Stryker NBCRV Reliability Growth

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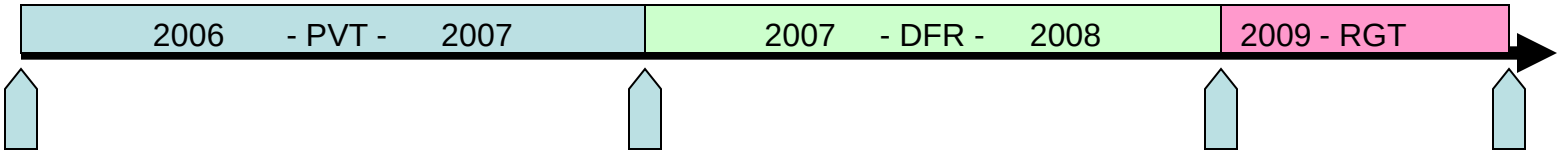
Agenda

- Sections
  - Production Verification Testing (4/2006-7/2007)
  - Design For Reliability (12/2007-12/2008)
  - Reliability Growth Testing (4/2009-11/2009)
  - Conclusion

Time Line



Product Verification Test (PVT)

- April 2006 through July 2007
- NBCRV ORD requirement is 1000 MMBSA
- NBCRV Hardware / Software (w/o Government Furnished Equipment) requirement is 2000 MMBSA

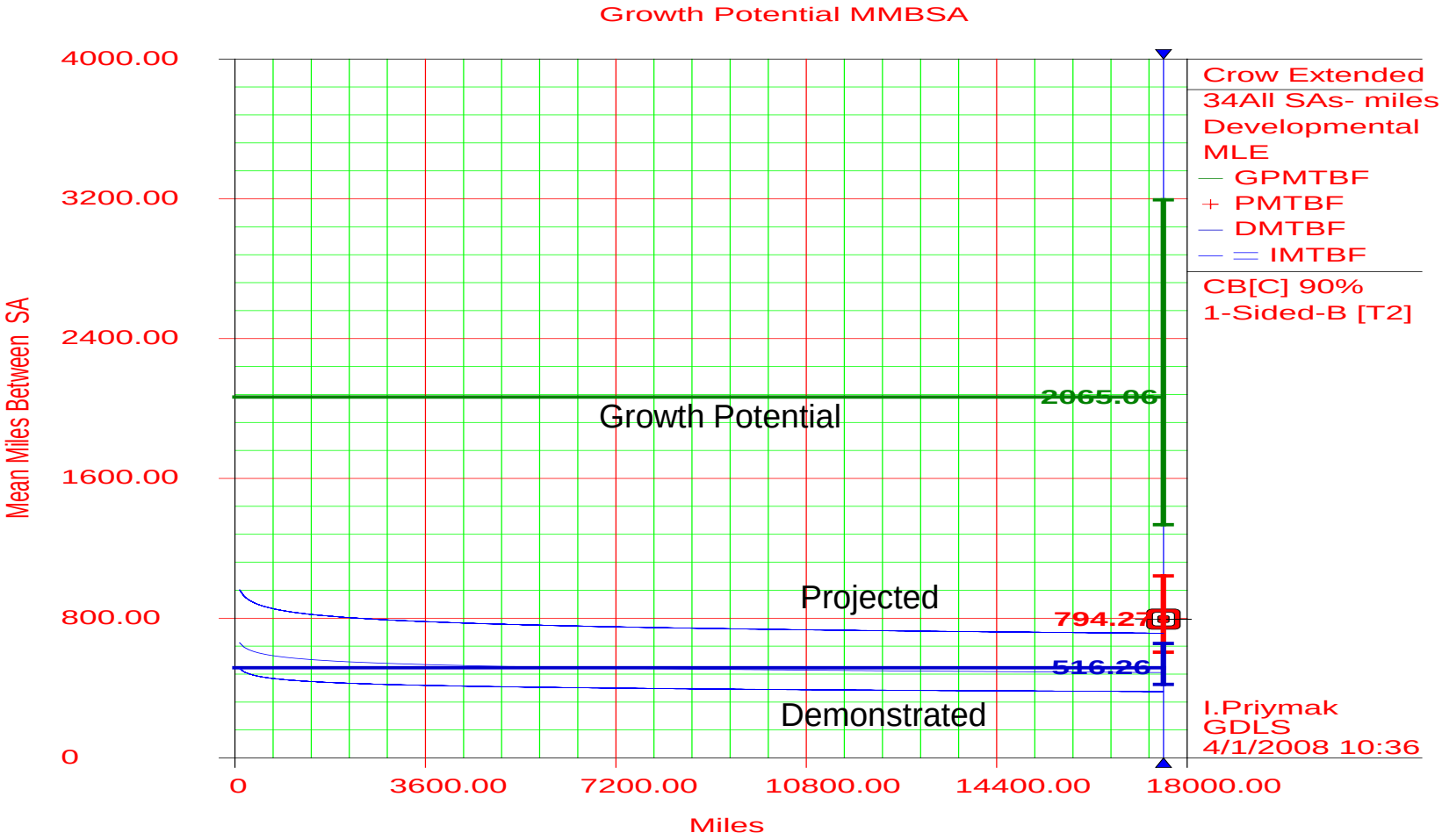
PVT Results

- PVT (Production Verification Test) / Durability testing
  - Stopped at ~70% of planned 24,000 mile RAM test
  - Multitude of CFE (Contractor Furnished Equipment) HW/SW System Abort's
  - Slightly over a half of the requirements demonstrated during PVT
  - No growth during PVT / Durability testing
  - Testing was halted due to low Reliability

NBCRV PVT was halted due to Low Reliability

Reliability Growth Analysis

ReliaSoft's RGA 6 PRO - RGA.ReliaSoft.com



Beta (hyp.)=1.0000, Beta=1.0564

PVT was halted due to Low Reliability

Post-PVT Discussion - DFR

- **Execute a System Engineering based Reliability Growth Program to satisfy User Requirements**
- **Exit Criteria:**
  - **Off Ramp based on demonstration of an instantaneous 1,333 MMBSA with 70% confidence**
  - **Demonstration of a point estimate of 1,333 MMBSA or better over 14K Miles**

What is DFR?

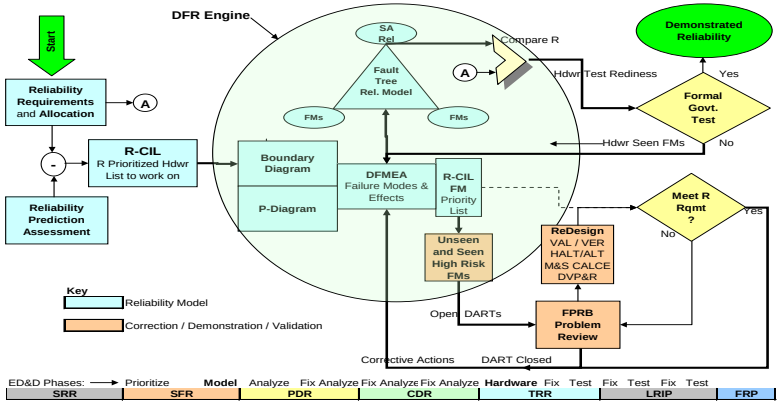
- DFR is Design for Reliability
  - Up front use of Reliability Tools to influence design
  - Infusing a mindset in the design process that promotes striving for improved Reliability
  - Produce a higher growth potential of design
- A change in attitude
  - Aggressive use of Reliability principles
  - Commitment to the DOD directive of Reliability Growth
- DFR tools:
  - Boundary Diagram
  - P-Diagram (Parameter Diagram)
  - DFMEA (Design Failure Modes Effects Analysis)
  - FTA (Fault Tree Analysis) / Prediction
  - DVP&R (Design Verification Plan and Report)

Up Front Use of Reliability Tools to change the Growth Potential of a Design

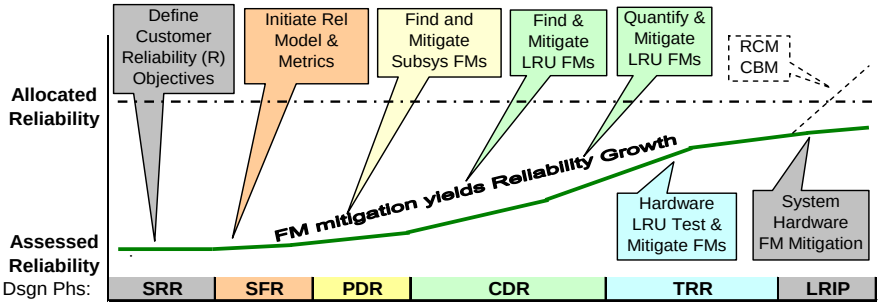
New Reliability Standard ANSI/GEIA-STD-0009 Objectives

DFR Quad Chart

ED&D Process to Grow R - Identify & Mitigate FMs

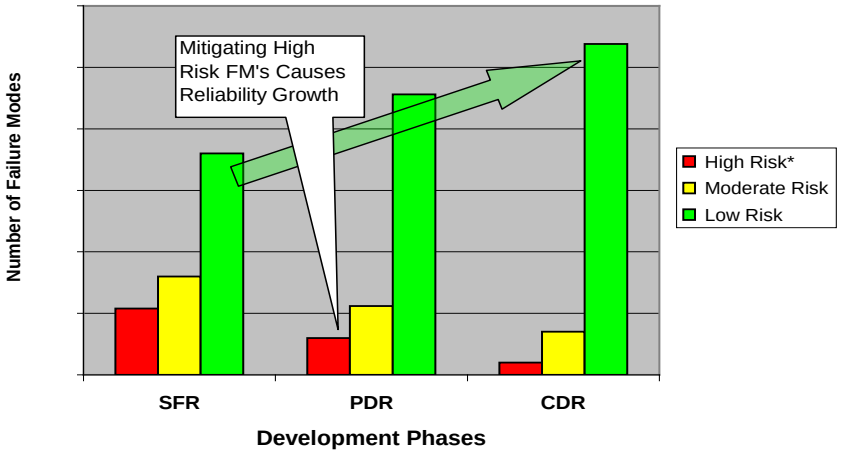


DFR - Mitigation of Potential FMs yields Reliability Growth



GDLS Dev Phase	GEIA R Standard Objectives	DFR Activities	DFR Tools	Reliability Deliverable
SRR	1. Customer / User Requirements and Constraints.	Understand and define Customer Reliability (R) Objectives	Required Rel. Assess Rel. R-CIL	Customer Requirements Constraints List
SFR		Define "R" constraints Initiate R Growth Program Plan Initiate System R model	Sys FTA / RBD Trade Studies Sys DFMEA	Reliability Model & Metrics System R-CIL
PDR	2. Design and Redesign for Reliability - DFR (Proactively assess, improve and optimize reliability)	Model subsys to LRU level. Qualitatively find high risk FMs Mitigate critical FMs to grow R	B-Diag P-Diag LRU DFMEA RCIL-DVP	Reliability Subsystem and LRU R-CIL
CDR		Identify root causes of FMs Quantitatively identify and Mitigate critical FMs to grow R	DVP Early Detection FM Mitigation	Reliability LRU FM & CA R-CIL
TRR		Early hardware FM detection Demonstrate & Mitigate Mitigate Subsys FMs to grow R	PQT FM Mitigation Validate Relibility	Reliability Hardware FM R-CIL
LRIP	3. Produce Reliabile Systems / Products	Early Sys R demonstration Failure Analysis (FA) and write corrective actions (CA) grow R	FRACAS (Detect & Mitigate)	Reliability Subsys & Sys Hrdwr R-CIL
FRP	4. Monitor & Assess User Reliability	Actively Assess R TAF TAF Capture R growth opportunities for FRP	FRACAS Monitor R Growth	Vehicle Verification & Hdwr FM R-CIL

Manage Reliability Growth with Metrics



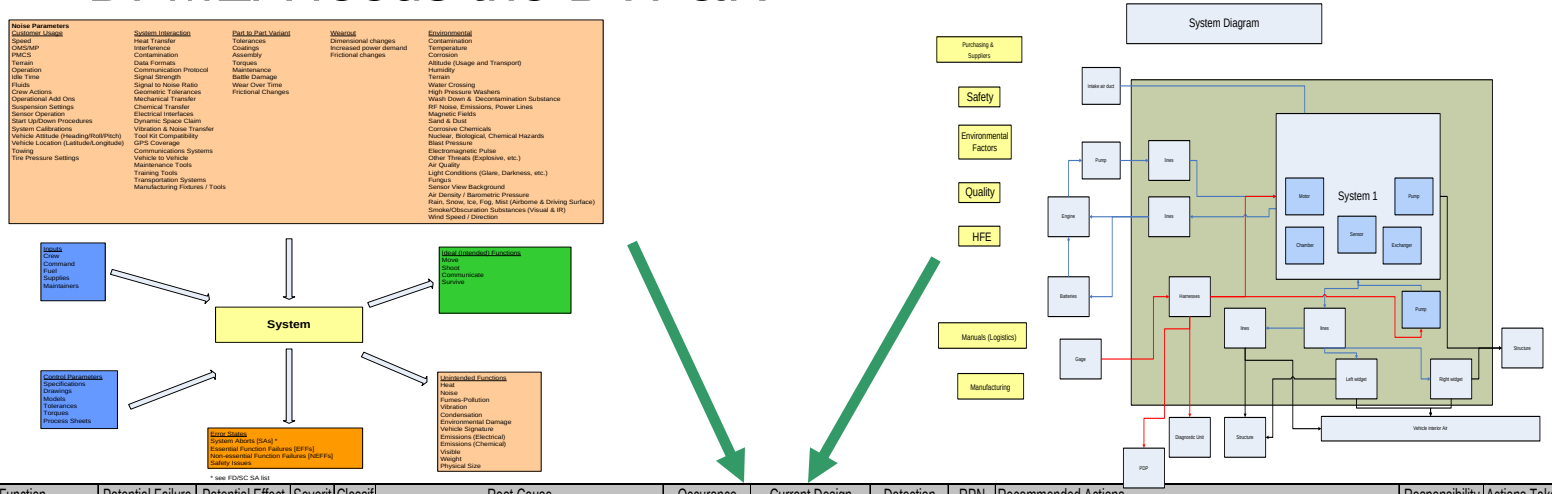
Top Level DFR Summary

- Major steps toward start of design and test
  - Hardware Reliability – Design for Reliability Methodology
    - Boundary Diagrams
    - Parameter Diagrams
    - Design FMEA (Failure Mode and Effect Analysis)
    - Incident Screening Team
    - Failure Prevention Review Board (FPRB)
    - Steering FPRB
  - Operational Reliability
    - Personnel/Maintainer/Operator Training
    - Manuals
  - Quality/Manufacturing
    - Vehicle Shake down
    - Process FMEA
    - Vendor/Supplier Training

Three Major Areas to Facilitate Reliability Growth Potential

DFMEA

- **Center Piece of the DFR Process**
  - DFMEA uses the Boundary Diagram and P-diagram as a jump off point for analysis
  - DFMEA allows for Risk assessment
  - DFMEA targets candidates for redesign
  - DFMEA feeds and compliments the Fault Tree Analysis
  - DFMEA feeds the DVP&R



Item / Function	Potential Failure Mode	Potential Effect of Failure	Severity	Classification	Root Cause	Occurance	Current Design Controls	Detection	RPN	Recommended Actions	Responsibility & Target Date	Actions Taken
Failure of item	Item won't operate	delay mission start	3		Root Cause from P-diagram	2	Preventative	1	6	Redesign item	name and date	
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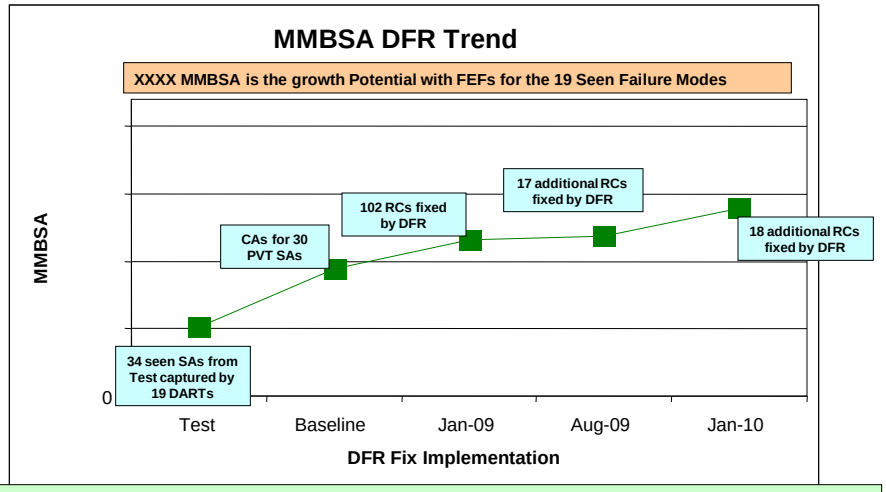
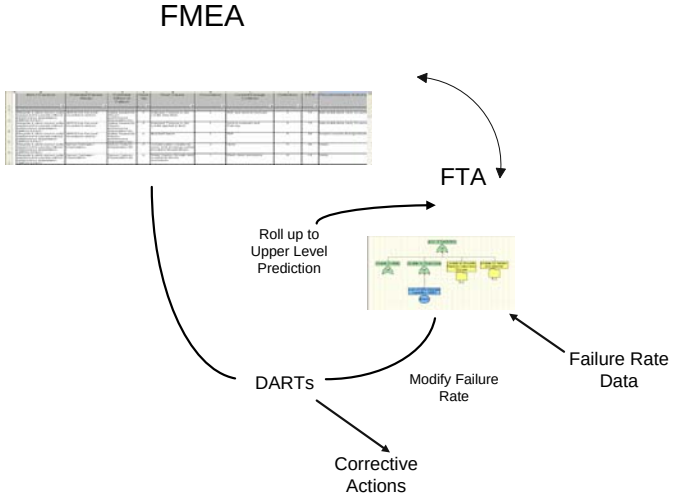
Failure of item	Item won't operate	delay mission start	3		Root Cause from P-diagram	1	Preventative	5	15	Redesign item	name and date	
Failure of item	Item won't operate	Stop mid mission	5		Root Cause from P-diagram	4	Preventative	5	100	Redesign item	name and date	
Failure of item	Item won't operate	Stop mid mission	5		Root Cause from P-diagram	4	Detection	4	80	Redesign item	name and date	
Failure of item	Item won't operate	Stop mid mission	5		Root Cause from P-diagram	2	Detection	5	50	Redesign item	name and date	
Failure of item	Item won't operate	Stop mid mission	5		Root Cause from P-diagram	2	Detection	5	50	Redesign item	name and date	
Failure of item	Item won't operate	Stop mid mission	5		Root Cause from P-diagram	2	Detection	5	50	Redesign item	name and date	

Fault Tree Analysis

- **Fault Tree Analysis (FTA)**
  - Top-down analysis identifies failure modes of parts that could cause System Abort (SA)
  - Failure Definition Scoring Criteria (FDSC) for Production Verification Testing (PVT) used to guide tree contents
  - Failure modes identified during Failure Modes Effects Analysis (FMEA) included in Fault Tree
  - Failure Rate Data from known sources used in





FTA results predict failure to meet RGT entrance criteria (see Oct. '07 PM OSD brief)

Screening Team Work Flow Progress

IST: Filter ~2500 Root Causes found during DFMEA

NBCRV SUB SYSTEM	ROOT CAUSES					Corrective Actions
	Root Causes	RPN >39	DFR IST Reviewed	DFR IST Approved	DFR IST Rejected	
Subsystem 1	37	8	8	6	2	5
Subsystem 2	177	22	23	17	6	4
Subsystem 3	54	13	13	0	13	0
Subsystem 4	35	3	3	3	0	2
Subsystem 5	23	6	6	3	3	3
Subsystem 6	192	12	13	4	9	2
Subsystem 7	833	142	65	37	28	5
Subsystem 8	90	30	30	21	9	2
Subsystem 9	290	118	116	33	83	10
Subsystem 10	137	69	71	22	49	5
Subsystem 11	121	46	46	17	29	7
Subsystem 12	70	56	58	14	44	
Subsystem 13	185	5	5	2	3	
Subsystem 14	34	3	3	0	3	
Subsystem 15	128	19	18	2	16	
Subsystem 16	19	3	3	3	0	1
Total	**2425**	**555**	**481**	**184**	**297**	**55**
		Progress	87%			

FPRB: Filter > 50 Corrective Actions proposed by Engineering

NBCRV SUB SYSTEM	Corrective Actions	Current Corrective Actions		
		FPRB Reviewed	FPRB Approved	FPRB Rejected
Subsystem 1	5	5	4	1
Subsystem 2	4	4	3	1
Subsystem 3	0	0	0	0
Subsystem 4	2	2	1	1
Subsystem 5	3	3	2	1
Subsystem 6	2	2	2	0
Subsystem 7	5	5	3	2
Subsystem 8	2	2	1	1
Subsystem 9	10	10	8	1
Subsystem 10	5	5	4	1
Subsystem 11	7	7	8	1
Subsystem 12	6	6	4	2
Subsystem 13	2	2	2	0
Subsystem 14	0	0	0	0
Subsystem 15	1	1	0	1
Subsystem 16	1	1	1	0
Total	**55**	**55**	**43**	**13**
		Progress	100%	

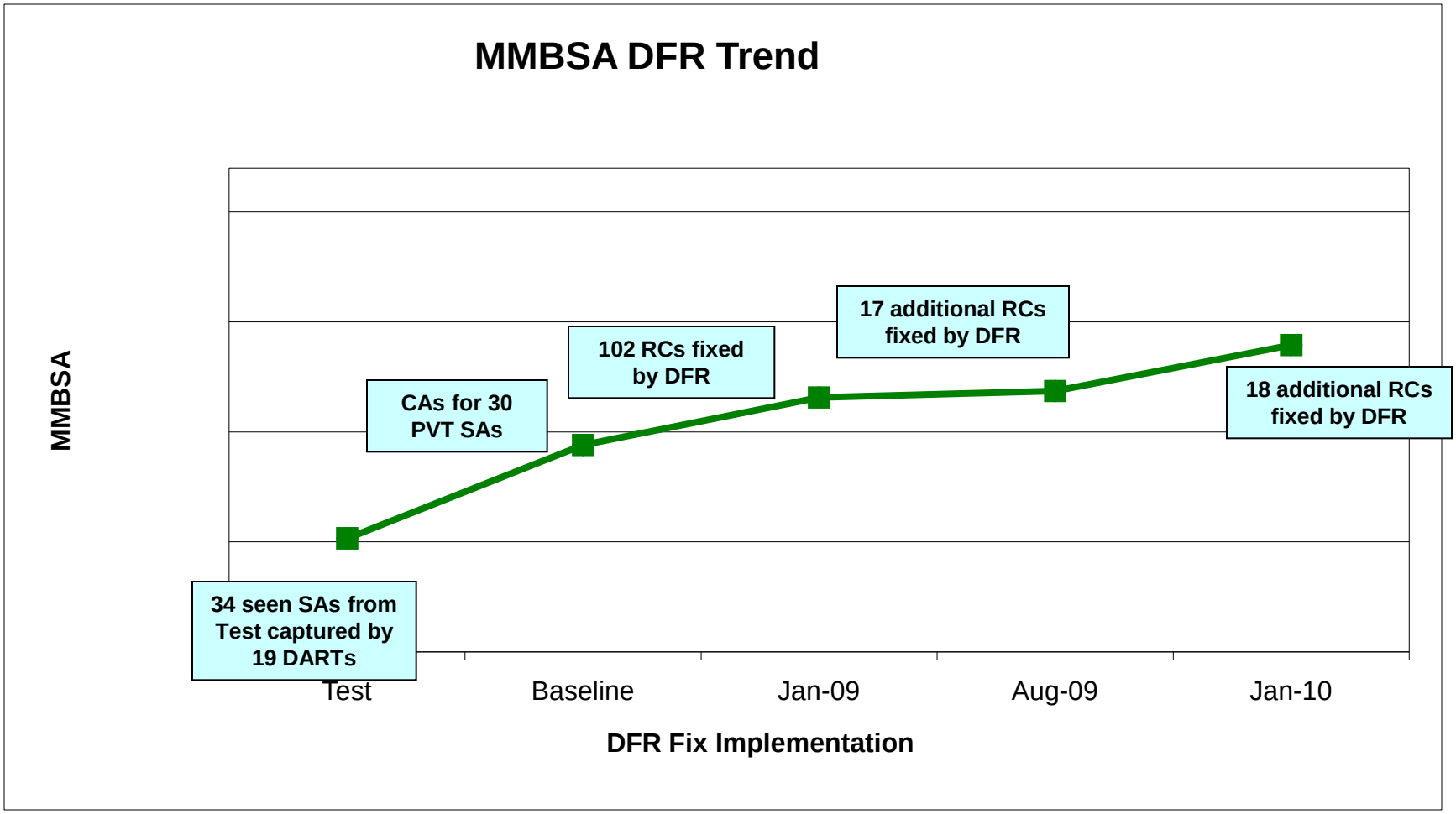
Steering Committee: Final Filter on Corrective actions

NBCRV SUB SYSTEM	Corrective Actions	Current Corrective Actions		
		SFPRB Reviewed	SFPRB Approved	SFPRB Rejected
Subsystem 1	4	4	4	0
Subsystem 2	3	3	2	1
Subsystem 3	0	0	0	0
Subsystem 4	1	1	1	0
Subsystem 5	2	2	2	0
Subsystem 6	2	2	1	1
Subsystem 7	3	3	3	0
Subsystem 8	2	2	1	1
Subsystem 9	8	7	6	1
Subsystem 10	4	4	3	1
Subsystem 11	6	6	6	0
Subsystem 12	4	4	3	1
Subsystem 13	2	2	1	1
Subsystem 14	0	0	0	0
Subsystem 15	0	0	0	0
Subsystem 16	1	1	1	0
Total	**42**	**41**	**34**	**7**
		Progress	98%	

Summary of DFR

- DFR is a Two step process
  - Discover Failure Modes
  - Mitigate Failure Modes
- Statistical and Engineering Analysis
  - Calculate Reliability using Fault Tree Model
  - Fix it using Failure Prevention Review Board (Corrective Actions)
  - Using the NBCRV FDSC (Failure Definition and Scoring Criteria) 15 vehicle systems were chosen as candidates for improving the vehicle
    - DFMEAs were then performed on those systems concentrating on System Abort Failure Modes
  - Discovered near 2.5k root causes of failure modes which cause System Aborts
  - Those failure modes were screened and selectively addressed by corrective actions through FPRB
  - 230 root causes fixed with Design changes
  - Predicted MMBSA (Mean Miles Between System Abort) of approximately 1150 to start Reliability Growth Test (RGT) based on Fault Tree Analysis

FTA Results Using Corrective Action Cut-in Timeline



Fault Tree Showed an RGT start around 1150 MMBSA

Operational Reliability

- Training of crews and maintainers
  - Classes were conducted by GDLS certified trainers
    - OPNET November '08 Classroom and then Vehicle
    - RGT delta teach: 2/20/09-2/26/09
    - FLMNET CCS delta teach: 3/16-3/20 2009

- Technical Manuals (TMs)
  - TMs delivered: 2/02/09
  - Items that did not make the February drop were made into ERRATA sheets and sent to be incorporated into the Manuals
  - Vendor TMs delivered in Jan. '09.

Operational Failures Mitigated by Training and Improved Manuals

Quality and Manufacturing

- PFMEA's conducted by major suppliers
  - CCOPS supplier
  - Harness supplier

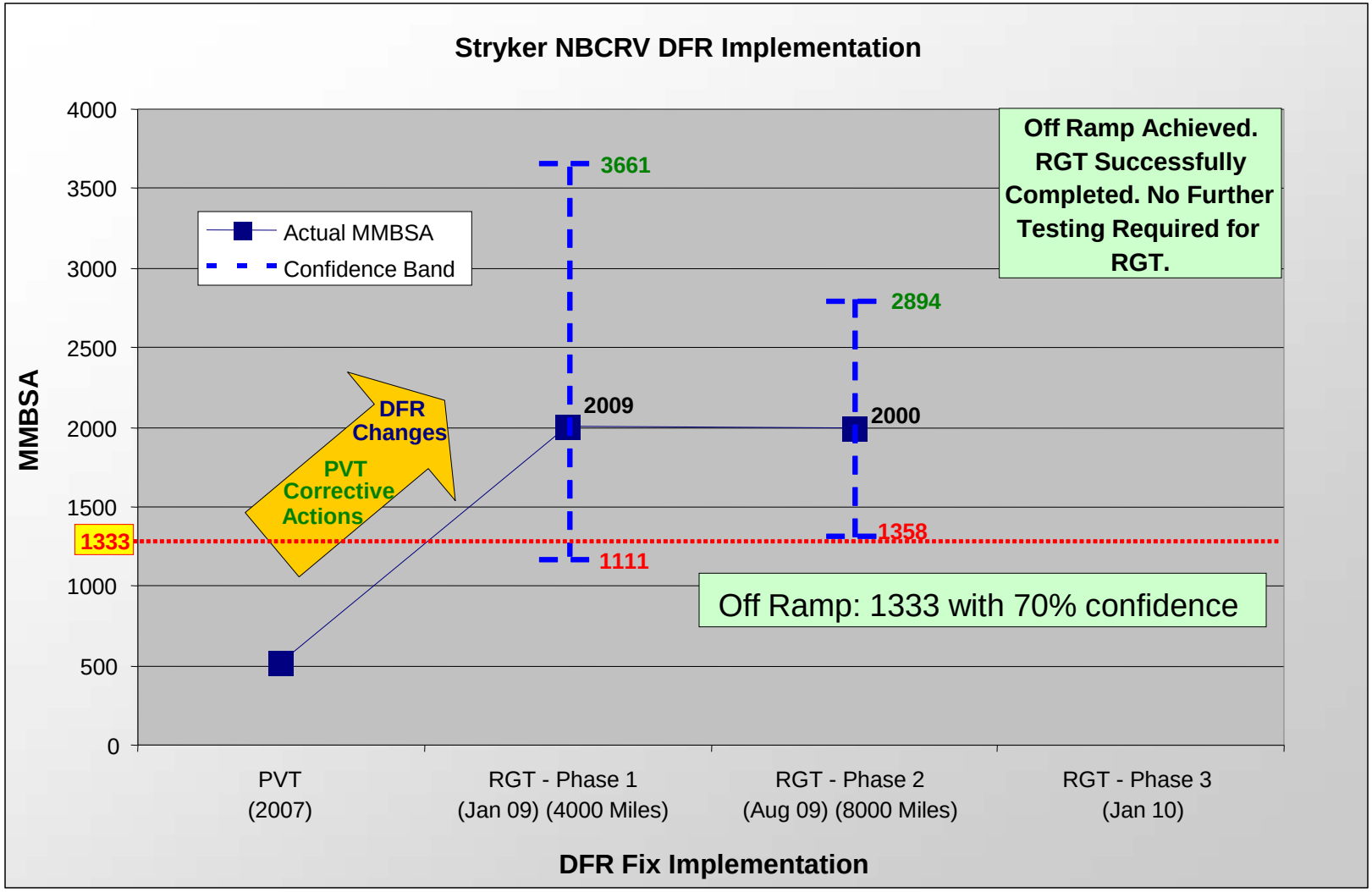
- Production quality
  - 2009 vs 2006 – Number of defects reduced by 15 times.

Production Quality along with Supplier Quality addressed

Reliability Growth Test Parameters

- April 2009 through November 2009
- 14000 miles
  - Phase I - 4000 miles / Phase II - 4000 miles / Off Ramp Opportunity / Phase III – 6000 miles
- Off-ramp opportunity at 8000 miles
- Shakedown
  - 400 before start of test
  - 100 after insertion points
  - Failures during shakedown not scored if they were directly attributable to DFR modifications

Graph PVT to RGT Comparison



SUMMARY

- NBCRV PVT/Durability was halted due to poor reliability
- The Design For Reliability resulted in a drastic jump in Reliability that was demonstrated in RGT
- RGT was ended early (8k miles vs. 14k miles) because the Reliability Requirements (1333 MMBSA) were exceeded with Confidence.

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