

Kevin Otto

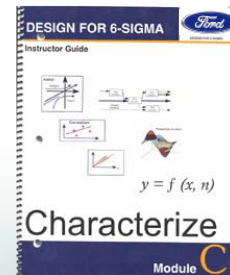
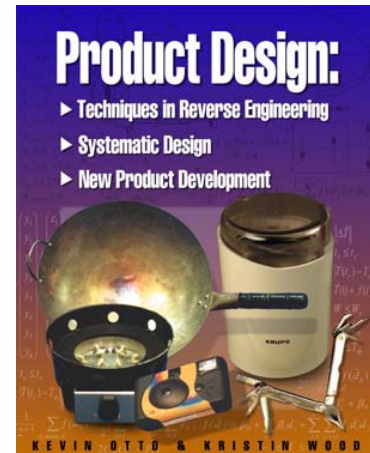
- Kevin_N_Otto@yahoo.com

- www.kevinotto.com

- Experience

- Lead Consultant, Product Genesis Inc.
- Lead Consultant, PDSS Inc.
- Former Associate Professor, MIT
- Six Sigma Master Black Belt
- Many past clients

```
nWindowState = START_WINDOW;  
DisableDIRQ();  
nRowCounter++;  
nLEDTurn = 0;  
  
SetGain( 1 );  
ControlLED( DIRX, OFF );  
  
if ( nRowCounter > 8 ) {  
  dirQPosition += ( ENCODER_RES - nWindowEnd + nWindowStart );  
  In629_setDirQ( dirQPosition );  
  
  goto END_OF_TEST  
  DisableMotorIRQ();  
  In629_ResetIRQMask( DIRQPT05 );  
  
  nLength = (int)( (long)pInpData - (long)&nTempBuffer[0] );  
  nLength >>= 4; // Data length in paragraphs  
  nTempBuffer += (int)nDataLength; // Copy length to output buffer  
  nLength <<= 4; // Data length in bytes again  
  memcpy( pOutDataBuffer, nTempBuffer, nDataLength );  
  
  nTempBuffer += nDataLength;  
  nDataLength = In629_readDirQ();  
  nTempBuffer += (int)nDataLength;  
  nDataLength = (int)nDataLength;  
  nTempBuffer += (int)nDataLength;  
}
```



What is DFSS?

What if you were asked not to develop your product instantly, but to “do it right”?

A “shift from deterministic to a probabilistic design culture”

(from DFSS: 15 Lessons Learned; *Quality Progress*; Jan. 2002)

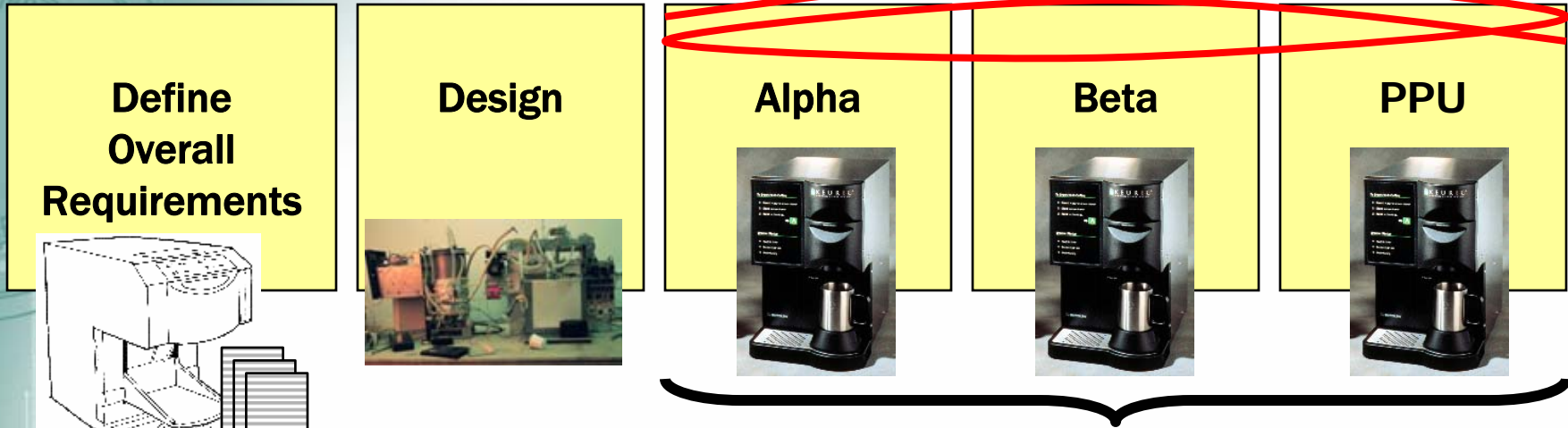


product **GENESIS**

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Historical Development Process

Development Process: Do it quick!



BUILD, TEST, FIX CYCLES!

BUILD, TEST, FIX CYCLES!

Product Evolution

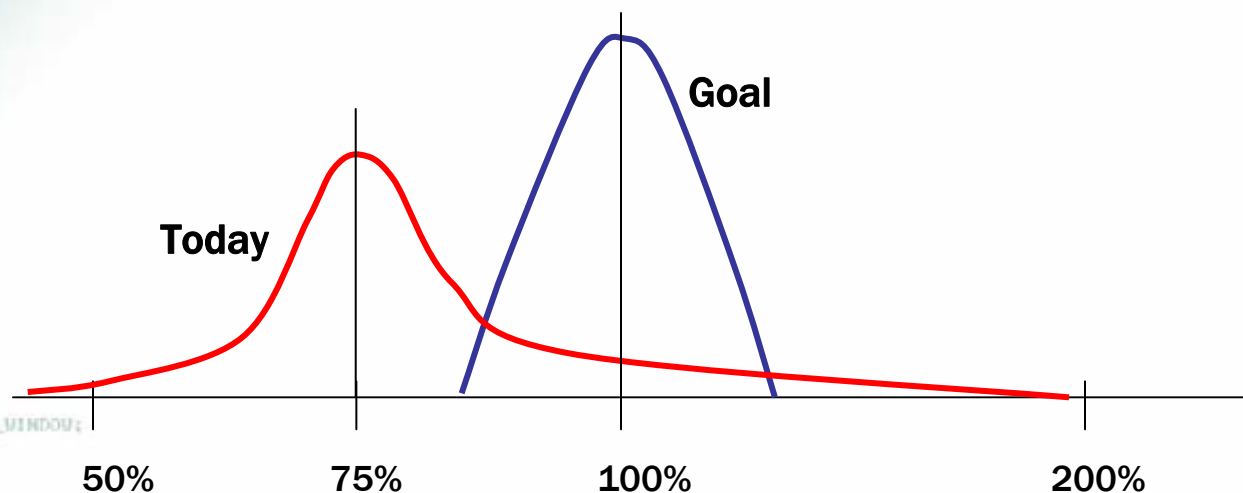


Quality: What it Means



MOTOROLA

$$\text{"Say / Do Ratio"} = \frac{\text{Actual Margin \$ Delivered}}{\text{Margin Promised in the Business Case}}$$



2002 Say/Do Ratio Shortfall = \$1.0 Billion.

Less than 1/2 of their product development projects earned their entitlement business case margin.



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Quality: What it Means

The cost of fixing a single defect:

- \$35 during the design phase
- \$177 before procurement
- \$368 before production
- \$17,000 before shipment
- \$690,000 on customer site

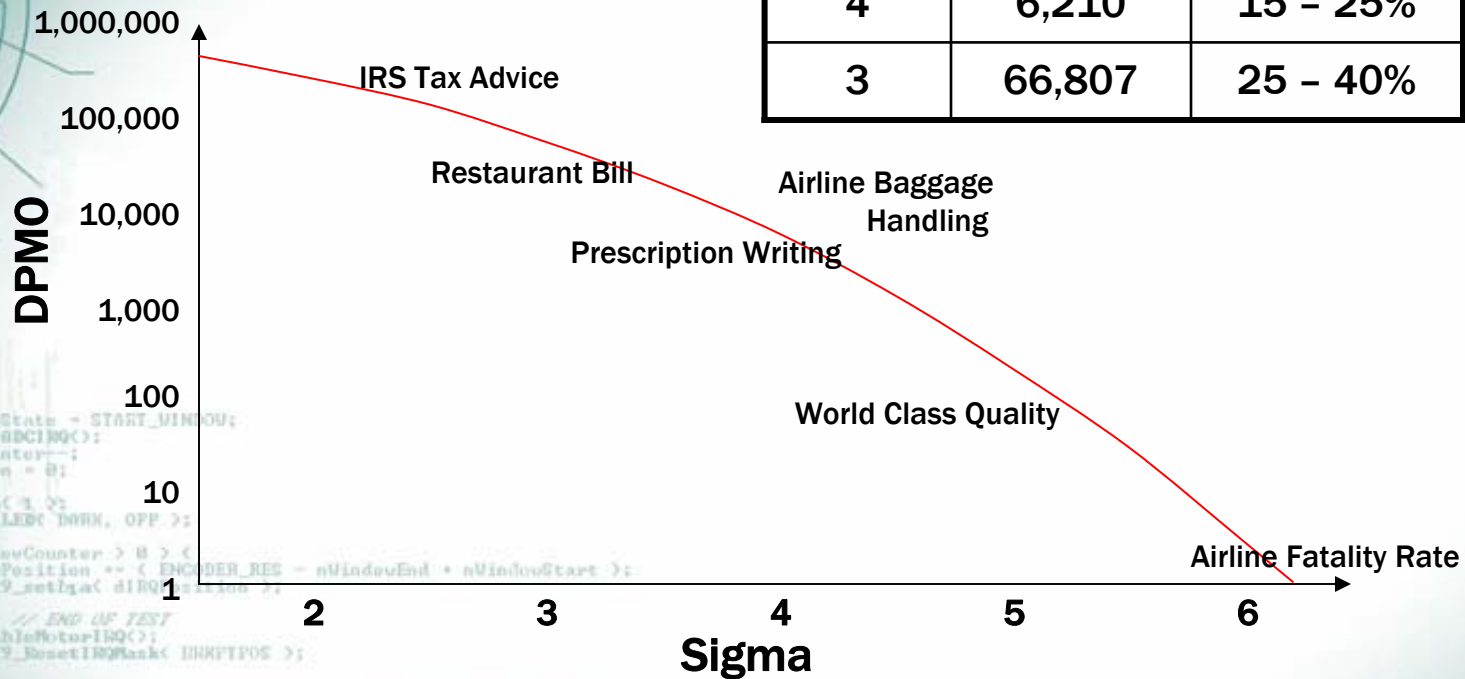


Mr. Hiroshi Hamada, President of Ricoh

Source: *European Community Quarterly Review*, Third Quarter 1996

Capability

Sigma	Defects / Million	Cost as % Sales
6	3.4	< 1%
5	233	5 - 15%
4	6,210	15 - 25%
3	66,807	25 - 40%



Most companies operate at ≤ 4 sigma

What are your warranty and service costs?

Operations & Production Six Sigma



What's the problem

Clarify it

- Defect data
- What defects
- What productn steps

Tools:

- Fishbone diagrams
- Observation
- Discussion

How to measure it

- Not defect counts
- Output variation
- Measurement system

Tools:

- P-diagram
- MSA
- Data collection

What changes it

- Controllable
- Noise
- Signals

Tools:

- DoE
- Robust Design

What to change

- Controllable

Tools:

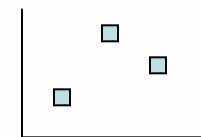
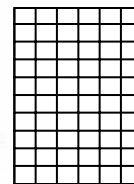
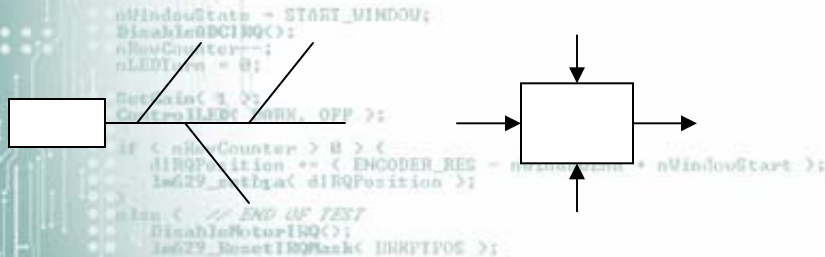
- Robust Design
- Signal to Noise
- CPM
- Stat. Tolerances

How to keep it there

- Control plans

Tools:

- SPC
- MSA



Generates “bottom line” financial value by eliminating Cost-Of-Poor-Quality (COPQ) in production & business transactions



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It works

- GE published a net benefit of \$2 billion in its 1999 annual report
- Jack Welch, has said Six Sigma will save his company \$12 billion over five years and will add \$1 to its earnings per share



- Allied Signal has saved \$1.2 billion in direct costs since 1994
- Asean Brown Boveri (ABB) saved \$898 million each year for two years



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Six Sigma Across the Enterprise

Product Strategy & Planning



Product Development



Research & Development



Support Engineering



Manufacturing



Sales and Marketing

The six-sigma data-driven approach is expanding out of manufacturing and into every aspect of business.



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Improve Existing or New Products First?

- Bob Galvin, CEO of Motorola stated that...

**If he would start six sigma again,
he would focus on product development
rather than manufacturing.**

- Galvin's view is that mfg. process improvement is often the result of poor product development.

- With any corporate Six Sigma implementation, there occurs a natural evolution out into the organization

- R & D offers the highest leverage against the cost of poor quality. DFSS.



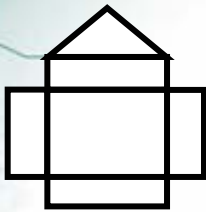
Design for Six Sigma

Generates “top line” financial value by providing new products with no problems and thereby generate new revenue.

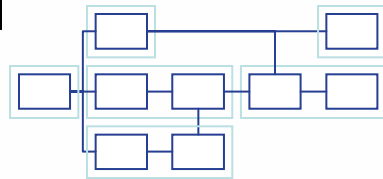
VOC



QFD



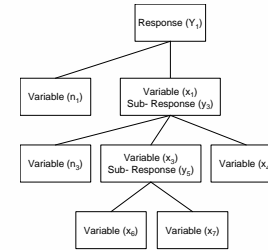
Functional Architecture



Module Concept Gen & Sel

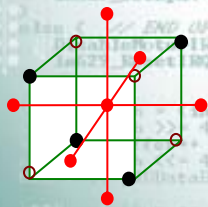


CPM

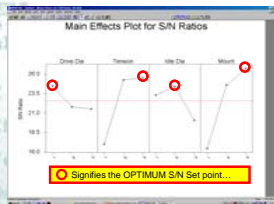


FMEA

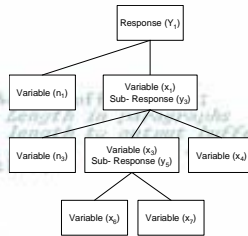
Design of Experiments



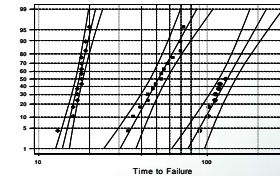
Robust Design



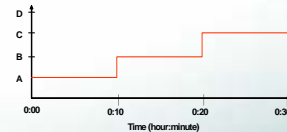
Capability Equations



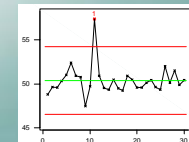
Reliability Prediction



System Stress Tests



Capability Verification



What's Different

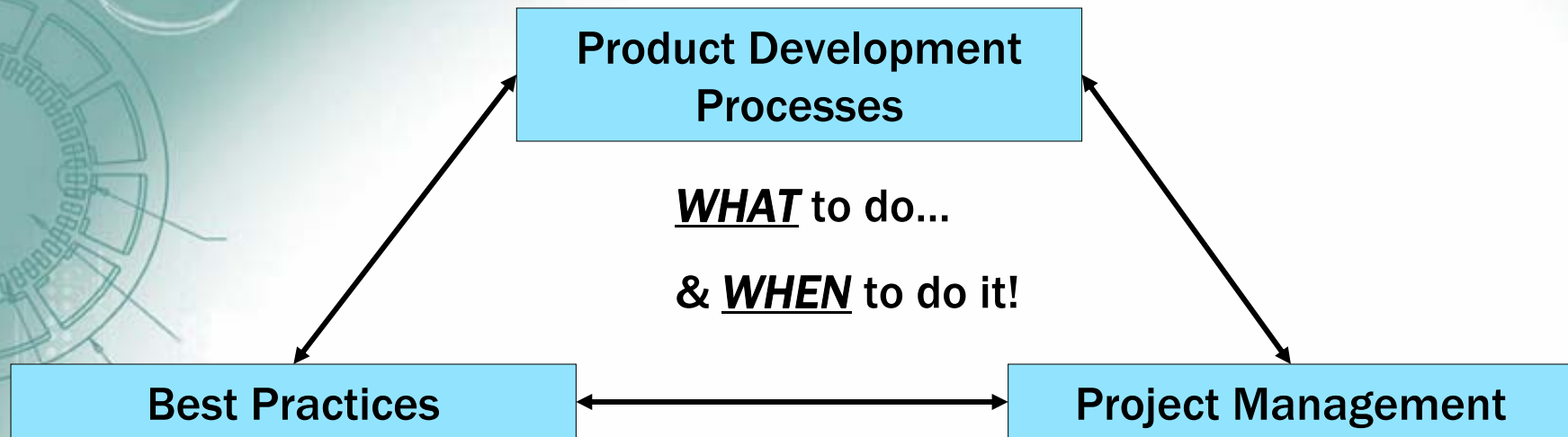
- Statistical tools for design
- Eliminate or accommodate variability
- Functionally Parametric Designs – Data and Equations
- Shared Focus – Critical Parameter Management
- Process Scorecards
- Test Planning
- Subsystems first
- Experimentation over regions of the design space

Result:

1. No surprises, scrambles, ECOs at manufacturing launch.
2. Confidence against any surprise at manufacturing launch.



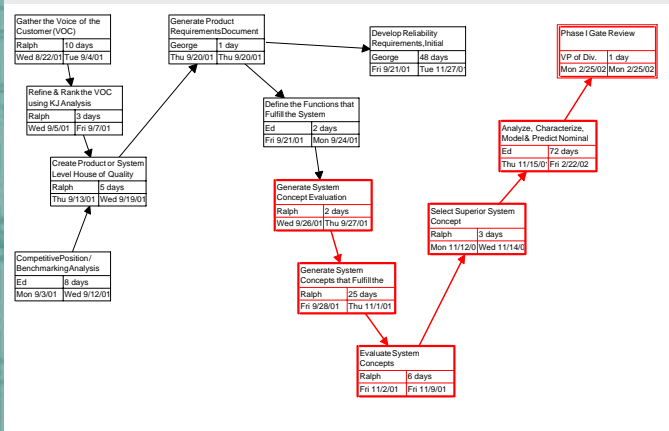
Key Elements in Improving Product Development



- Schedule your project activities with risk and backup planning project management tools
- Map specific project activities to standard work with Phases & Gates of an End-to-End Development Process
- Insert appropriate Tools & Best Practices with your detailed Project Activities



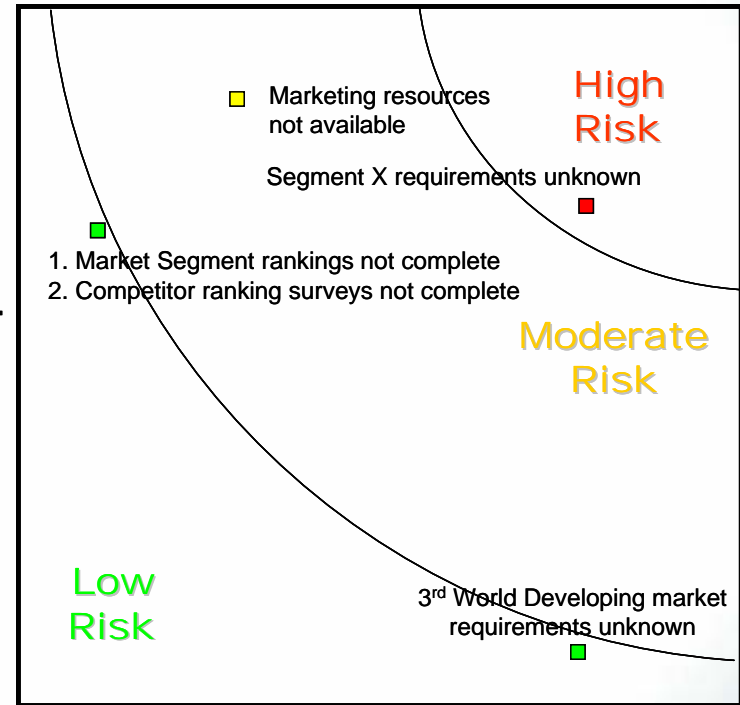
Project Risk Management



Microsoft Project

Phase Task:	% Task Fulfillment	Task Result vs. D&R Reqts	Red	Yellow	Green	Deliverable Requirements
			Red	Yellow	Green	
			Red	Yellow	Green	
			Red	Yellow	Green	

Risk Scorecard for each Task



Gate Review: Risk Summary and backup plans

Manage not only time, but risk.



Standard Work – The CDOV Process

Concept

- Value Proposition
- Voice of Customer
- Platform and Portfolio Architecture
- Development Plan and Risks

Superior Concept Gate

Design

- Minimize Complexity – System Arch
- Minimize Risk – FMEA, Scorecards
- Requirements Flowdown - CPM
- Identify Noise – DOE / RSM

Characterized Design Gate

Optimize

- Optimize – Taguchi DOE
- Stress the Design – HALT
- Statistical Tolerancing

Robust Design Gate

Verify

- Reliability Engineering – ALT
- Product Launch – CPM, SPC

Reliable Launch Gate

```

nWindowState = START_WINDOW;
DisableDCIRQ();
nRowCounter++;
nLEDTurn = 0;

SetGain( 1 );
ControlLED( DARK, OFF );

if ( nRowCounter > 8 ) {
    dirQPosition += ( ENCODER_RES - nWindowEnd + nWindowStart );
    In629_sethqa( dirQPosition );
}

// END OF TEST
DisableMotorIRQ();
In629_ResetIRQMask( INTERRUPT );

// length = (int)( (long)pTempData - (long)&nTempBuff );
// length >>= 4; // Data length in
// nTempBuff += (int)nDataLength; // Copy length to
// length <<= 4; // Data length in
// memcpy( pDestBuffer, nTempBuffer, nDataLength );

// nTempBuff += nDataLength;
// nTempBuff = In629_readw1C2;
// nTempBuff += (int)nOnloadMeLocity;
// nTempBuff = (int)nOnloadMeLocity >> 8;
    
```

Critical Parameter Management

- **Critical:** focus on only the critical 10% of all requirements
- **Parameter:** we will be quantitative, measurable and testable
- **Management:** we will improve, control, tradeoff with a total systems perspective

```
nWindowState = START_WINDOW;
DisableBDCIRQ();
nRevCounter = 0;
nLEDTurn = 0;

SetGain( 1 );
ControlLED( DARK, 0 );

if ( nRevCounter > 0 ) {
    dirQPosition += ( ENCODER_RES - nWindowEnd + nWindowStart );
    In629_setba( dirQPosition );
} else { // END OF TEST
    DisableMotorIRQ();
    In629_ResetIRQMask( INTERRUPT05 );
}

nLength = (int)( (long)pInpData - (long)&nTempBuffer[0] );
nLength >>= 4; // Data length in paragraphs
nTempBuffer += (uint)nDataLength; // Copy length to output buffer
nLength <<= 4; // Data length in bytes again
memcpy( pOutDataBuffer, nTempBuffer, nDataLength );

pOutDataBuffer += nDataLength;
In629_readba( 2 );
// In629 readba( 2 ); // (int8)OnloadVelocity;
// In629 readba( 3 ); // (int8)OnloadVelocity >> 0);
```



Criticality Scorecards

CFR Output (Y)

$$Y = f(x_1, \dots, x_n)$$

CFR Output Variability

Design For Six Sigma Scorecard

Performance		Transfer Function		Specification			Predicted Performance Capability				6σ Score		
Characteristic	Units	Y/N	Formula (enter below)	Target	USL	LSL	mean: μ	s.d.: σ	Short/Long	Confidence	z	σ-shift	DPM
Voltage	V	Y	2	2	2.1	1.9	2	0.008654			11.55	0.00	0.0

Estimates Based on Mean Condition of x's and n's Listed Below

x's, Input Control Factors

Variables		Range		Contribution to Variability		Specification		Sample/Database Statistics				6σ Score			
No.	Characteristic	Units	Min	Max	Sensitivity	%	USL	LSL	mean: μ	s.d.: σ	Short/Long	Confidence	z	σ-shift	DPM
1	X1	ohms	20	500	0	0.00%			20	0.04899			-408.25		1000000.0
2	X2	ohms	2	50	-0.3108194	32.03%			6.433029	0.015758			-408.25		1000000.0
3	X3	ohms	2	50	0.4176437	32.04%			4.788771	0.01173			-408.25		1000000.0
4	X4	volts	1.2	30	0	0.00%			30	0.03873			-774.60		1000000.0
5	X5	ohms	2	50	0	0.00%			2	0.004899			-408.25		1000000.0
6	X6	ohms			0.7444038	32.04%			2.686714	0.006581			-408.25		1000000.0
7	I	amp			-10.449776	3.89%			0	0.000163			0.00		933192.8
8															
9															
10															
11															
12															
13															
14															

CTS Control factors (x)

CTS Control factor Variability

Tracing Critical Relationships

Requirement allocation
flows down...

Y: System Level CFRs

Rqmt 

S, C_p

y: Subsystem Level CFRs

Rqmt 

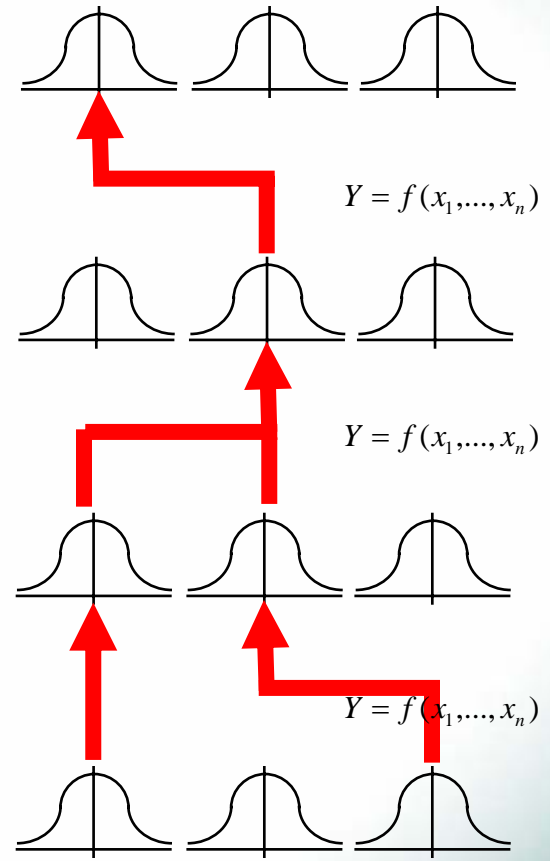
S, C_p

x: Component Level
CTFspecs.

Rqmt 

S, C_p

p: Mfg. Process Level CFRs



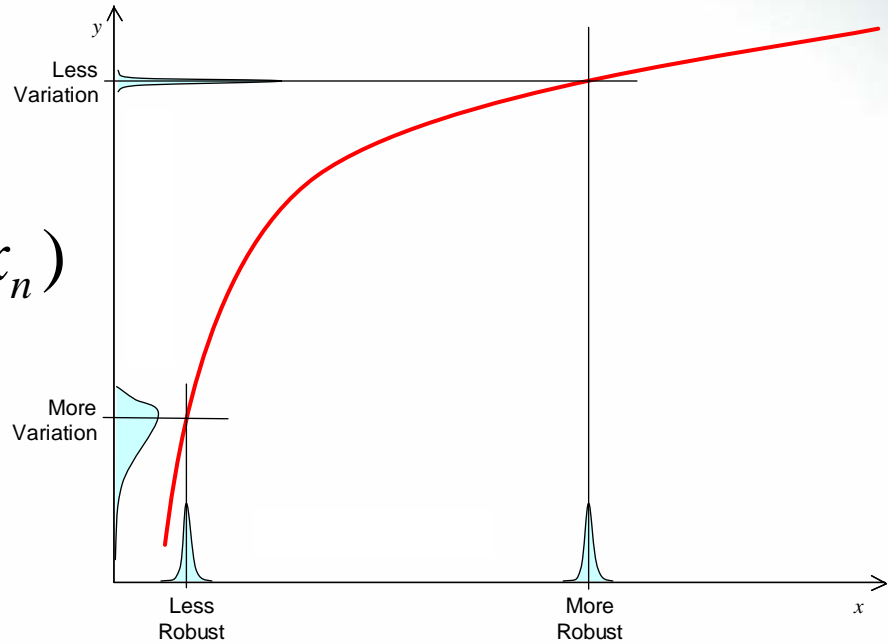
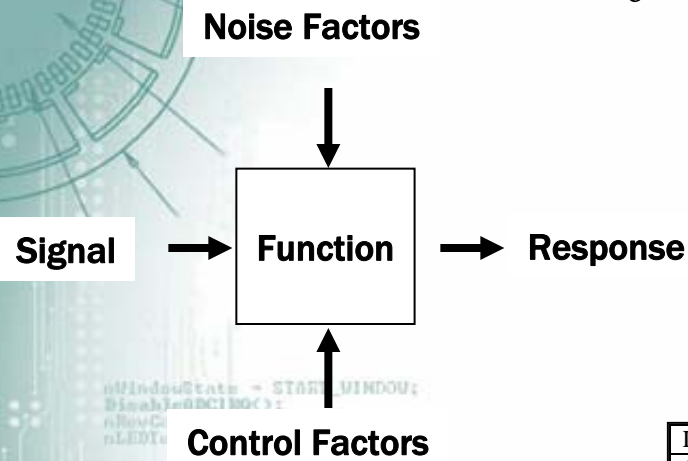
Effects of variation flow
up...

$$C_p = \frac{\text{Reqmt}}{\text{Capability}} = \frac{\text{USL-LSL}}{6s}$$

Design of Experiments and Robust Design

Generate equations to relate responses to factors.

$$Y = f(x_1, \dots, x_n)$$



```

nWindowState = START_WINDOW;
DisableEncoder();
nRevCounter = 0;
nLEDs = 0;

SetGalvanometer( GALV, OFF );
ControlLED( DIRK, OFF );

if ( nRevCounter > 0 ) {
    dirQPosition += ( ENCODER_RES - nWindowEnd * nRevCounter );
    In629_SetDirA( dirQPosition );
}

// END OF TEST
DisableMotorIRQ();
In629_ResetIRQMask( INTERRUPT );

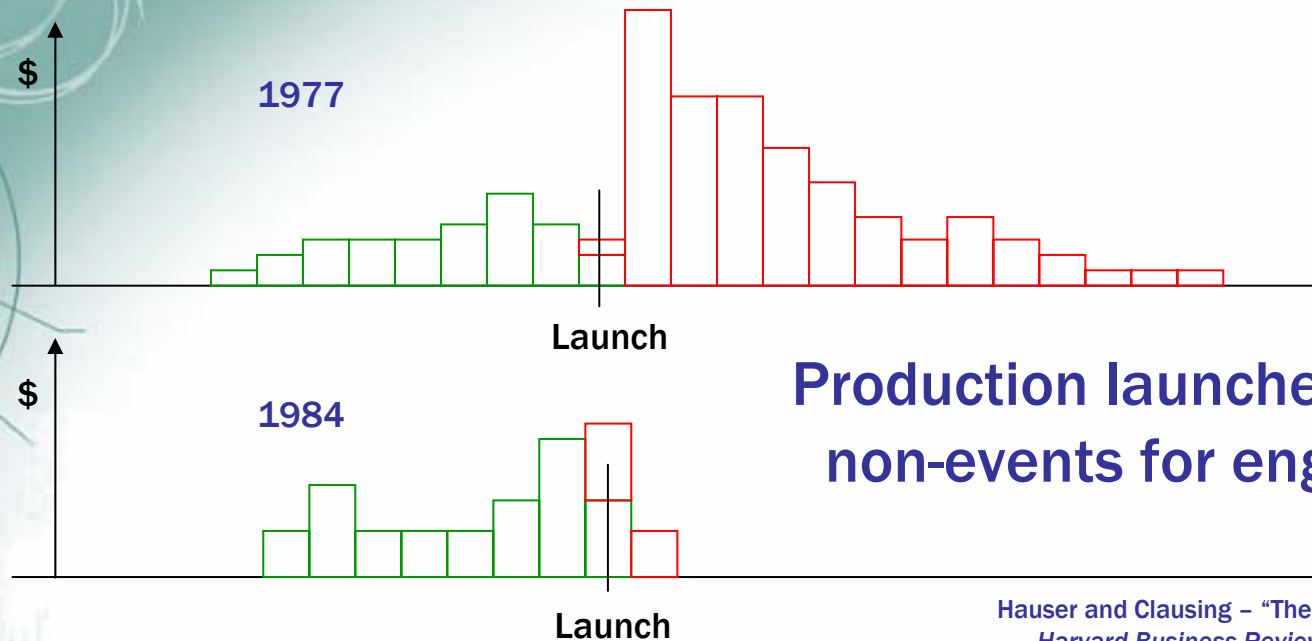
// Length = (int)( (long)pTempData - (long)&data );
// Length >>= 4;
// Copy buffer to (int)nDataLength; // Copy Length
// Length <<= 4;
// Copy data from buffer to (int)nDataLength;

// Copy buffer to nDataLength;
// Copy data from buffer to nDataLength;

// Copy buffer to nDataLength;
// Copy data from buffer to nDataLength;
    
```

L ₁₂	N _A	N _B	N _C	N _D	N _E	N _F	N _G	N _H	N _I	N _J	N _K	Y ₁	Y ₂	...	Y _n
1	1	1	1	1	1	1	1	1	1	1	1				
2	1	1	1	1	1	2	2	2	2	2	2				
3	1	2	2	2	2	1	1	1	2	2	2				
4	1	2	1	2	2	1	2	2	1	1	2				
5	1	1	2	1	2	2	1	2	1	2	1				
6	1	1	2	2	1	2	2	1	2	1	1				
7	2	2	2	2	1	1	2	2	1	2	1				
8	2	2	2	1	2	2	2	1	1	1	2				
9	2	1	1	2	2	2	1	2	2	1	1				
10	2	1	2	1	1	1	1	2	2	1	2				
11	2	2	1	2	1	2	1	1	1	2	2				
12	2	2	1	1	2	1	2	1	2	2	1				

Effect of Critical Parameter Modeling at Toyota



Production launches become non-events for engineering

Hauser and Clausing – “The House of Quality”
Harvard Business Review, May-June 1988

- What will happen when product starts, and there is a problem with a component, assembly step, ...?
 - Off target, Too much variation
 - Acting differently than the development prototypes
- With DFSS, you know what to do $Y = f(x_1, \dots, x_n)$
 - You have pre-defined factors x to shift every response (Y or y)
 - Factors x that production and design agree to use



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Problems You Will Encounter

- Lack of executive support
- Yet another program of the month
- We already do this
- We don't need to do this
- Hired external design firms are incapable

```
nWindowState = START_WINDOW;
DisableDCIRQ();
nRowCounter = 0;
nLEDTurn = 0;

SetGain( 1 );
ControlLED( DARK, OFF );

if ( nRowCounter > 0 ) {
    dirqPosition += ( ENCODER_RES - nWindowEnd + nWindowStart );
    In629_setDirq( dirqPosition );
}

else { // ENCODER ?
    DisablePhotoIRQ();
    In629_ResetIRQBank( INTERRUPT0 );

    nLength = (int)( (long)pInpData - (long)&nTempBuffer[0] );
    nLength >>= 4; // Data length in paragraphs
    nTempBuffer += (int)nDataLength; // Copy length to output buffer
    nLength <<= 4; // Data length in bytes again
    memcpy( pOutDataBuffer, nTempBuffer, nDataLength );

    nTotalLength += nDataLength;
    nTotalLength = In629_readout(2);
    nTotalLength = (int)nTotalLength;
    nTotalLength = (int)nTotalLength >> 8;
}

for ( n = 0; n < nTotalLength; n++ )
    pOutDataBuffer[n] = nTempBuffer[n];
break;
default:
break;
break;
```



Success Factors

- **Executive champion**
 - One who believes and is staking their job on DFSS success
 - Clears obstacles faced by project champion
- **Project Manager**
 - One who believes and is staking their job on DFSS success
 - Person skills: can attain buy-in from support functions
- **DFSS Master Black Belt**
 - Training and consulting, reports to Executive and PM
 - Responsible for launch quality and lifetime reliability
 - Ensure effective tool use
- **Defined Development Process**
- **Test facilities, Field data collection, Supply chain support**





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