Lot Dependency in COTS Radiation Performance: Insights on SEE and TID Variability

Alberto Moreno

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AGENDA

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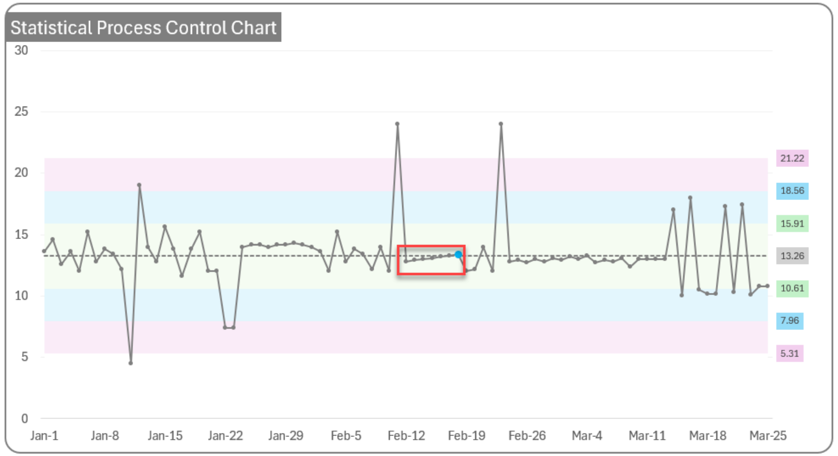
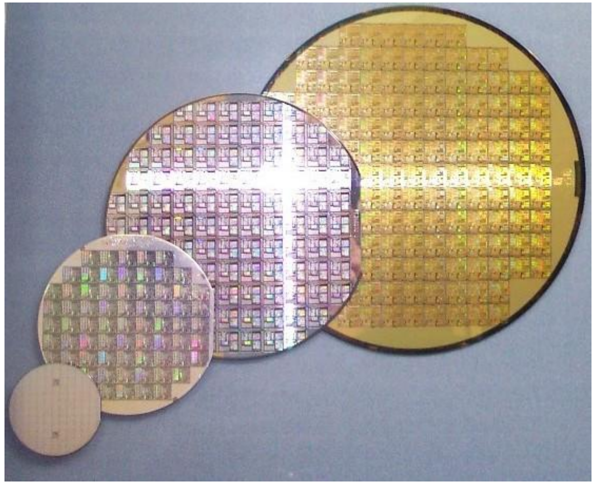
INTRODUCTION

COTS (Commercial Off The Shelf)

- COTS SPC (Statistical Process Controls)
  - Parametric variability is normally limited
  - But radiation relevant parameters are not controlled
  - Wide differences between levels, e.g. industrial vs. AEC
  - Differences between manufacturers' SPC, even for AEC
  - If your test



- Radiation
  - SEE and TID lot-to-lot and part-to-part variability are known and may be critical to the functionality [1] [2] [3]
  - Lot-to-lot and part-to-part variability is however uncommon [4] so you need a big data set to identify such variability
  - TESAT has a NewSpace list with 199 radiation sensitive part types and most of them have seen SEE and TID on multiple lots



» ECSS-Q-ST-60-15C Rev.1 §5.1 (TID):

» The 4-years-rule has been removed

g. TID test data used to assess TIDS shall comply with the following rules to be acceptable:

1. tests are performed in conformance to ESCC 22900, MIL-STD-883L method 1019, or MIL-STD-750E method 1019, and
2. devices that contain bipolar transistors are tested at a dose rate of less than 360 rad/h, and
3. tested parts are manufactured with technology identical to the technology of flight parts: same process, same diffusion mask, and same wafer fabrication facility, and
4. test bias conditions are worse or equivalent to the application.

y. If flight model part diffusion lot number is different from tested part diffusion lot number radiation verification test (RVT) on flight lot shall be performed according to the following condition:

1. for optoelectronic parts, all lots;
2. for all other part if TID RMM < 2.

» ECSS-Q-ST-60-15C Rev.1 §5.3 (SEE):

f. SEE test data shall meet the following criteria to be acceptable:

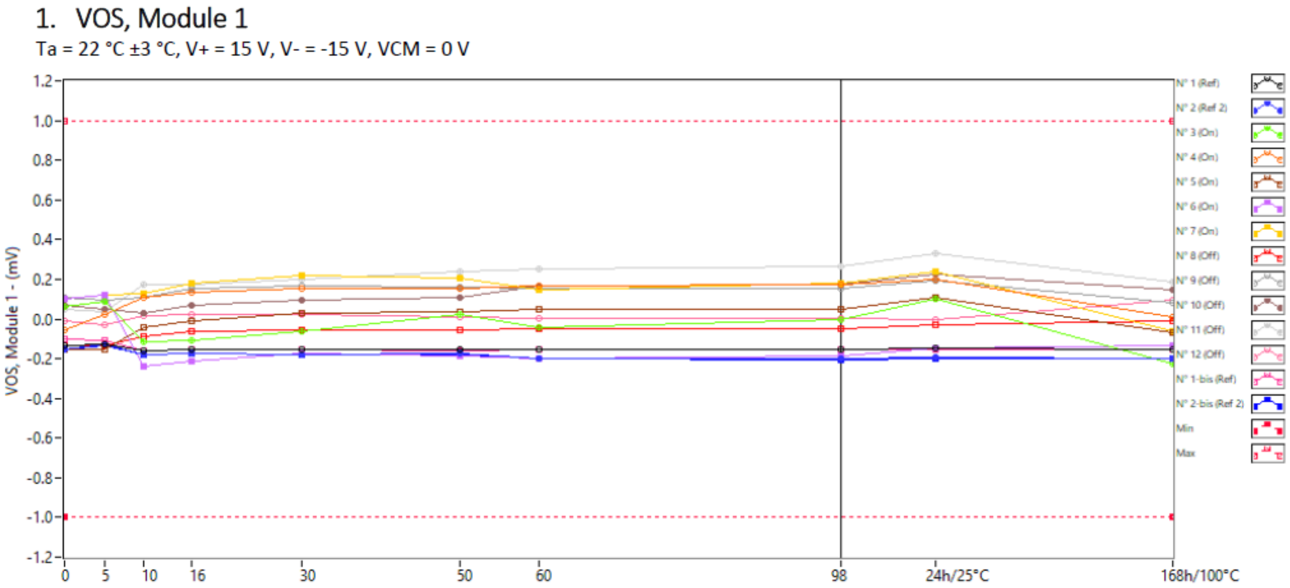
1. Test are performed in conformance to
   (a) MIL-STD-750E method 1080 for power MOSFET,
   (b) ESCC 25100 for all other parts.

   NOTE Useful information about SEE testing is also provided in EIA/JESD 57.
2. Tested parts are manufactured with technology identical to the technology of flight parts: same process and same diffusion mask.
3. Test conditions are worse or equivalent to the application.

LOT DEPENDENCY EXAMPLES

TID Si

- Precision JFET Op Amp (silicon)
  - Two fabs
    - New fab since 2023 with PCN
    - Every lot that we have received comes from the older fab but the behaviour of the new fab may differ
  - Drifting parameter: Offset voltage – typically 0.4mV maximum 1mV
    - Normally passes 100krad
    - Example on the right
  - 6 reels tested, 5 assembly lots

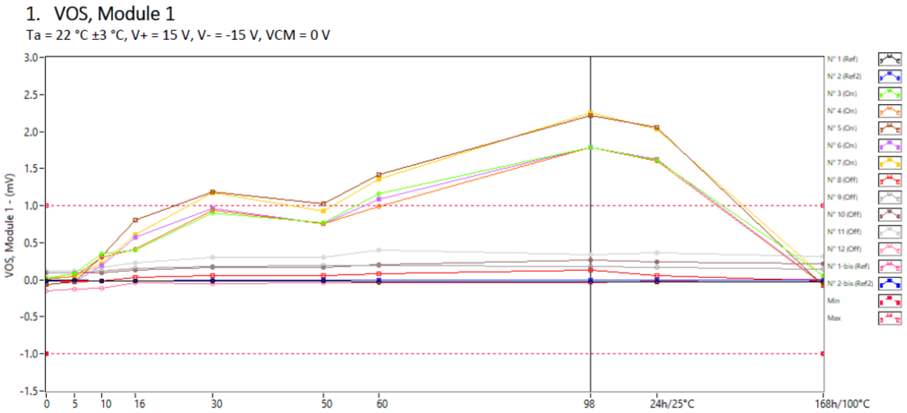


DC2350, example of 100krad pass

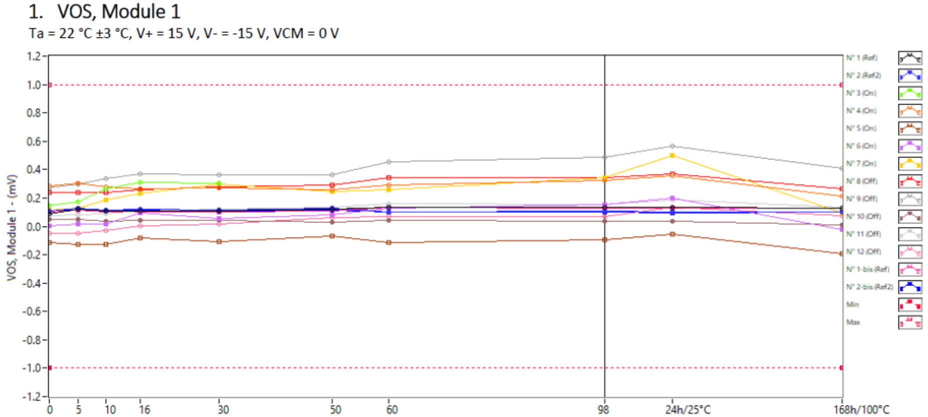
Lot dependency examples

TID Si

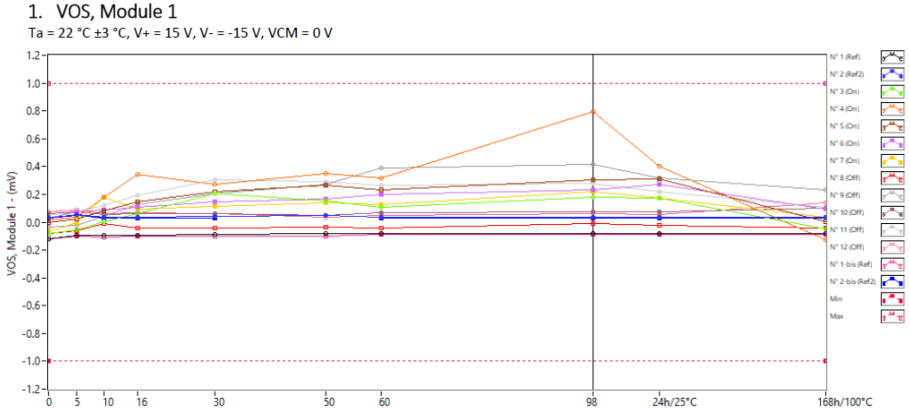
- Anomaly – DC2317
  - Two reels from the same assembly lot and same wafer (confirmed by the manufacturer):
    - One passes 100krad whereas the other one fails before 30krad (20.7krad by interpolation)
    - Part-to-part variability, possibly dependent on die position in the wafer
  - 2317M (mixed) performs nominally for the 10 tested pcs. but other parts in the reel may behave differently



DC2317, lot A – 1st delivery



DC2317M, lot B



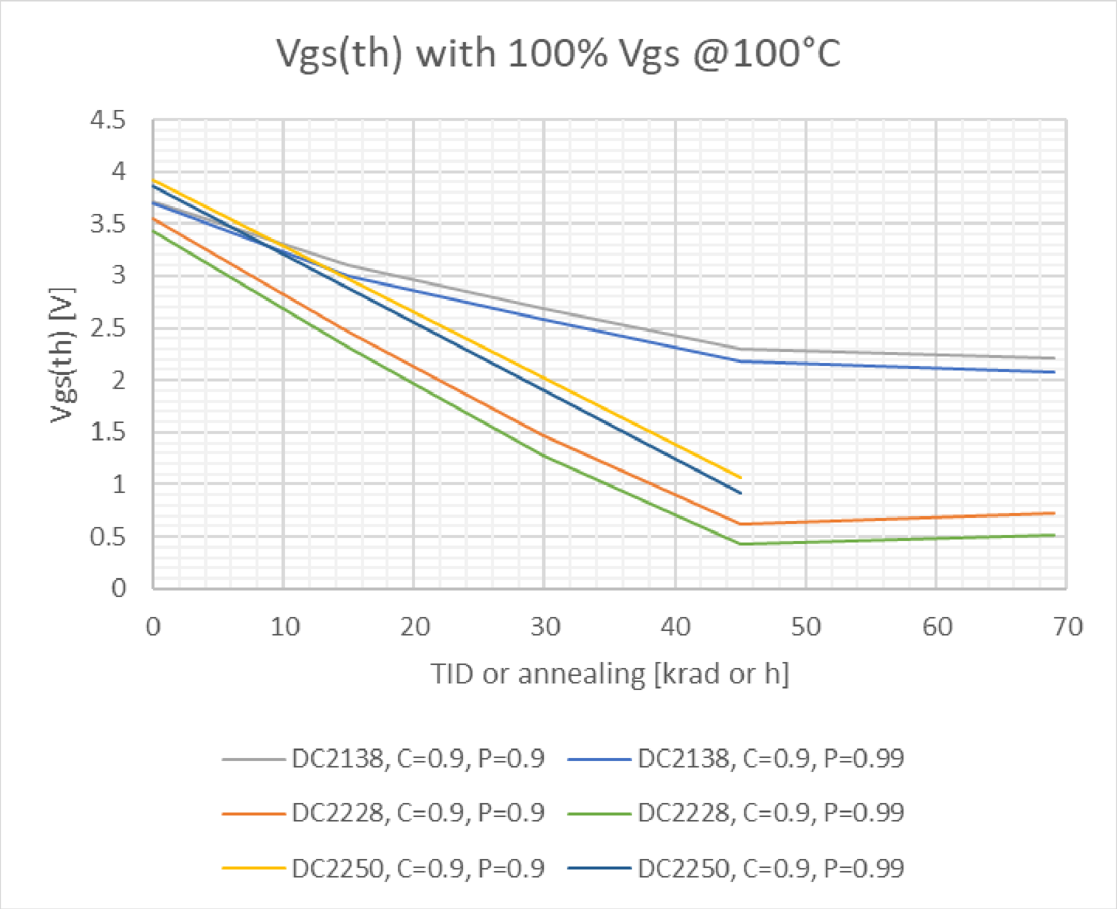
DC2317, lot A – 2nd delivery

Lot dependency examples

TID SiC

» Trench SiC

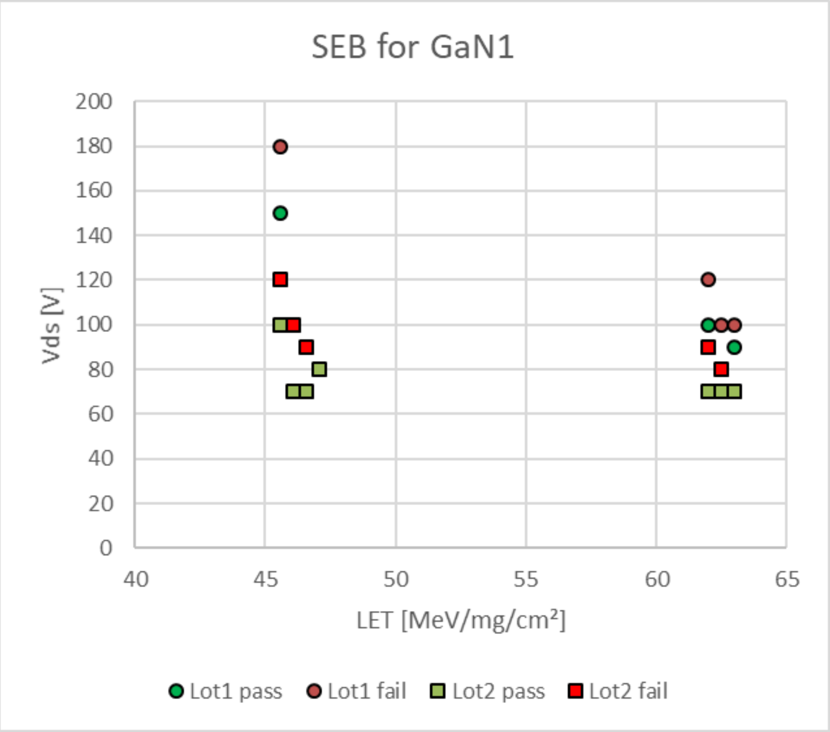
- » Results:
  - » First tested assembly lot, DC 2138, reaches 54krad and fulfils thus mission requirements
  - » All subsequent wafer lots pass <30krad. 10 additional wafer lots tested.
- » Confirmed by the manufacturer:
  - » No PCNs because the part is still FFF (Fit-Form-Function) identical
  - » Same fab
  - » Fab processes were adjusted but no PCN was needed because the changes have no impact on the electrical characteristics
- » TESAT design had to be changed



Lot dependency examples

SEE GaN

- Power GaN variability for SEB observed in 2 GaN part types
  - GaN1:
    - 47% lot-to-lot variability (80V vs. 150V)
    - 20% part-to-part variability in the weak lot (80V vs. 100V)
  - GaN2:
    - 38% lot-to-lot variability (150V vs. 240V)
    - 29% part-to-part variability in the weak lot (150V vs. ≥210V)
- Weak lots show significant part-to-part variability
- Talk "Commercial GaN FETs. Radiation destructive events: Lot to lot and intra lot variability" by Miguel Pérez Cerdán
  - Plenary room at 16:50



Mitigation

TESAT approach

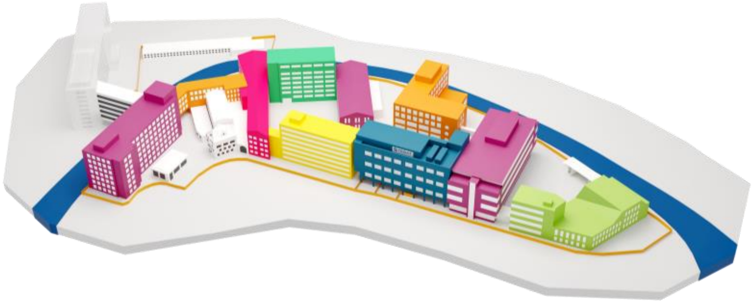
- Select COTS with margin
  - RDM=1.2 may be insufficient even with TID on the diffusion lot
  - Test emerging technologies extensively
    - Every generation may have very different radiation performance
    - Immature processes that may be adjusted without PCN and may impact SEE and TID performance
- Collect statistics
  - Initially, test TID on several lots even if the part passes 100krad
  - Test TID on every fab if you want to use parts from all fabs
  - Test TID periodically on discrete and analogue parts
  - Test SEE on more than one lot, especially if it is a new technology
    - Example on the right with the first 30 lines of TESAT NewSpace list (199 radiation sensitive part types in total). Red is fail, green is selected despite radiation sensitivity.
    - Compare dice periodically if you do not have manufacturer confirmation of mask freeze
  - If you see part-to-part variability, test extensively and design with margin
- Traceability and manufacturer support may significantly help with this

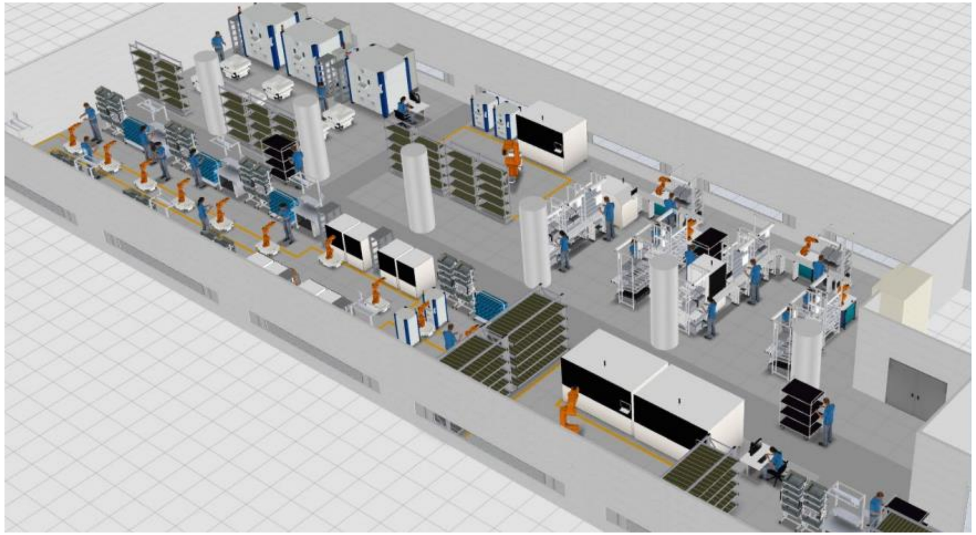
SEE	Family
02-18, 05-18	IC-Quad SPST Switches
02-18, 05-18	IC-P-Ch Switch
05-18, 06-18 (1xSEL), 03-19, 09-21	IC-Gate Driver
09-18	IC-8-CH MUX
06-18	IC-Gate Driver
06-20	IC-OP Power
09-20	IC-dig Isolator
07-19	IC-FRAM
05-18, 06-18	IC-Analog switch
09-20, 02-23, 05-23	IC-Differential Comparator
05-18 (1xSEL)	IC-CMOS Timer
06-20, 02-23, 03-23, 05-23	IC-Voltage regulator
07-19, 11-20	IC-Shunt reg.
06-20	IC-Shunt ref.
04-19	IC-Amp precision
04-19	IC-Quad SPST Switches
04-19, 02-23, 03-23, 05-23	IC-Voltage regulator
04-19	IC-dig Isolator
06-20	IC-LVDS (De-)serializer 18-bit
06-20	IC-ADC 18-bit
06-20, 11-20	IC-Oscillator 156MHz
06-20, 11-20, 07-21 (SEL), 09-24	IC-Oscillator 200MHz
06-20	IC-Oscillator
09-20, 02-22, 03-23, 05-23	IC-voltage reference
09-20, 02-22	IC-voltage reference
09-20, 03-22	IC-HEX Inverter
09-20, 03-22	IC-NOR Gate
09-20 (SEL), 02-24	IC-OpAmp
09-20	IC-LIMA
07-21, 06-24	Optocoupler

Mitigation

TESAT high volume programs

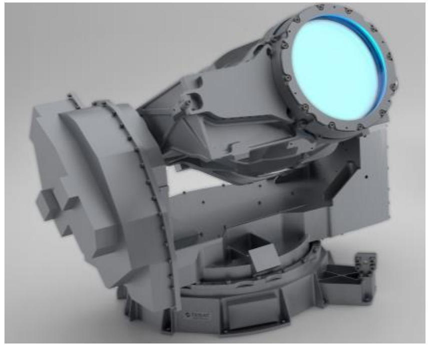
- High volume – ConLCT (Constellation Laser Communication Terminal)
  - 25 OCT (Optical Communication Terminals) built per week so we cannot have radiation surprises
  - Parts without margin are removed from the design
  - All lots will be tested before the production starts
  - 792 OCT for MDA Lightspeed

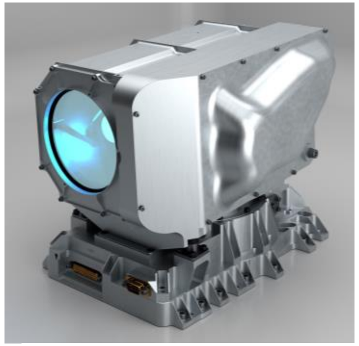


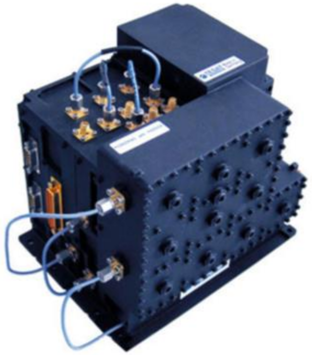


Conclusions

- Part selection
  - Aim for sufficient margin
  - Be careful with lot-to-lot and part-to-part variability
  - Pay special attention to emerging technologies and their generations
  - Prefer parts with traceability and manufacturer support
- Test to collect representative statistic
  - Test TID on multiple lots before assuming the radiation performance
  - Test TID periodically on at least discrete and analogue parts
  - Some technologies may require periodic SEE or even SEE per lot
- Specifications for COTS
  - Space parts and COTS differ in many radiation aspects
  - Including tailored recommendations for COTS may be helpful







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THANK YOU FOR YOUR ATTENTION

Acknowledgements:

Miguel Pérez Cerdán, Daniela Staerk

» Alberto Moreno Herrera
» alberto.moreno-herrera@tesat.de
» +49 151 1849 0562

Tesat-Spacecom GmbH & Co. KG
Gerberstraße 49
71522 Backnang
www.tesat.de