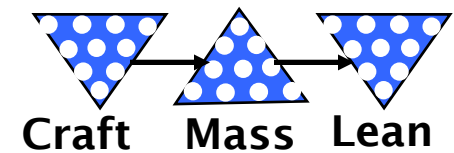


Quality Improvements and their Impact in a Lean CAE “Future World”

Mark P. Zebrowski - Independent Consultant
(mzebrowski@sbcglobal.net)
Former Technical Manager – Vehicle Attributes & CAE
Ford Motor Company



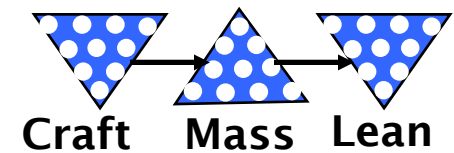
In 2020 ...



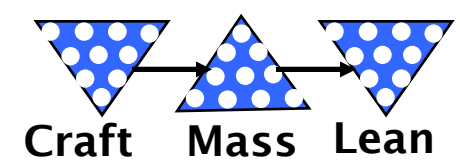
- In 1973, ... In 1977, ... In 1981, ... Etc.
- Vehicle Model sizes of 6M(small) / 12M(average) / 31M Grids(large) Want DOFs? Multiply by 6! (20% AAG)
- Installed Computer Power One Million Times greater than when I started. (35% AAG)
- Maxed Out Computer Capacity Billions of Times greater (60% AAG)
- Doing More at (Much) Less Cost.
- Models created and analyzed across the Globe.
- Cross Attribute / Multi-Physics Commonplace.
- Statistical Inputs to Deterministic Models.
- ***How do we begin to Manage this Mess?***
- ***What could be / will be Holding us Back?***

AAG – Average Annual Growth

To Remember ...



- \$250 Billion Worth of “Importance”, at Least
- Grand Strategy, Strategies, Tactics & Operations
- Machine that Changed the World as the Call to Action
- Craft to Mass to Lean as the **Grand Strategy**
- The Rework Cycle as the Connection of the Strategy to Quality Metrics
- Adopting / Adapting Toyota Production System (TPS) to CAE provides the **Low-Level Strategic and Tactical Elements**
- Experience fills in the **Operational Details**
- Process Quality as the Overall Driver and Delivers the \$250 Billion

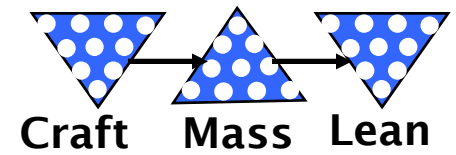


Who IS this Person?

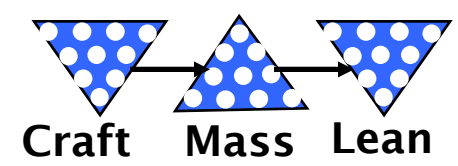
- Born in '47, Married to Marlene in '69 (39 years ago!)
- 2 Daughters and 2 Sons-in-Law & 4 Grand-Children
 - Maria & Byron & Ben (born 7/4/2002) & Luc (born 4/23/05), Maria & Byron (stay-at-home Dad) @ Ford in Koln
 - Ben likes John Philip Souza songs (But of course! He was born on...)
 - Margaret & Mike & Brendan (born 6/18/2003) & Kathrine (born 9/26/2006), Margaret a Nurse, Mike in US Army (West Point Grad) – Mike completed an MS at Georgetown – is now at the Pentagon
- BS, MS & “2/3” of a PhD
- 32 Years at Ford

Who IS this Person?

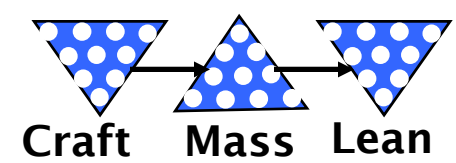
Byron – Luc – Maria – Margaret – Mike
Me – Kate – Marlene
Brendan - Ben



Manistique (Da UP)

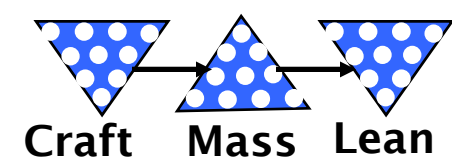


Also in the UP ...



(I am on the Right ... Same Hat)

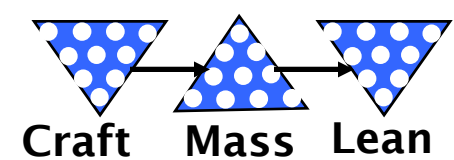




Who IS this Person?

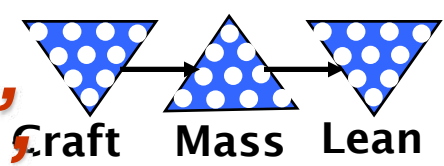
- At Ford,
 - **Training** - CAE and Test of Joints
 - **Doing** - NVH CAE Pre-Program Supervisor on Thunderbird, Mazda 626/Probe / Contour, Simplified Modeler Programming and Methods Development, NVH CAE Supervisor on Taurus, Continental, Core Methods Supervisor
 - **Probing** - FASTER Structures Team Co-Leader, **CAE Rep. on WCT/FPDS/GPDS**, including FPDS 30-Day Study Team
 - **Architecting** - CAE / PD Integration Team Leader, **CAE Critical Path Team Leader**, **CAE Quality Team Co-Leader**, CAE Quality Team Pilot Leader
- Was an LL5 – a “Technical Manager” – for 12 years, prior to retirement in July, 2005

My Credo (“I believe that...”)



- I believe that CAE has High Value because it can **PREDICT** Product Performance from a “Drawing”! (Dates me as a Person ...).
- I believe that CAE is More than JUST A TOOL.
- I believe that CAE works, **IF PROPERLY PERFORMED.**
- I believe that **CAE / VPD IS A BUSINESS** and should be treated as such.

Ken Rockwell – It's the "Approach" NOT the Tool



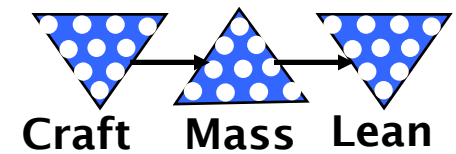
Your Camera? Canon? Nikon? Kodak? Pentax? Olympus? Sony? Lieca?
LG?

Your Camera doesn't matter

When it comes to the arts, be it music, photography, surfing or anything, there is a mountain to be overcome. What happens is that for the first 20 years or so that you study any art you just know that if you had a better instrument, camera or surfboard that you would be just as good as the pros. You waste a lot of time worrying about your equipment and trying to afford better. After that first 20 years you finally get as good as all the other world-renowned artists (maybe!), and one day when someone comes up to you asking for advice you have an *epiphany* where you realize that it's never been the equipment at all.

You finally realize that the right gear you've spent so much time accumulating just makes it easier to get your sound or your look or your moves, but that you could get them, albeit with a little more effort, on the same garbage with which you started. **You realize the most important thing for the gear to do is just get out of your way.** You then also realize that if you had spent all the time you wasted worrying about acquiring better gear woodshedding, making photos or catching more rides that you would have gotten where you wanted to be much sooner.

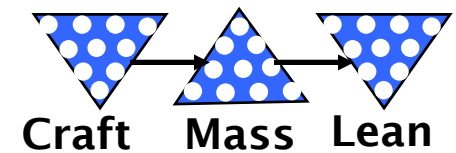
So, the Secret is to ...



- Learn How to See – The “*Epiphany*” allows this
- To Appreciate the Learning Opportunities all Around You
- To Adopt Principles from a Wide Variety of Sources
- To Adapt the Principles to your “Unique” Situation

Don't Tell This to Anyone ... It's a Proprietary Secret!

The Screenplay -



The Two Worlds of Your Screenplay

by Charles Deemer (May-06-2002)

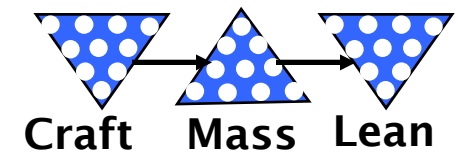
When we watch a movie, we enter a world created by the screenwriter. From the very first scene, events and characters begin to define a world, set in time and place, with implied values and social nuances. However, this initial world we see early on is only the first of **two worlds that the screenwriter will create to tell the story.**

The Ordinary World

This first world is called the Ordinary World. Think of it as a point of reference. It's "ordinary" in the sense that this is the world where our main character, the protagonist, lives. Screenwriters must define this early on and clearly because the story really begins when **the protagonist accepts a challenge to leave the ordinary world** for another -- the world of the story. But more about this second world in a moment.

The Ordinary World tells us where we are, and where the protagonist is.

The Screenplay -



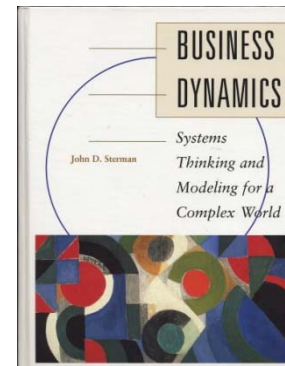
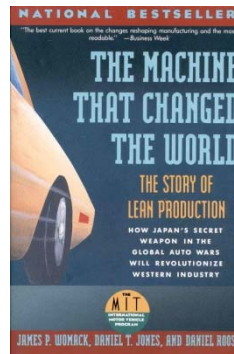
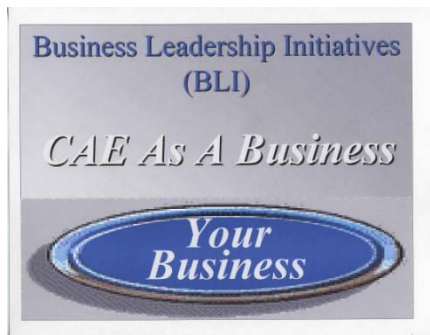
The Call to Action

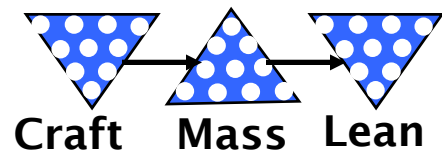
Stories do not happen in ordinary worlds -- **stories happen when choices and events propel the main character into a world far more exciting, different and challenging than the ordinary day-to-day experience** represented by the Ordinary World.

The "call to action" is an early story moment when the protagonist makes a choice that will cause him or her to leave the Ordinary World and enter the world of the story, which is called the Extraordinary World. The reference point (to what makes it extra-ordinary) is always the "ordinary" experience of the main character.

The Extraordinary World

So the world of the story, the extraordinary world, is entered by a definitive action by the protagonist. The Extraordinary World is the world of the story. **The first act ends when the protagonist has moved into this new world beyond the point of no return. The second act, which contains most of the conflict in any story, is firmly rooted in this world.**





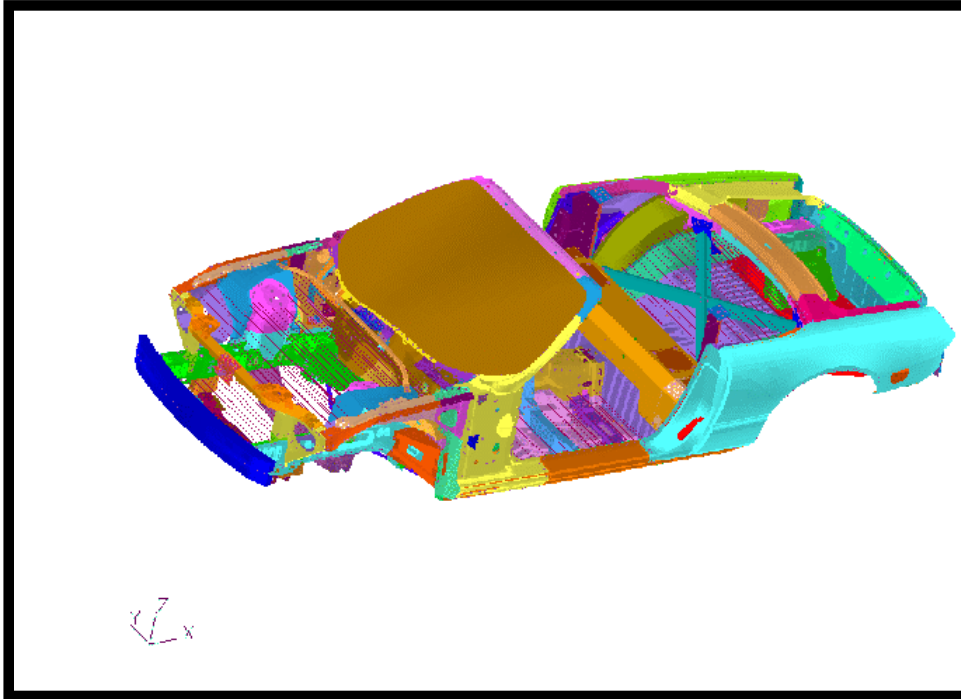
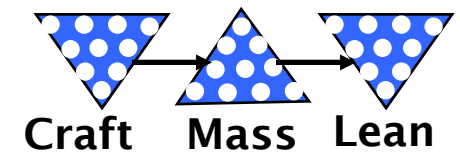
We Pretend CAE Looks like This ...Always Have, Probably Always Will



CAE Task	Estimated Time (Man Hours)
Body-In-Prime (Sheet Metal)	
CAD Data Gathering	~16-24
Weld Data Gathering	~16-24
Parts Modeling	150
Assembly (Welds)	16
Trimmed Body	
Closure and Trim Items	100
Display Model	10
Acoustic Cavity Model	10
Debugging	50
TOTAL	440
ANALYSIS	
Normal Modes	8-24
Static Stiffness	8
Equivalent Stiffness	8
Point Mobilities	4-8
Vibration Transfer Functions	4-8
Acoustic Transfer Functions	4-8
TOTAL	40
GRAND TOTAL	480

480 Total Hours

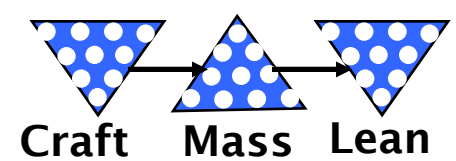
Sometimes, CAE within Product Variability



Characteristic	Vehicle 1	Vehicle 2	CAE
Torsional Stiffness (ft.-lbf./deg.)	4945	4967	4870
Bending Stiffness (lbf./in.)	21190	22030	21770
Torsional Frequency (Hz.)	20.75	21.00	20.81
Bending Frequency (Hz.)	21.75	22.00	21.74

Demonstrates that we can do the right thing ...

Other Times, 8 Analysts, Each Using 6 Models



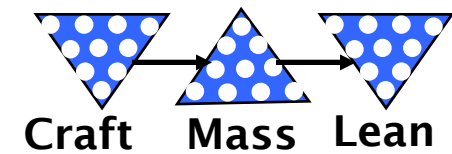
#	A1	A2	A3	A4	A5	A6	A7	A8
M1	3.30	2.53	3.00	3.33	2.68	2.82	2.52	2.98
M2	2.81	2.25	2.32	2.76	2.50	2.18	2.42	2.46
M3	3.56	2.75	3.12	3.43	2.80	2.91	2.72	3.03
M4	2.08	2.05	2.94	3.14	2.79	2.12	2.89	1.92
M5	2.60	2.29	2.82	3.01	2.56	2.38	2.39	2.53
M6	4.00	2.51	3.39	3.57	3.10	3.02	2.69	3.34

6 models built from identical CAD data by designers using “well” documented procedures

Care to Comment on the Process Capability?

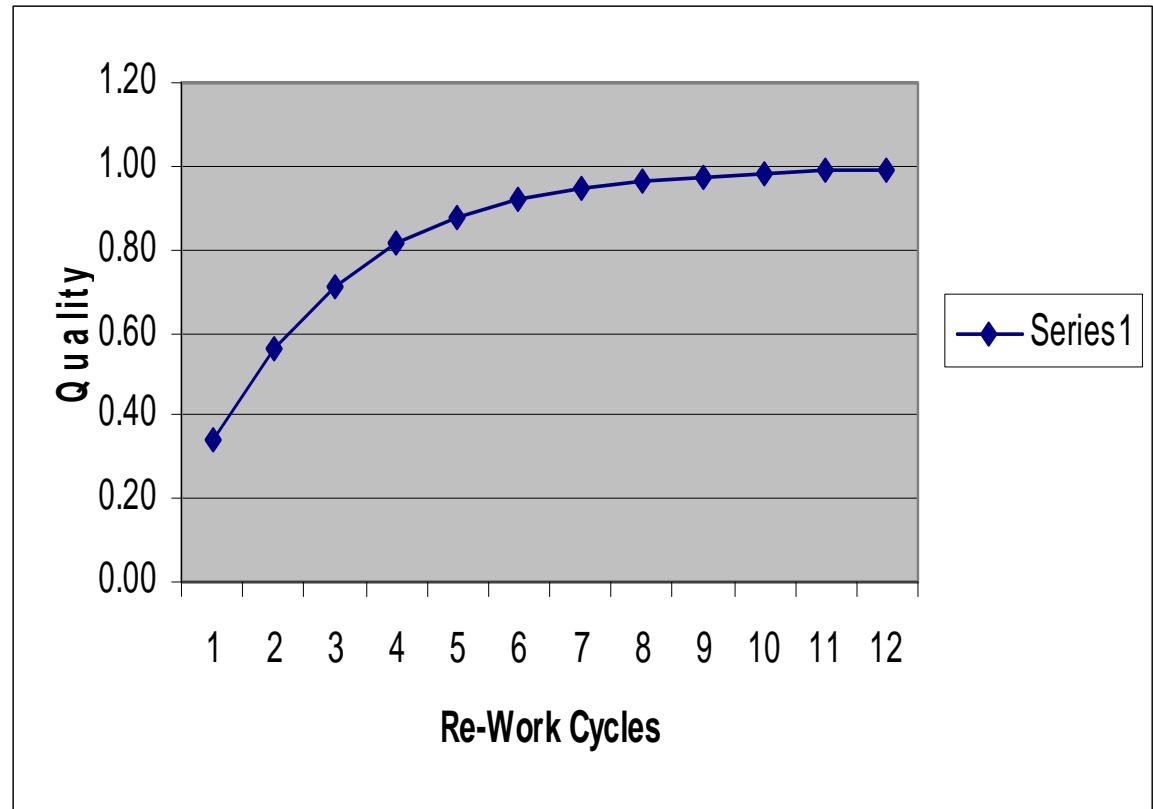
What do I do if the Design Target is 2.9?

CAE Quality Project – Average Quality vs. Model and Analysis Iteration

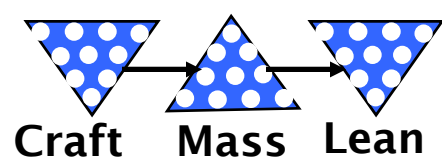


Cycle Overall Quality

Cycle	Overall Quality	Level	Description
1	0.34	Level 1-	Prediction of
2	0.5644		Better or
3	0.7125		Worse than Base (maybe!)
4	0.8103	Level 2 –	How Much
5	0.8748		Better or Worse,
6	0.9173		But with Low
7	0.9454		Confidence at Low End of Scale
8	0.9640	Level 3 –	High Confidence
9	0.9762		And Within
10	0.9843		Production/Test
11	0.9896		Variation At
12	0.9932		High End of Scale



A VPs "Trust" in CAE on the SN95

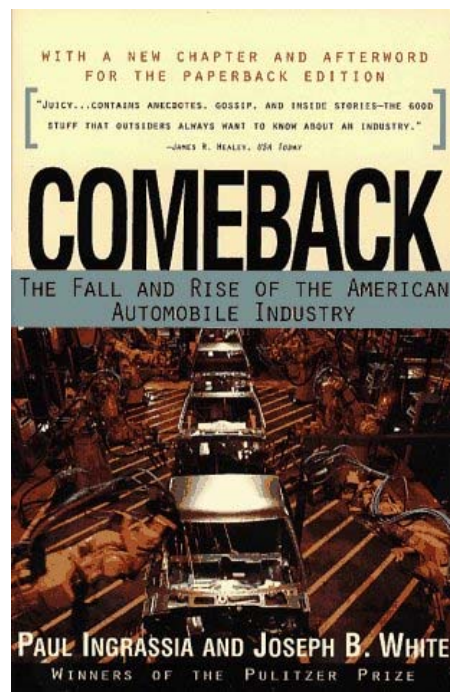


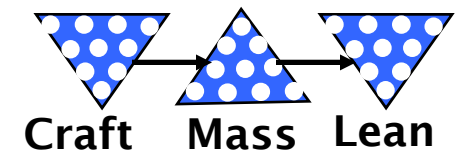
Will Boddie relied on Physical Testing & "SWAT Teams" to "Save" the Program.

He had no Confidence and Trust In CAE.

He was misled by CAE TWICE on the same Program, within a year of calendar time.

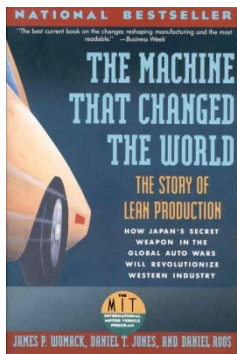
Will Boddie was, for a Number of Years, the Direct Boss of the CAE Organization



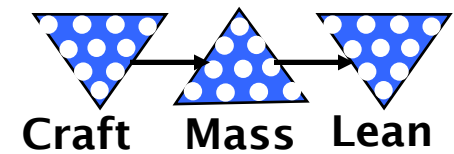


No New Idea Springs Full-Blown from a Void.

Rather, New Ideas Emerge from a Set of Conditions in which Old Ideas no Longer Seem to Work.



CAE IS a Business!



Many People are Involved @ the Larger Corporations, not all full time

Cost per Year – Hundreds of Millions (People, Software & Infrastructure)

ROI could be 5 to 20 (to 200 on “simple” cases). What it is ...

The ROI is reduced by the **Process Quality**

Potential Revenue is Huge.

Actual Revenue = **Process Quality** * Potential Revenue

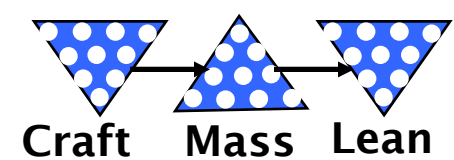
World-Wide Numbers for CAE – 50,000 People, \$2B (or more) in software infrastructure costs alone

Potential World-Wide Revenue - **\$50 to \$250B** (or more ...)

Call to Action – Slide 1



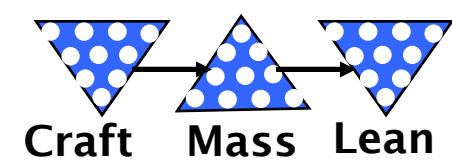
As a Business, These Key Elements should be Operational



- A **Business Model** having measured inputs and outputs, with a known **ROI**
- A **Business Plan**, with an evaluation of the present and future business conditions, including a technical and operational plan in order to sustain and grow the business
- A well-defined series of **Processes**, with supporting documentation, with process flexibility, when such flexibility does not influence the final process quality, and process rigidity when required (CTQs – Critical To Quality - defined).
- **Appropriate Metrics** throughout the various processes and keyed to the final product – the prediction of functional performance
- A **Quality Operating System** (QOS) to guide continuous enhancements and improvements.
- An **Operational Model** that looks beyond the traditional CAE process steps of getting data, building a math model, processing thru a solver and post-processing the results to a model that includes the true process steps in the engineering prediction process.

Call to Action – Slide 2





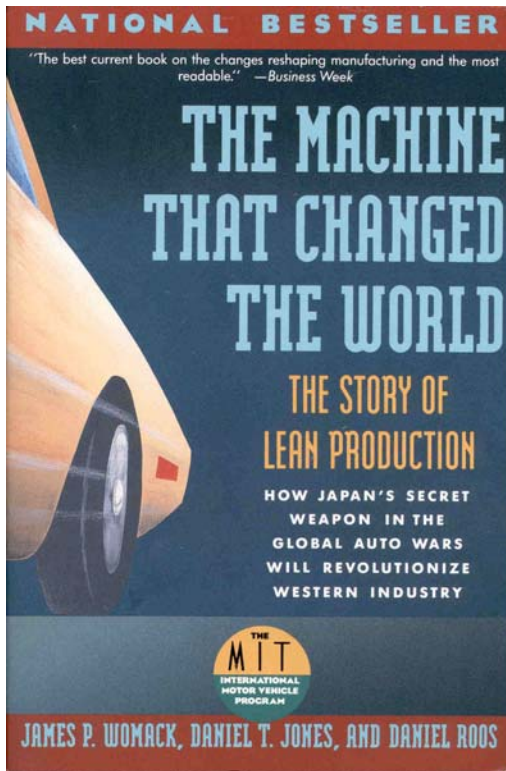
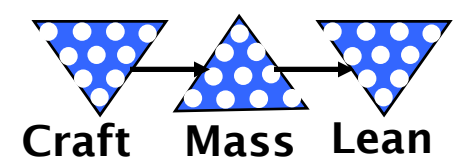
Key Elements – Cont'd

- An **Evaluation System** that includes various quality elements and does not solely focus on cost or speed.
- A knowledge of various **Change Concepts** and their impact upon a virtual predictive world

Examples can shown how these various elements result in **improved technology, better prediction quality and higher reliance and trust** in virtual predictions of product performance.

Finally, if the above systems of practices, procedures and tool development and evaluation were to be implemented, how would the environment surrounding CAE and Virtual Predictions be transformed? How would Product Development be impacted?

One of the Most Influential References – CAE Critical Path Team



What's in The Machine that Changed the World ?

- **Craft to Mass to Lean** – A 100 year history of automotive production
- How Toyota took Henry Ford's processes and made them better
- Attributes of Lean
- Could We do the same thing? – Adopt Toyota's processes? - And apply them to an "Advanced Technology" (Virtual Prototyping) where we once had the lead?

Point of No Return

Call to Action – Slide 4



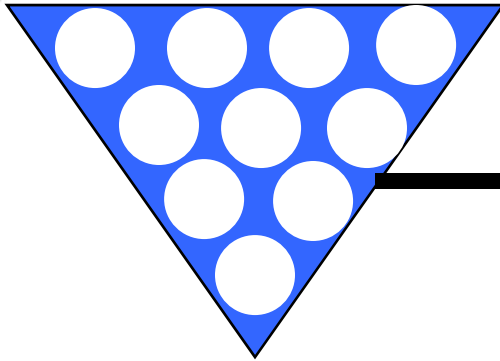
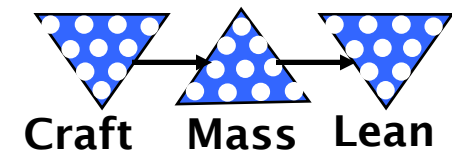
“The craft producer uses highly skilled workers and simple but flexible tools to make exactly what the consumer asks for— one item at a time. Custom furniture, works of decorative art, and a few exotic sports cars provide current-day examples. We all love the idea of craft production, but the problem with it is obvious: Goods produced by the craft method—as automobiles once were exclusively—cost too much for most of us to afford. So mass production was developed at the beginning of the twentieth century as an alternative. ...”

*(Ed. Note: To Assess the Quality of the Product,
You simply have to know the Name of The Craftsman.
Also, Large Amounts of Product are Impossible)*

*“The mass-producer uses narrowly skilled professionals to design products made by unskilled or semiskilled workers tending expensive, single-purpose machines. These churn out standardized products in very high volume. Because the machinery costs so much and is so intolerant of disruption, the mass-producer adds many buffers—extra supplies, extra workers, and extra space—to assure smooth production. Because changing over to a new product costs even more, the mass-producer keeps standard designs in production for as long as possible. The result: The consumer gets **lower costs but at the expense of variety and by means of work methods that most employees find boring and dispiriting.** ...”*

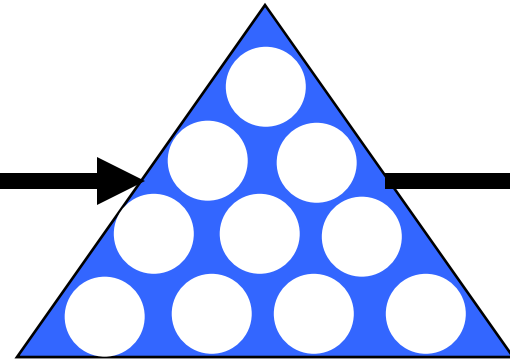
“The lean producer, by contrast, combines the advantages of craft and mass production, while avoiding the high cost of the former and the rigidity of the latter. Toward this end, lean producers employ teams of multi-skilled workers at all levels of the organization and use highly flexible, increasingly automated machines to produce volumes of products in enormous variety. ...”

CAE – From “Craft” to “Mass” to “Lean”



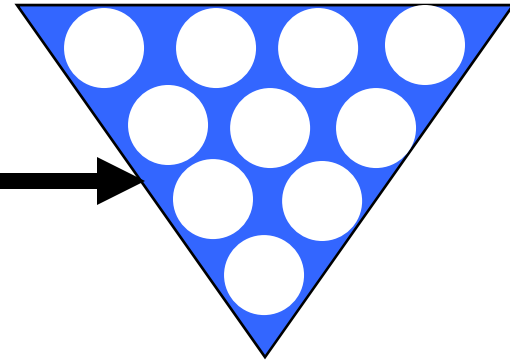
Craft

- Person power intensive (labor)
- Low entry cost
- Long Apprenticeship
- Highly skilled crafts people called Technical Specialists
-



Mass

- Facilities intensive
- Generalist
- Short training period
- Few barriers for moving from one job to another
-

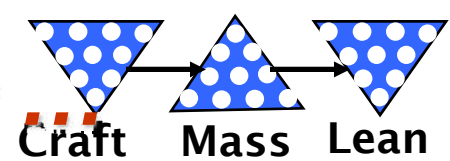


Lean

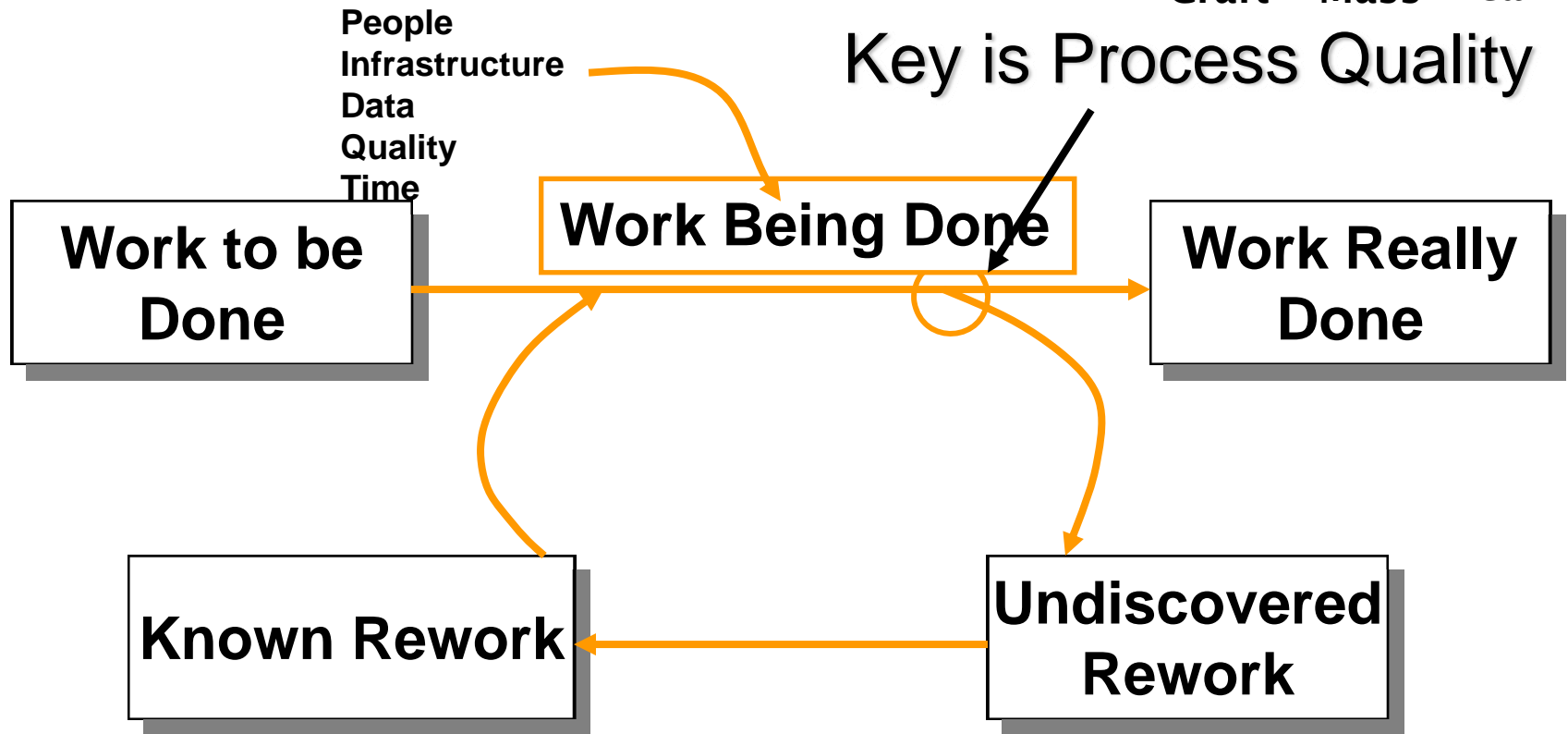
- Control back to the Analyst
- Flexible Tools
- Value Stream Mapping
- Eliminate Waste
- Continuous Improvement
- ...

How does the Grand Strategy of Lean CAE effect the CAE Metrics of Quality, Cost, Speed?

“Real” CAE Work is Done like This



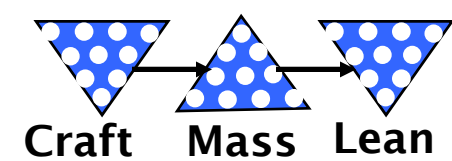
Key is Process Quality



The rework cycle portrays the real-world phenomenon that work is executed at varying, but usually less than perfect, “Quality” . . .

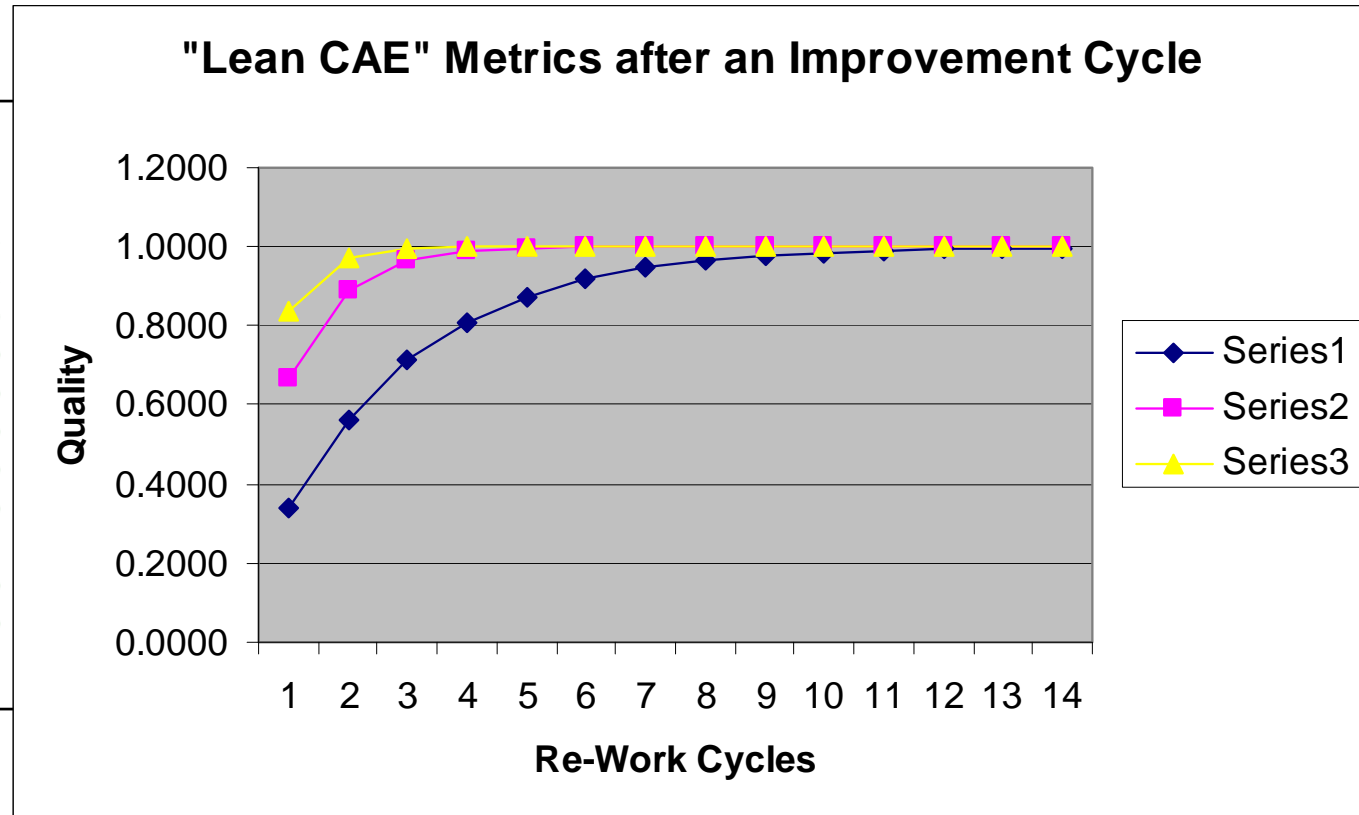
Undiscovered rework is the single most important source of project cost and schedule crises.

LEAN CAE Quality Metrics – Halving the Defect Rate per “Methods” Iteration



*First Run Capability after
2 Improvement Cycles*

1	0.3400	0.67	0.835
2	0.5644	0.8911	0.9728
3	0.7125	0.9641	0.9955
4	0.8103	0.9881	0.9993
5	0.8748	0.9961	0.9999
6	0.9173	0.9987	1.0000
7	0.9454	0.9996	1.0000
8	0.9640	0.9999	1.0000
9	0.9762	1.0000	1.0000
10	0.9843	1.0000	1.0000
11	0.9896	1.0000	1.0000
12	0.9932	1.0000	1.0000
13	0.9955	1.0000	1.0000
14	0.9970	1.0000	1.0000

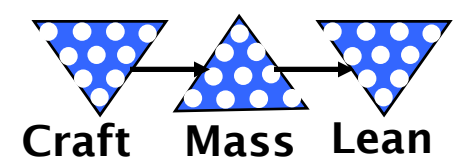


Future State Vision of CAE / VPD – Take it LEAN.

Toyota Production System as a Model for CAE / VPD

Improvements

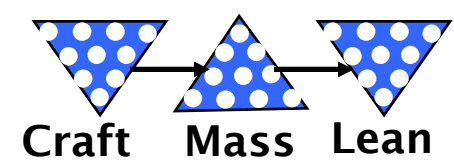
Extraordinary World – Slide 3 **NA**



The Performance Of The System with Re-Work Included

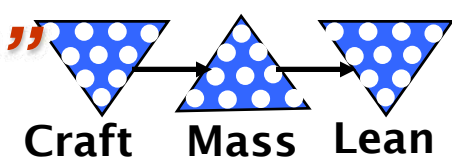
- 1200 Tasks to be Performed
- 20 Tasks per Day is the Average Performance, 10 Tasks per Day is the “Discovery” Rate, longer than the “Original” Performance, but only Performed on the “Defective” Tasks
- .34 is the Task Quality
- Nominal Rates
 - 480 Hours, 60 Days, 12 Weeks, 3 Months for One Person – A second or third person can reduce the Duration to 1 month
- These are all very reasonable numbers

Now, Add Re-Work

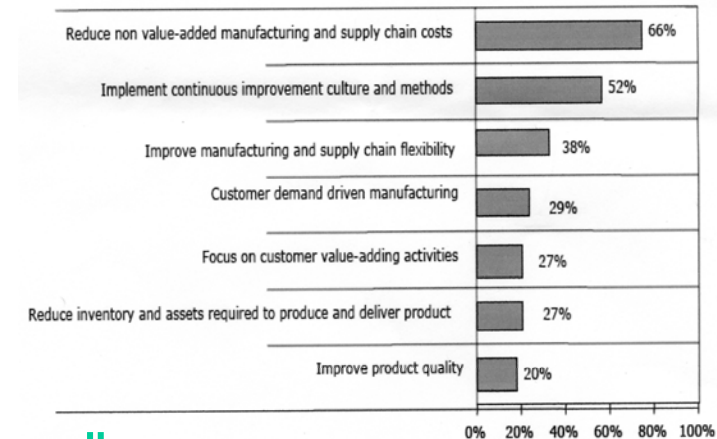


- Nominal was 480 Hours, 60 Days, 12 Weeks, 3 Months
- First Modeling Cycle - 139.2 Days (60+79.2) – Only 408 Task Complete – Overall Quality of .34
- Second Modeling Cycle - 91.9 Days (39.6+52.3) – 677 Tasks Now Complete – Overall Quality of .56
- Third Modeling Cycle – 60.6 Days (26.1+34.5) – 855 Tasks Now Complete – Overall Quality of .71
- To Get to 90% Quality? – 376 Days Total, 3004 Total Hours, 6.26 Times the Nominal Rate
- In Normal Work Environments – to 90% → Hardly Ever, except in “Correlation-Driven” Activities

What Is an “Improvement Cycle?”



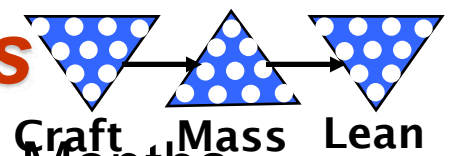
- JIT CAD, etc.
- Processes Control “Sheets” to make sure all Processes are Stable and under (Tight?) Control.
- CTQs defined in Procedure Web Documents
- Quality Responsibility with Individual Modeler / Analyst
- No model QC (element quality, etc. – may be necessary for Mass)
- Waste / NVA Found and Driven Out
- Review All Steps in Process, not just ...
- Process Capture (in Software) for CTQs (SBT)
- Standard Process with Quick “Changes”
- Value Stream Mapping
- Continuous Improvement



Source: AberdeenGroup, March 2006

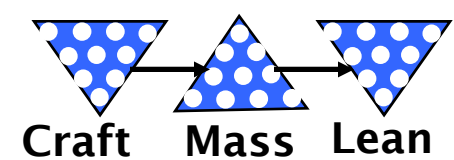
Figure 2: Best-in-class Strategic Actions of Lean

One and Two Improvement Cycles



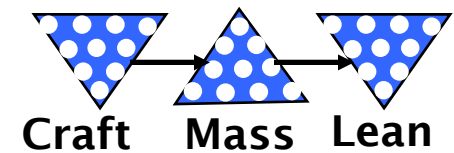
- Nominal was 480 Hours, 60 Days, 12 Weeks, 3 Months
- Base with Re-Work - At .34 Task Quality, At 20 Tasks per Day, 10 Discoveries per Day, to get to 90% Quality – 376 Days Total, 3004 Total Hours, 6.26 Times the Nominal Rate
- One Cycle of Lean Improvements - At .68 Task Quality, At 20 Tasks per Day, 10 Discoveries per Day, to get to 90% Quality – 143 Days Total, 1147 Total Hours, 2.39 Times the Nominal Rate (Note: 2 modeling and Analysis Cycles gets REALLY close to the required quality at 132 Days / 1060 Hours / 2.21 Times)
- A second Cycle of Lean Improvements - At .84 Task Quality, to get to 90% Quality – 93 Days Total, 744 Total Hours, 1.54 Times the Nominal Rate
- Two Improvement Cycles get you to almost a First Run Capability and And To a Quality Level where Most / All Testing Could be Eliminated, with Timing and Cost near the Nominal Values

In Addition, ...



- This data is the performance impact of reducing rework and improving quality, the highest leverage point.
- If we also include “normal” performance enhancements plus procedures to improve the discovery times, CAE Quality, Cost and Speed improve greatly (reducing the Nominal Values).
- If we ignore the Quality Improvements, we are highly constrained and may never understand why our good people and tools sometimes produce rather poor results.

Lean CAE is a Growth Strategy



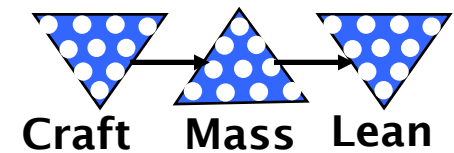
- Supports “Fast to Market” Product Planning, allowing Development of Emerging Market Segments
- Tools becomes usable by a “Generalist” – Less Specialized Tools
- CAE Is “Plug Compatible” with Hardware Testing
- Quality / Accuracy Improves, Allowing High Confidence Levels
- CAE Becomes 1st Choice for Experimentation, Design, Cascading, Validation, and Final Verification
- Models become Larger – Less Approximations
- Metrics appropriate to Attribute Function guide Improvement Actions
- Scope of Applications grow over Time
- Personnel are Dedicated to Continuous Improvement
- Plug-and-Play of Systems, Sub-Systems and Components supports Reuse of Product Designs
- Vehicle Designs are Fresh and Well-Accepted by End Customers
- Cost are Reduced as a “By-Product” of Improved Efficiencies
- Cost and Timing for CAE Experiment are Less than Any other Alternative
- Recommendations from CAE are Readily Acted Upon
- Reliability and Robustness Simulations lead to “Six Sigma” Designs
(*MS³ PLUS Quality, Cost, Speed*)

This is NOT a Cost-Reduction Strategy

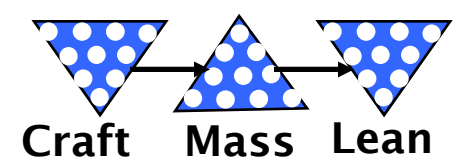
Cost WILL be Reduced as a Secondary Effect

Extraordinary World – Slide 9 

To Remember ...



- \$250 Billion Worth of “Importance”, at Least
- Grand Strategy, Strategies, Tactics & Operations
- Machine that Changed the World as the Call to Action
- Craft to Mass to Lean as the **Grand Strategy**
- The Rework Cycle as the Connection of the Strategy to Quality Metrics
- Adopting Toyota Production System to CAE provides the **Low-Level Strategic and Tactical Elements**
- Experience fills in the **Operational Details**
- Process Quality as the Overall Driver and Delivers the \$250 Billion



*“There is no Fate but what
We Make for Ourselves”*

Terminator 2: Judgment Day

Thank You
Questions(?)
Or
Comments(!)

