

OM300 - GeoThermal MWD Navigation Instrument (A High Temperature 300° C Directional Drilling Tool)

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Principal Investigator(s)

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- OM300 – Develop a 300°C capable directional drilling navigation tool using MEMS* accelerometers and flux-gate magnetometers.

*MEMS = Micro Electro-Mechanical Systems

- Project Overview:

- Timeline

- Start: May-2010; End: May-2012; Percent Cmplt: 0%

- Budget

- Total project funding: Total: \$4.75M
 - DoE: \$3.80M; Honeywell/APS: \$0.95M
 - FY10: \$1.37M DoE (expected)

- Barriers

- High Temperature Sensors, Electronics, and Assemblies

- Partners

- Honeywell Aerospace – Defense & Space, Redmond, WA
 - Honeywell Aerospace - SSEC, Plymouth, MN
 - Applied Physics Systems – Mountain View, CA

OM300 – Geothermal Direction Drilling Navigation Tool

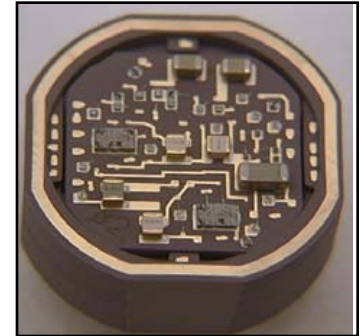
- Design and produce a prototype directional drilling navigation tool capable of high temperature operation in geothermal drilling
 - Accuracies of 0.1° Inclination and Tool Face, 0.5° Azimuth
 - Environmental Ruggedness typical of existing oil/gas drilling
 - Multiple Selectable Sensor Ranges
 - High accuracy for navigation, low bandwidth
 - High G-range & bandwidth for Stick-Slip and Chirp detection
 - Selectable serial data communications
- Reduce cost of drilling in high temperature Geothermal reservoirs
- Innovative aspects of project
 - Honeywell MEMS* Vibrating Beam Accelerometers (VBA)
 - APS Flux-gate Magnetometers
 - Honeywell Silicon-On-Insulator (SOI) High-temperature electronics
 - Rugged High-temperature capable package and assembly process

*MEMS = Micro Electro-Mechanical Systems

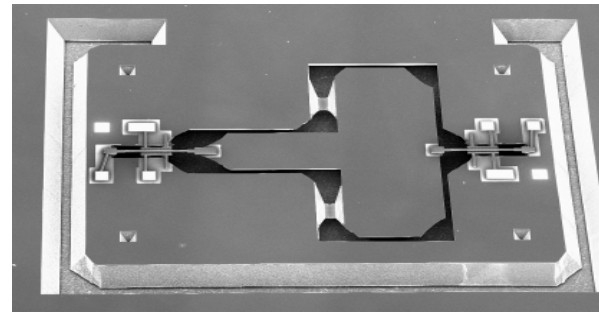
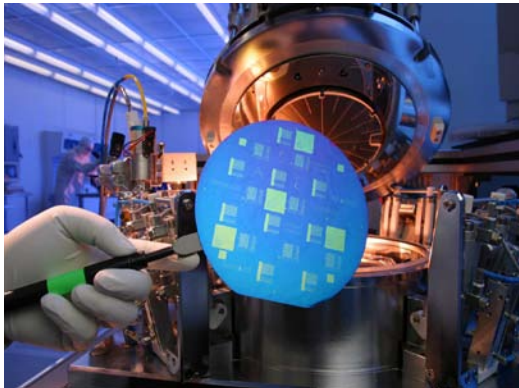
- OM300 Design Characteristics

- MEMS silicon-based Vibrating Beam Accelerometers (VBA)

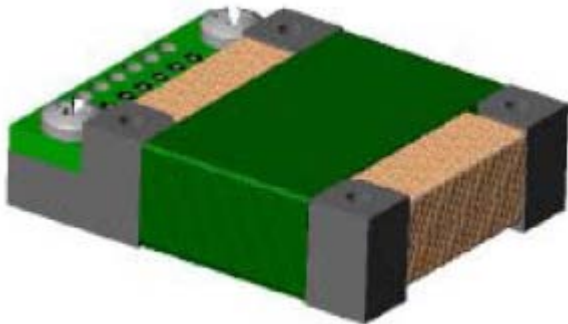
- Rugged, small die-size sensor mechanism
 - Similar Honeywell sensors survive >10,000 G shocks
 - Large G-range with high accuracy
 - >60G Range; better than 1 milli-g accuracy
 - Inherent VBA scale factor stability
 - Direct digital output (frequency proportional to acceleration)
 - Selectable Dual-Range Outputs
 - $\pm 1G$ navigational accuracy to 0.1°
 - high-bandwidth for Stick-Slip and Chirp vibration



Honeywell OM200 Silicon
MEMS VBA Die and HTCC
Packaging Examples



- OM300 Design Characteristics
 - Flux-Gate Magnetometer (Applied Physics Systems)
 - Two-axis
 - High Temperature Ruggedized
 - SOI Electronics
 - Based upon 30yrs experience in oil & gas exploration sensors
 - Digitized using Proprietary Honeywell SOI Quad-sVFC ASIC

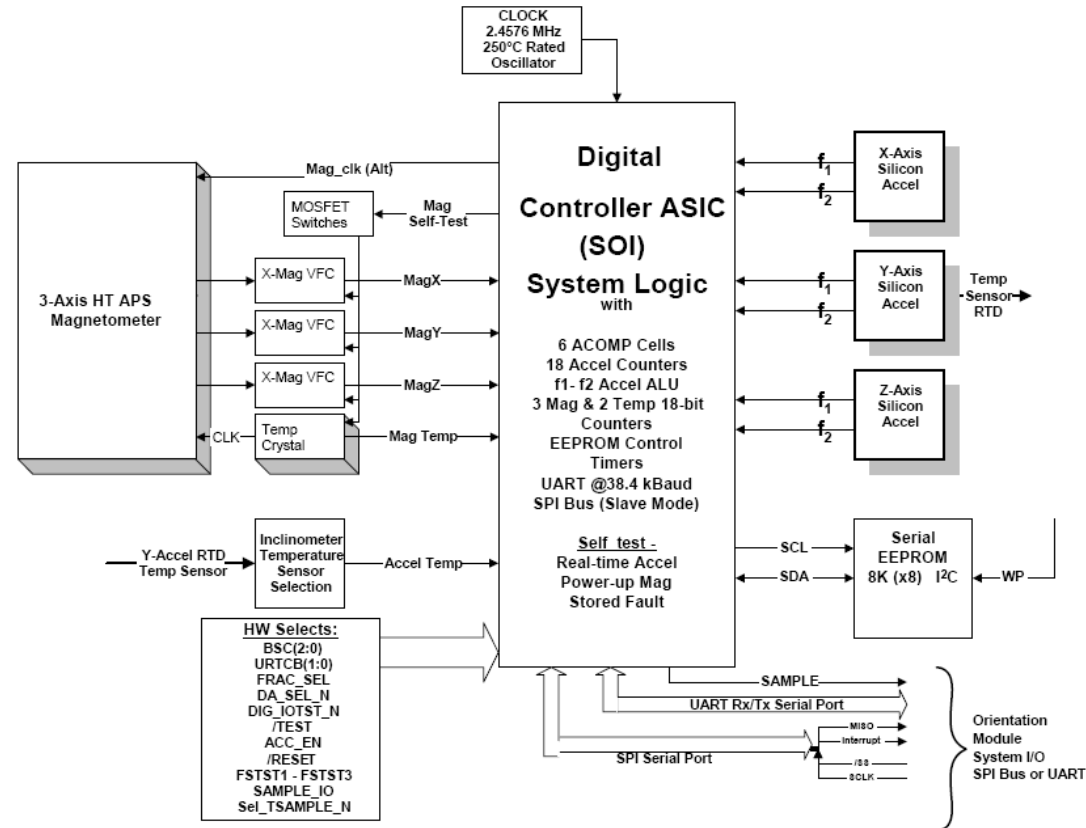


APS Flux-gate Sensor
and Direction Drilling
Navigation tool



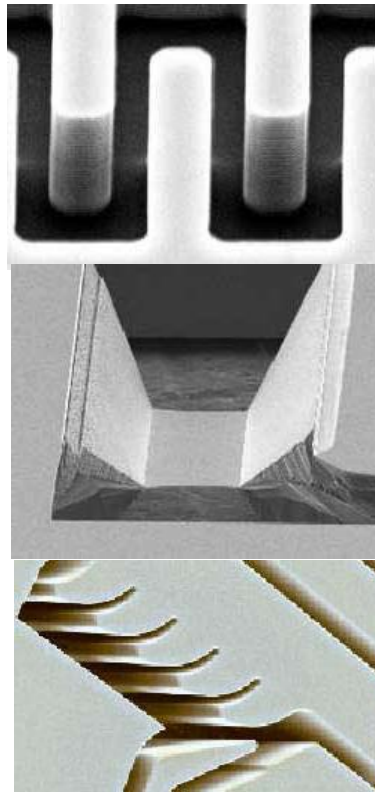
Courtesy: Applied Physics Systems

- System Design Approach
 - HTSOI Digital Controller
 - MEMS VBA Accelerometers
 - QsVFC* Magnetometer Outputs
 - Signal Processing Counters
 - Serial Data I/O
 - Selectable Operating States
 - Navigation Mode
 - ~20 μ g LSB resolution
 - High-G Range Mode
 - >50G Response
 - High Bandwidth
 - 200Hz Data rate
 - Bi-Directional Communications



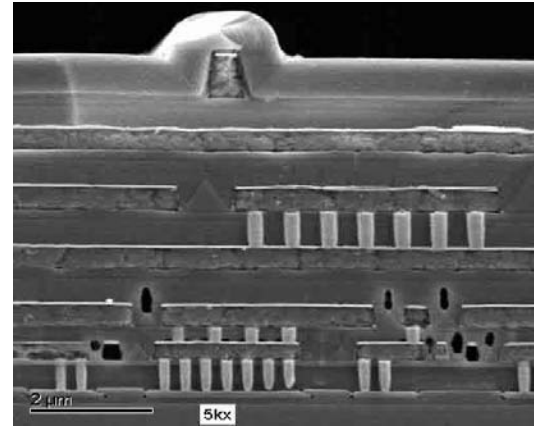
*QsVFC = Quad synchronous Voltage-to-Frequency Converter

- Class 10/100 Clean Room MEMS facility (Redmond, WA)
 - 10,000 sq ft; 6” and 4” wafer processing
 - Mask design, lithography, wet/dry etch, bonding, dicing, packaging



– HTSSOI Foundry (Plymouth, MN)

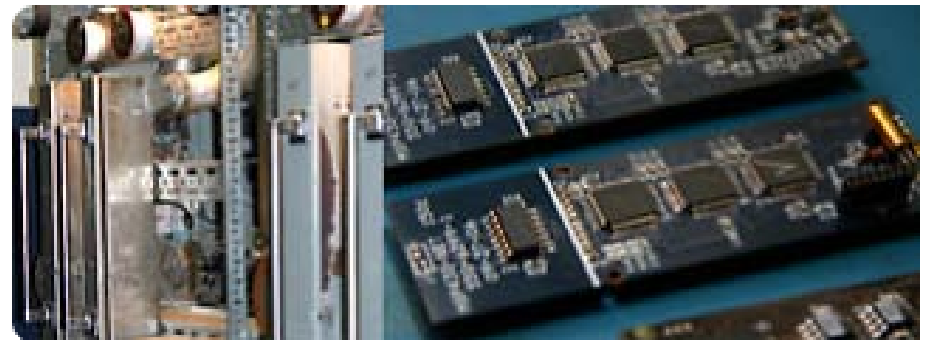
- Analog & digital ASIC; design, fabrication, packaging, and test
- Clean-rooms: 6-in. 0.8/0.35um fab = 40K Ft². 8-in 150nm = 10K Ft²



Honeywell 6-metal
Layer Process SOI

– APS Testing (Mountain View, CA)

- Directional drilling sensor system production and testing



•OM300 Project Status

- Conceptual design tasks funding released late-April
 - System and Product Definition – Discussions with directional drillers
 - VBA Accel design study – define MEMS approach
 - Hi-temp ASIC evaluation – define system electronics, QsVFC ASIC
 - Electronic and mechanical interface definition

•Contract Deliverables (24 month duration)

- Phase 1:
 - Specification
 - Report / design review: accel enhancements
 - Report / design review: high temp electronics enhancements
 - Report / design review: magnetometer enhancements
- Phase 2:
 - Accel, Magnetometer, and System electronics development
- Phase 3:
 - Integration, assembly and test: Best effort demonstration unit
 - Final Report

- **Management Review and Coordination**
 - Monthly program reviews per Honeywell Aerospace procedures
 - Program health
 - Earned value
 - Milestone fidelity
 - Risk and opportunity management
 - Honeywell IPDS (Integrated Product Delivery and Support)
 - Project is currently at phase 3 in our IPDS
 - Will move to phase 4 after program baseline and product specification, via official review cycle
 - Cost share is RDE, so program is reviewed in monthly RDE cycle
 - DOE review cycle and ARRA reporting requirements

- **Additional Management Practices**
 - **Subcontracts manager in place**
 - **APS interface and oversight**
 - **Export Compliance**
 - **Procedures and training in place**
 - **Baseline Change Management**
 - **In compliance with Honeywell Aerospace Procedure AP-1338**
 - **Staffing and Resource Plans**
 - **Core team is in place**

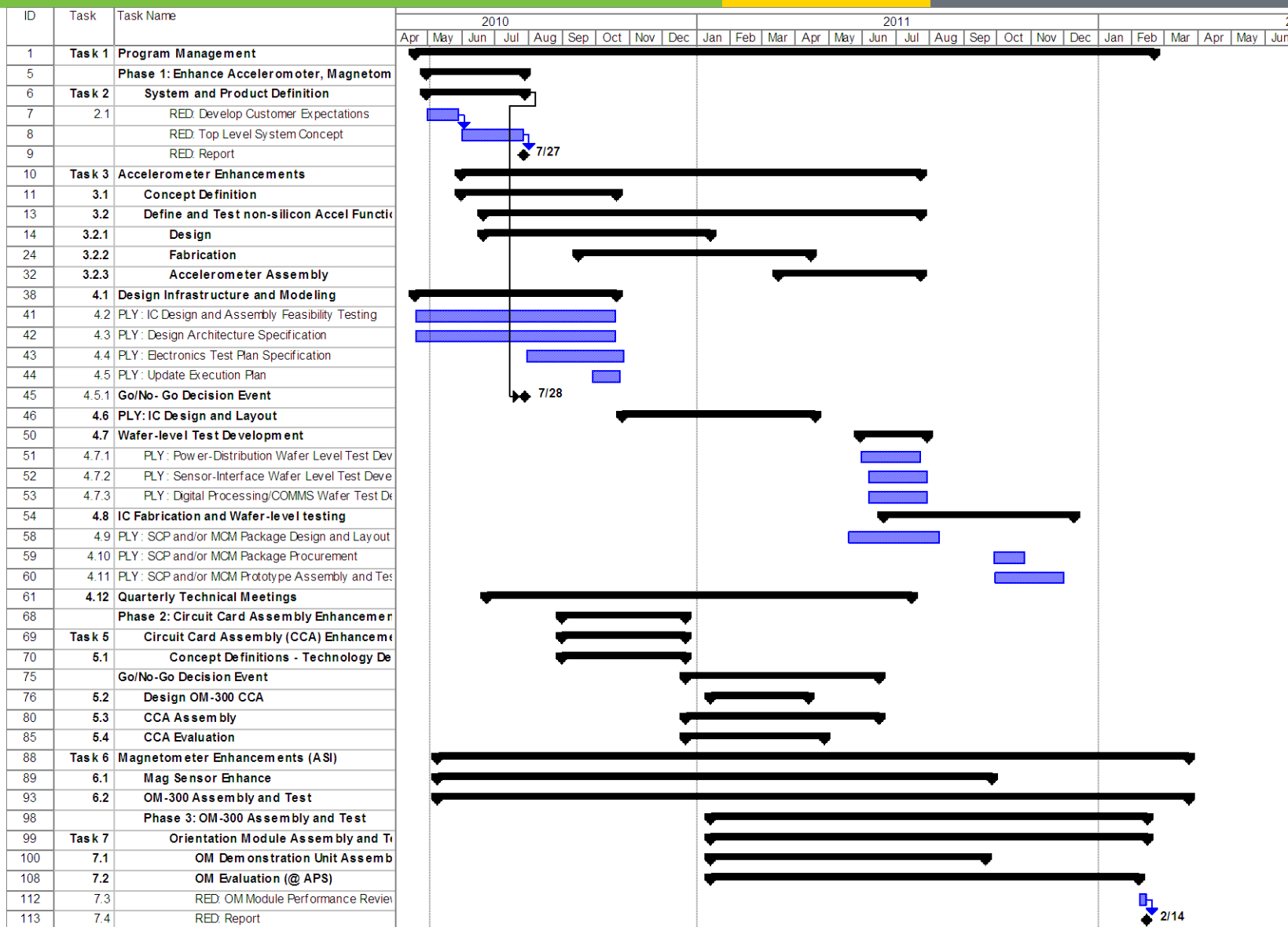
- **Spend Plan**

Fiscal Year	2010			2011				2012	
	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Quarterly Spend	\$ 63,166	\$ 711,843	\$ 940,696	\$ 960,033	\$ 819,673	\$ 534,114	\$ 267,337	\$ 327,561	\$ 128,915
Cumulative Spend	\$ 63,166	\$ 775,009	\$ 1,715,705	\$ 2,675,738	\$ 3,495,411	\$ 4,029,525	\$ 4,296,862	\$ 4,624,423	\$ 4,753,338

Project Management-Schedule



Energy Efficiency & Renewable Energy



- **Project Plan – development and deployment**
 - **FY10 - FY12**
 - **Phase 1**
 - Conceptual design of system, VBA, magnetometer, and hi-temp electronics
 - **Phase 2**
 - VBA design, fabrication and tests
 - Magnetometer design, fabrication and tests
 - Hi-temp electronics: design, ASIC fabrication
 - System architecture design
 - **Phase 3**
 - Prototype design, fabrication and assembly
 - » Integration of components: Chassis, sensors, electronics
 - Prototype performance evaluation and demonstration
- **Possible follow-on activity**
 - Test deployment with directional drilling services
 - Market introduction planning
 - Production planning
 - Production deployment

- Honeywell and APS bring a wealth of knowledge and capability toward development of an Enhanced Geothermal Directional Drilling Navigation Instrument
 - Expertise in rugged silicon MEMS accelerometers – HI-Redmond
 - Expertise in SOI Hi-Temperature electronics – HI-Plymouth
 - Expertise in MWD magnetic sensors & systems – APS
- OM300 module will reduce cost of directional drilling into hotter, deeper, larger Geothermal reservoirs

Supplemental Slides

- Honeywell “Integrated Product Development System”

IPDS Mission: Innovative and rapid product, process, and people development, based on defined new technologies, to create High Sigma next generation products that meet customer requirements and that will be smoothly transitioned into the Momentum business.

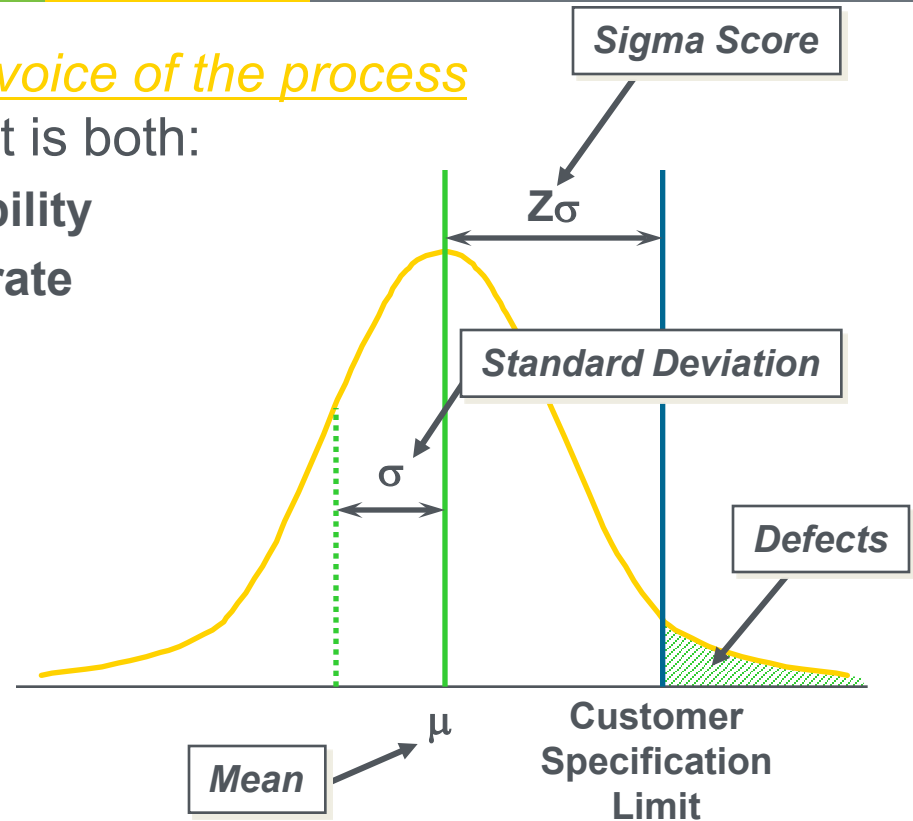
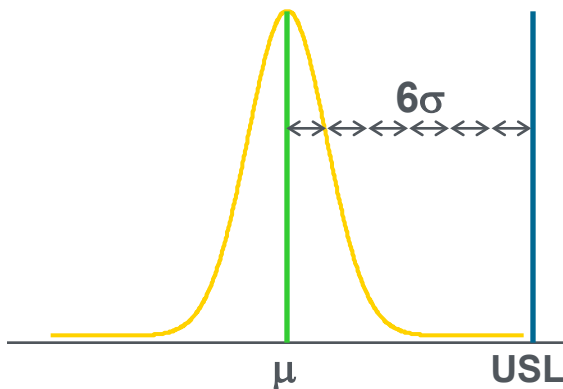


What is Design For Six Sigma? (DFSS)

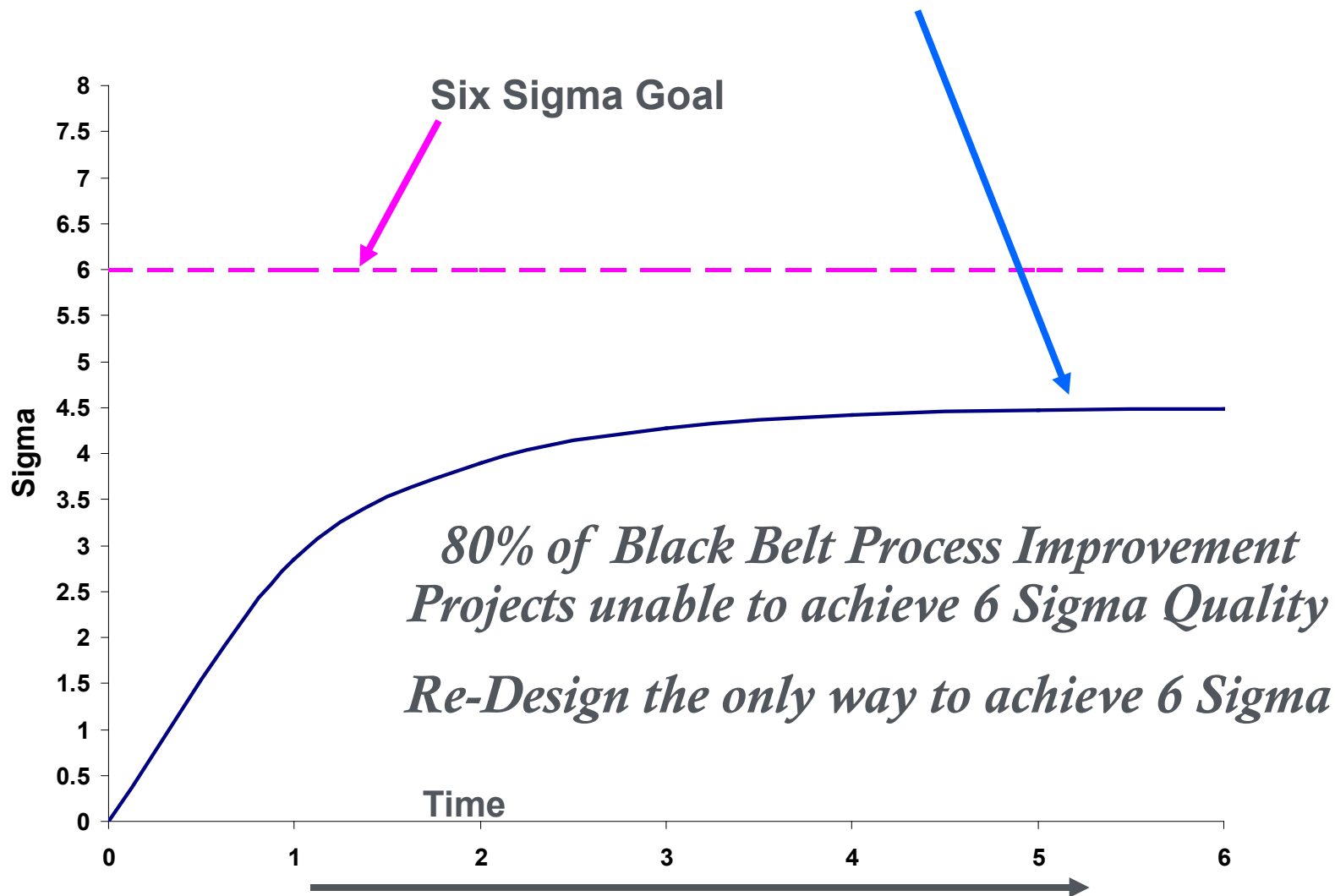
- What it is ...
 - a method
 - a set of tools
 - a process enabler
 - a strategy
 - an analytical approach
 - a statistical approach
- What is is not ...
 - a replacement for solid engineering
 - the answer to all of your issues (cure-all)
 - the development process

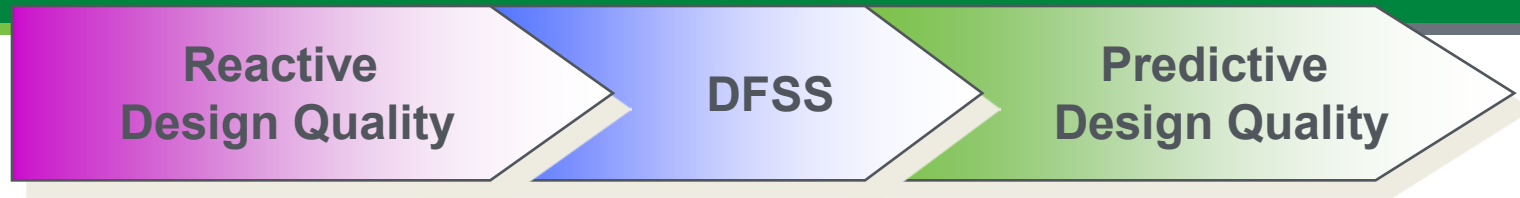
DFSS is an “add-on” to the product development process that uses statistical methods & tools to measure the design and then optimize it to meet the customer's needs.

- A Sigma Score compares the *voice of the process* to the *voice of the customer*. It is both:
 - A general measure of capability
 - Directly related to a defect rate
- *Six Sigma* refers to a process having 6 standard deviations between the process center and the specification limit.



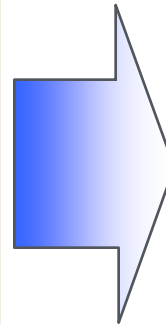
4.5 Sigma "Process Improvement" Wall





From

- Evolving design requirements
- Extensive design rework
- Product performance assessed by “build and test”
- Performance and producibility problems fixed after product is released
- Product development ‘siloes’
- Quality “tested in”



To

- Disciplined customer requirements flow-down
- Understood design parameters
- Product performance modeled and simulated
- Designed for robust performance and producibility
- Functionally integrated product development
- **Quality “designed in”**

***Six Sigma Systems and Products
will be the AES market discriminator***