TCAD milestones for the next 5 years:

• M1: Comparison of commercial TCAD tools; preparation of a recommendation for parameters and physics models. (Q4/2019)

• M2: Development of a reliable radiation damage model covering the HL-LHC fluences for protons and neutrons for a given operation temperature. The model shall be able to reproduce I-V, C-V, CCE and the E-field including double junction effects. (Q4/2020)

• M3: Model M1 extended to cover temperature dependence of the bulk-damage related effects from room temperature down to -30 °C. (Q3/2021):

• M4: Model from M2 extended to cover annealing effects (Q3/2022):

• M5: Model of the donor and acceptor removal (SiPMs, LGAD, CMOS,..) (Q3/2020):

• M6: Surface damage model with correct modelling of surface damage in p-type segmented sensors. (Q1/2021)

• M7: Evaluation of the possibility of the implementation of cluster related defects in the commercial TCAD device simulators by using a charge carrier occupation dependent energy level distribution. (Q2/2021)
Synopsys and Silvaco TCAD use different parameterizations and models for band gap, density of states, thermal velocities etc.

• Examples:
  - band gap:

```python
#### Synopsys ####
def E_g(T):
    Eg0 = 1.16964  # Bandgap at T=0K
    alpha = 4.73E-4  # Schwdt
    beta = 636.0
    return Eg0 - alpha * T**2 / (T + beta)
```

```python
#### Silvaco ####
def E_g_Silvaco(T, EG300=1.08):
    EG300 = 1.08  # Bandgap at T=300K
    EGALPHA = 4.73E-4  #
    EGBETA = 636.0
    return EG300 + EGALPHA*(300**2 / (300.0+EGBETA) - T**2 / (T + EGBETA))
```

- hole effective density of state:

```python
#### Synopsys ####
def mass_p(T):
    a = 0.4435870
    b = 0.3609528E-2
    c = 0.1173515E-3
    d = 0.1263218E-5
    e = 0.3025581E-8
    f = 0.4683382E-2
    g = 0.226895E-3
    h = 0.7469271E-6
    I = 0.1727481E-8
    return (((a+b * T + c * T**2 + d * T**3 + e * T**4) / 
              (1.0+f * T + g * T**2 + h * T**3 + I * T**4))**2.0/3.0)
```

```python
#### Silvaco ####
def N_v_Silvaco(T, NV300=1.04e19):
    NVF = 1.5
    return NV300*(T / 300.0)**NVF
```

- Synopsys and Silvaco TCAD use different parameterizations for band gap, density of states, thermal velocities etc.
Synopsys and Silvaco TCAD comparison using the HPTM
- 1D diode, n⁺-p, thickness 200 µm

I-V at T = -20°C

All Silvaco TCAD simulations done by Marco Bomben
$1/C^2-V$ at 1kHz and $T = -20^\circ C$
E-Field at different voltages

\[ \Phi_{eq} = 3 \cdot 10^{14} \text{ cm}^{-2} \]

\[ \Phi_{eq} = 3 \cdot 10^{15} \text{ cm}^{-2} \]

\[ \Phi_{eq} = 8 \cdot 10^{15} \text{ cm}^{-2} \]

\[ \Phi_{eq} = 13 \cdot 10^{15} \text{ cm}^{-2} \]