Tailoring Halt & Hass Testing for Aerospace Applications

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- Circa 1940 – 50.   Mil Stds used for testing this aircraft.
- Today we are using many of the same testing Mil Stds for modern support systems.
- The US DoD has indicated that defense contractors should not depend on Mil Stds only and should learn the science of Accelerated Stress Testing for improvement of Reliability and Robustness.

As the stresses of combat on this aircraft cannot be fully described, neither can the testing for it be fully described

Mil Std testing does not always do the job

A flight control system problem caused an F/A-22 Raptor to crash on the runway at Nellis Air Force Base, Nev., on Dec. 20 2004, according to an Air Force report.

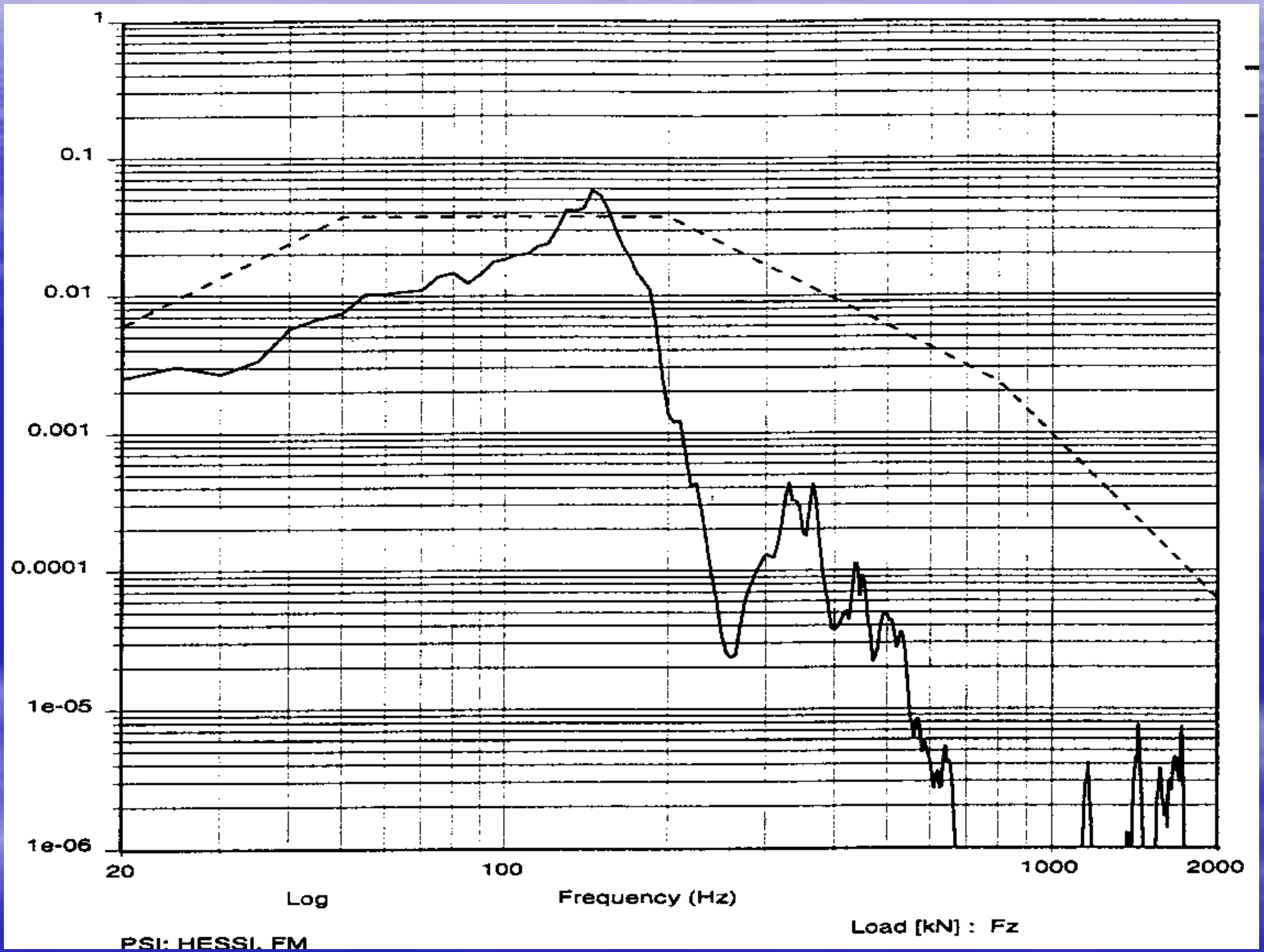
Date: 10 May 2005
Airline: Northwest Airlines
Aircraft: Douglas DC-9-51
Location: Minneapolis, Minnesota

Photographer: Cyrus Cambata

The crew of DC-9-51 N736NC reported loss of right hydraulic system fluid quantity during the climb to cruise after takeoff from Columbus, Ohio. Upon landing at MSP, the aircraft cleared the runway and began the taxi to its gate. Shortly thereafter, the crew reported that a total loss of steering and braking occurred. The aircraft impacted the right wing of Northwest A319 N368NB, which was pushing back off gate G10. Both cockpit crew members aboard the DC-9 were seriously injured; the remaining passengers on both aircraft were uninjured.

- The non-manned 2003 HESSI solar lab orbitor was tested using NASA testing techniques.
- Vibration notching and force limiting methods were used to prevent harming the expensive system.
- Static G analysis was performed on various parts and subsystems.
- The spacecraft successfully completed its solar investigative mission.

HESSI Imager Acceptance test



Z Axis acceleration with notches from the force limiting test

$$S_{FF} = C^2 \cdot mass^2 \cdot S_{AA} \cdot (9.8m/s^2)^2 \cdot (f_o/f)^2 \qquad f > f_o$$

$$S_{FF} = C^2 \cdot mass^2 \cdot S_{AA} \cdot (9.8m/s^2)^2 \qquad f \leq f_o$$

Force Limit Development

The force limits were developed by estimation using the semi-empirical method as described in "Force Limited Vibration Testing Monograph."

***SFF* in N2/Hz, is calculated from the acceleration spectral density, *SAA* in G2/Hz, according to the following expressions.**

***C* is a configuration constant, *mass* is the test item mass in kg, *f* is the frequency in Hz, and *fo* is the first resonant frequency.**

One thing they all have in common

Stimulate vs. Simulate

Stimulate

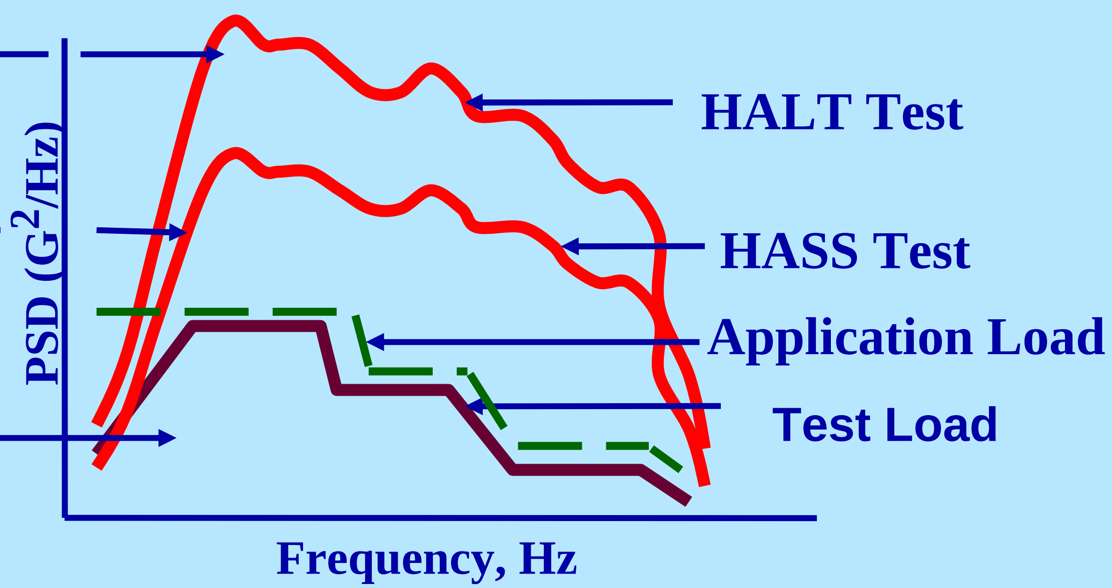
find Op Limits, TAAF, improve Op Limits.

Stimulate

to find Mfg defects

Simulate

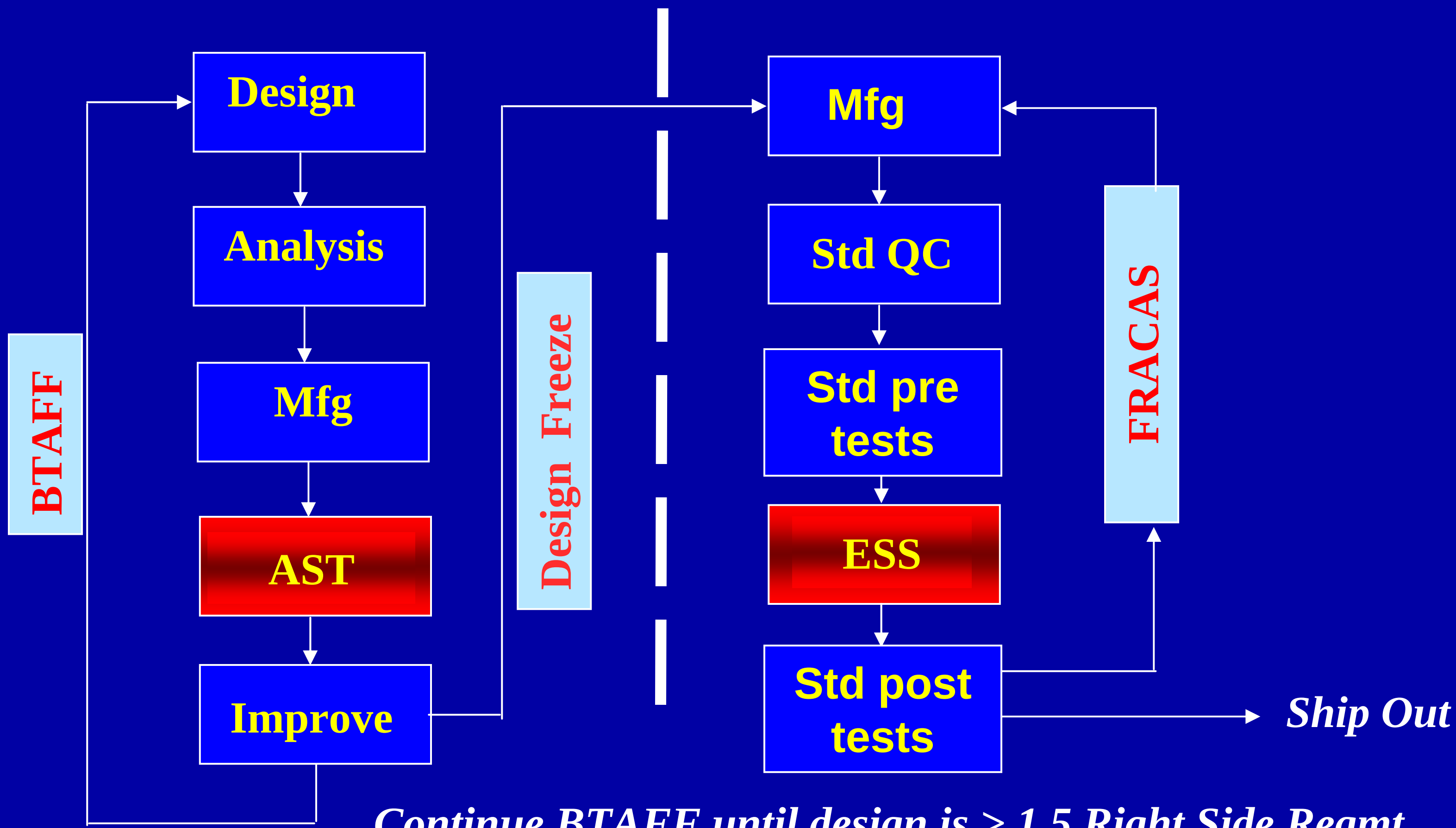
Field Load - Pass / Fail



***Stimulate*: Products have high Robustness and Reliability.**

***Simulate*: Products pass or fail spec level and have lower Robustness and Reliability.**

Left and Right Side Testing



Continue BTAFF until design is > 1.5 Right Side Reqmt

Tailoring the Temperature Test – Upgrade or Downgrade ?

BOM shows good and poor choices

System temp rating goal was 125C

COMPONENT Loc	Type	Make	P/N	Class	Upper Vibration Limit G's (Table) X	Y	Z	OEM Temp Range Deg C (HASS) Low	High	Est OP RangeDeg C Low	DegC High	Est Field Deg C Actual	Vendor Rating Max	Notes
xxxx Circuit Card								0	70					
R26	Resistor	Dale	RNC 50H	M				-65	125	-65	150	125	175	1,2
R28	Resistor, Pwr	Precision	SM 094	M				-55	125	-55	90	125	125	1,2
	Resistor, SIL	Bourns	4306R	M				-55	125	-55	90	125	125	2,3
												125		
C49	Ceramic Cap	Mepco		M				-55	95	-55	115	125	125	1,2
C1	Tantalum Cap	Sprague	135D107	M				-55	85	-55	100	125	125	1,2,4
C48	Ceramic Cap	Kmet	C062C	M				-30	125	-30	125	125	125	1,2
												125		
U1	Micro Comp	Motorola	68HC811	C				0	70	-30	100	125	85	7
U3	DC Controller	Maxim	Max771	M				-55	125	-55	125	125	125	5,6
U6	Volt Ref	Analog	195GS	I				-40	85	-55	100	125	100	8
U33	Q Switch	Siliconix	DG412DY	I				-40	85	-55	100	125	100	9,10
U2	FPGA	Actel	1240A	M				-55	90	-55	105	125	125	11
U14	Flash Mem			C				0	70	-30	95	125	85	Obs, ,12
U11	Volt Conv	Intersil	ICL7662	M				-55	100	-55	105	125	125	13
U4	OP Amp	Adv Lin D	ALD 2711	C				0	70	-20	95	125	85	14
U5	Dual Comp	Adv Lin D	ALD2301	C				0	70	-20	95	125	85	14
U27	Analog Mux	Siliconix	8T01	I				-40	85	-40	100	125	100	15
U31	Clk Calendar	Phillips	PCF8583	I				-40	85	-40	100	125	100	16

Tailoring the Random Vibration Test -

Upgrade or Downgrade ?

Instrument System Test Results:

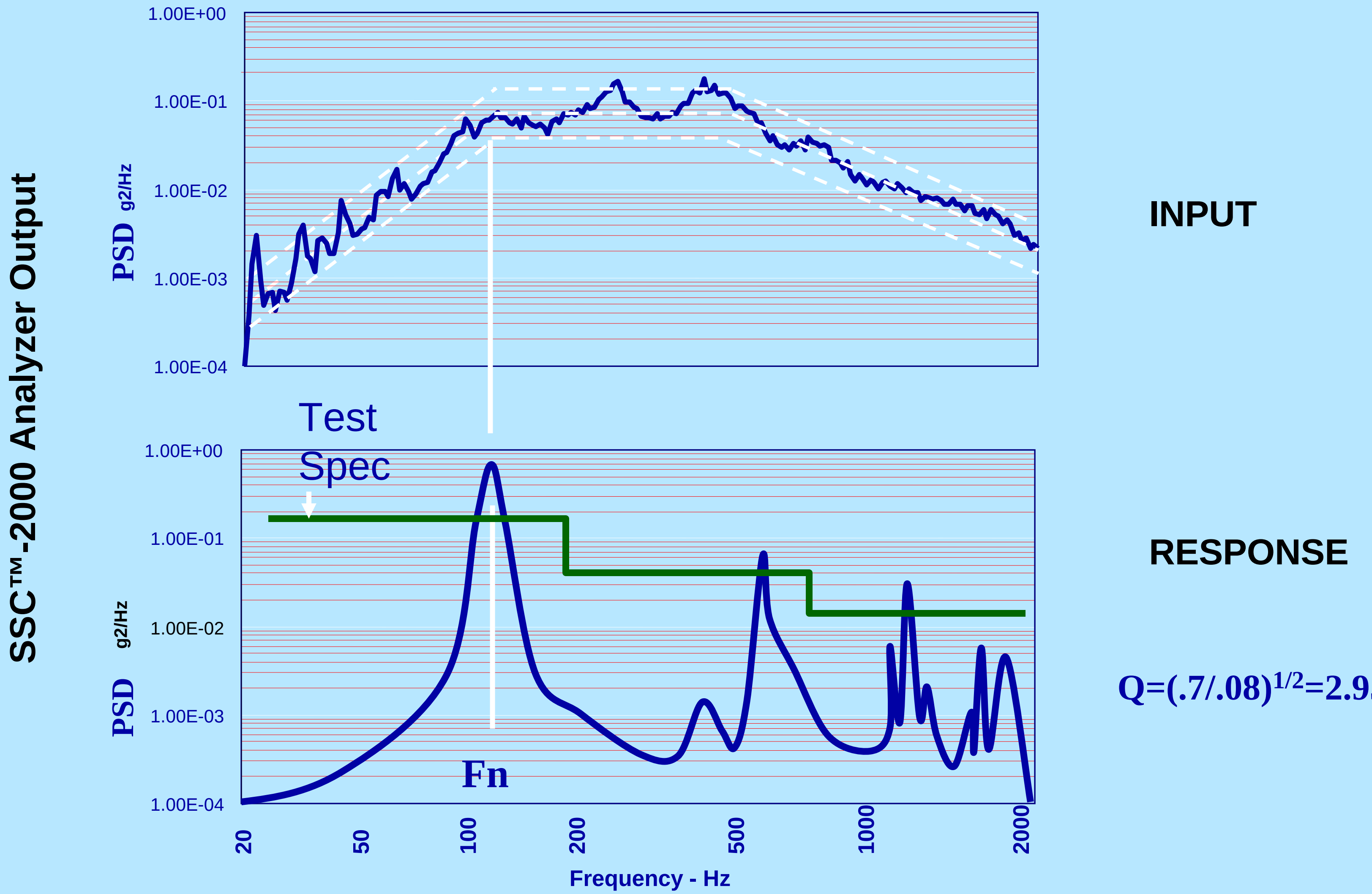
Axis	U116	C34	T228	SW 3	Con 2	U73	Target	Spec	PSD Lim
X	.01	.03	.08	.005	.09	1.0	.06	.04	.005
Y	.07	.04	.02	.06	.01	.03	.06	.04	.01
Z	.09	.02	.04	.06	.08	1.3	.08	.04	.02

Recommended Test Plan:

- **Do not notch the spectrum to exclude weak components.**
- **Upgrade weaknesses.**
- **Force results to target level of test.**

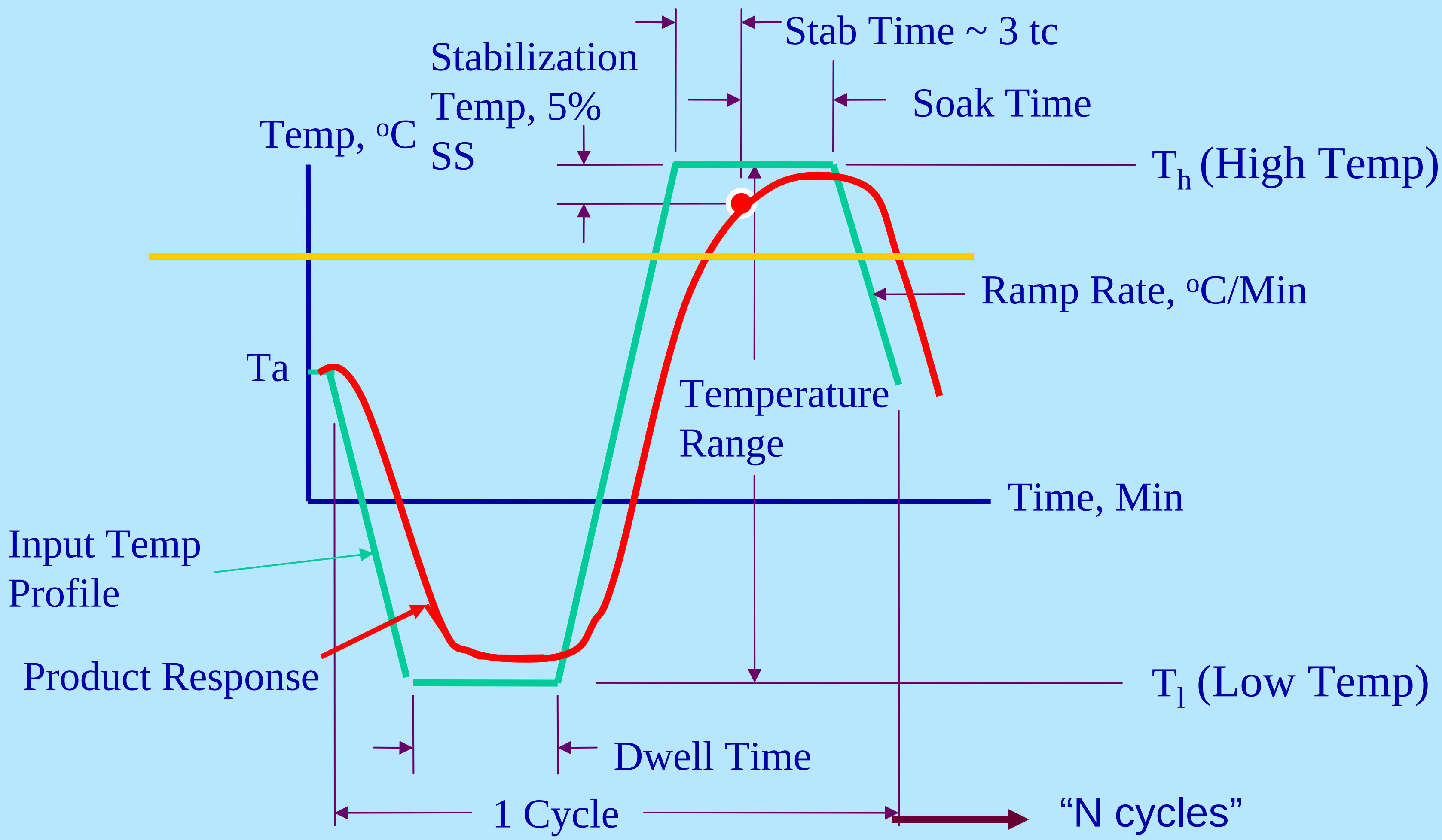
Random Vibration Testing

Notching and Limiting - Upgrade or Degrade ?



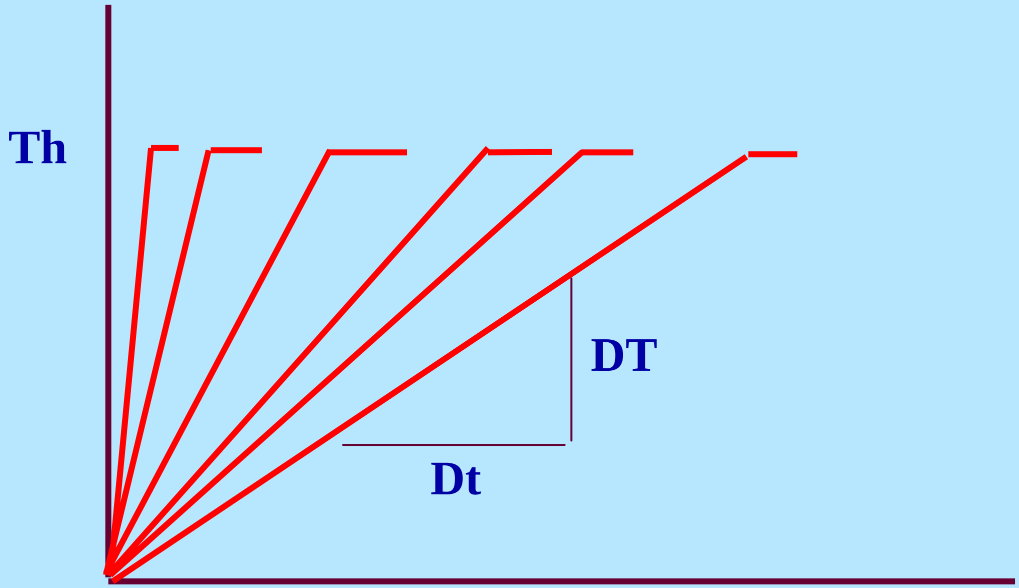
Q=(.7/.08)$^{1/2}$=2.95

Tailoring the Temperature Cycle Test



Tailoring Ramp Rate for Temp Cycle Profile

Ramp Rate, ^{o}C/Min



RR	Failures
10	0
15	1
20	3
25	3
30	1
35	0
40	0
45	0
50	0

Conclusions/Comments

- **Test Notching and Limiting may lead to premature product failure.**
- **Determine limitations of the systems & sub systems.**
- **Set real value test goals above the limitations.**
- **Upgrade the systems to a margin of safety above the test goals.**
- **Don’t fall into the trap of predetermined AST levels.**
- **Dare to raise test standards above older Mil Stds that are in many cases obsolete.**
- **Perform risk analysis of test damage vs. high test goals.**
- **Learn to predict failure by Virtual Test analysis.**

Thank You for listening and for your courtesy.