CNES components activities:
focus on the development of microsensors for contamination detection

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PART 1: COMPONENTS DEVELOPMENT PROGRAM AT CNES
  • OBJECTIVES
  • ADVANCED AND STANDARD STRATEGIC COMPONENTS ROADMAP (update)

PART 2: FOCUS ON CONTAMINANTS DETECTION
  • CONTAMINATION ISSUES FOR SPACE PROJECTS
  • NEW DEVELOPMENT FOR CHEMICAL CONTAMINANTS MONITORING
  • NEW DEVELOPMENT FOR PARTICLES MONITORING

CONCLUSION
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OBJECTIVES OF THE COMPONENTS DEVELOPMENT PROGRAM

To contribute to the European non dependence

- Increase the share of European components in our projects
- Improve the quality assurance by the use of the ESCC standard
- Using the European capabilities in terms of space components
- Propose, on time, state of the art technologies and components with a good readiness level and at a reasonable cost
OBJECTIVES OF THE COMPONENTS DEVELOPMENT PROGRAM

To Support the competitiveness of European Space industry

- Equipment manufacturers
  - Allow the space industry to have access to state of the arts components
  - Increase systems and equipment performances
  - Be able to propose new applications (New Generation telecom payloads, …)

- Component manufacturers
  - Develop a production capacity of HiRel and radiation hardened components to a reduced number of component manufacturers
  - Develop as much as possible their products portfolio in order for them to be attractive and get back a significant revenue
OBJECTIVES OF THE COMPONENTS DEVELOPMENT PROGRAM

- Program harmonization through the ESCC/CTB and coordination with ESA (European Space Agency)

- Collaboration with JAXA
  - Components development
  - Staff exchange
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Digital ASIC’s

Medium gates count needs: ASIC’s up to 10Mgates

--- Space qualified ASIC platform availability on CMOS 180nm ---
Atmel

180 nm Obsolescence risk anticipation

150nm SOI Devlpt Evaluation
Atmel

High gates count needs: ASIC’s up to 30 Mgates (65 nm DSM program)

65nm development (Libr. devt, Reliab., …)
STm

65nm Lib Devt (con’t) + Evaluation

Atmel STm-ATMEL Agreement

1st Space 65nm ASIC platform availability

65nm Library and DK improvements con’t (HSSL, …)
STm Evaluation

2nd Space 65nm P/F ASIC availability
RadHard HSSL IP+ Complete library + Flip Chip


CNES CNES/ESA CNES/JAXA Not yet funded

Next generation preparation
High pin count packages

Columns for MCGA’s (NTK columns obsolescence)

- Evaluation of alternative solutions to replace NTK columns, Selection and Evaluation
- SixSigma columns /Astrium process development
- European columns development

Flip Chip for 65nm products (Mandatory for High gates count ASIC’s, FPGA NG, …)

- Flip Chip Pre study
- Flip Chip Technology development (French PIA)
- Evaluation

Not yet funded

CNES
ESA
CNES/JAXA

CNES/ESA
FPGA’s and associated products

**FPGAs**

- **FPGA 280kgates development** (180nm CMOS) by Atmel, Evaluated.
- **FPGA 450kg development** (Lapis150nm SOI) JAXA-CNES collab. Atmel+HIREC (1.25M€), Place & Route IDS tool Optimisation/ User Atmel, users, agencies Evaluated.
- **Reprogrammable FPGA devt** (equ. 560Kgates) (2xFPGAs 280kgates+EEPROM 4M) Atmel (0.4M€), Evaluation.

**FPGA’s NG 2.5 Mgates Devt** on 65nm STm

NanoXplore, Atmel, STm, ..., TAS, Astrium

**Multiple Die Products (LEON µP + 4MB EEPROM + FPGA 280Kgates)**

- **EEPROM 4Mb Develop.** (FPGA comp. chip) by Atmel Evaluated.
- **Reprogrammable FPGA devt** (equ. 560Kgates) (2xFPGAs 280kgates+EEPROM 4M) Atmel (0.4M€), Evaluation.

CNES, CNES/ESA, CNES/JAXA Not yet funded.

CNES, ESA.
Low noise

D01MH development and space evaluation (mHEMT)

Ommic

UMS

PH10 space evaluation (pHEMT)

Ommic

Enabling of D007IH

Space eval of ultra low noise processes

Power GaN

GREAT² phase 1 & 2
GH50 / GH25 (UMS)

TESAT+UMS+IAF+FBH+IMEC+Univ.

Rel. of GH50-10 in multicarrier mode

TAS+UMS

Pre-eval GH25-10

Assessment of InAlN/GaN (3-5 Lab)

Thales 3-5 Lab

CNES

CNES/ESA

CNES/JAXA

Not yet funded

CNES

ESA

CNES/ESA

CNES/JAXA

Development +ESCC evaluation of GaN processes for mmwave applications

1st Generation of GaN/SiC
Urgent need of european GaN High Power for RF products (SSPA,..)

2nd & 3rd Gen. of GaN/SiC
Improved perfos for all programmes

100 nm

70 nm or less

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Standards components

**STm portfolio development**

- Development/eval./qual. Op Amps, Converters, PWM, diodes, Comparators, Voltage Ref, LVDS, MUX ... (around 30 types, since 2004)
- STm
- FO activities

**Memories, Microprocessors**

- Atmel 40 Mb SRAM devlpt
- Evaluation
- µP LEON 2 Devl (180nm)
- Atmel Evaluation
- NGMP development (65nm)

**High speed converters**

- DAC high speed development
  - 12b, 3Gbps
  - e2v Evaluation
- ADC high speed development
  - 10b, 1.5Gbps
  - e2v
- 12b ADC Devlpt (FP7)
- Qualification
- Low Power ADC high speed development
  - 12b, 1.5Gbps
  - e2v

**Not yet funded**

- CNES
- CNES/ESA
- CNES/JAXA
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Contaminant
Any unwanted molecular or particulate matter on the surface or in the environment of interest, that can affect or degrade the relevant performance or life time (ECSS-Q-ST-70-01)

molecular contamination
undesired foreign film matter without definite dimension, often droplets
(size : from a few Å to several hundreds of Å)

essentially in flight but also on ground

particulate contamination
undesired foreign matter of miniature size
with observable length, width and thickness (size : µm)

essentially on ground

microbiological contamination
entity of microscopic size bacteria, fungi, viruses...

essentially on ground
examples of contaminants

- condensed outgassed products on SiO$_2$
- pollution of connectors
- pollution after TVAC test
- residues on optical window
- fiber and particles on optical filter
- fibers and particles on optical filter
- darkening of molecular droplets after laser irradiation
- residues on a mirror revealed under UV light
- ionic contamination on PCB
- pollution in a mechanism
- droplets on optics
sources of contaminants

contaminant: rarely one product
multiple sources
3 physical forms: gas, liquid, solid

nature of materials
procedures of manufacturing,
Qualification and integration

personnel

during launch
• heating of the fairing
• outgassing of materials
• mechanical vibrations
• plume effects

during on ground activities
• manufacturing
• integration
• test
• transport
• storage

on ground

at launch site
• integration
• transport

in flight

induced environment
• outgassing of polymers
• plume effects

synergistic effects

space environment
• radiations
• atomic oxygen
• thermal cycling
• micrometeoroids

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airborne or surface contaminant ? main effects

problems of intrinsic material stability, lubrication...

increase of local pressure
condensation/re-emission
surface obscuration
other effects due to particles

 degradation of thermal coatings
   change of thermo-optical characteristics
     $\alpha_s$ solar absorptivity ; $\varepsilon$ emissivity

 degradation of optical elements
   modification of optical characteristics :
     - transmission of lenses / reflection of mirrors
     - scattering

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$\alpha_s$ => efficiency => $\Rightarrow$ heating
Contamination control plan depending on mission requirements

**Early stage**
- Identification of sensitive surfaces
- Identification of contaminant sources
- Selection of materials with strict criteria
- Design (events, heaters…)
- Quantification of contamination levels
- Contamination modelling

**Later stage**
- Assembly/integration in cleanroom
- Thermal vacuum bakeout
- Covers
- Purging
- Contamination control by different means
- Appropriate cleaning method
contamination monitoring

actual measurements according to 2 ECSS standards for cleanrooms or during TVAC test

ECSS-70-05C

ZnSe
4000 cm\(^{-1}\) to 400 cm\(^{-1}\)

CaF\(_2\)
4000 cm\(^{-1}\) to 1300 cm\(^{-1}\)

ECSS-70-50C

PFO witness plate
1: total area of sedimentation (18.9 cm\(^{2}\))
2: real measured surface (disc of 15 mm dia.)

4 types of contaminants:
- hydrocarbons
- esters
- methylsilicones
- phenylsilicones

measurement of the obscuration factor
no information on size distribution and number of particles

FTIR analysis

passive witness plates
**Cleanroom airborne analysis**

Air sampling on adsorbent phases / GC/MS or FID, FTIR analyses

**NVR**

- Direct FTIR analysis of the deposit with a spectrophotometer
- Mass measurement with microbalance

**Contamination monitoring**

**QCM**

\[ \Delta f = \alpha \left( f_0 \right)^2 \frac{\Delta m}{S} \]

- Sensitivity: 1.56 ng/cm²

**SAW**

- Sensitivity: 0.01 ng/cm²

Real-time measurement
contamination monitoring

- passive detection techniques with witnesses analysis after exposure duration
- active detection techniques with QCM or SAW (or FTIR) real-time measurement

Keywords for new sensors
real-time, quantification, high sensitivity chemical selectivity for molecular contamination size distribution for particulate contamination miniaturization, matrix of sensors wireless network
double interest to correlate the results with an event (in cleanroom or in orbit) to identify precisely the origin of the contamination reactivity risks on products, costs and time
quantification techniques

Quartz crystal microbalances (QCM)

Thin-film bulk acoustic wave resonators (TFBAR)

surface acoustic wave sensor (SAW)

microcantilever
Micro Electro-Mechanical Systems (MEMS)
micro and nanoporous materials
Molecularly imprinted polymers (MIP)
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new development for chemical contaminants monitoring at CNES

- surface functionalization of a QCM
  - different ways of deposition
    (chemical or physical vapor deposition, sputtering, spin-coating, spray-coating, dip-coating, painting, sol-gel process)
  - appropriate sensitive layer depending on the type of chemical contaminant

- surface functionalization of a SAW with zeolites: promising new research

Next steps: adsorption measurement of representative contaminants exposure in cleanroom for a long period
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recent development for particles monitoring

APMON (Advanced Particle Deposition Monitor) by Technology Of Sense

- Particle size: 25 – 1000 µm
- Witness plate surface: 31 cm²
- Sample time: 10 min – 1 hour
- Box size: 15 x 39 x 80 cm / 5 kg

PDM: Particle Deposition Monitor by SAC Netherlands

- Smallest channel for counting: 10 µm
- Witness plate surface: 48 cm²
- Snapshot every 60 sec.
- Box size: 26 x 20 x 55 cm / 15.3 kg
necessary to improve the control of the cleanliness of exposed surfaces by appropriate devices

new micro sensor concept currently developed (Nina Menant, PhD student)

Objective: to measure the real-time particulate sedimentation and to classify the particles according to their size, closest to contamination sensitive surfaces in a cleanroom – Compliant with the ISO 14644-9 standard –

Sensors requirements

- Particle size 1 – 20 μm
- Real-time measurement
- Integrated sensor for a local measurement
- Wireless sensor network
- Autonomy
New development for particles monitoring at CNES

Sensor measurement principle

Micro-optical system to measure the interaction particle-light (diffusion, transmission, reflection)

Modeling of 6 solutions

Optimization of parameters

- Spot size
- Scan time
- Data volume
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- Component activities are still a priority for satellite development
- DSM activities will give a good answer to next generation satellite needs
- Good collaboration/coordination
  ✦ within the ESCC/CTB and between CNES and ESA
  ✦ with JAXA (FPGA 450K gates, Contamination...)

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