ESCCON 2016

# RELIABILITY VS ON-OFF CYCLES

## METHODOLOGY & IMPLEMENTATION

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- ONGOING TESTS AT CNES FACILITIES
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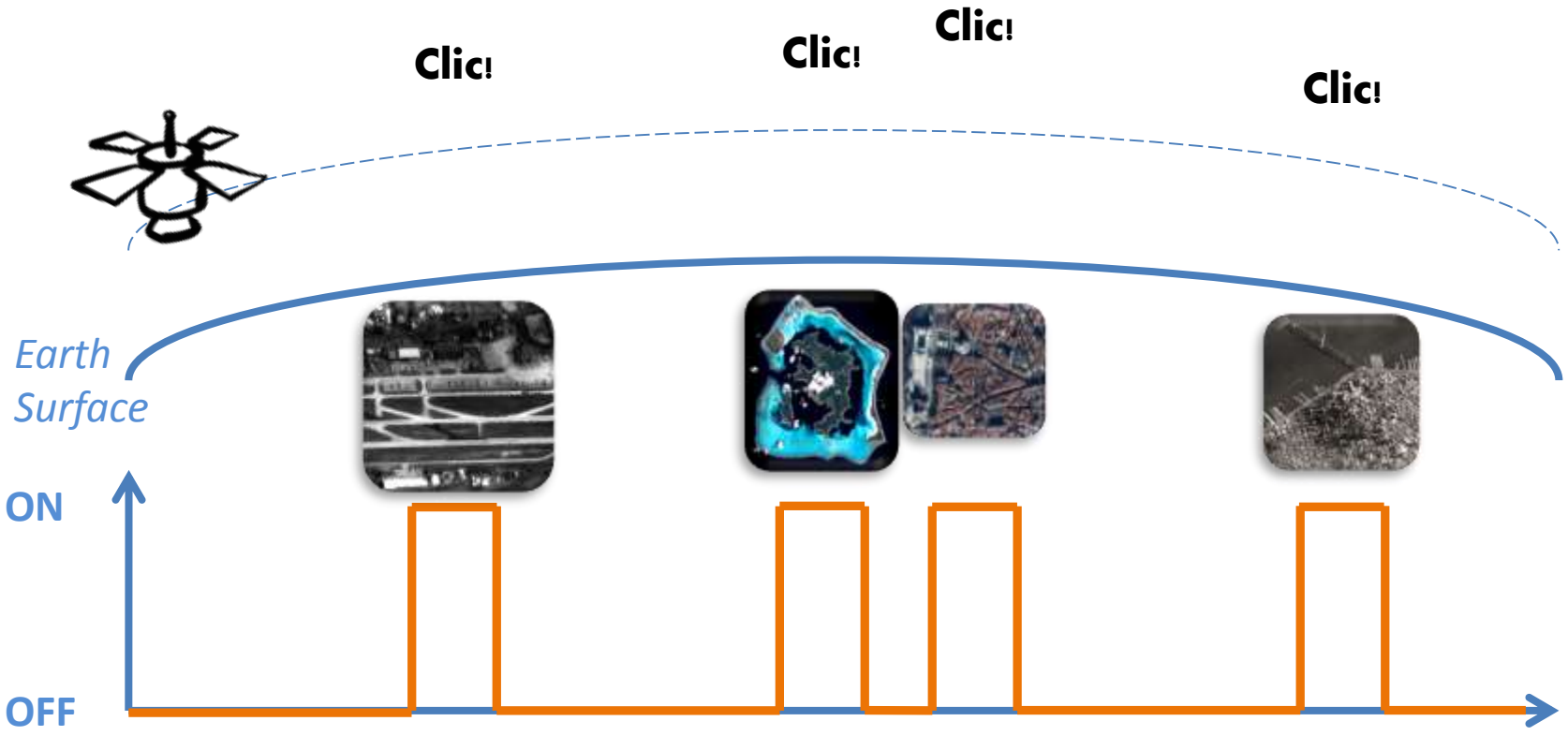
# ON-OFF CYCLES INTRODUCTION

- **What is an ON-OFF cycle?**
  - At satellite level



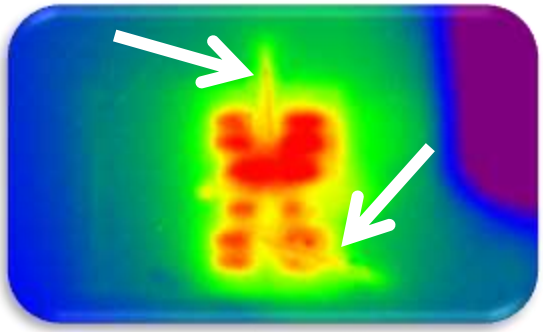

**Power of satellite equipment**

- About 20 ON-OFF cycles per orbit
- Up to 200,000 ON-OFF cycles during satellite lifetime

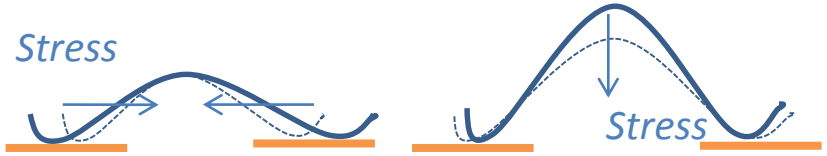
# ON-OFF CYCLES INTRODUCTION

- **What is an ON-OFF cycle?**
  - At component level

Wire heating due to junction heating and thermal conductivity

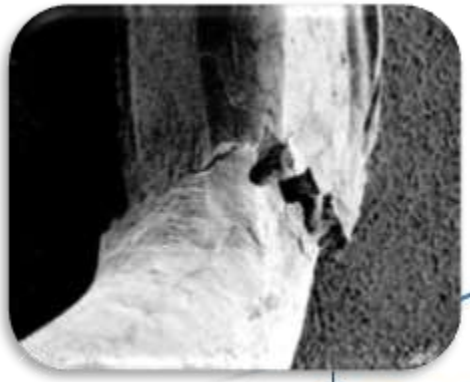


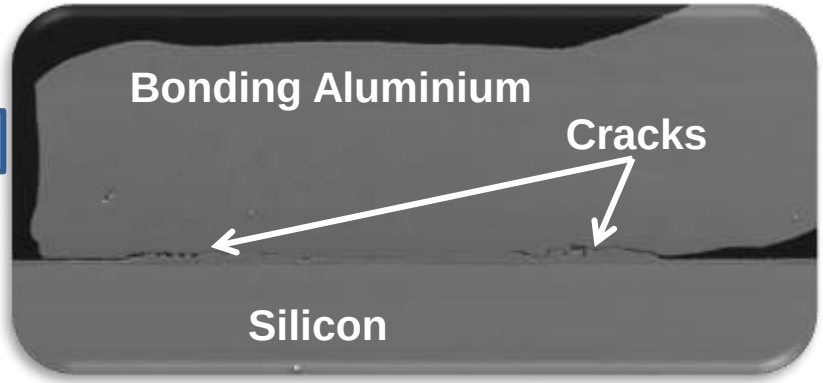
| Material | Expansion [$10^{-6}.K^{-1}$] |
|---|---|
| Aluminium | 23.5 |
| Silicon | 2.8 |



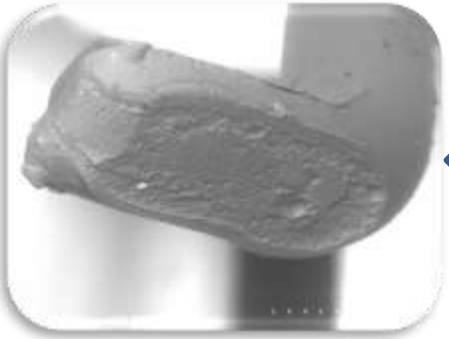

Mechanical stress at the interface, due to high expansion of aluminium

Repetitive stress creates cracks






Until bonding lift-off…



# ON-OFF CYCLES INTRODUCTION

- **What is an ON-OFF cycle?**
  - At component level

***For our concern***

$$N_{on-off} = f(\Delta_{Tj}^{-n})$$

$$where\ \Delta_{Tj} = \Delta_{Tc} + R_{th\ j-c} \cdot P_{dissipated}$$

$\Delta_{Tj}$ : junction temperature variation
$\Delta_{Tc}$: case temperature variation
$R_{th\ j-c}$ : Thermal resistance between junction and case
$P_{dissipated}$ : power dissipated

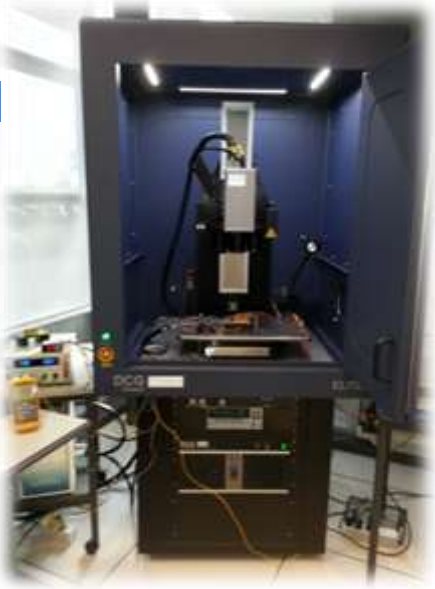
# ONGOING TESTS AT CNES FACILITIES

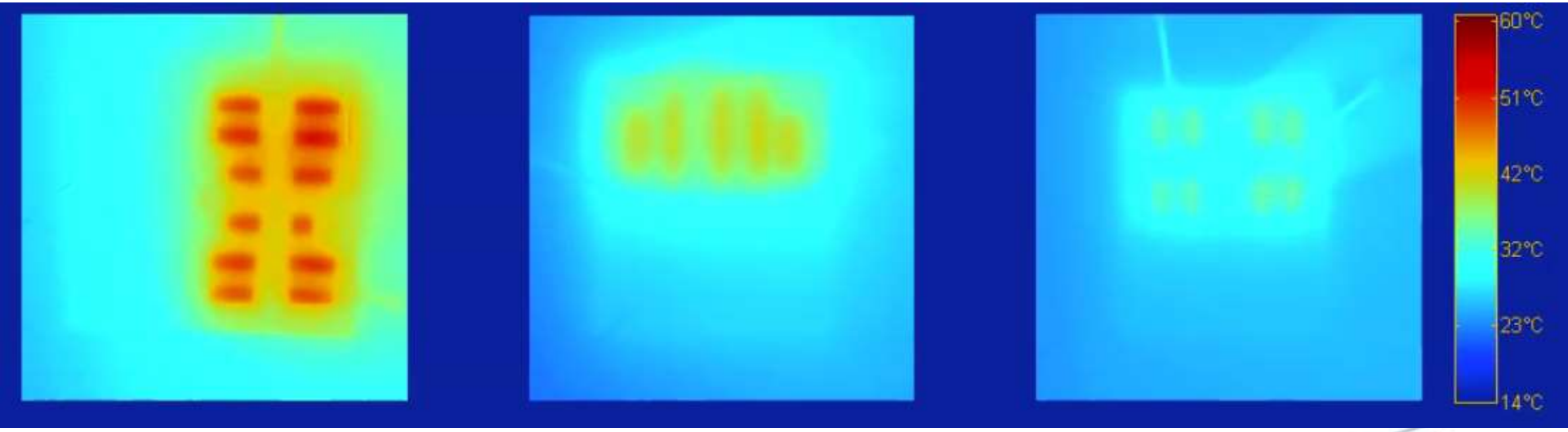
- **Development of an ON-OFF test bench**
  - **For bipolar : Vbe monitoring to precisely measure Tj**
  - **For MOSFET & IGBT : low inertia thermocouple to measure Tcase**

# ONGOING TESTS AT CNES FACILITIES

- **Development of a thermal camera test bench**
  - **Observe temperature gradient at chip level**
  - **Improve uncertainties on $Rth_{j-c}$**

$$\Delta T_j = \Delta T_c + Rth_{j-c} \cdot P_{dissip}$$



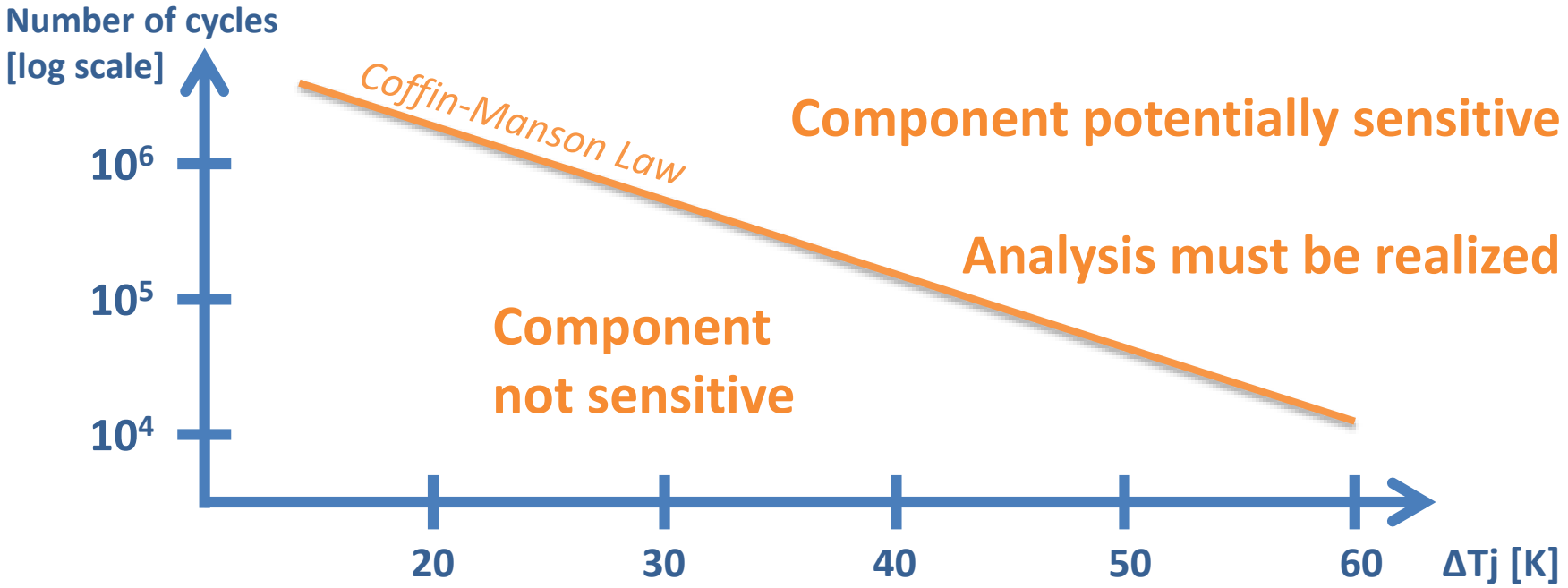


# ONGOING TESTS AT CNES FACILITIES

- **Main observations**
  - **Low power transistors (Ic or Id<2Amps) & Integrated Circuits can handle >400,000 ON-OFF cycles at ΔTj=60°C**
  - **Gold wire are more robust than aluminium wire**
  - **wire diameter and shape of the wire may have an important impact (a study on this subject is also ongoing)**
  - **Chip design have an important impact on ON-OFF behaviour**
  - **In first approach, current level has no impact**

# IMPACT ON PROJECTS

- **Method used on CNES projects to cope with ON-OFF issue**




| Type | ON-OFF cycle limit (margin included) @ ΔTj =60K |
|---|---|
| MOSFET, IGBT | 10,000 |
| Bipolar | 24,000 |
| Small signal discrete | 50,000 |
| Integrated circuits | 50,000 |

*Based on CNES R&D*

# IMPACT ON PROJECTS

- **Case study : satellite equipment subjected to on-off cycles**
  - **1st step : To know which component is the most stressed regarding ΔTj for each category**

*Reminder* : $\Delta T_j = \Delta T_c + Rth_{j-c} \cdot P_{dissip}$

| Type | ΔTj |
|---|---|
| MOSFET | 30 |
| Bipolar | 36 |
| Small signal discrete | 30 |
| Integrated circuits | 42 |

  - **2nd step : Define the ON-OFF cycle number through Coffin-Manson Law and results from R&D CNES**

| Type | ON-OFF Number |
|---|---|
| MOSFET | 160,000 |
| Bipolar | 185,000 |
| Small signal discrete | 500,000 |
| Integrated circuits | 166,000 |

# IMPACT ON PROJECTS

- **Case study : satellite equipment subjected to on-off cycles**
  - **3rd step : According to mission needs, component may be declared as sensitive**

| Type | ON-OFF Number | Mission needs | ON-OFF sensitivity ? |
|---|---|---|---|
| MOSFET | 160,000 | 165,000 | Potentially sensitive |
| Bipolar | 185,000 | 165,000 | Not sensitive |
| Small signal discrete | 500,000 | 165,000 | Not sensitive |
| Integrated circuits | 166,000 | 165,000 | Not sensitive |

- **Last step : For each component as potentially sensitive, a risk analysis must be initiated**

Design analysis

Temperature gradient

Wire diameter

Possible failure?

Number of wire

Deeper environment analysis

Feedback

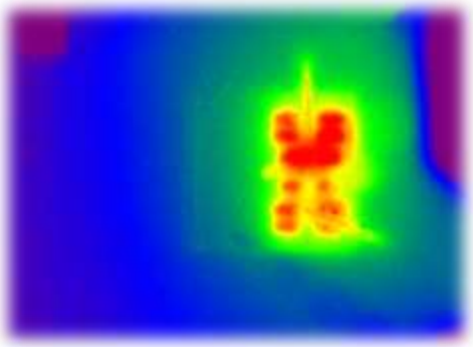
Bonding shape

Wire material

# NEXT STEPS

- **GaN/SiC evaluation**
  - **R&D 2016 & thesis to study ON-OFF behaviour**
- **What about commercial parts ?**
  - **Study focused on power MOSFET that could be used in constellations**
- **Lifetime of project is increasing**
  - **Follow the ON-OFF cycle number requirements to define more precisely the ‘ON-OFF boundary’**
- **Suggest a technical note to describe ON-OFF methodology**

# THANK YOU FOR YOUR ATTENTION



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