VCSEL reliability analysis for technical feasibility assessment

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Introduction to reliability criteria

Reliability and unreliability

- Reliability is defined as the probability that a system or component will function over some time period *t*. Let *T* be the time to failure a continuous random variable, then reliability is defined as:

$$R(t) = \Pr\{T \geq t\}, \; R(t) \geq 0 \text{ for } \forall t \geq 0, \; R(0) = 1, \; \lim_{t \to \infty} R(t) = 0$$

- For a given *t*, *R(t)* is the probability that time to failure *T* is greater or equal to *t*
- Unreliability is then defined as:

$$F(t) = 1 - R(t) = \Pr\{T < t\}, \; F(t) \geq 0 \text{ for } \forall t \geq 0, \; F(0) = 0, \; \lim_{t \to \infty} F(t) = 1$$

- For a given *t*, *F(t)* is the probability that failure occurs before *t*
- *F(t)* is the cumulative distribution function (CDF) of the failure probability

Failure probability density function

- Let's define *f(t)* as the failure probability density function (PDF) as:

$$f(t)=\frac{dF}{dt}(t)=-\frac{dR}{dt}(t),\ f(t)\geq 0 \text{ for } \forall t\geq 0,\ \int_0^\infty f(\tau)d\tau=1$$

$$F(t)=\int_0^t f(\tau)d\tau$$

$$R(t)=\int_t^\infty f(\tau)d\tau$$

- Based on the previous definitions, we have:

$$MTTF=\int_0^\infty \tau f(\tau)d\tau$$

$$TTF_{1\%}=F^{-1}(0.01)$$

$$TTF_{50\%}=F^{-1}(0.5)$$

Reliability criteria: failure-rate

- Let's define the conditional probability of a failure in a period of time *Δt* provided the system or component has survived operation time *t*:

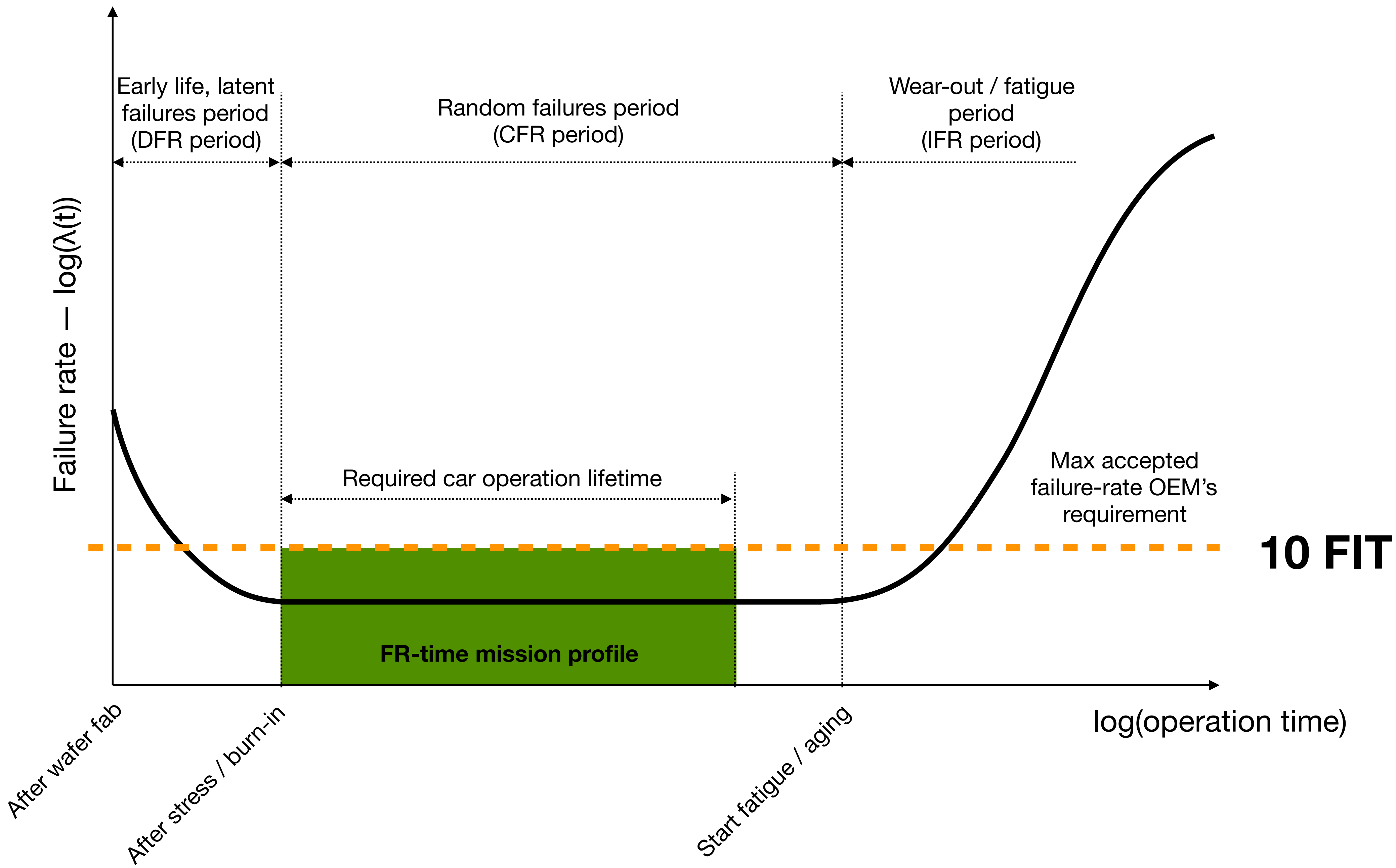
$$\Pr\left\{t \le T \le t+\Delta t \middle| T \ge t\right\} = \frac{F\left(t+\Delta t\right)-F\left(t\right)}{R\left(t\right)}$$

- Failure rate is defined as this conditional probability per unit time:

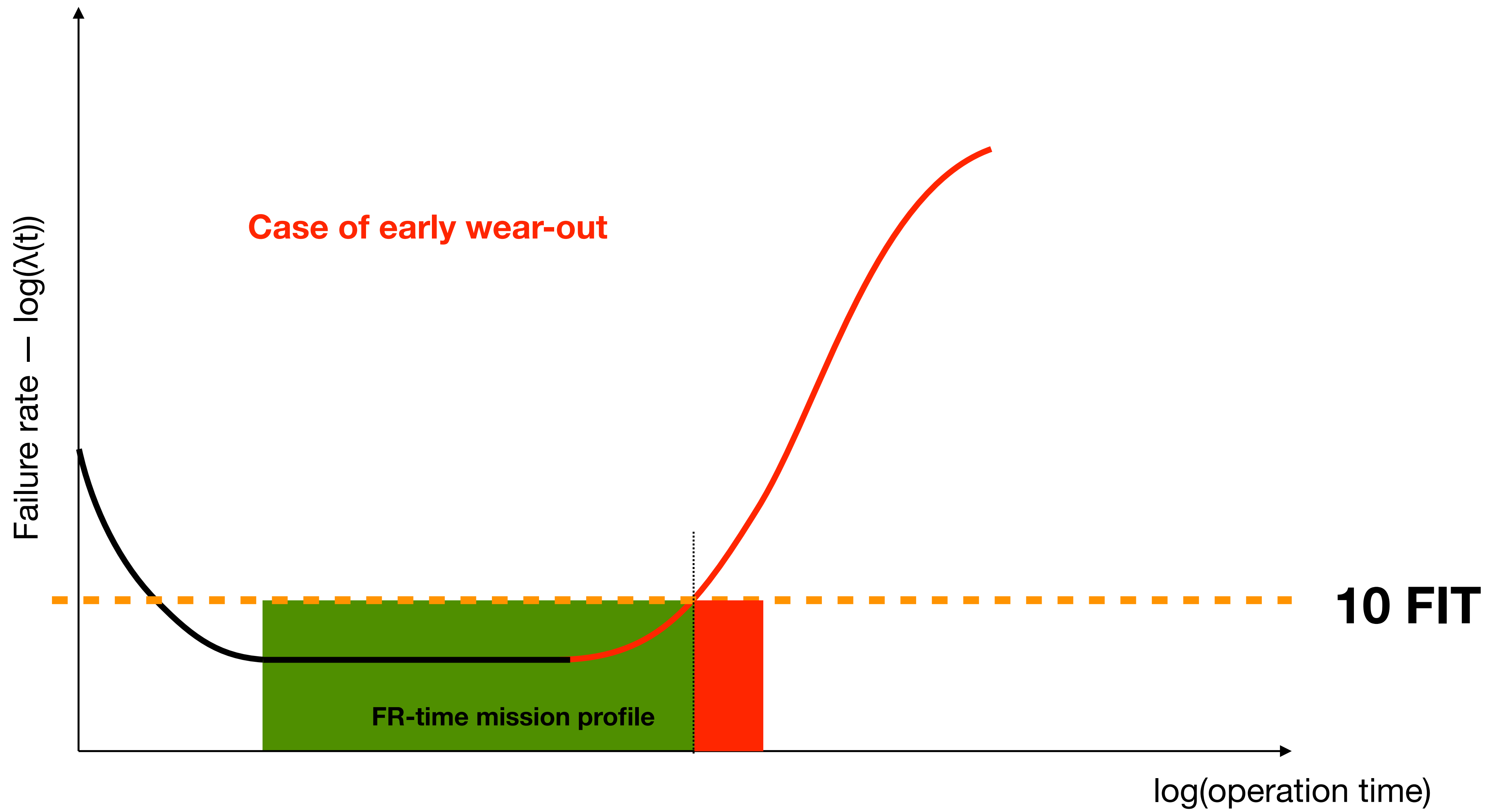
$$\lambda\left(t\right)=\lim_{\Delta t\to 0}\frac{F\left(t+\Delta t\right)-F\left(t\right)}{R\left(t\right)\Delta t}=\frac{dF\left(t\right)}{dt}\frac{1}{R\left(t\right)}=\frac{f\left(t\right)}{R\left(t\right)}=-\frac{d\ln\left(R\left(t\right)\right)}{dt}$$

- Pay attention that in general *λ(t)* is not constant and depends on how much time the component has survived in operation
- Failure-rate is typically measured in Failures In Time (FIT), number of failures per 10^9 (billion) device-hours
  - 1 FIT = probability of failure is 10^{-9} / 1 hour (operation)
  - 1 FIT = probability of failure is 1 ppm / 1000 hours
  - 1 FIT = 1 failure per 1000 devices operating 1 million hours

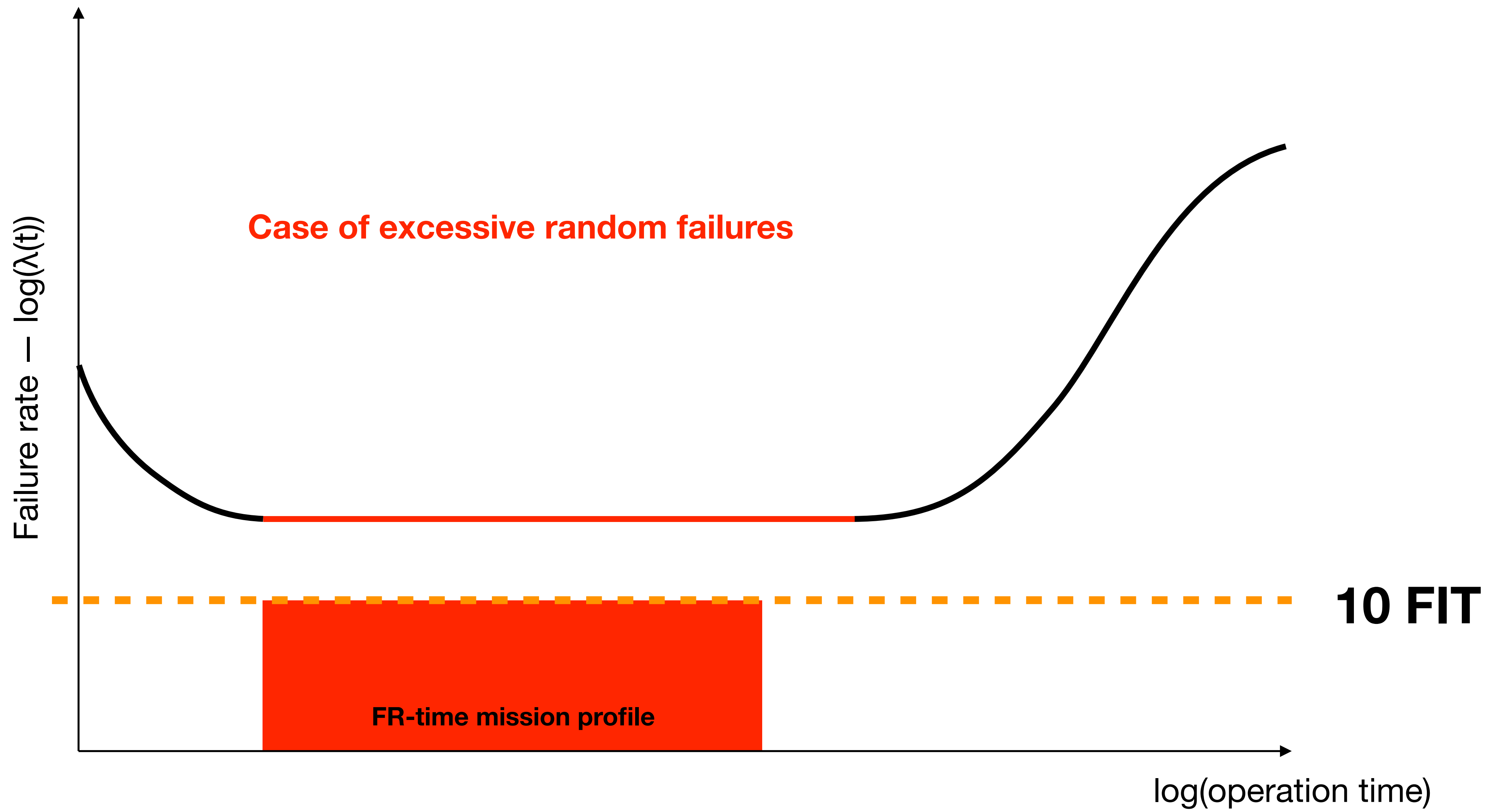
Reliability requirements: max accepted $\lambda(t)$



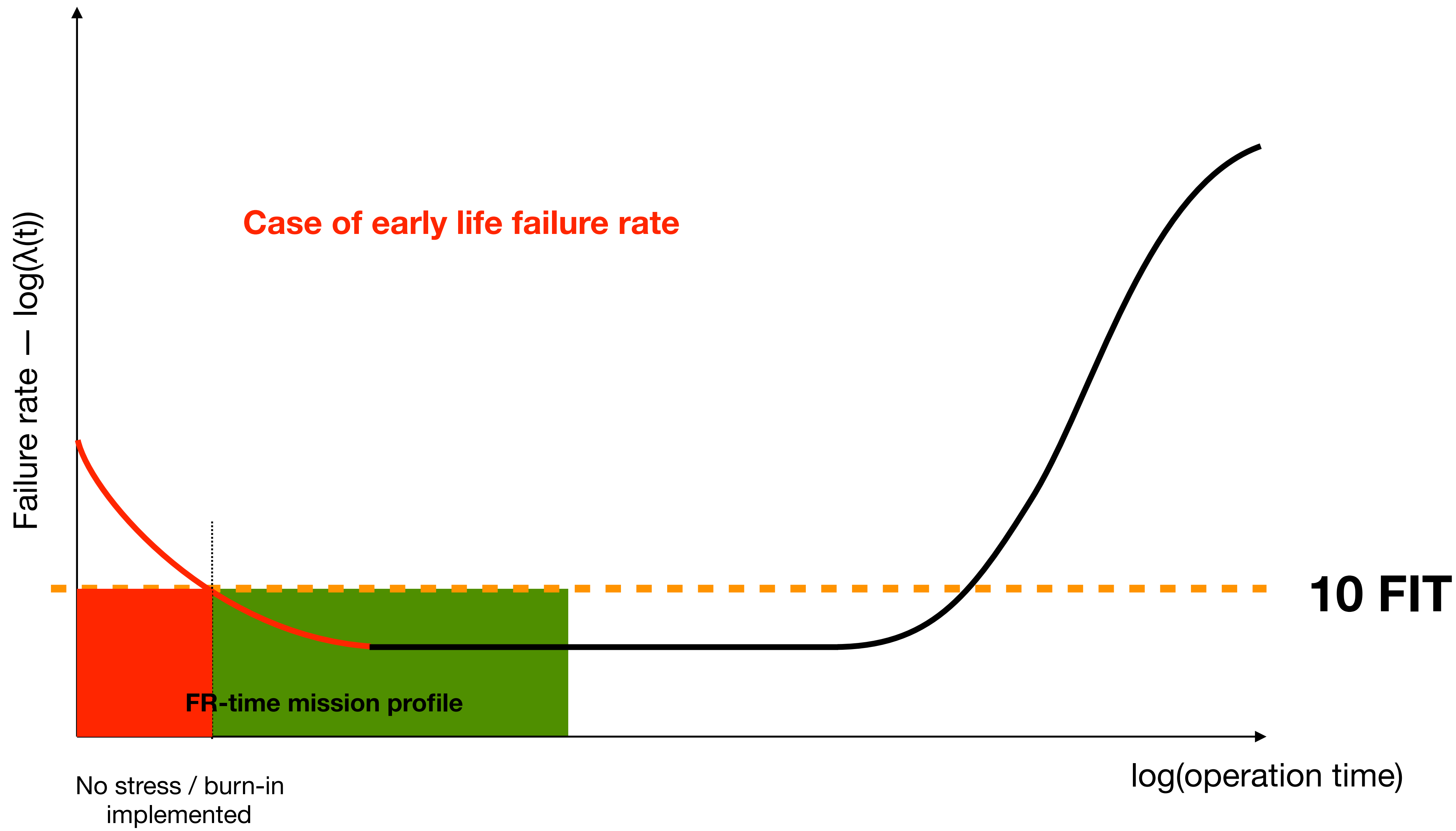
Not meeting reliability requirements



Not meeting reliability requirements



Not meeting reliability requirements



VCSEL reliability

VCSEL reliability

- The presented reliability analysis will be based on the reliability measurements reports given in the following publications for InGaAs 28G VCSEL designs:
  - [1] Thomas R. Fanning et al, ”28-Gbps 850-nm oxide VCSEL development and manufacturing progress at Avago," Proc. SPIE 9001, Vertical-Cavity Surface-Emitting Lasers XVIII, 900102 (27 February 2014); doi: 10.1117/12.2039499
  - [2] J R Kropp et al, “Accelerated aging of 28 Gb s^{-1} 850 nm vertical-cavity surface-emitting laser with multiple thick oxide apertures,” 2015 Semicond. Sci. Technol. 30 045001
  - [3] James Guenter et al, "The range of VCSEL wearout reliability acceleration behavior and its effects on applications," Proc. SPIE 8639, Vertical-Cavity Surface-Emitting Lasers XVII, 86390I (13 March 2013); doi: 10.1117/12.2002840
  - [4]: Jingyi Wang et al, "28 Gb/s 850 nm oxide VCSEL development at Avago," Proc. SPIE 8639, Vertical-Cavity Surface-Emitting Lasers XVII, 86390K (13 March 2013); doi: 10.1117/12.2004521
- The VCSEL reliability analysis for in-vehicle applications will be based on the J and T accelerated aging (wear-out) tests reported in [1] and [2]
- Regarding to crystallographic dislocation and sudden failures it is stated:
  - [1]: *“**Gradual degradation in optical output power** (or gradual increase in threshold current) was the primary mode of failure observed. **No crystal dislocations were found in the degrading VCSELs**. The rate at which the output power decreases is relatively uniform across the population from each wafer, as shown in Figure 5.1, indicating a consistent wearout behavior for each of the devices.”*
  - [2]: *“**Catastrophic random defects (‘sudden death’)**, which can be caused by **dislocation** growth in GaAs, or as a consequence of electrostatic discharge or other process and handling related damage [14], **have not been observed in any of the stress groups**”*
  - [3]: *“wearout failures were verified by electrical signature and by TEM to be **dislocation-free**”*
- Based on these reports, we can assume that random failures are not a reliability problem, provided that burn-in is conducted to eliminate latent defects that would produce ELFR

VCSEL wear-out statistics — lognormal PDF

- Many publications on VCSEL reliability have demonstrated that the aging failures are produced according to a lognormal distribution of time
  - This is very different of the general consideration of exponential distribution used in complex CMOS integrated circuits (λ is constant)
- Because VCSEL lifetime statistics follow a lognormal distribution, λ is not constant
- Lognormal PDF is defined as:

$$f\left(t'\right)=\frac{1}{\sigma'\sqrt{2\pi}}\exp\left(-\frac{1}{2}\left(\frac{t'-\mu'}{\sigma'}\right)^{2}\right)$$

  where:
  - *t'* is the natural logarithm of the time to failure
  - *μ'* mean of the natural logarithms of the time to failure
  - *σ'* standard deviation of the natural logarithms of the time to failure
- Therefore, the unreliability function is:

$$F\left(t\right)=\Phi\left(\frac{\ln\left(t\right)-\mu'}{\sigma'}\right)$$

  where *Φ* is the standard normal distribution (i.e. *N*(0,1))

VCSEL wear-out reliability model

- Reliability model is as follows. The time to failure is reduced with temperature (T) according to Arrhenius's equation and with a negative power of the average current density (J):

$$TTF_{x\%} = C \cdot J^{-n} \cdot \exp\left(\frac{E_a \cdot e}{k_B \cdot T}\right)$$

where:

  - E_a is the activation energy of failure mechanism (eV)
  - e is the electron charge (SI units)
  - k_B is the Boltzmann's constant (SI units)
  - T is absolute temperature (Kelvin)
  - C is a constant
  - $TTF_{x\%}$ is the time to x% failures (e.g. in hours)

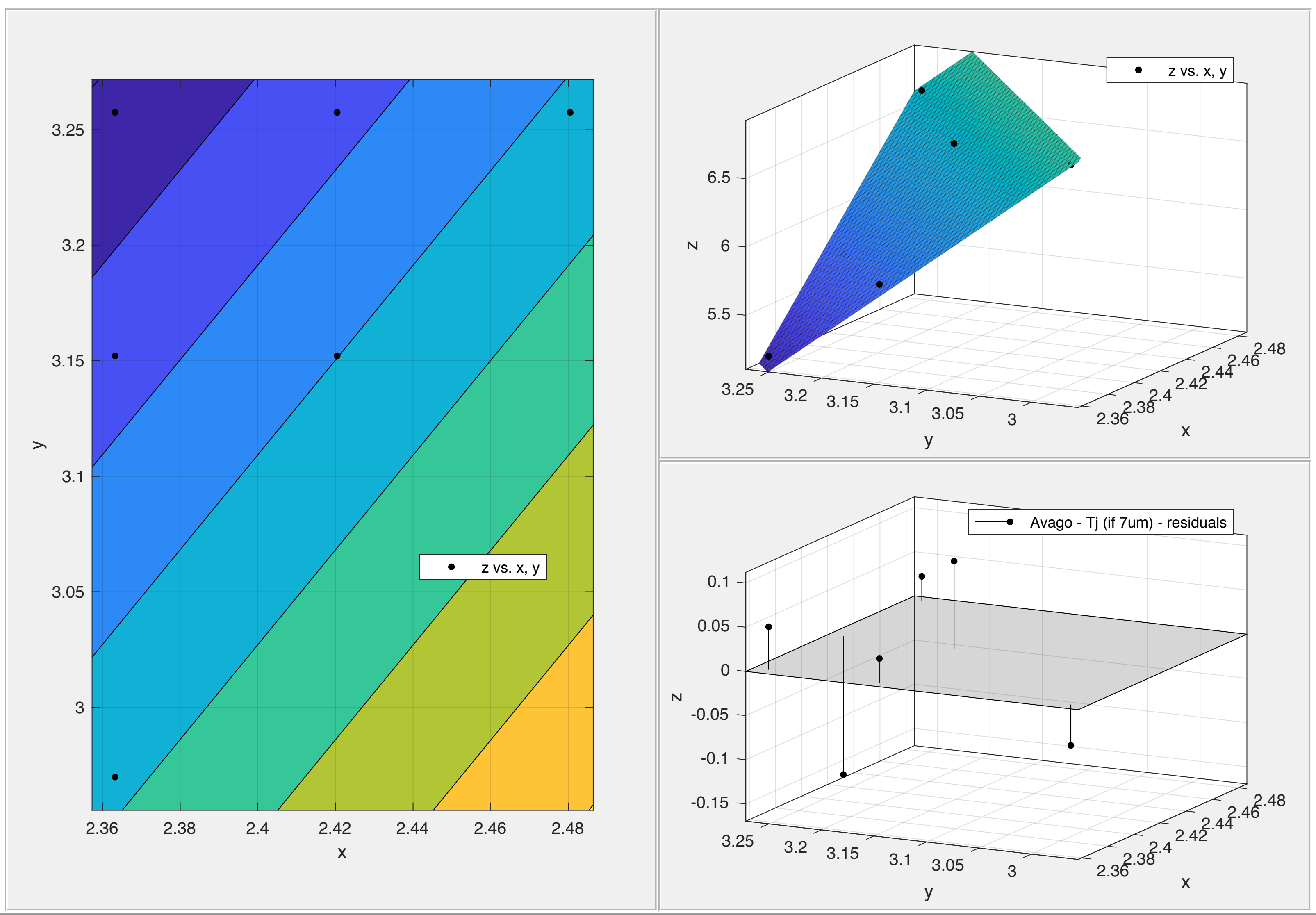
- Reliability model can be built on T_J (junction or active region temperature) or it can be built on T_S (substrate or heat-sink temperature, direct to measure)

- For fitting procedures, it is convenient from numerical stability point of view to consider the following equivalent expression:

$$\ln\left(TTF_{x\%}\right) = \ln\left(C\right) - n \cdot \ln\left(J\right) + \frac{E_a \cdot e}{k_B} \cdot \frac{1}{T}$$

VCSEL wear-out analysis based on [1]

- External assumption: oxide aperture diameter of 7 um
  - Based on the bandwidths and bias currents reported in [4] for the same VCSEL design, the diameter is estimated to get similar bandwidth per current densities reported in other papers for compressively strained InGaAs MQW VCSELs (e.g. [2])
- From Figure 5.2, $TTF_{50\%}$ and $TTF_{15.85\%}$ are extracted for each test condition in the stress matrix
  - Reliability model based for $TTF_{50\%}$ and T_J is fitted
  - Lognormal shape (σ') is calculated from $TTF_{50\%}$ and $TTF_{15.85\%}$ of each stress condition and considered the maximum one



$$z = \ln(C) - n \cdot y + \frac{E_a \cdot e}{1000 \cdot k_B} \cdot x$$

$$z = p_{00} + p_{01} \cdot y + p_{10} \cdot x$$

$$E_a = 1.075 \text{ eV}$$

$$n = 6.084$$

$$C = 1.070547E-02$$

$$\sigma' = 0.32 \ln(\text{hours})$$

VCSEL wear-out analysis based on [1]

VCSEL is biased as in data-centers applications

Reliability parameters

Operation	Operation total time (h)	32000	Reliability model	Wear-out Ea (eV) @ T_J	1.075
	Service life (years)	15		Wear-out n @ T_J	6.084
	Min oxide aperture diam. (um)	7.0		Arrhenius C factor (hours) @ T_J	1.070547E-02
	I_{OP} (mA) max	7.50		TTF x%	50
	J_{OP} (kA/cm^2)	19.50		Log-normal σ', ln (hours)	0.32
	V_F (V) w/c	2.0		Qe	1.6022E-19
	P_{opt} (mW) w/c	0.2		K_B	1.3806E-23
	P_{DIS} (mW)	14.80		Qe/K_B	1.1605E+04
	R_{JS} (K/W) W/C	2500		ºC to Kelvin	273.15
	ΔT_{AS} (ºC)	20			

Reliability result

	Temperature profile					Failure rate					
	Percentage	Time per Temperature (h)	T_A (ºC)	T_S (ºC)	T_J (ºC)	TTF 50% (hours)	TTF 50% (years)	Equivalent time in max T (hours)	Log-normal mu', ln (hours)	Failure-rate upper bound (FIT)	ppm / year (op)
T_0	**6 %**	1920	**-40**	-20	17.0	7.253E+08	8.280E+04	0.00	20.4021		
T_1	**20 %**	6400	**23**	43	80.0	3.375E+05	3.852E+01	8.21	12.7293		
T_2	**65 %**	20800	**50**	70	107.0	2.743E+04	3.131E+00	328.16	10.2194		
T_3	**8 %**	2560	**100**	120	157.0	6.040E+02	6.895E-02	1834.28	6.4035		
T_4	**1 %**	320	**105**	125	162.0	4.328E+02	4.940E-02	320.00	6.0702		
Cummulative		32000						**2490.64**	**6.0702**	**7078023.0**	**15099782.38**

VCSEL wear-out analysis based on [1]

Max current density with VCSEL of [1] to meet FIT ≤ 10

Reliability parameters

Operation	Operation total time (h)	32000	Reliability model	Wear-out Ea (eV) @ T_J	1.075
	Service life (years)	15		Wear-out n @ T_J	6.084
	Min oxide aperture diam. (um)	7.0		Arrhenius C factor (hours) @ T_J	1.070547E-02
	I_{OP} (mA) max	5.0766		TTF x%	50
	J_{OP} (kA/cm^2)	13.20		Log-normal σ', ln (hours)	0.32
	V_F (V) w/c	2.0		Qe	1.6022E-19
	P_{opt} (mW) w/c	0.2		K_B	1.3806E-23
	P_{DIS} (mW)	9.9532		Qe/K_B	1.1605E+04
	R_{JS} (K/W) W/C	2500		ºC to Kelvin	273.15
	ΔT_{AS} (ºC)	20			

Reliability result

	Temperature profile					Failure rate					
	Percentage	Time per Temperature (h)	T_A (ºC)	T_S (ºC)	T_J (ºC)	TTF 50% (hours)	TTF 50% (years)	Equivalent time in max T (hours)	Log-normal mu', ln (hours)	Failure-rate upper bound (FIT)	ppm / year (op)
T_0	6 %	1920	-40	-20	4.9	5.079E+10	5.798E+06	0.00	24.6509		
T_1	20 %	6400	23	43	67.9	1.273E+07	1.453E+03	5.32	16.3592		
T_2	65 %	20800	50	70	94.9	8.685E+05	9.915E+01	253.19	13.6746		
T_3	8 %	2560	100	120	144.9	1.505E+04	1.718E+00	1798.88	9.6188		
T_4	1 %	320	105	125	149.9	1.057E+04	1.207E+00	320.00	9.2660		
Cummulative		32000						2377.38	9.2660	10.0	21.23

VCSEL wear-out analysis based on [1]

Assuming same reliability model for the characterized InGaAs VCSEL (slow corner)

Reliability parameters

Operation	Operation total time (h)	32000	Reliability model	Wear-out Ea (eV) @ T_J	1.075
	Service life (years)	15		Wear-out n @ T_J	6.084
	Min oxide aperture diam. (um)	7.5		Arrhenius C factor (hours) @ T_J	1.070547E-02
	I_{OP} (mA) max	4.00		TTF x%	50
	J_{OP} (kA/cm^2)	9.06		Log-normal σ', ln (hours)	0.32
	V_F (V) w/c	2.0		Qe	1.6022E-19
	P_{opt} (mW) w/c	0.2		K_B	1.3806E-23
	P_{DIS} (mW)	7.80		Qe/K_B	1.1605E+04
	R_{JS} (K/W) W/C	2500		ºC to Kelvin	273.15
	ΔT_{AS} (ºC)	20			

Reliability result

	Temperature profile					Failure rate					
	Percentage	Time per Temperature (h)	T_A (ºC)	T_S (ºC)	T_J (ºC)	TTF 50% (hours)	TTF 50% (years)	Equivalent time in max T (hours)	Log-normal mu', ln (hours)	Failure-rate upper bound (FIT)	ppm / year (op)
T_0	6 %	1920	-40	-20	-0.5	1.216E+12	1.388E+08	0.00	27.8267		
T_1	20 %	6400	23	43	62.5	2.259E+08	2.579E+04	4.32	19.2356		
T_2	65 %	20800	50	70	89.5	1.418E+07	1.619E+03	223.86	16.4675		
T_3	8 %	2560	100	120	139.5	2.192E+05	2.503E+01	1782.39	12.2979		
T_4	1 %	320	105	125	144.5	1.526E+05	1.742E+01	320.00	11.9358		
Cummulative		32000						2330.57	11.9358	0.0	0.00

VCSEL wear-out analysis based on [1]

Assuming same reliability model for the characterized InGaAs VCSEL (fast corner)

Reliability parameters

Operation	Operation total time (h)	32000	Reliability model	Wear-out Ea (eV) @ T_J	1.075
	Service life (years)	15		Wear-out n @ T_J	6.084
	Min oxide aperture diam. (um)	6.5		Arrhenius C factor (hours) @ T_J	1.070547E-02
	I_{OP} (mA) max	3.00		TTF x%	50
	J_{OP} (kA/cm^2)	9.05		Log-normal σ', ln (hours)	0.32
	V_F (V) w/c	2.0		Qe	1.6022E-19
	P_{opt} (mW) w/c	0.2		K_B	1.3806E-23
	P_{DIS} (mW)	5.80		Qe/K_B	1.1605E+04
	R_{JS} (K/W) W/C	2500		ºC to Kelvin	273.15
	ΔT_{AS} (ºC)	20			

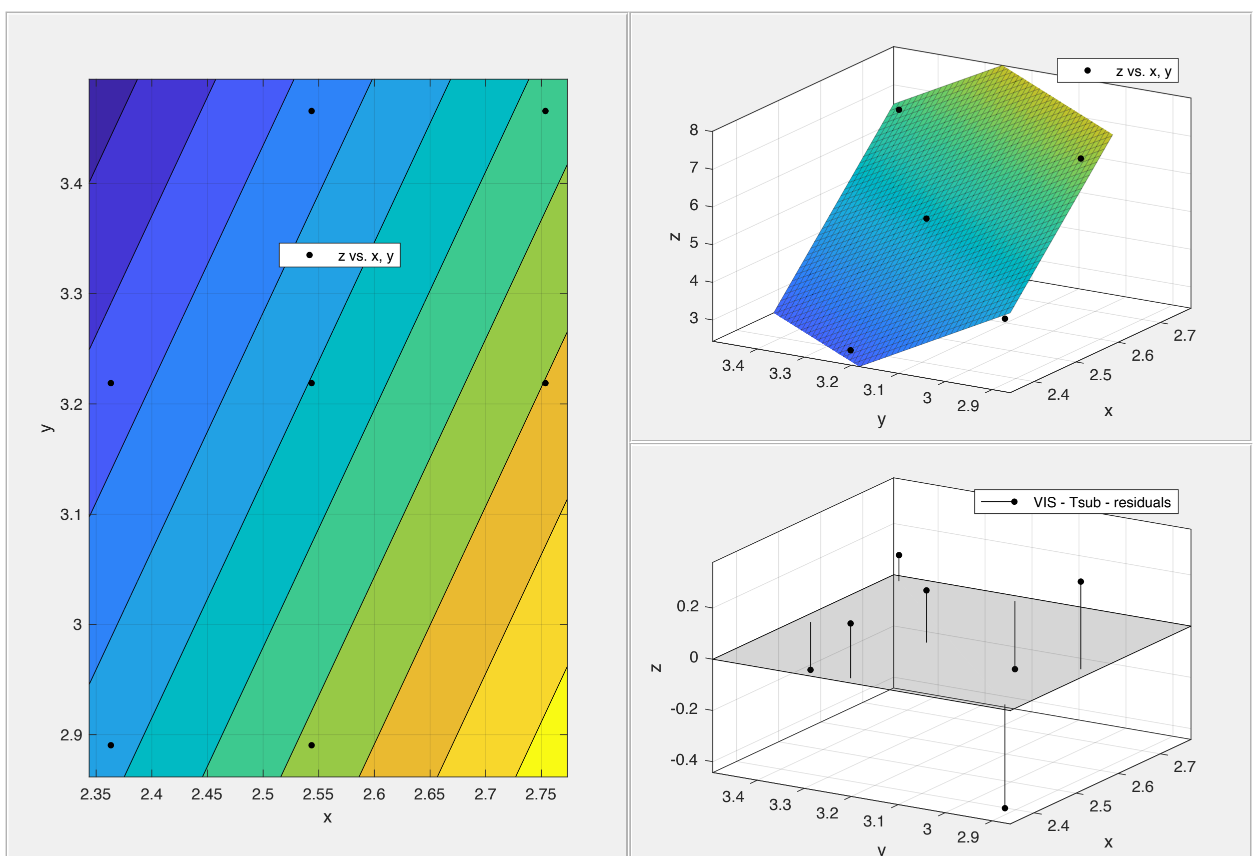
Reliability result

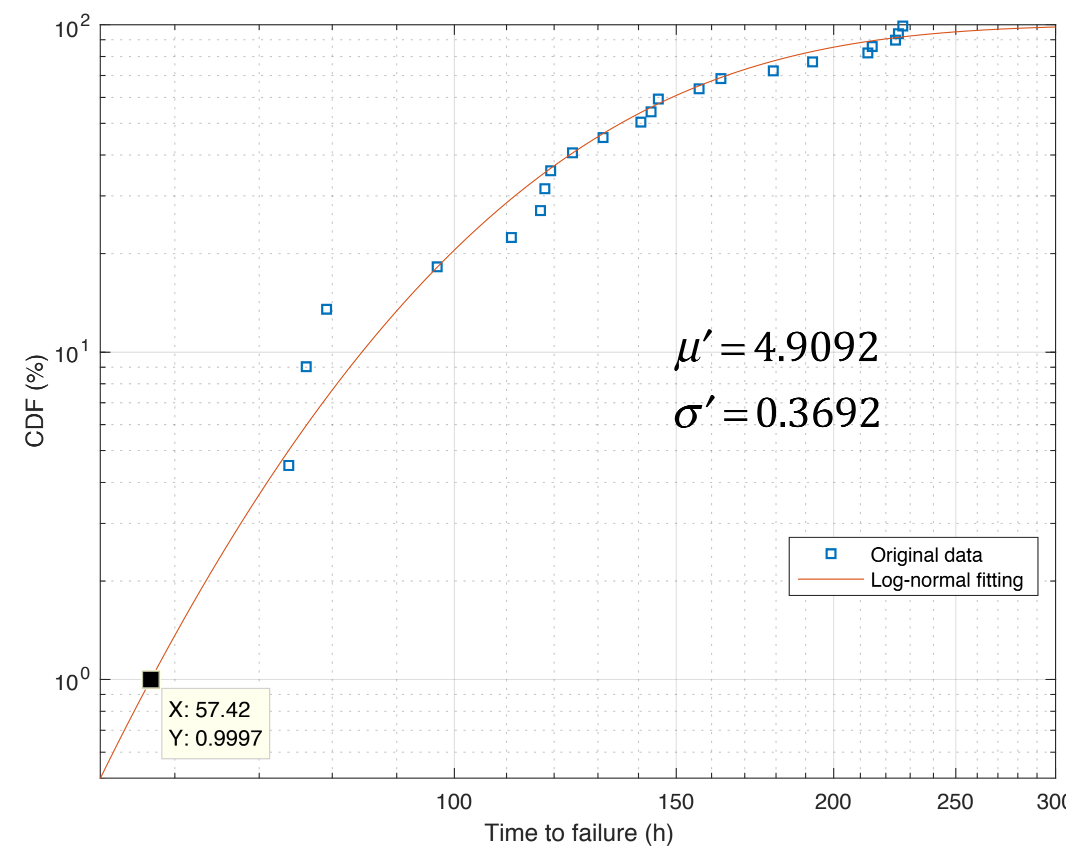
	Temperature profile					Failure rate					
	Percentage	Time per Temperature (h)	T_A (ºC)	T_S (ºC)	T_J (ºC)	TTF 50% (hours)	TTF 50% (years)	Equivalent time in max T (hours)	Log-normal mu', ln (hours)	Failure-rate upper bound (FIT)	ppm / year (op)
T_0	6 %	1920	-40	-20	-5.5	2.886E+12	3.294E+08	0.00	28.6907		
T_1	20 %	6400	23	43	57.5	4.000E+08	4.566E+04	3.54	19.8069		
T_2	65 %	20800	50	70	84.5	2.315E+07	2.643E+03	198.74	16.9576		
T_3	8 %	2560	100	120	134.5	3.206E+05	3.659E+01	1766.63	12.6778		
T_4	1 %	320	105	125	139.5	2.212E+05	2.525E+01	320.00	12.3069		
Cummulative		32000						2288.90	12.3069	0.0	0.00

VCSEL wear-out analysis based on [2]

- From Figure 5, $TTF_{1\%}$ is extracted for each test condition in the stress matrix
  - Reliability model based for $TTF_{1\%}$ and T_S is fitted
- Lognormal CDF is fitted from Figure 4
  - Shape parameter σ’ is considered equal for every stress condition
  - Location parameter μ’ is estimated and correction factor calculated for $TTF_{1\%}$
  - Correction factor is applied to every $TTF_{1\%}$ reported in Figure 5

$$z=\ln\left(TTF_{1\%}\right)=\ln\left(C\right)-n\cdot y+\frac{E_a\cdot e}{1000\cdot k_B}\cdot x,\ E_a=1.225\text{ eV},\ n=6.588,\ C=4.044972E-05$$





VCSEL wear-out analysis based on [2]

VCSEL is biased as in data-centers applications

Parameters for reliability results

Operation	**Operation total time (h)**	32000	**Reliability model**	**Wear-out Ea (eV) @ T_S**	1.225
	Service life (years)	15		**Wear-out n @ T_S**	6.588
	Min oxide aperture diam. (um)	6.0		**Arrhenius C factor (hours) @ T_S**	4.044972E-05
	I_{OP} (mA) max	5.00		**TTF x%**	1
	J_{OP} (kA/cm^2)	17.69		**Log-normal σ', ln (hours)**	0.37
	V_F (V) w/c	2.0		**Qe**	1.6022E-19
	P_{opt} (mW) w/c	0.2		**K_B**	1.3806E-23
	P_{DIS} (mW)	9.80		**Qe/K_B**	1.1605E+04
	R_{JS} (K/W) W/C	2500		**ºC to Kelvin**	273.15
	ΔT_{AS} (ºC)	20			

Reliability result

	Temperature profile					**Failure rate**					
	Percentage	**Time per Temperature (h)**	**T_A (ºC)**	**T_S (ºC)**	**T_J (ºC)**	**TTF 1% (hours)**	**TTF 1% (years)**	**Equivalent time in max T (hours)**	**Log-normal mu', ln (hours)**	**Failure-rate upper bound (FIT)**	**ppm / year (op)**
T_0	**6 %**	1920	**-40**	-20	4.5	6.036E+11	6.891E+07	0.00	27.9869		
T_1	**20 %**	6400	**23**	43	67.5	8.311E+06	9.487E+02	0.61	16.7938		
T_2	**65 %**	20800	**50**	70	94.5	2.414E+05	2.756E+01	67.93	13.2549		
T_3	**8 %**	2560	**100**	120	144.5	1.242E+03	1.417E-01	1625.49	7.9849		
T_4	**1 %**	320	**105**	125	149.5	7.884E+02	9.000E-02	320.00	7.5307		
Cummulative		32000						**2014.03**	**7.5307**	**1485799.1**	**3169704.83**

VCSEL wear-out analysis based on [2]

Max current density with VCSEL of [2] to meet FIT ≤ 10

Parameters for reliability results

Operation	Operation total time (h)	32000	Reliability model	Wear-out Ea (eV) @ T_S	1.225
	Service life (years)	15		Wear-out n @ T_S	6.588
	Min oxide aperture diam. (um)	6.0		Arrhenius C factor (hours) @ T_S	4.044972E-05
	I_{OP} (mA) max	3.9335		TTF x%	1
	J_{OP} (kA/cm²)	13.92		Log-normal σ', ln (hours)	0.37
	V_F (V) w/c	2.0		Qe	1.6022E-19
	P_{opt} (mW) w/c	0.2		K_B	1.3806E-23
	P_{DIS} (mW)	7.6670		Qe/K_B	1.1605E+04
	R_{JS} (K/W) W/C	2500		°C to Kelvin	273.15
	ΔT_{AS} (°C)	20			

Reliability result

	Temperature profile					Failure rate					
	Percentage	Time per Temperature (h)	T_A (°C)	T_S (°C)	T_J (°C)	TTF 1% (hours)	TTF 1% (years)	Equivalent time in max T (hours)	Log-normal mu', ln (hours)	Failure-rate upper bound (FIT)	ppm / year (op)
T_0	6 %	1920	-40	-20	-0.8	2.932E+12	3.347E+08	0.00	29.5675		
T_1	20 %	6400	23	43	62.2	4.037E+07	4.608E+03	0.61	18.3743		
T_2	65 %	20800	50	70	89.2	1.173E+06	1.338E+02	67.93	14.8354		
T_3	8 %	2560	100	120	139.2	6.031E+03	6.885E-01	1625.49	9.5654		
T_4	1 %	320	105	125	144.2	3.829E+03	4.371E-01	320.00	9.1112		
Cummulative		32000						2014.03	9.1112	10.0	21.31

VCSEL wear-out analysis based on [2]

Assuming same reliability model for the characterized InGaAs VCSEL (slow corner)

Parameters for reliability results

Operation	**Operation total time (h)**	32000	**Reliability model**	**Wear-out Ea (eV) @ T_S**	1.225
	Service life (years)	15		**Wear-out n @ T_S**	6.588
	Min oxide aperture diam. (um)	7.5		**Arrhenius C factor (hours) @ T_S**	4.044972E-05
	I_{OP} (mA) max	4.00		**TTF x%**	1
	J_{OP} (kA/cm^2)	9.06		**Log-normal σ', ln (hours)**	0.37
	V_F (V) w/c	2.0		**Qe**	1.6022E-19
	P_{opt} (mW) w/c	0.2		**K_B**	1.3806E-23
	P_{DIS} (mW)	7.80		**Qe/K_B**	1.1605E+04
	R_{JS} (K/W) W/C	2500		**ºC to Kelvin**	273.15
	ΔT_{AS} (ºC)	20			

Reliability result

	Temperature profile					Failure rate					
	Percentage	**Time per Temperature (h)**	**T_A (ºC)**	**T_S (ºC)**	**T_J (ºC)**	**TTF 1% (hours)**	**TTF 1% (years)**	**Equivalent time in max T (hours)**	**Log-normal mu', ln (hours)**	**Failure-rate upper bound (FIT)**	**ppm / year (op)**
T_0	**6 %**	1920	**-40**	-20	-0.5	4.967E+13	5.670E+09	0.00	32.3972		
T_1	**20 %**	6400	**23**	43	62.5	6.839E+08	7.807E+04	0.61	21.2040		
T_2	**65 %**	20800	**50**	70	89.5	1.986E+07	2.267E+03	67.93	17.6651		
T_3	**8 %**	2560	**100**	120	139.5	1.022E+05	1.166E+01	1625.49	12.3951		
T_4	**1 %**	320	**105**	125	144.5	6.487E+04	7.405E+00	320.00	11.9409		
Cummulative		32000						**2014.03**	**11.9409**	**0.0**	**0.00**

VCSEL wear-out analysis based on [2]

Assuming same reliability model for the characterized InGaAs VCSEL (fast corner)

Parameters for reliability results

Operation			Reliability model		
	Operation total time (h)	32000		Wear-out Ea (eV) @ T_S	1.225
	Service life (years)	15		Wear-out n @ T_S	6.588
	Min oxide aperture diam. (um)	6.5		Arrhenius C factor (hours) @ T_S	4.044972E-05
	I_{OP} (mA) max	3.00		TTF x%	1
	J_{OP} (kA/cm^2)	9.05		Log-normal σ', ln (hours)	0.37
	V_F (V) w/c	2.0		Qe	1.6022E-19
	P_{opt} (mW) w/c	0.2		K_B	1.3806E-23
	P_{DIS} (mW)	5.80		Qe/K_B	1.1605E+04
	R_{JS} (K/W) W/C	2500		ºC to Kelvin	273.15
	ΔT_{AS} (ºC)	20			

Reliability result

	Temperature profile					Failure rate					
	Percentage	Time per Temperature (h)	T_A (ºC)	T_S (ºC)	T_J (ºC)	TTF 1% (hours)	TTF 1% (years)	Equivalent time in max T (hours)	Log-normal mu', ln (hours)	Failure-rate upper bound (FIT)	ppm / year (op)
T_0	6 %	1920	-40	-20	-5.5	5.016E+13	5.726E+09	0.00	32.4069		
T_1	20 %	6400	23	43	57.5	6.906E+08	7.883E+04	0.61	21.2138		
T_2	65 %	20800	50	70	84.5	2.006E+07	2.290E+03	67.93	17.6749		
T_3	8 %	2560	100	120	134.5	1.032E+05	1.178E+01	1625.49	12.4049		
T_4	1 %	320	105	125	139.5	6.551E+04	7.478E+00	320.00	11.9507		
Cummulative		32000						2014.03	11.9507	0.0	0.00

Conclusions

- VCSEL reliability depends fundamentally on the operation conditions: current density and temperature
- InGaAs VCSEL reliability for automotive mission profile has been calculated for two different VCSEL devices, demonstrating that a failure rate of less than 10 FIT is achievable provided that current densities in high temperatures are below 13 kA/cm^2
- Although final reliability for an specific VCSEL device will depend on the particular characteristics of the VCSEL design, we can conclude that the automotive target failure rate is achievable based on the margin between the current density considered for link budget analysis, i.e. 9 kA/cm^2, and the calculated upper limit, i.e. 13 kA/cm^2
- This margin is advantageous to allocate process production variations (e.g. driving current, oxide aperture, binning accuracy, etc) and might also be used to further improve the link margin

Thank you