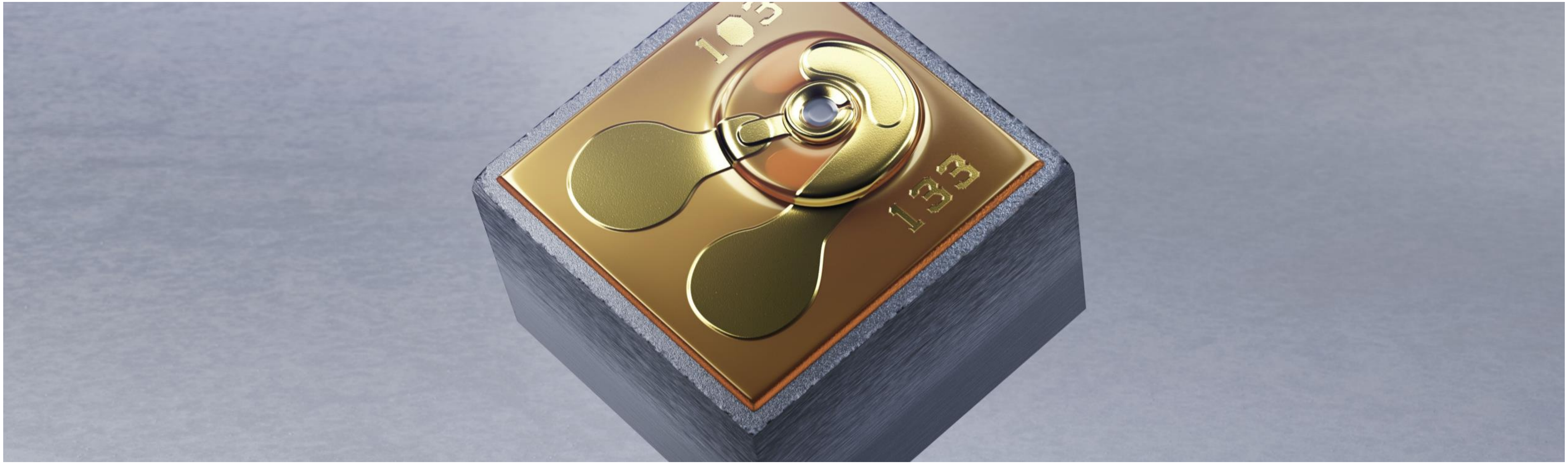


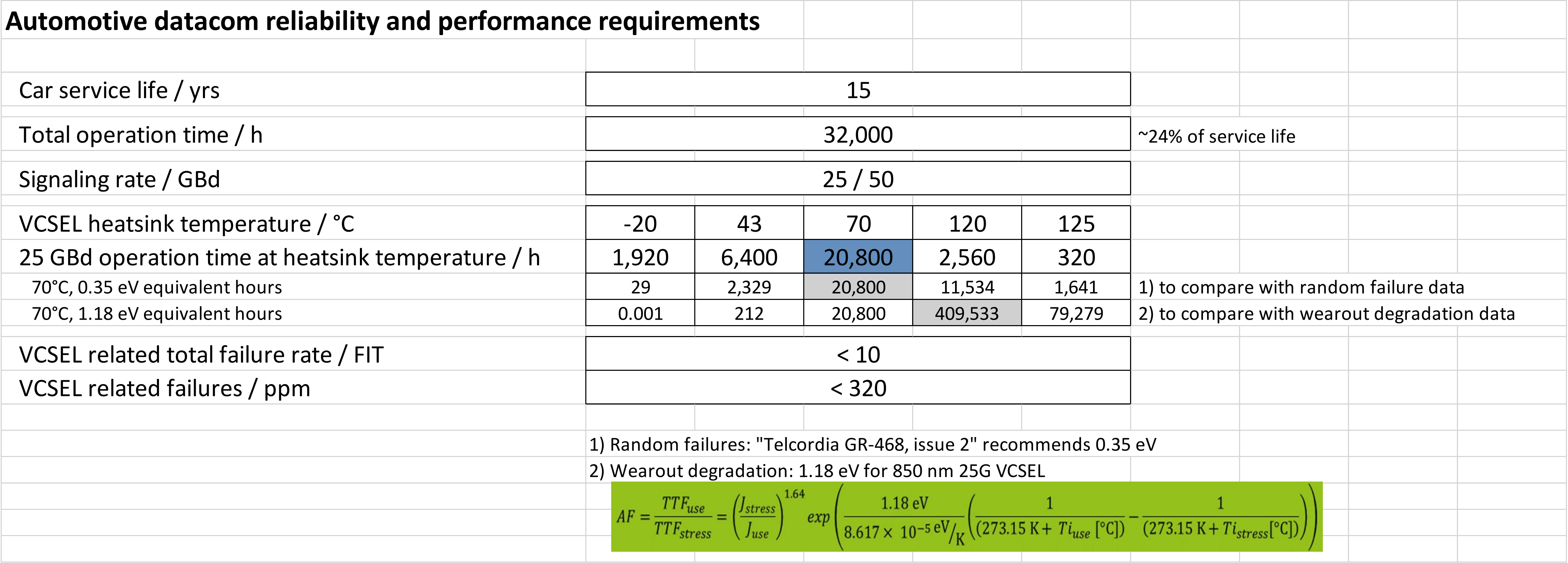
IEEE 802.3cz Multi-Gigabit Optical Automotive Ethernet Task Force – 10, 17, 18 Nov 2020 Teleconferences

A comparison between 850 nm and 980 nm VCSEL for automotive datacom

---

Roger King
TRUMPF Photonic Components GmbH

Automotive datacom from a VCSEL point of view



Automotive datacom reliability and performance requirements

Car service life / yrs	15					
Total operation time / h	32,000					~24% of service life
Signaling rate / GBd	25 / 50					
VCSEL heatsink temperature / °C	-20	43	70	120	125	
25 GBd operation time at heatsink temperature / h	1,920	6,400	20,800	2,560	320	
70°C, 0.35 eV equivalent hours	29	2,329	20,800	11,534	1,641	1) to compare with random failure data
70°C, 1.18 eV equivalent hours	0.001	212	20,800	409,533	79,279	2) to compare with wearout degradation data
VCSEL related total failure rate / FIT	< 10					
VCSEL related failures / ppm	< 320					

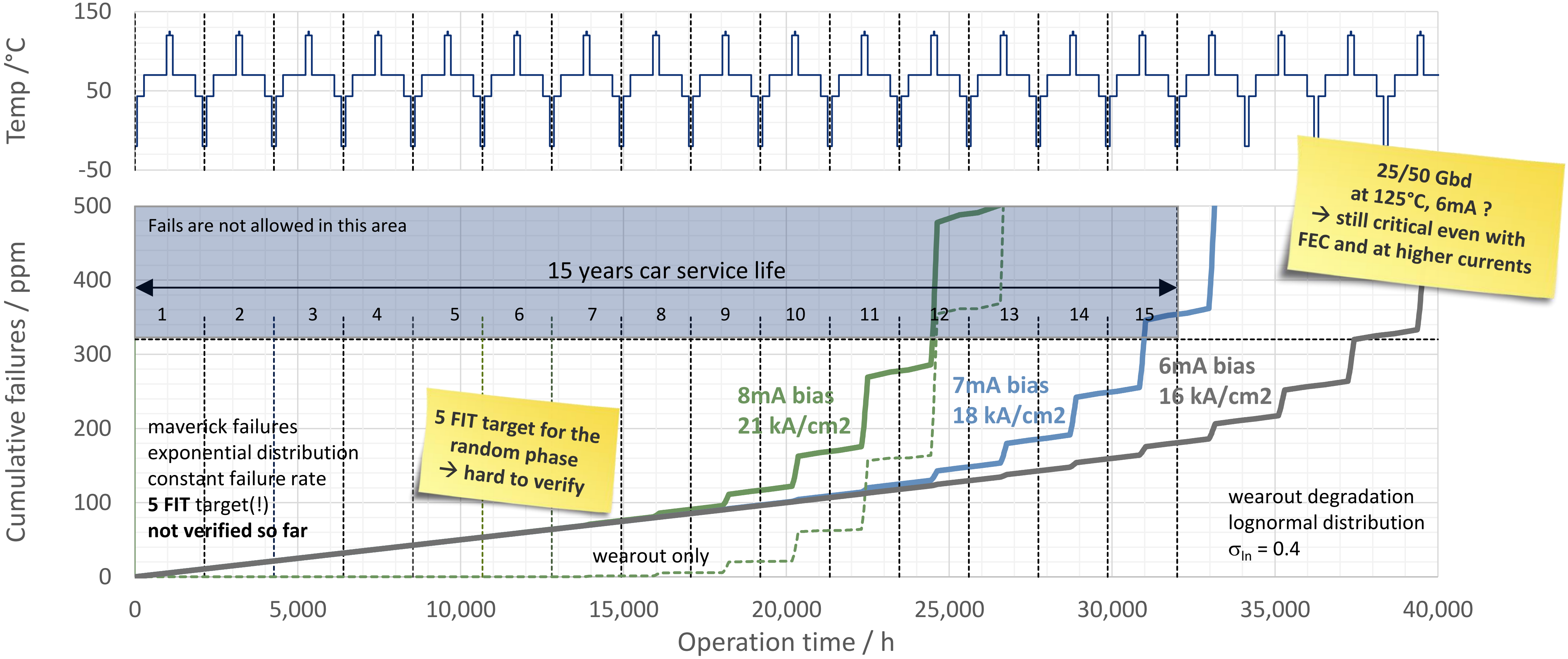
1) Random failures: "Telcordia GR-468, issue 2" recommends 0.35 eV

2) Wearout degradation: 1.18 eV for 850 nm 25G VCSEL

$$AF = \frac{TTF_{use}}{TTF_{stress}} = \left(\frac{J_{stress}}{J_{use}}\right)^{1.64} exp\left(\frac{1.18\ \mathrm{eV}}{8.617 \times 10^{-5}\,\mathrm{eV}/_{\mathrm{K}}}\left(\frac{1}{(273.15\,\mathrm{K} + Ti_{use}\,[°\mathrm{C}])} - \frac{1}{(273.15\,\mathrm{K} + Ti_{stress}[°\mathrm{C}])}\right)\right)$$

Impact of drive current on VCSEL failure counts

Estimation based on 850 nm 25G VCSEL data

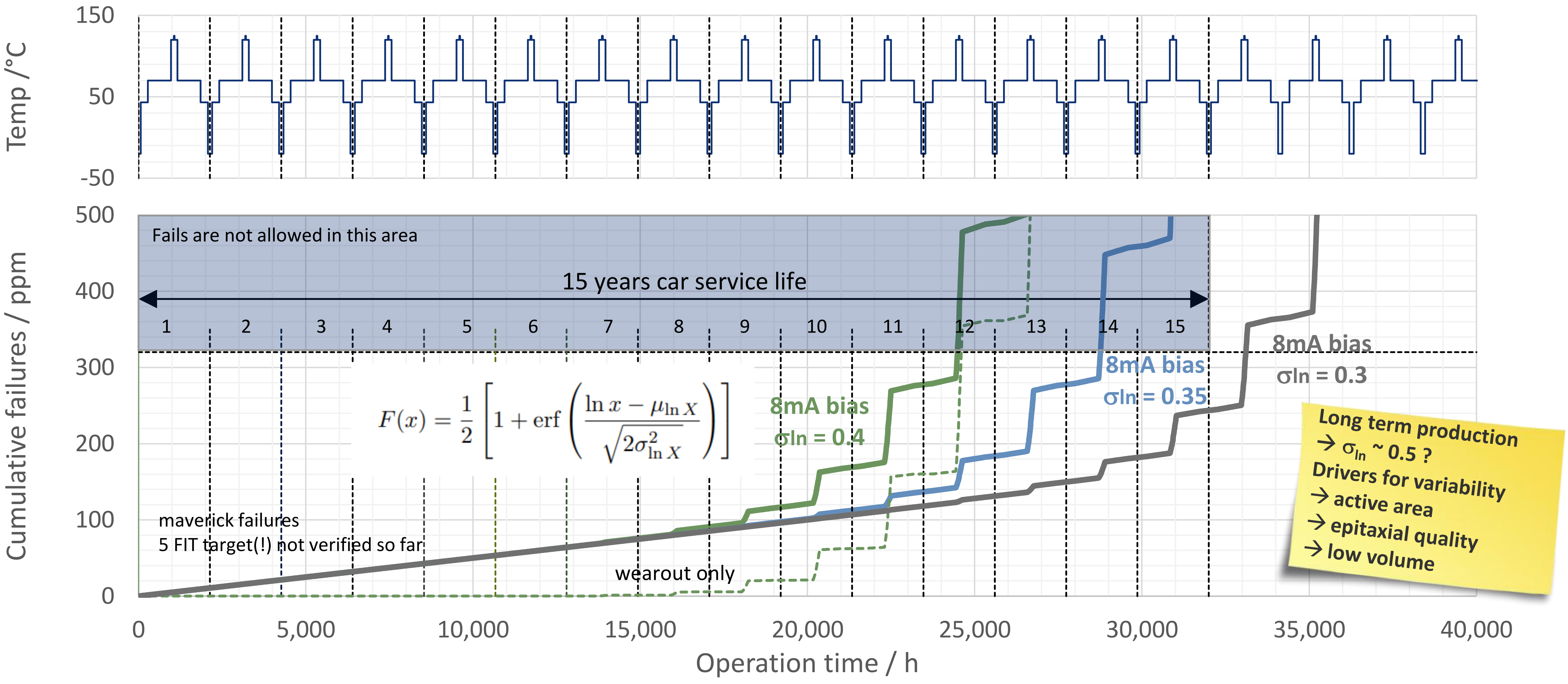


5 FIT target for the random phase
→ hard to verify

25/50 Gbd
at 125°C, 6mA ?
→ still critical even with FEC and at higher currents

Impact of variability in wearout degradation on failure counts

Estimation based on 850 nm 25G VCSEL data



Fails are not allowed in this area

15 years car service life

$$F(x) = \frac{1}{2}\left[1 + \operatorname{erf}\left(\frac{\ln x - \mu_{\ln X}}{\sqrt{2\sigma^2_{\ln X}}}\right)\right]$$

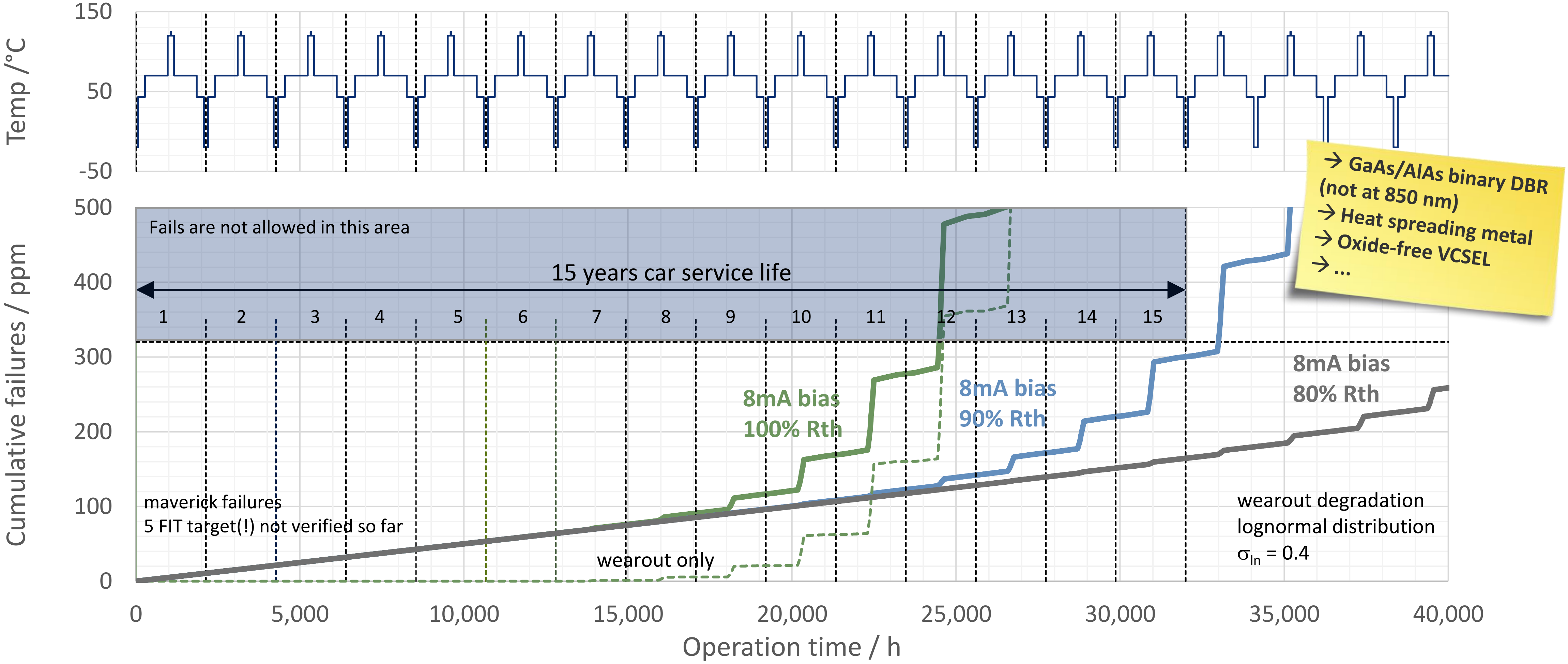
maverick failures
5 FIT target(!) not verified so far

wearout only

Long term production
→ $\sigma_{\ln}$ ~ 0.5 ?
Drivers for variability
→ active area
→ epitaxial quality
→ low volume

Impact of thermal resistance on VCSEL failure counts

Estimation based on 850 nm 25G VCSEL data



→ GaAs/AlAs binary DBR (not at 850 nm)
→ Heat spreading metal
→ Oxide-free VCSEL
→ …

VCSEL design options for 25/50 GBd automotive datacom

Chances of 850 nm and 980 nm VCSEL

	850 nm VCSEL	980 nm VCSEL
lower current, lower power dissipation, better heat removal @ 25/50 Gbd, 125°C operation		
compressive strain (for differential gain)	lower	higher
thermal conductivity of Bragg mirror	lower	higher
free carrier absorption	less	more
DBR layer stack	thinner	thicker
turn on voltage	higher	lower
thermal escape of carriers from quantum wells	more	less
less variability in wearout		
quantum well growth window	tighter	wider
quantum well thickness	thinner	thicker
wafer quantities	low	high (at 940 nm)
higher resistance to maverick defect propagation		
compressive strain (for dislocation pinning)	lower	higher
better robustness		
flip-chip	top emission	top or bottom emission

Summary

The 980 nm VCSEL design is the better choice for optimization towards 25/50 GBd automotive applications

- with respect to an 850 nm VCSEL design approach
- both, in terms of performance and durability

A feasibility study shall provide more confidence

- 850 nm and 980 nm VCSEL are fabricated and will be extensively tested in reliability at TRUMPF
- Results will be provided to the 802.3cz group in July 2021 to take a good decision about the right wavelength
  - Performance measured at automotive temperature ranges
  - Wearout degradation statistics extrapolated to automotive temperature ranges
  - Random failure data at ~100 FIT level

Thank you!

Roger King
roger.king@trumpf.com