



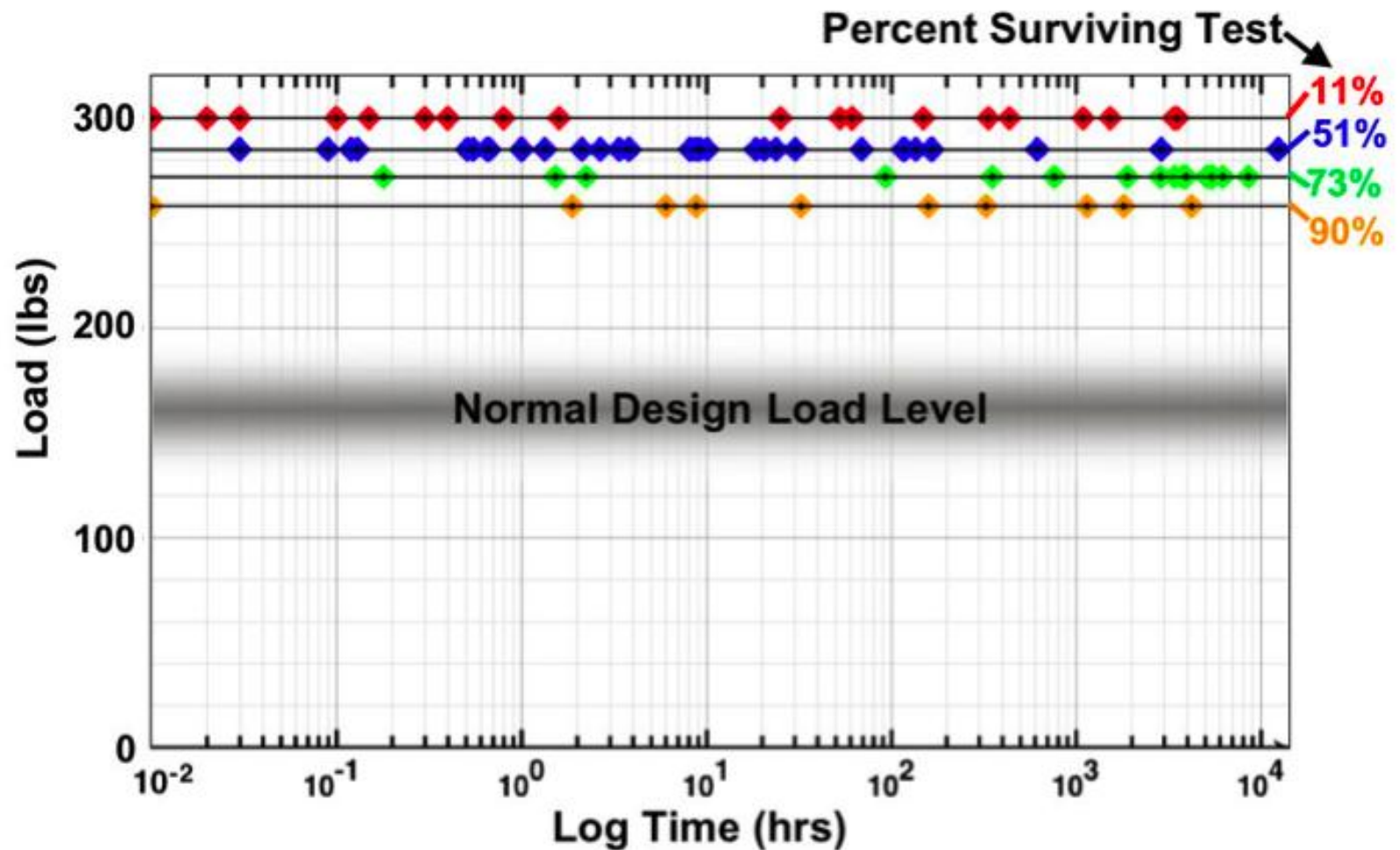
Strength Decay Model

James Reeder

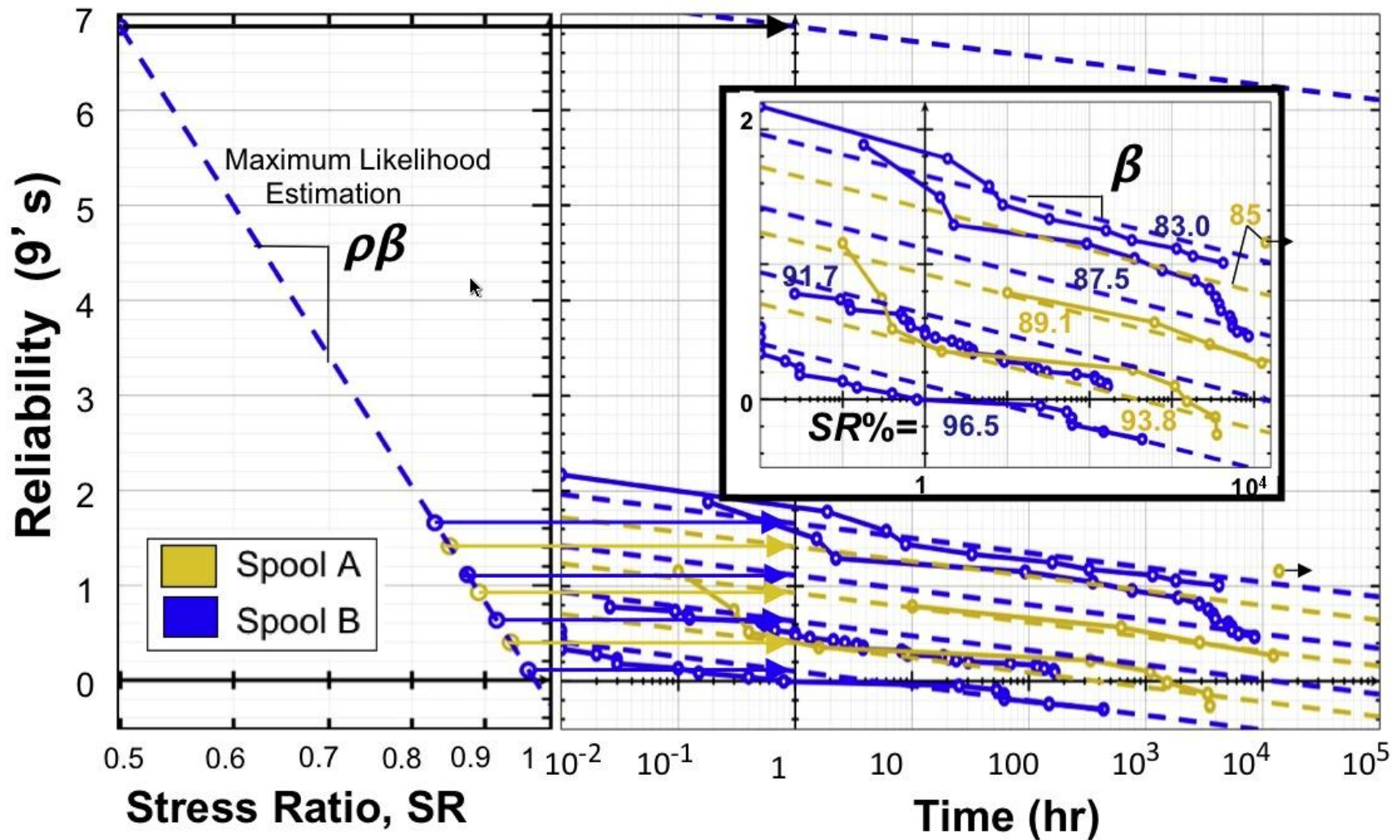
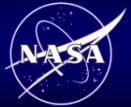
NESC Material Technical Discipline Team
Jet Propulsion Laboratory, Pasadena CA
February 13/,2013



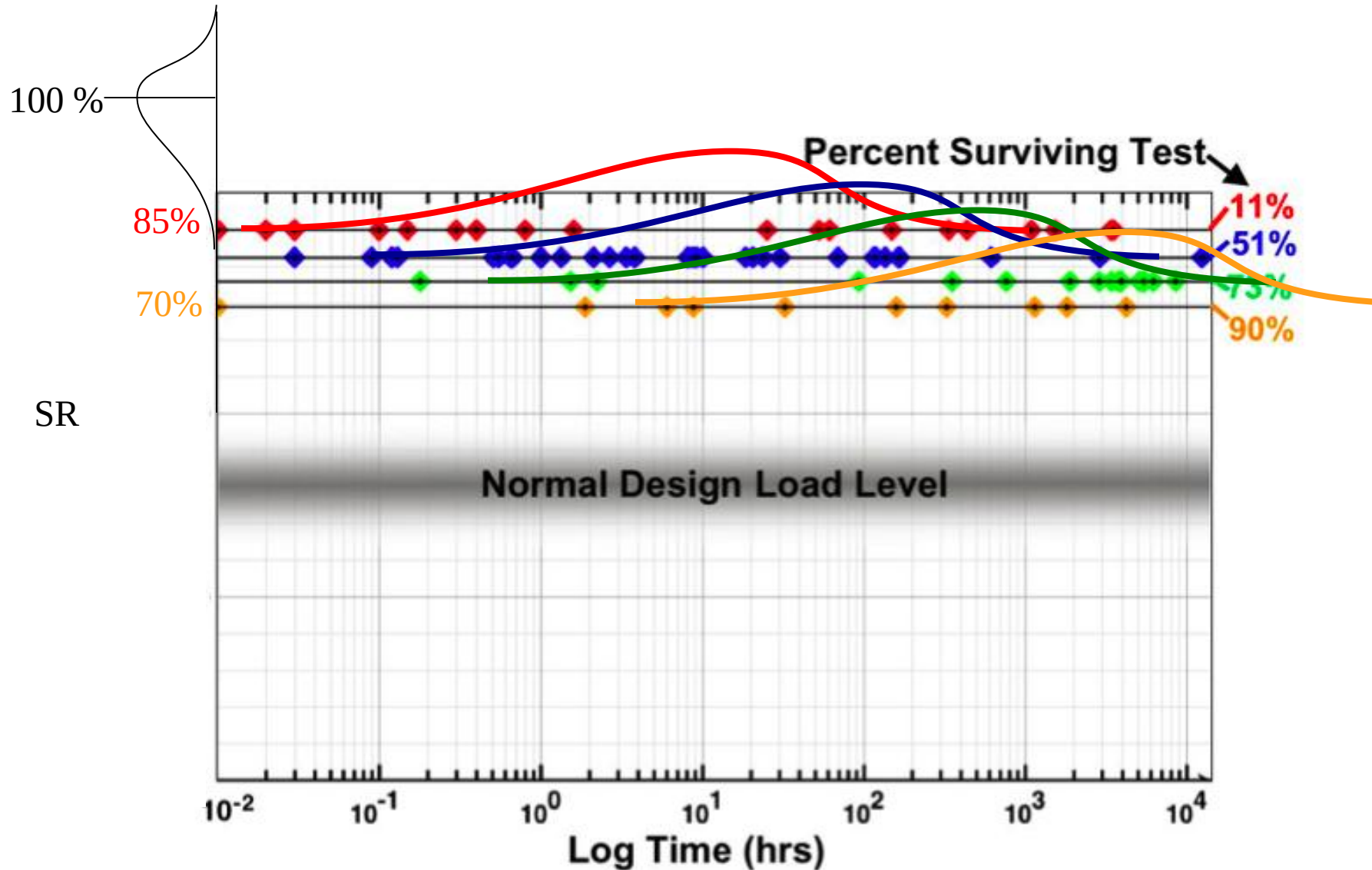
Creep Rupture Data



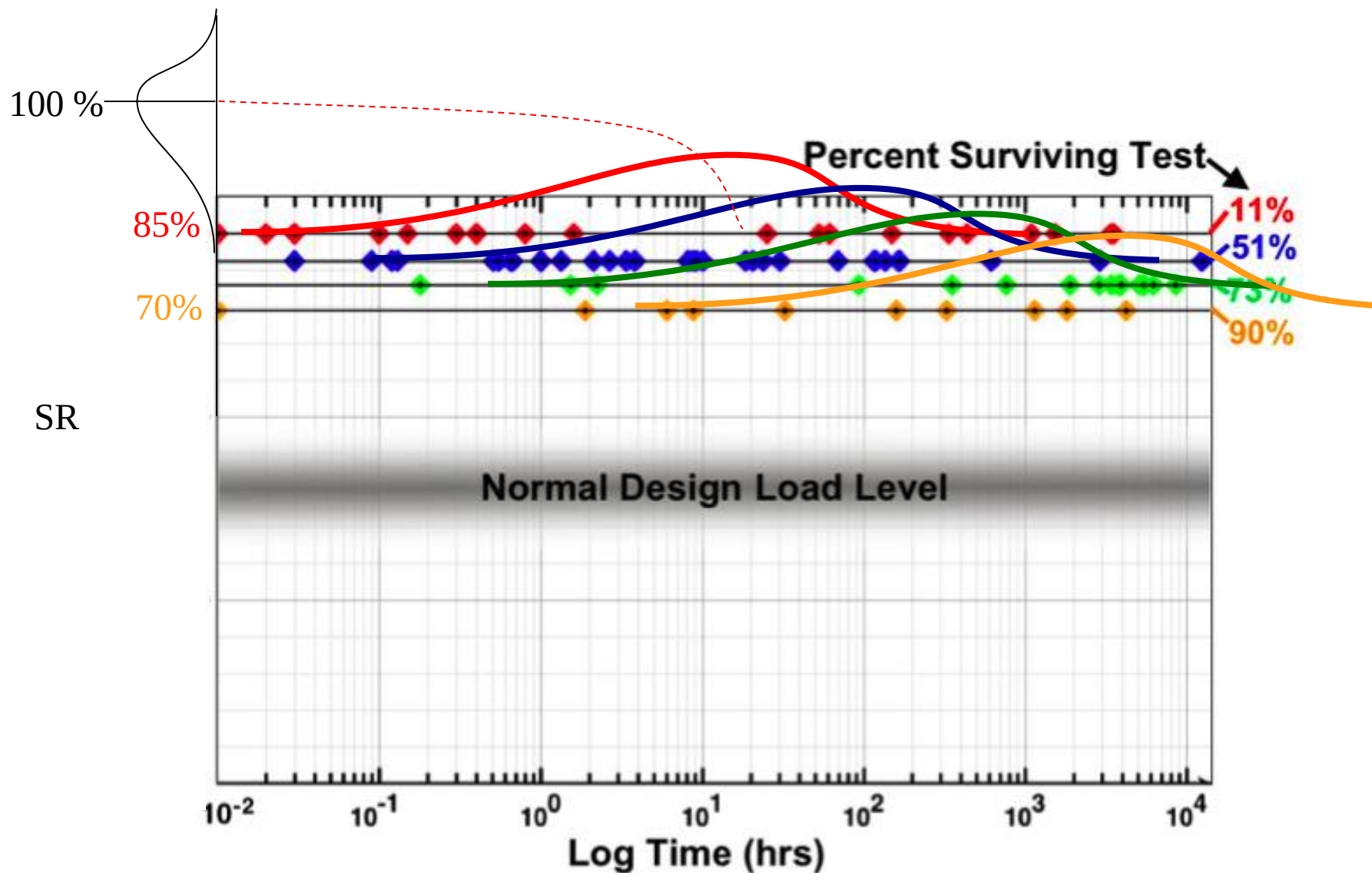
Classic Model



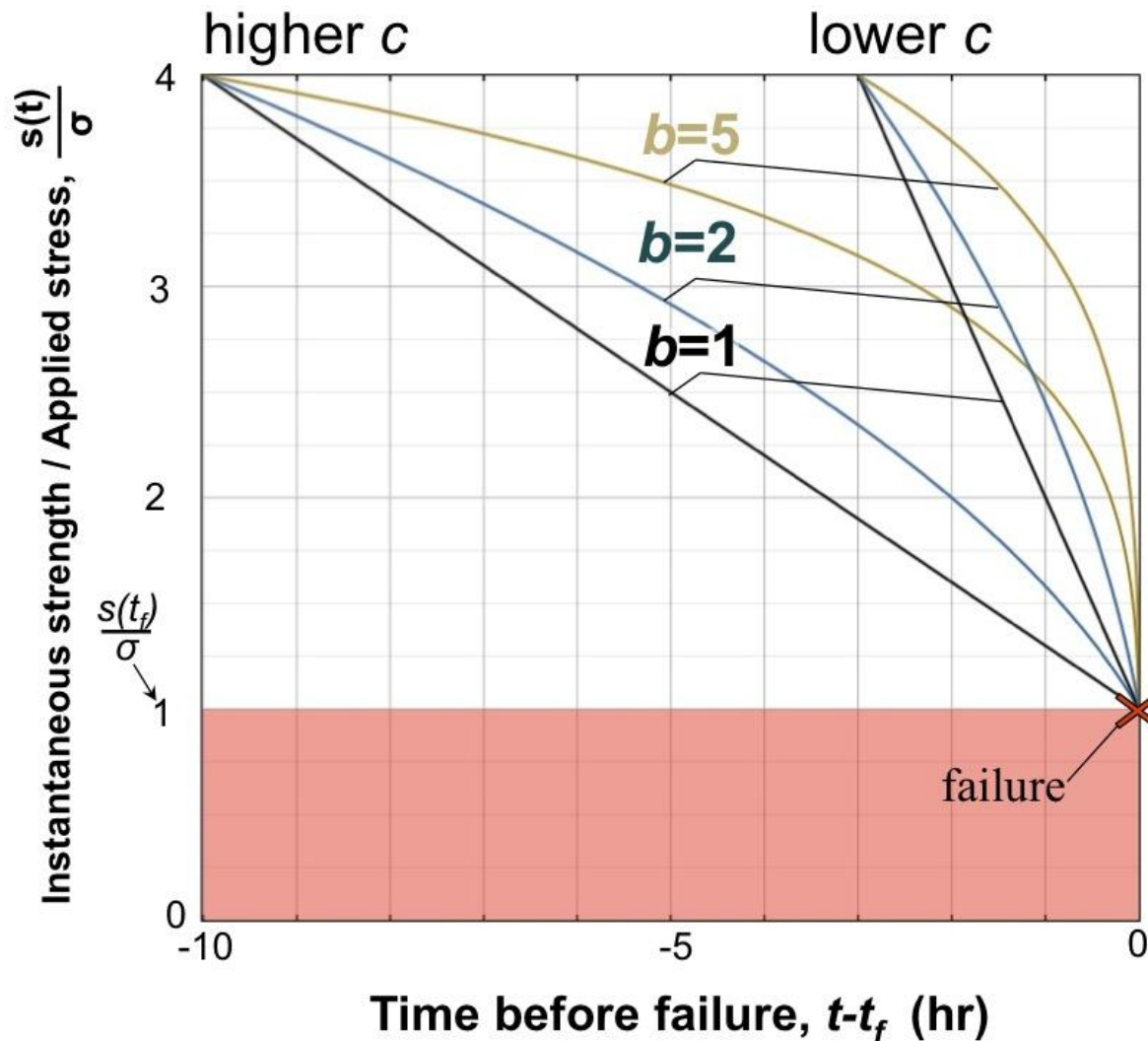
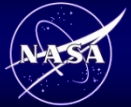
Creep Rupture Data



Strength Decay



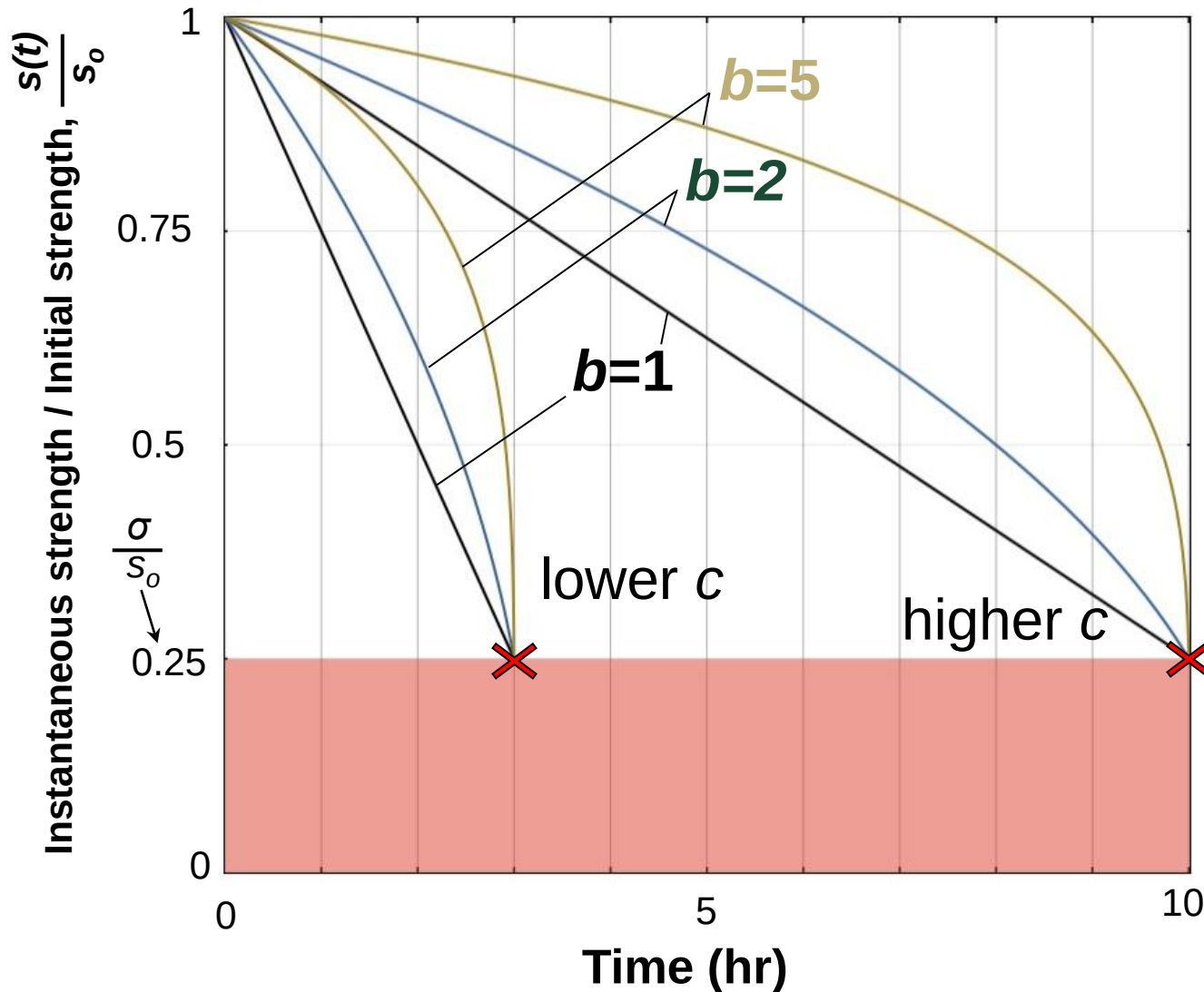
Strength Decay



$$\frac{s(t)}{\sigma} = \frac{1}{c} \left(1 - \frac{t - t_f}{c} \right)^{\frac{1}{b}}$$

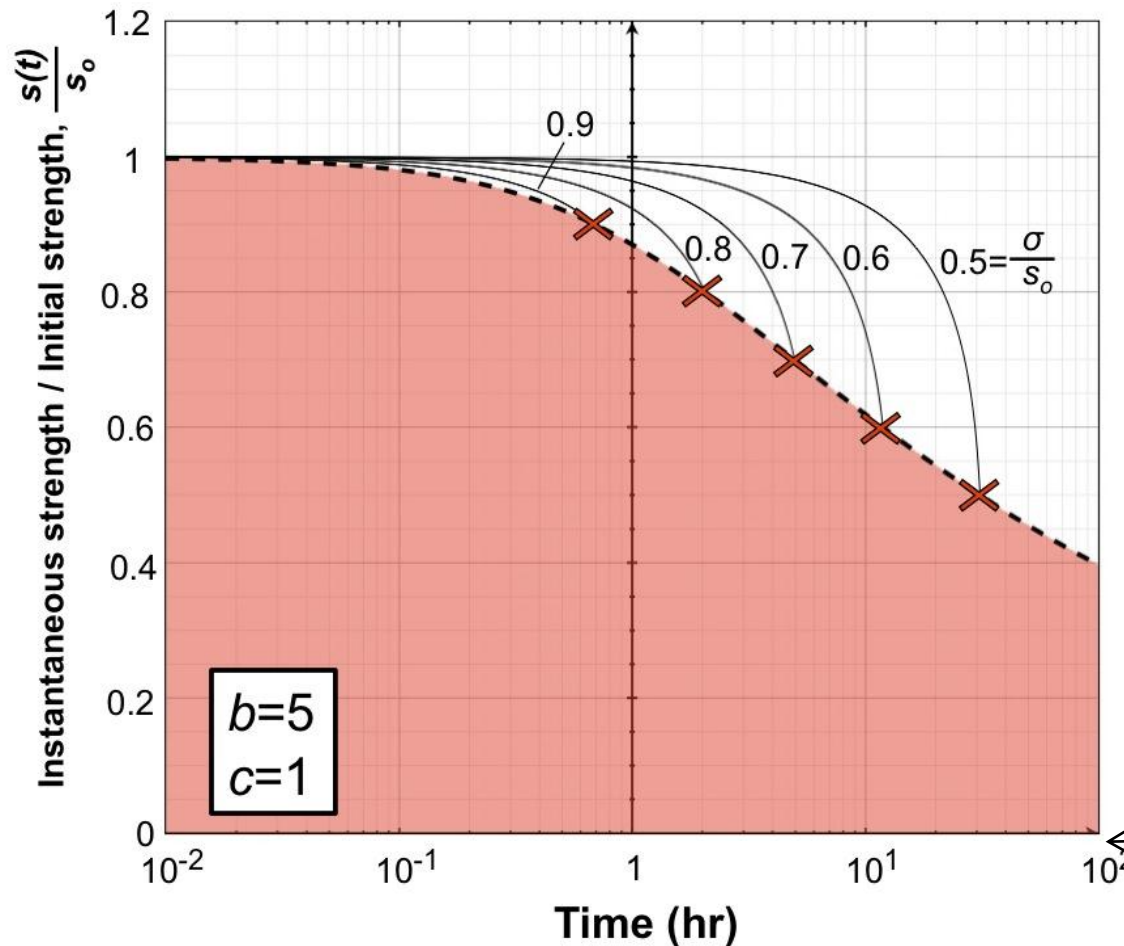
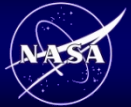
Decrease in strength accelerates as strength approaches stress level.

Strength Decay



$$\frac{s(t)}{s} = \frac{1}{c} \left(1 - \frac{t - t_f}{c} \right)^{\frac{1}{b}}$$

Time to Failure at Various Stress Levels

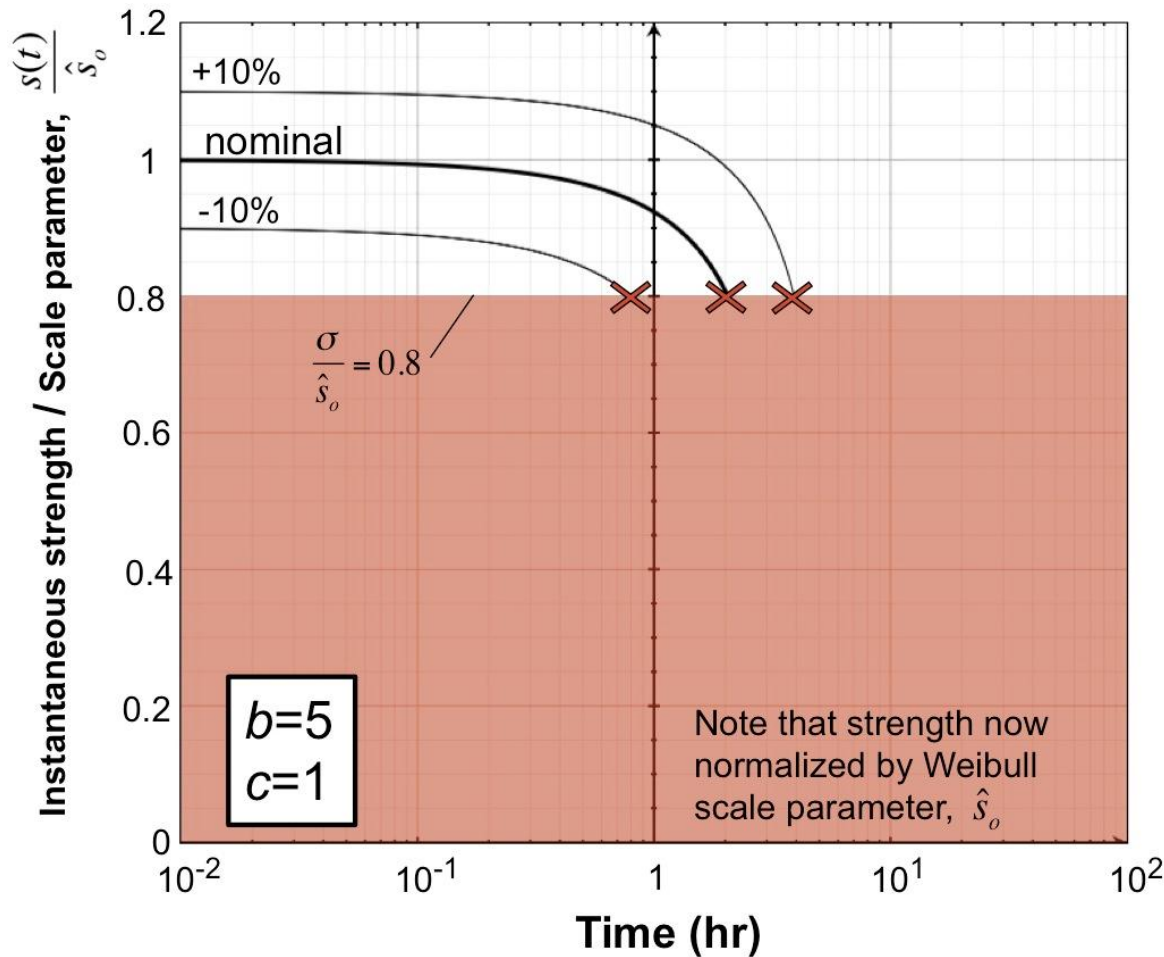


Most strength decay occurs late in life

Might explain why strength tests following stress rupture did not detect a strength loss

Notice log scale

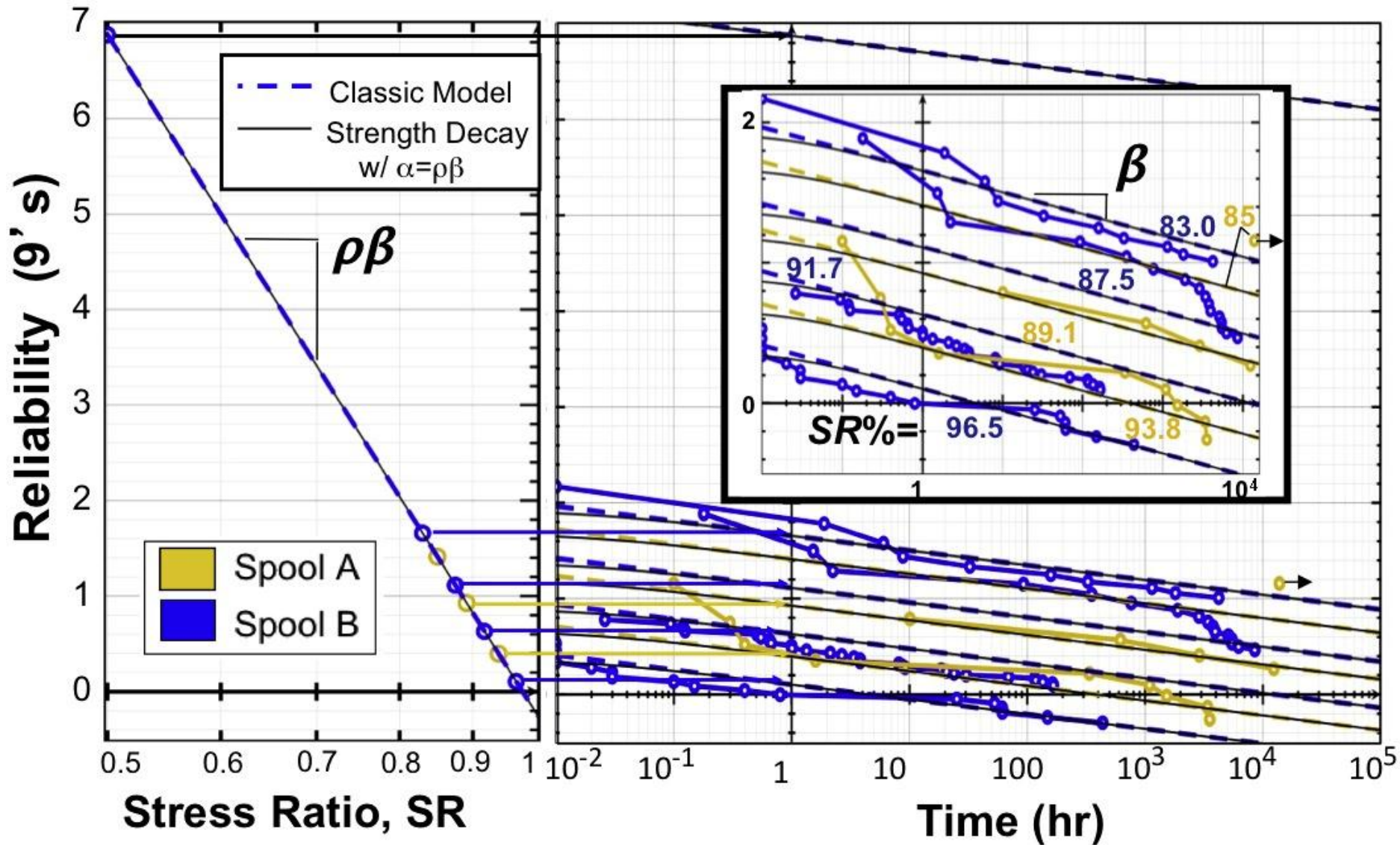
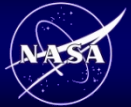
Initial Strengths Are Not All the Same



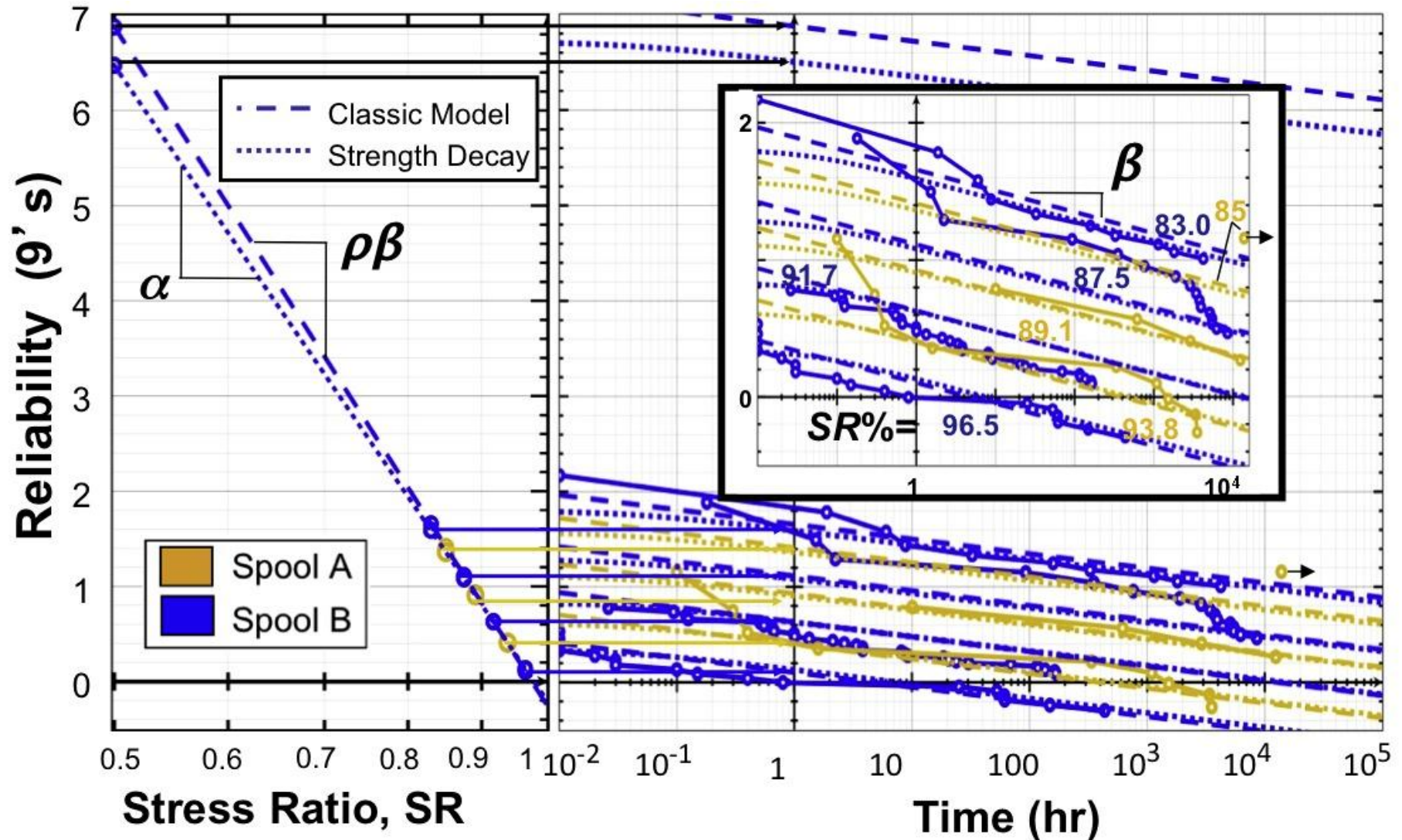
We actually start with a distribution of strengths

$$R(t) = P(t_f > t) = e^{-\frac{1}{c} \left(\frac{t}{\hat{s}_0} \right)^{\frac{b}{c}}} = e^{-\frac{1}{c} \left(\frac{t}{\hat{s}_0} \right)^{\frac{b}{c}}}$$

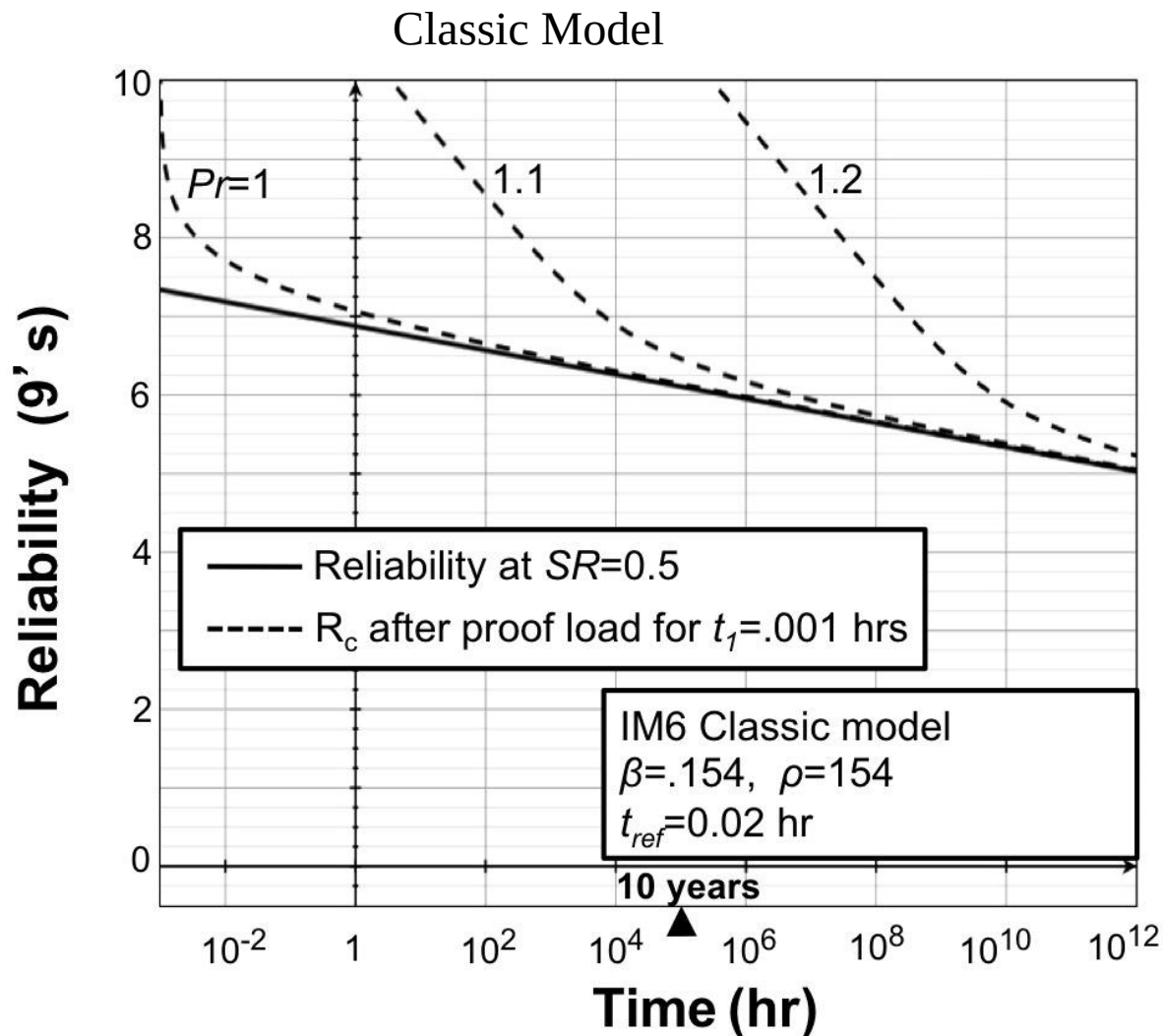
IM6 Data $\alpha=\rho\beta$



IM6 Data α =strength shape parameter

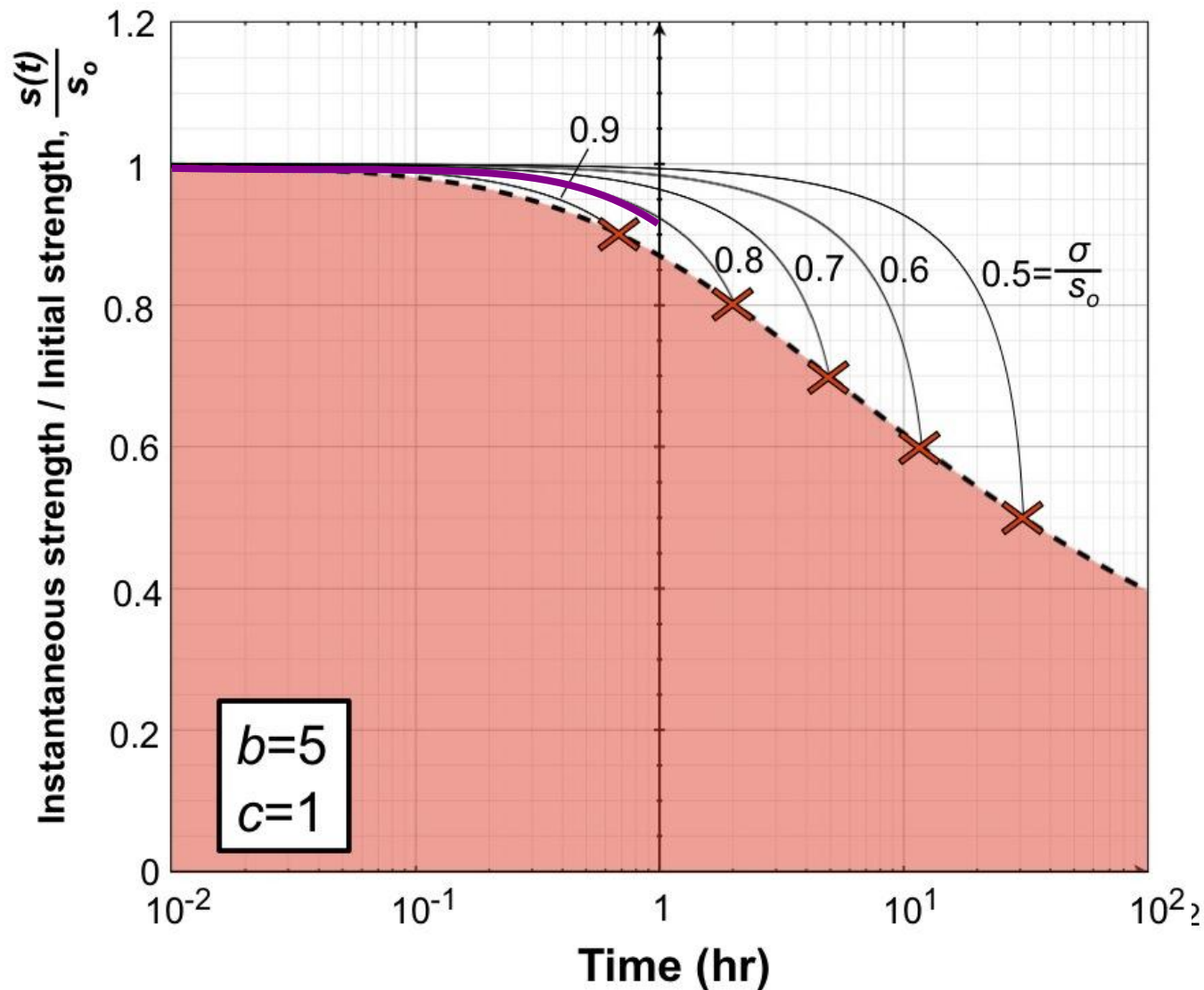
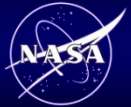


Effect of Proof Loading



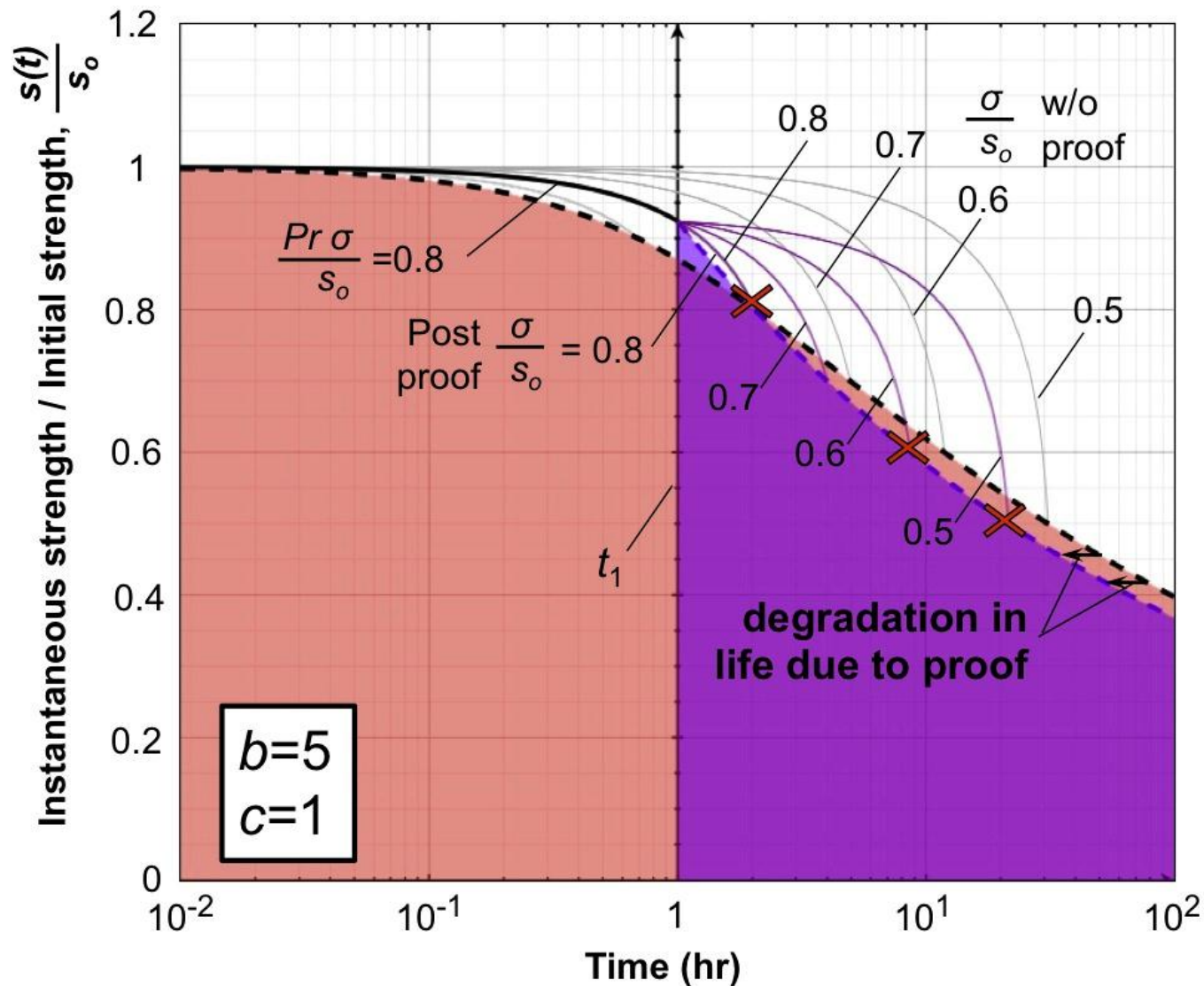
Conditional Reliability

Strength Decay Following Proof



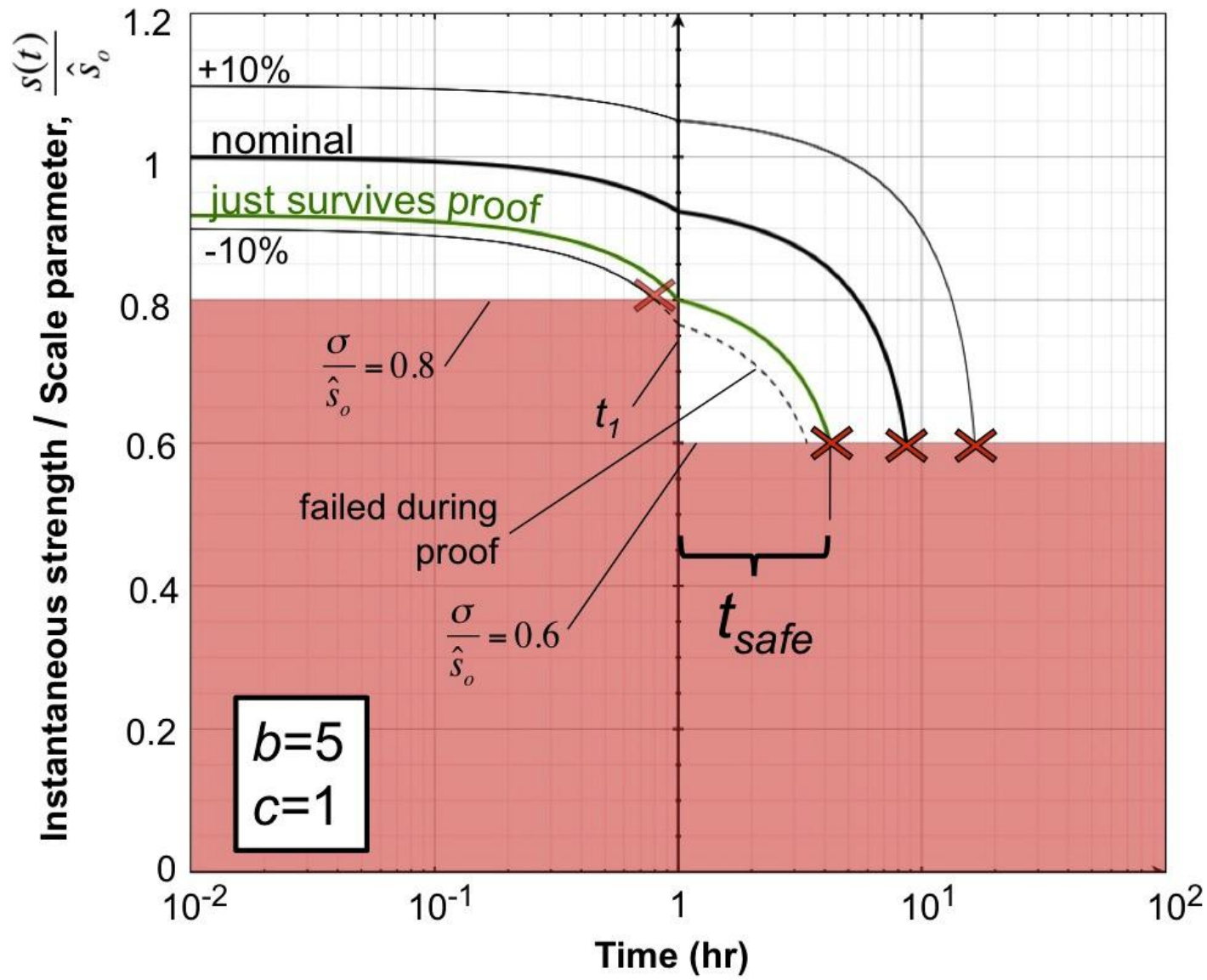
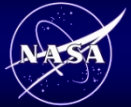
$$\frac{s(t)}{s} = \frac{\sigma}{c} \left(1 - \frac{t - t_f}{c} \right)^{\frac{1}{b}}$$

Strength Decay Following Proof

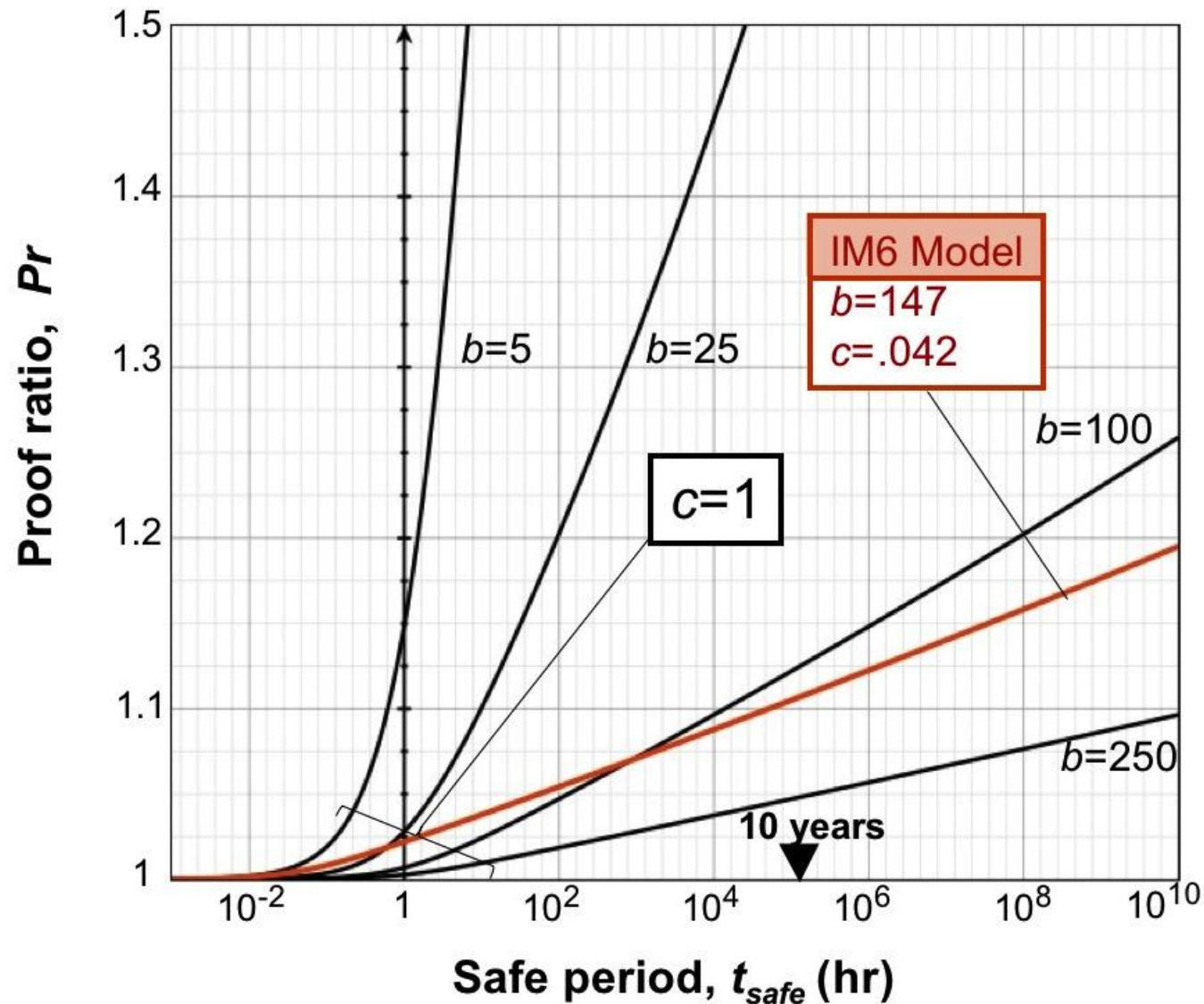
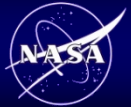


$$\frac{s(t)}{s} = \frac{a}{c} \left(1 - \frac{t - t_f}{c} \right)^{\frac{1}{b}}$$

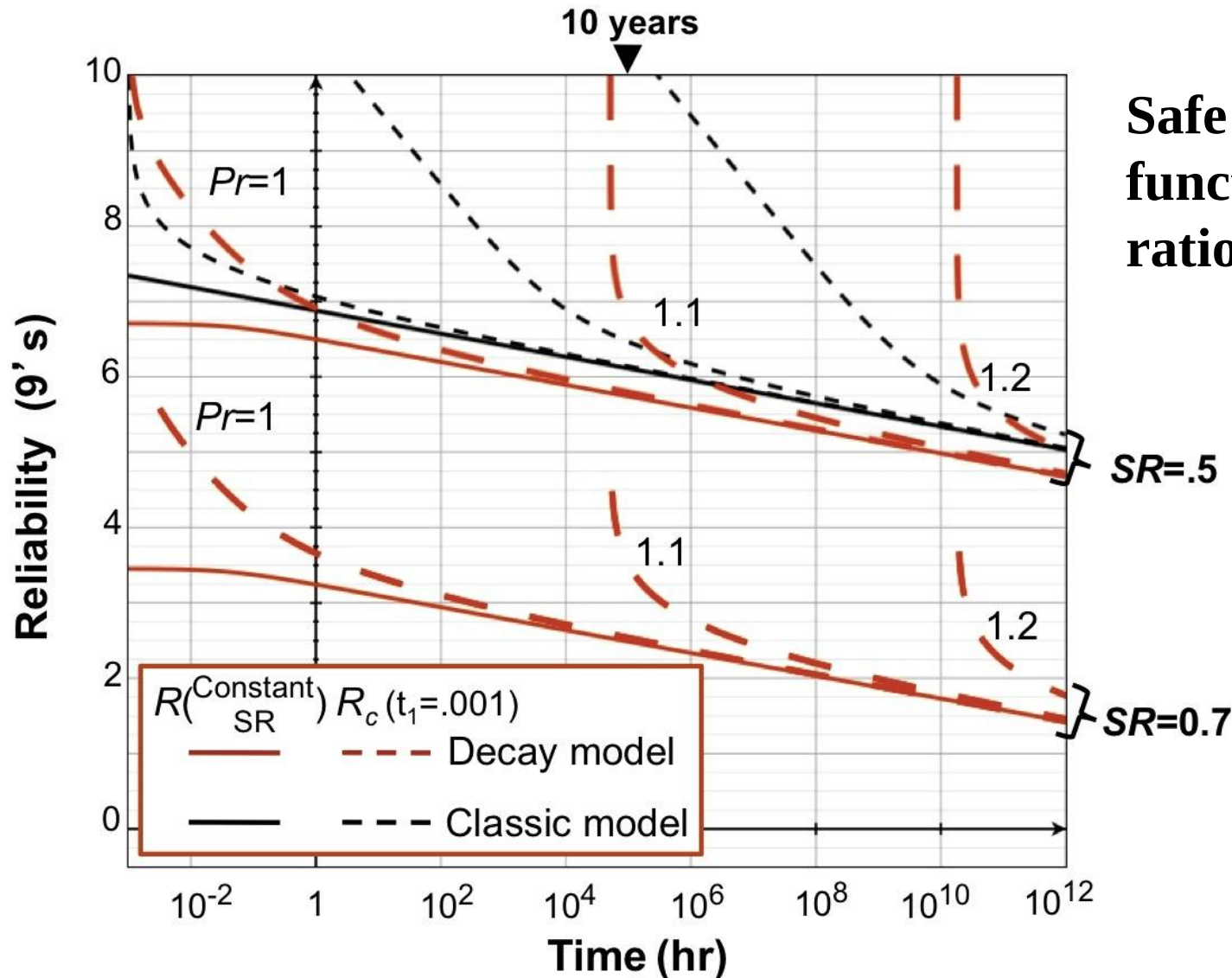
Safe Period



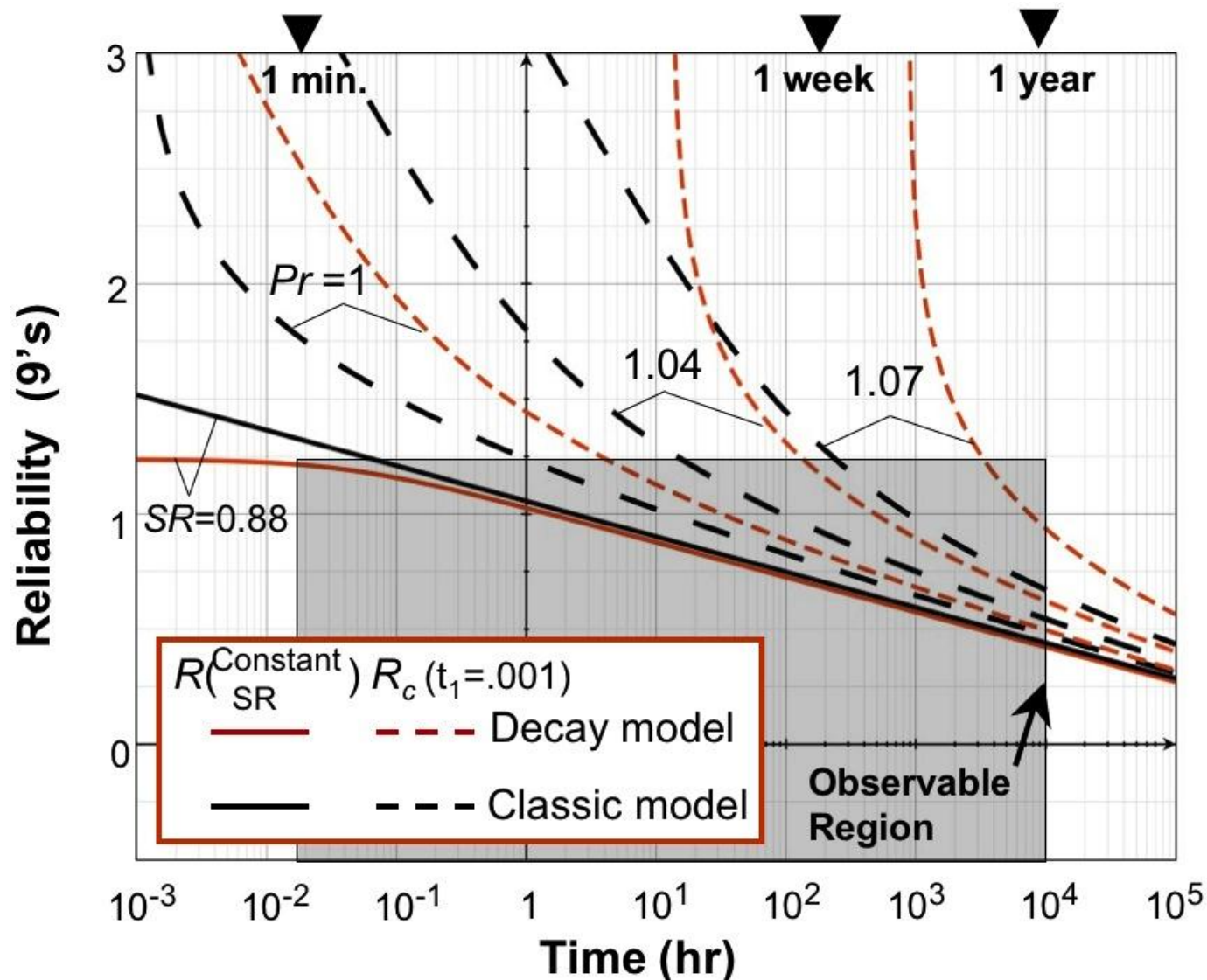
Length of Safe Period



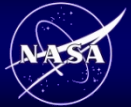
Proofed Reliabilities



How Can We Test the Theory



Proposed Study



Proof Level	Operating Stress	Proof Ratio	Number of Specimens					Time, hrs	
SR_p	SR	Pr	Initial	survive proof	on test	survive testing	$t_1 + t_{safe}$	$t_{first failure}$	end
Strength Tests									
Strength			30						
Stress Rupture Tests									
88%	88%	1	21	20	5	15	0.001	1	10,000
95.0%	88%	1.04	23	20	4	16	13.4	60	10,000
99.4%	88%	1.07	26	20	2	18	876	2024	10,000

100 specimens tested for about a year

Conclusion



- ◆ New model proposed based on strength decay
- ◆ Produces same expected result as classic model for single stress time on test
- ◆ Produces significantly improved reliabilities following proof load including substantial safe periods
- ◆ Accounts for the damaging effect of proof loading
- ◆ Consistent with no measurable strength decay following stress rupture testing
- ◆ Study of reasonable size can be used to test the theory