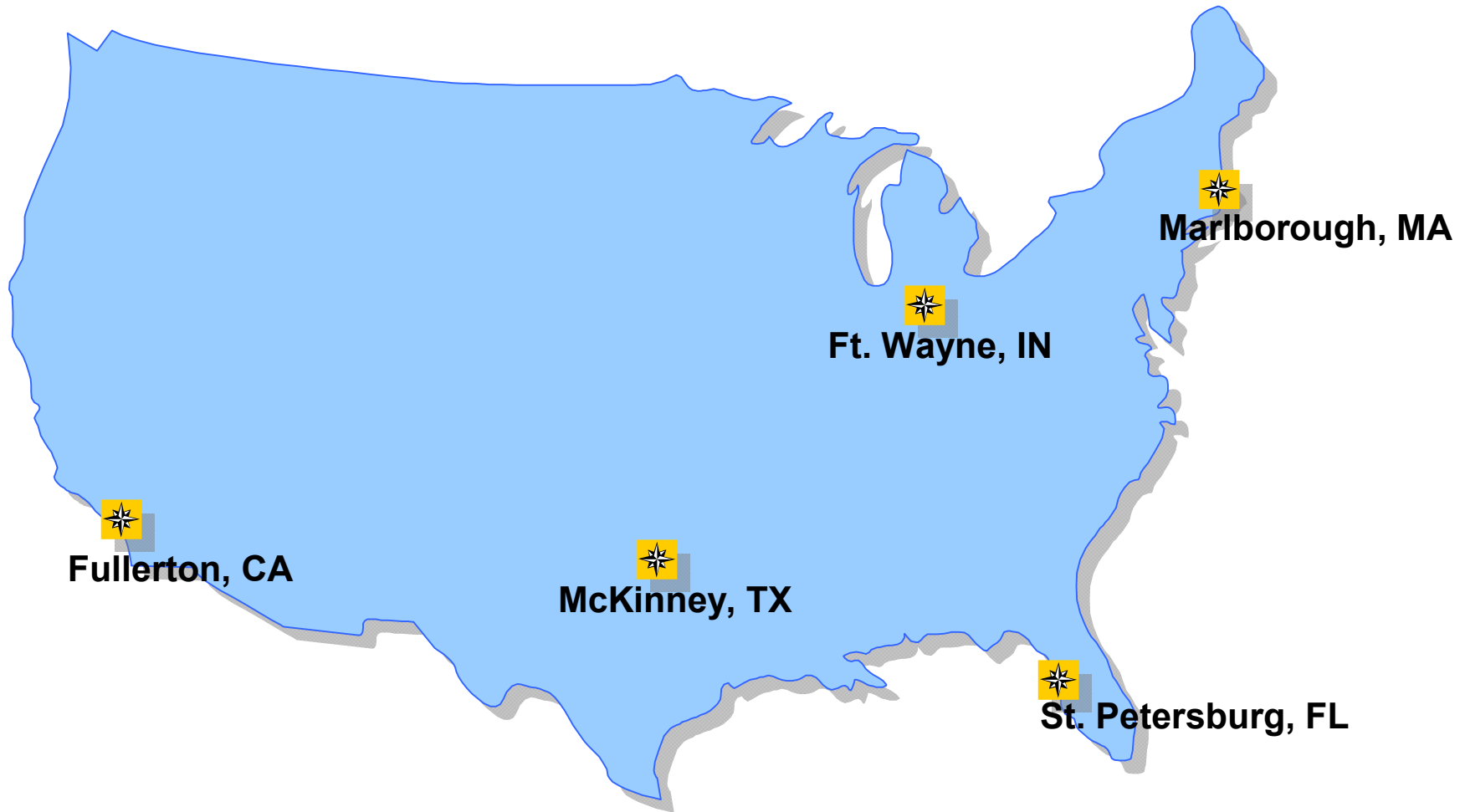
- Introduction to Raytheon
- Introduction to Productivity
- Pieces of the Puzzle
- The Puzzling Issues
- Q & A



# Raytheon and NCS

- Raytheon is an industry leader in defense and government electronics, space, information technology, and technical services
- Network Centric Systems (NCS) develops and produces mission solutions for networking, command and control, battle space awareness, homeland security and air traffic management





- ” NCS Engineering Organization = Over 5,000 individuals
- ” Appraised as CMMI Level 5 for Systems, Hardware and Software Engineering is June, 2007

# Productivity

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- Per Webster.com, productivity is:

## Main Entry:

- . pro·duc·tiv·i·ty

## Pronunciation:

- . \ prō-dək- ti-və-tē, prä-, prə- dək-\

## Function:

- . *noun*

## Date:

- . circa 1810

**1** : the quality or state of being productive

**2** : the rate per unit area or per unit volume at which biomass consumable as food by other organisms is made by producers

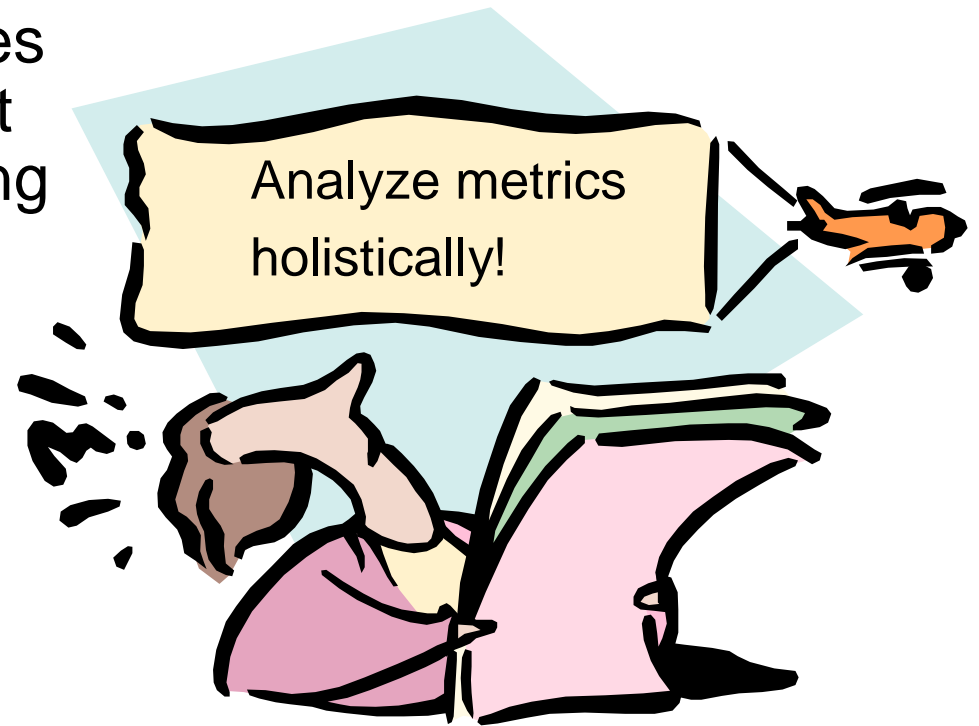
## Productivity (continued)

- In the manufacturing world, productivity is number of widgets created per time
- Use productivity as input for estimation and planning: If we know we can produce  $X$  widgets / hour, and we have an order for  $100X$  widgets, then it will take us 100 hours to meet the order



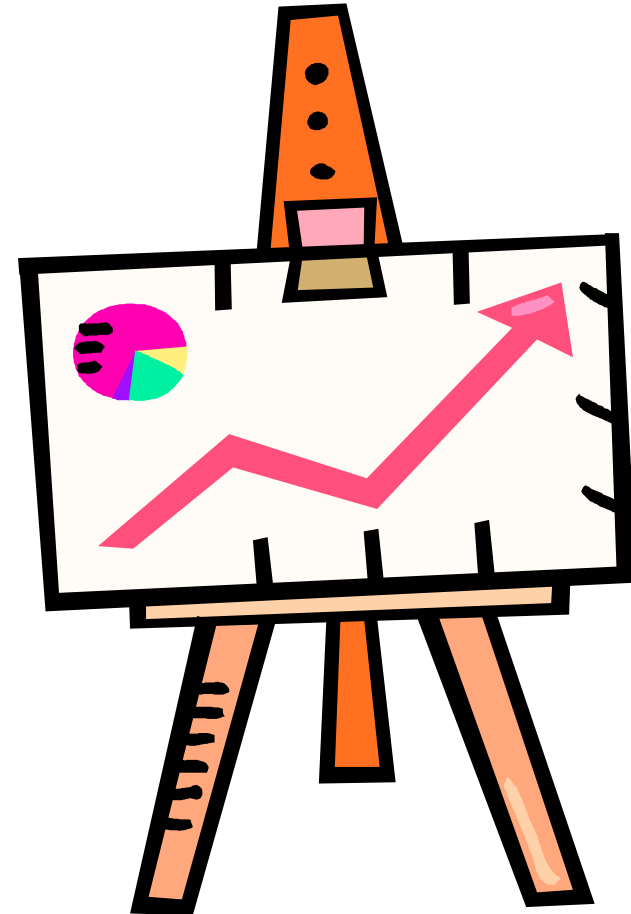
## Productivity (continued)

- Also use productivity to aide with analysis regarding program progress, if CPI (Cost Performance Index) and SPI (Schedule Performance Index) appear to be good, the program could still have issues if productivity is not near what was originally planned. Rolling up measurements can mask issues



## Productivity (continued)

- Increased productivity can be used as a measure of process improvement, if all else is held constant
- Let's look at an example .





## Productivity (continued)

- In the Olympic sprint events, the distance is the size that is produced- so the 200 meter dash is twice as far as the 100 meter race
- Productivity is measured as size per time such as meters / second
- If you change the size, the time will have to change, assuming that productivity remains constant (and it is fairly constant at the Olympic level)



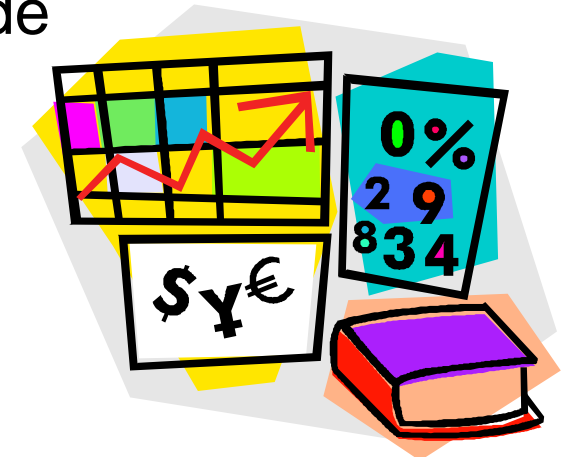
Photos: Credit Getty Images

# Puzzle: Productivity

Productivity = Size / Hours

Size = ELOC = Equivalent Lines of Code

Hours = SW development hours  
= (ACWP<sub>CTD</sub> + ETC)



ACWP<sub>CTD</sub> = Actual Cost of Work Performed (cumulative to date)

ETC = Estimate to Complete

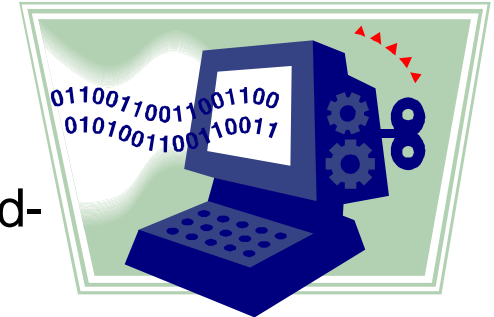
= the remaining hours expected to complete the work

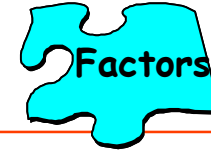
## Puzzle: Size



Size data includes these counts, in lines of code, or thousands of lines of code, KSLOC

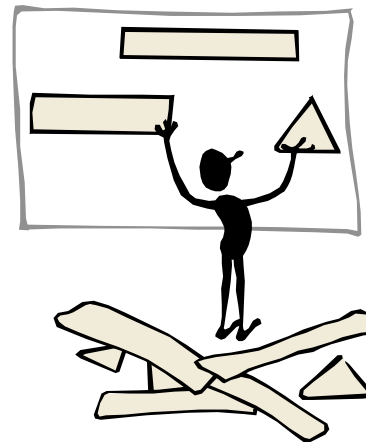
- New:** Any software or firmware unit that is to be newly developed or does not fit the reused or modified software definitions
- Reused:** If no lines of the actual component code are going to be changed. This includes comments. If the component is to be edited for any reason, it cannot be classified as reused. If the component is to be converted to a different language, it cannot be classified as reused
- Modified:** Estimated SLOC modifications for that component do not exceed 50% of the actual counted SLOC. If the SLOC modifications exceed 50% of the actual size, the effort associated with understanding and modifying the component is likely to be equal to or exceed the effort required to develop it new, so treat it as new





Size data includes these factors:

- Reuse Factor ( $F_R$ ):**  $F_R$  is the factor for converting reused code (SLOC to ELOC). It represents the percent of overall effort that the estimator believes will be required to adapt the existing software component and artifacts, versus developing the software and all associated artifacts from scratch
- Modified Factor ( $F_M$ ):**  $F_M$  is the factor for converting modified code (SLOC to ELOC). It represents the percent of overall effort that the estimator believes will be required to adapt the existing software component and artifacts, versus developing the software and all associated artifacts from scratch



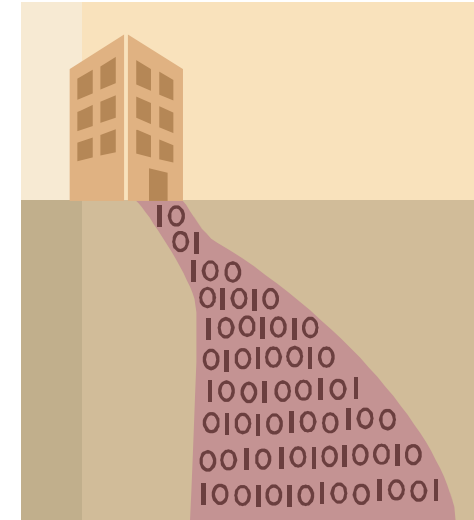
## Puzzle: Size (cont.)

- Delivered Lines of Code:

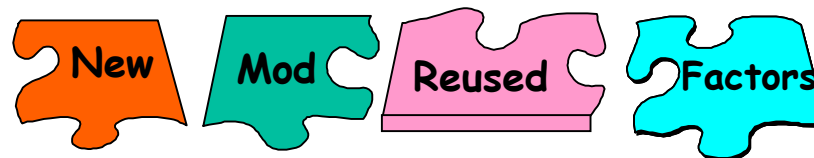
$$DLOC = New + Reused + Modified$$

- Equivalent Lines of Code:

$$ELOC = New + (Modified * F_M) + (Reused * F_R)$$



ELOC is generally used for productivity as it results in a more representative measure



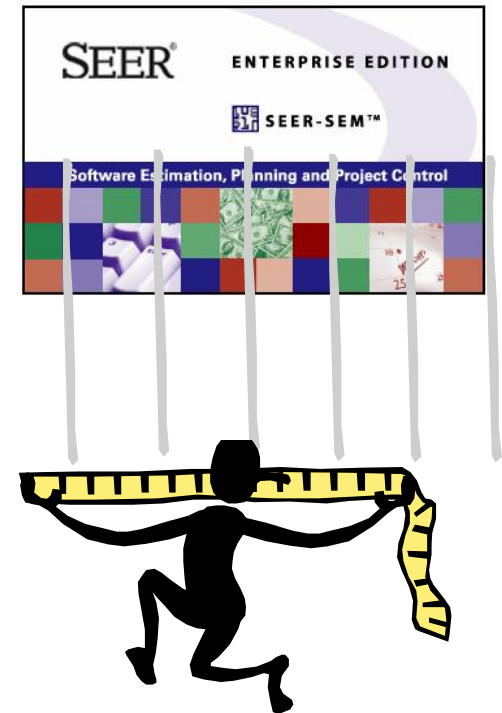
## Puzzle: Size (cont.)

- You can't attribute an increase in productivity to reuse
- Reuse/modification means that there is less work to do or, going back to the Olympic Sprint analogy, less distance to cover
- The productivity equation takes this into account using the Reuse and Modified factors

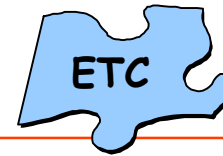


## Puzzle: Size (cont.)

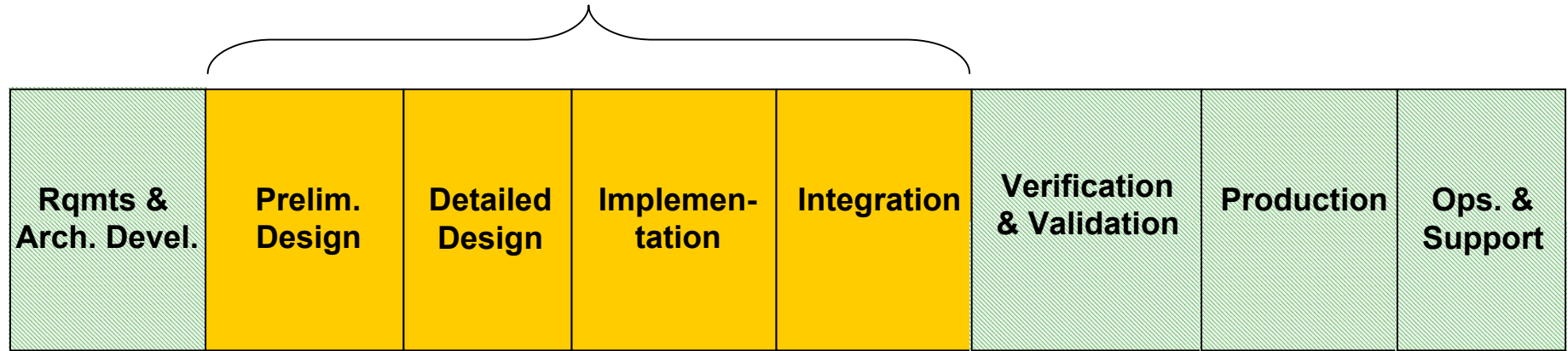
- Raytheon has used parametric SW models such as COCOMO, COCOMO II, REVIC, Price-S, and SEER-SEM for many years
- Specific alignment was made to the SEER-SEM SW Application types to allow stratification of data such as productivity
- NCS SW Size measures support these models with parameters of Source Lines of Code (SLOC) categorized by Reused, Modified, and New, with Reuse and Modified Factors
- A standard NCS software line counting tool was deployed across all sites so that sizes are measured consistently and with automation
- Also aligned with customer expectations . they often use these models



# Puzzle: Hours



## SW Development Productivity Stages



$ACWP_{CTD}$  = Actual Cost of Work Performed (cumulative to date) = sum of all hours charged against SW Development Productivity Stages

ETC = Estimate to Complete = the remaining hours expected to complete the work

**Specific cost collection codes are used to capture hours for Productivity measures**



# Puzzle: Hours (cont.)

ACTIVITY TITLE	PE	SE	SW	HW				
				General Hardware	Analog	Digital	FPGA	Mechanical
<b>PROJECT PLANNING &amp; MANAGEMENT</b>								
Planning and Management								
Quality Engineering								
Configuration Management								
<b>REQUIREMENTS DEVELOPMENT</b>								
System Requirements Definition								
System Design & Architecture								
Product Requirements Definition								
Product Design & Architecture								
Component Requirements Definition								
<b>PRODUCT DESIGN &amp; DEVELOPMENT</b>								
Requirements Management								
Simulation and Modeling								
Preliminary Design								
Detailed Design								
Implementation								
Integration								
<b>SYSTEM INTEGRATION &amp; VALIDATION</b>								
Product Verification & Validation								
System Integration								
System Acceptance Test								
System Field Test								

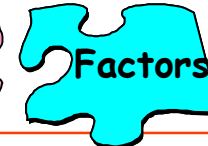
These elements contribute to the denominator in the productivity equation

- Aligns disciplines and activities
- Used to identify and collect costs for Work Breakdown Structure (WBS) elements
- Scheme is aligned with Cost Estimation
- Facilitates collection of consistent historical data
- Defect data can also be collected in these bins



Clearly define the denominator (e.g. hours) in the productivity equation

sues

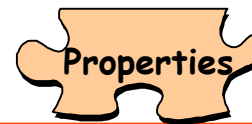


- How to modification of existing code/reuse of code

$$\text{Equivalent} = \text{New} + (\text{Modified} * F_M) + (\text{Reused} * F_R)$$

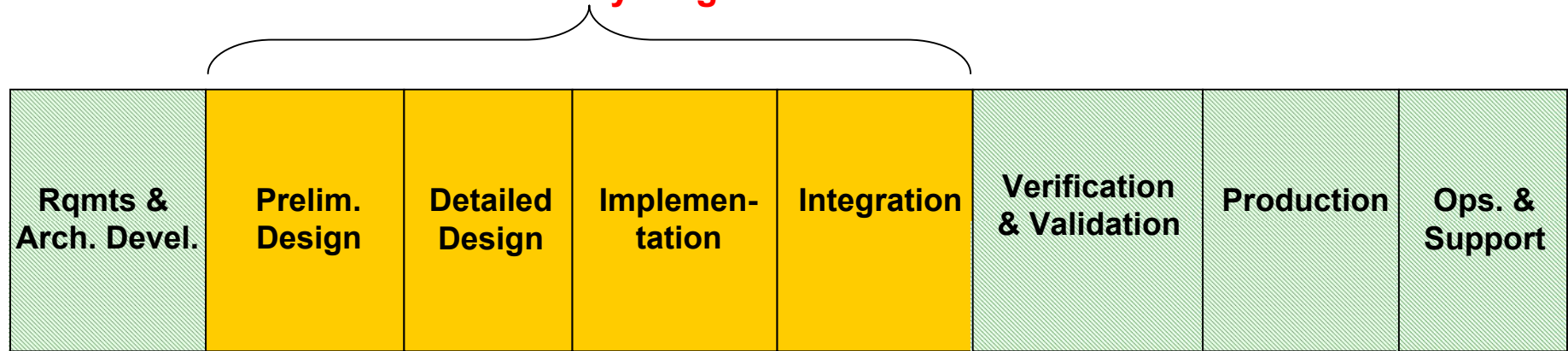
- 50% or less modification threshold, or counted as new
- If many products are at 50% while other products are at 10%, would this skew the data?
- No changes, used as is, or counted as modified/new
- Cost of integration, and verification/validation will vary from product to product
- If you adjust the factors to account for this, how do you round trip the data to ensure that your estimates will improve? Too many variables, not enough equations? We can't really measure the factors

## Issues (cont.)



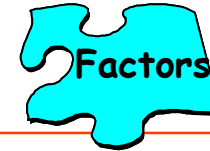
- How to measure productivity of non-traditional/partial lifecycles, such as modeling and simulation / demo products or maintenance versus mission software

### SW Development Productivity Stages



- May not fully execute all activities/stages
- Flag modified lifecycle, via properties, to allow stratification to avoid comparing % apples and oranges+

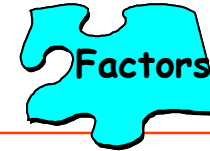
## Issues (cont.)



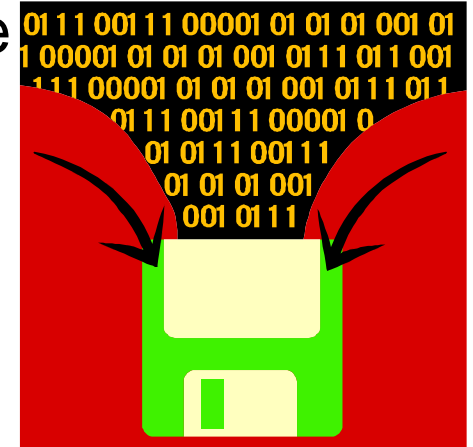
- How to handle inclusion of COTS
- When using COTS, there is no effort to create the code, but extensive effort can be spent on integration
- If the COTS code size is folded in with %~~65~~ additional+code size, the productivity will be skewed
- One solution is to put this data into a separate %~~65~~ bucket+so that it can be evaluated independently and then a factoring determined so that it can be rolled up
- Alternatively, COTS can be counted as Reused



## Issues (cont.)



- How to handle inclusion of autogenerated code
- When using autogenerated code, the effort spent on creating the code itself is negligible
- If the autogen code size is folded in with %additional+code size, the productivity will be skewed
- One solution is to count the code as Reused with a low factor
- Alternatively put this data into a separate %bucket+so that it can be evaluated independently and then a factoring determined so that it can be rolled up



## Issues (cont.)



- Variation in measurement of size
- Not all using the same line counting tool
- Not measuring at the same level of granularity with regard to new/mod/reused
- Language impacts size
- Line counting tool evolution- handling historical data
- Standardization/refine of organization tools/process on-going



## Issues (cont.)



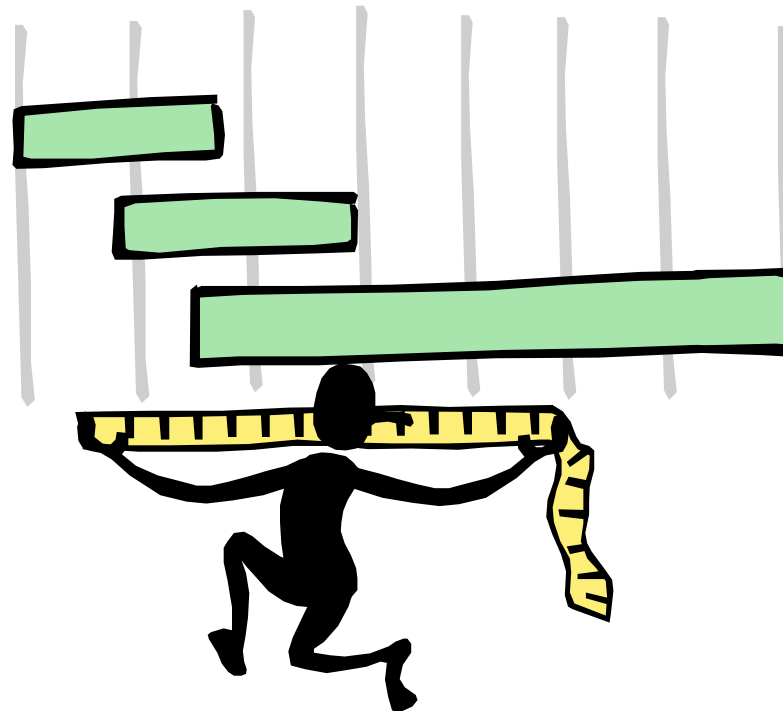
- Variation in measurement of hours
- Unpaid Overtime issue
- Supplier/Contractor labor → \$ instead of hours
- Challenging issues due to financial policies / requirements / tooling



## Issues (cont.)

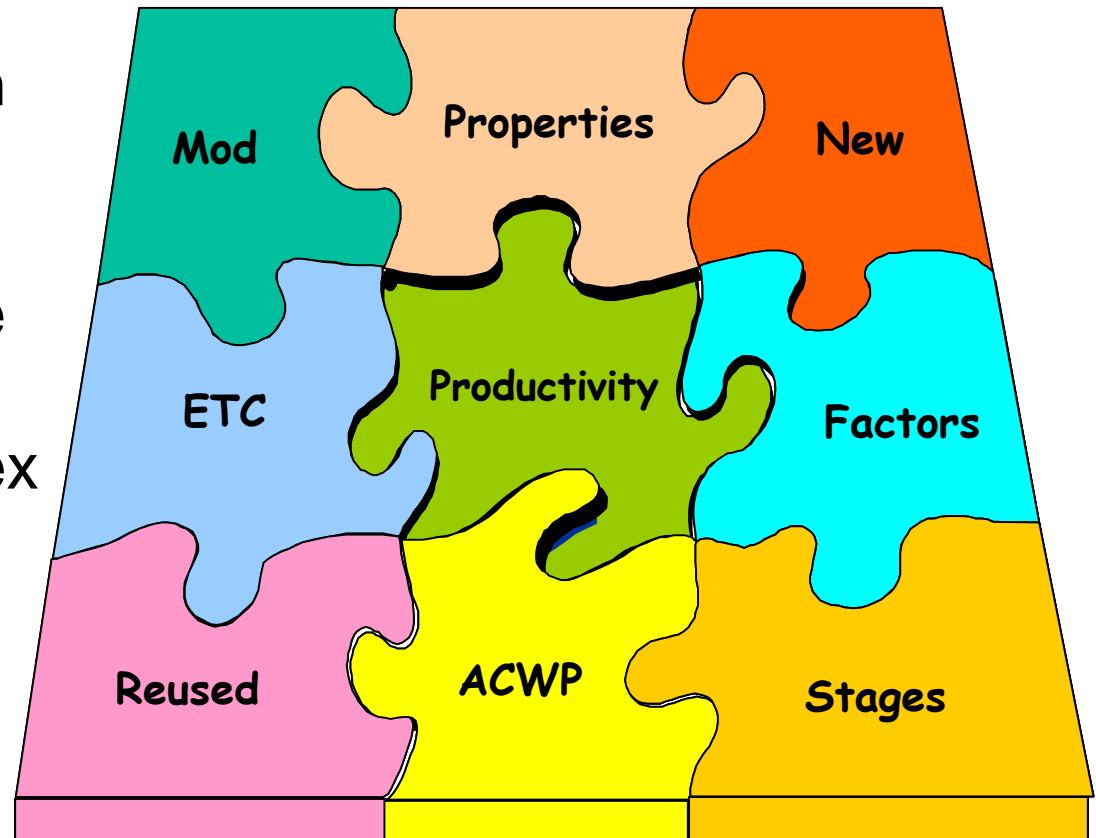


- Use of productivity during development vs. at program completion- projected vs actual
- Limited value during program
- Actuals used for planning and estimating





- Several factors contribute to the calculation of productivity
- Although the calculation of productivity is fairly simple, ensuring collection of appropriate data and the use of the measurement is complex
- Solving the puzzle of productivity is a continuing journey





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# QUESTIONS ?



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