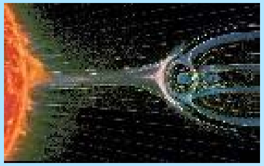

USAGE of COTS ADC's for SPACE APPLICATIONS

(COTS: Commercial Of The Shelf)

Nicoletta Ratti

ALENIA SPAZIO - LABEN

Vimodrone, MILANO

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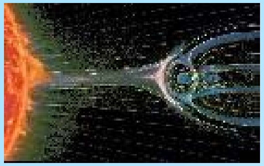
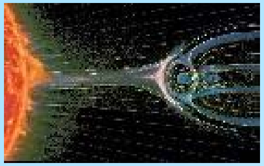
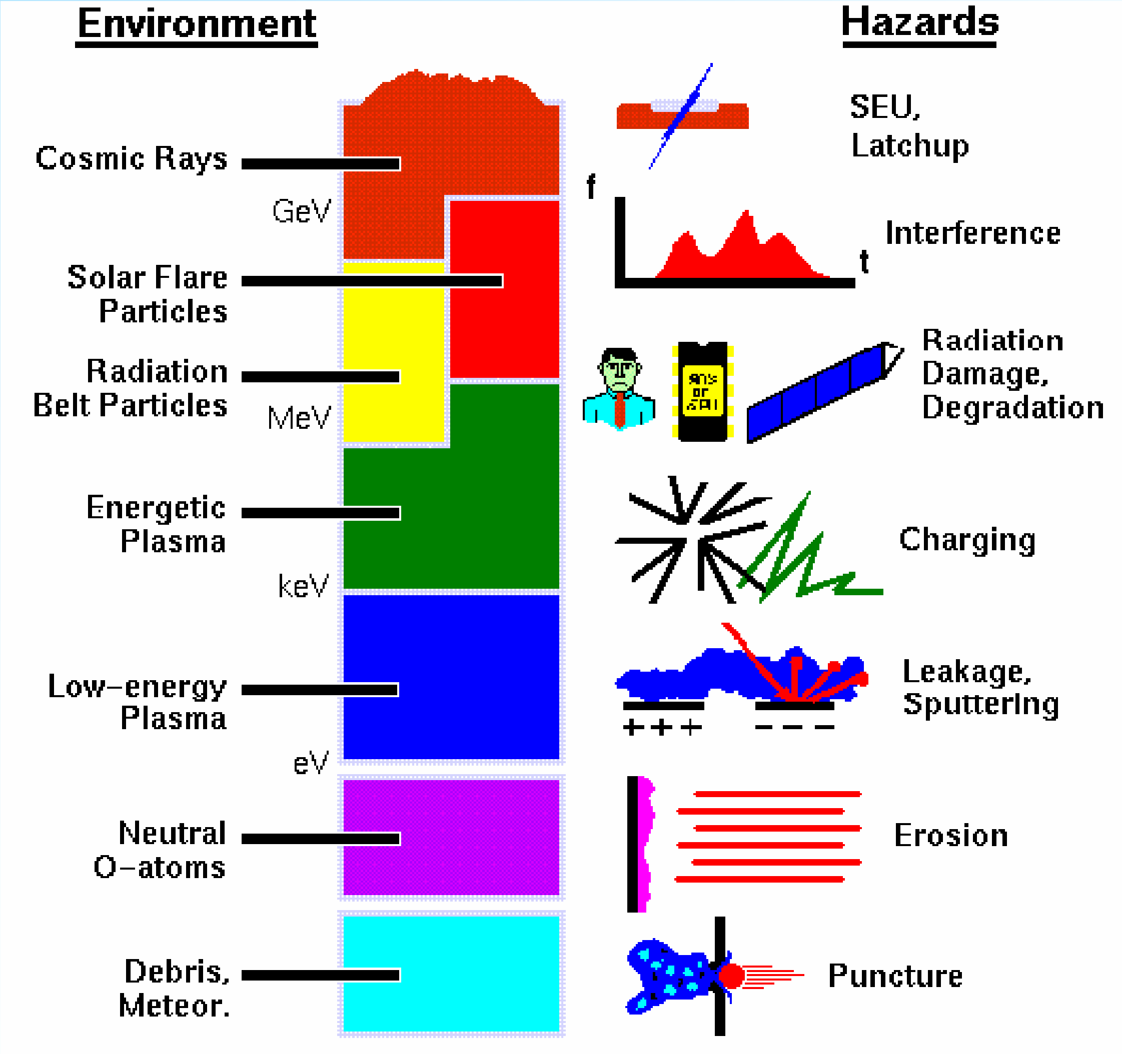
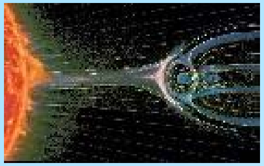


CONTENT



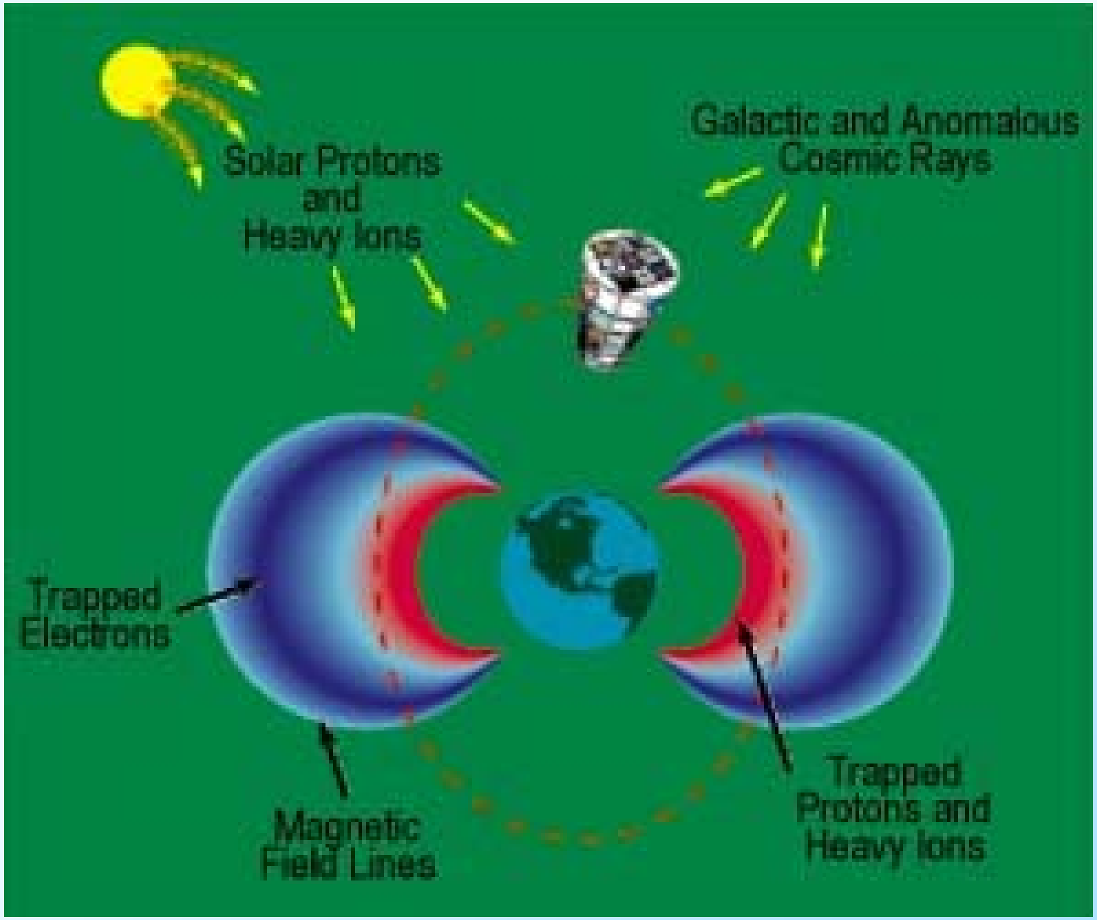


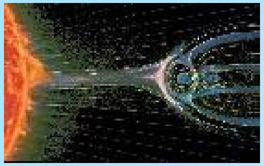
HAZARDS
in the
SPACE
ENVIRONMENT



MAIN SOURCES OF ENERGETIC PARTICLES (IONISING RADIATION)

- Protons and electrons trapped in the Van Allen radiation belts
- Cosmic or galactic ray protons and heavy ions from outside the solar system
- Protons and heavy ions from solar flares
- Heavy ions trapped in the magnetosphere





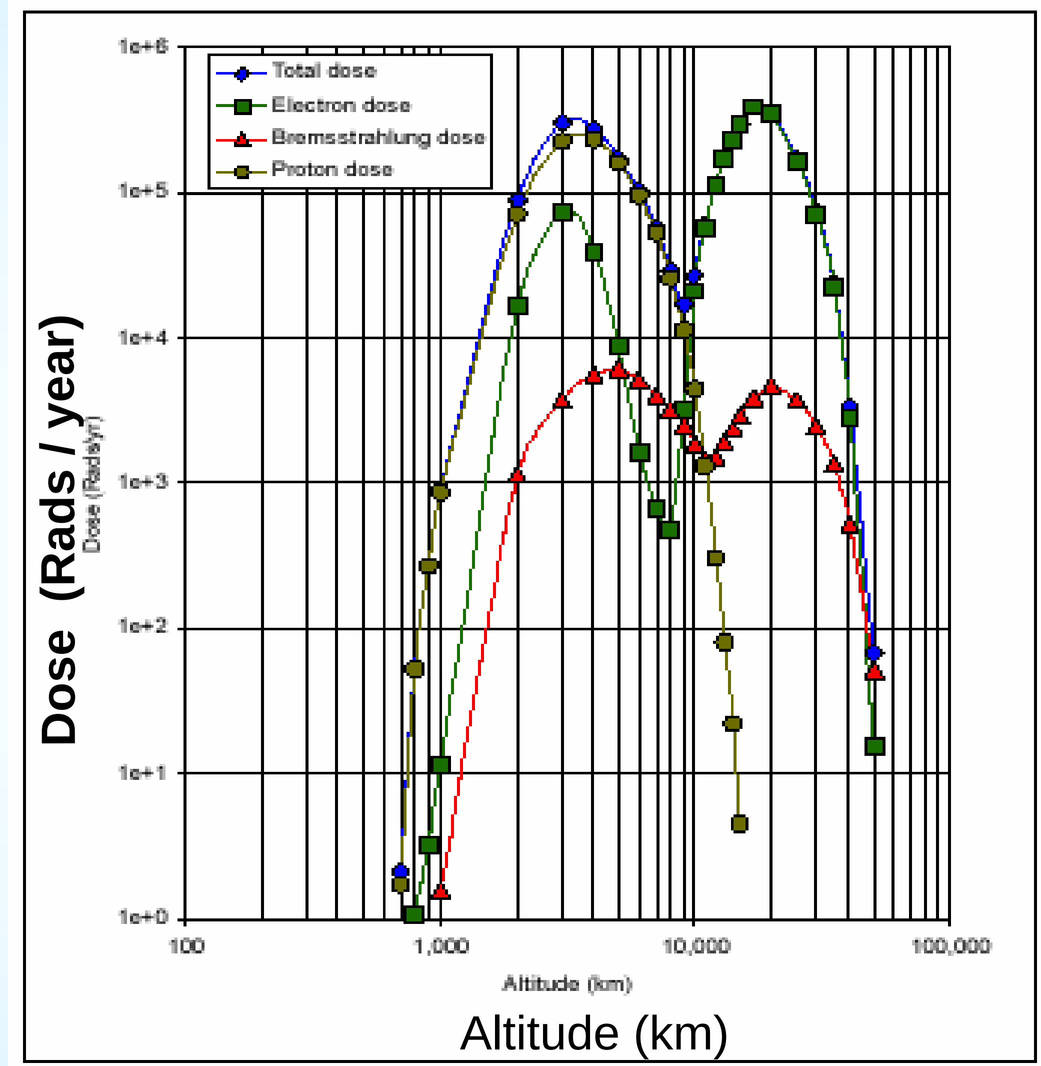
RAD. DOSE in ORBIT

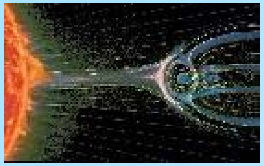
The radiation dose depends on type of orbit:

- Equatorial Near Earth (< 1000 km)
- Polar Orbit
- Geosynchronous Orbit (36.000 km)
- Interplanetary Orbit

FIGURE

Annual dose behind 4 mm Al shielding on circular equatorial orbit, as a function of height.

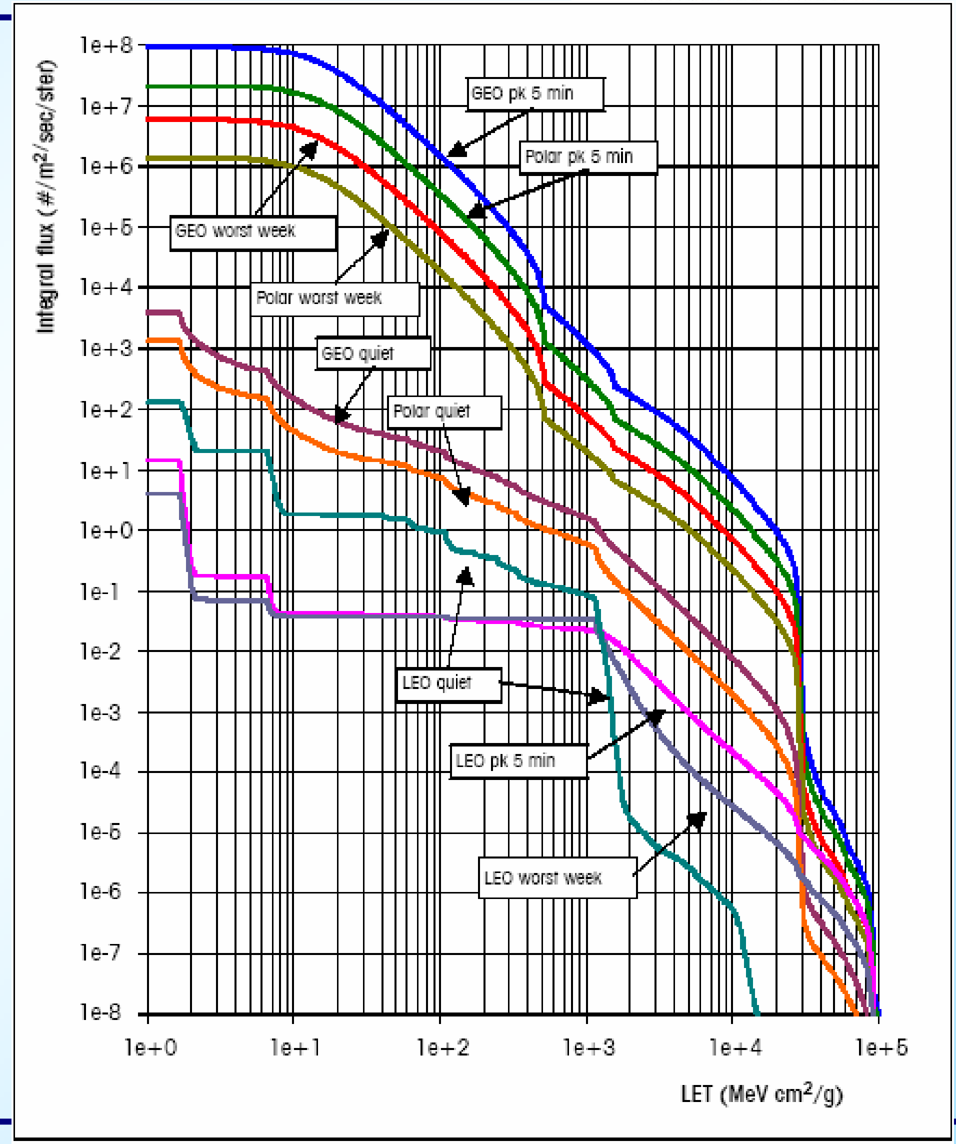


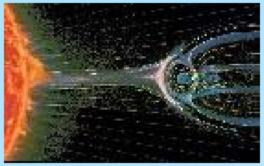


Cosmic Ray Flux

The Flux and the energy of Cosmic Ray depends on type of orbit and solar activity.

Figure shows composite LET spectra for three environments: nominal solar minimum, “worst week” and “worst day”, Three orbital situation: GEO, POLAR, LEO.





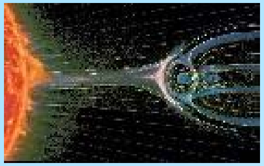
FAILURE MECHANISMS in ELECTRONIC DEVICES

1) Total Ionising Dose - TID

- long term failure mechanism, depends on orbit altitude, orientation and time and life time
- trapped protons in radiation belts
- trapped electrons in radiation belts
- protons from solar flares

2) Single Event Effect - SEE

- instantaneous failure mechanism
- Galactic cosmic ray
- Cosmic Solar particles (heavily influenced by solar flares)
- trapped proton in radiation belts

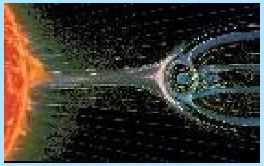


SELECTION of EEE COMPONENTS for SPACE PROGRAM

Available
EEE components
(COTS)

Orbit & Space-craft
rad. requirements

Flight Unit
components



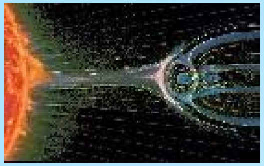
RADIATION ASSURANCE FOR SPACE PROGRAM

PURPOSE

of the space radiation assurance is to ensure that

- technology,
- manufacturing
- assembly processes

selected for a given mission are capable of maintaining the required electrical and operational performances over the life cycle of the experiment while operating in an extreme environment.

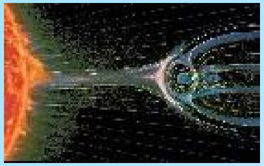


SPACE RADIATION HARDNESS ACTIVITIES

Space Radiation Hardness Activities to be performed for

1) Parts selection and/or characterisation
2) Calculation of deposited doses and SEE rates
3) Equipment worst case analysis
4) Corrective actions

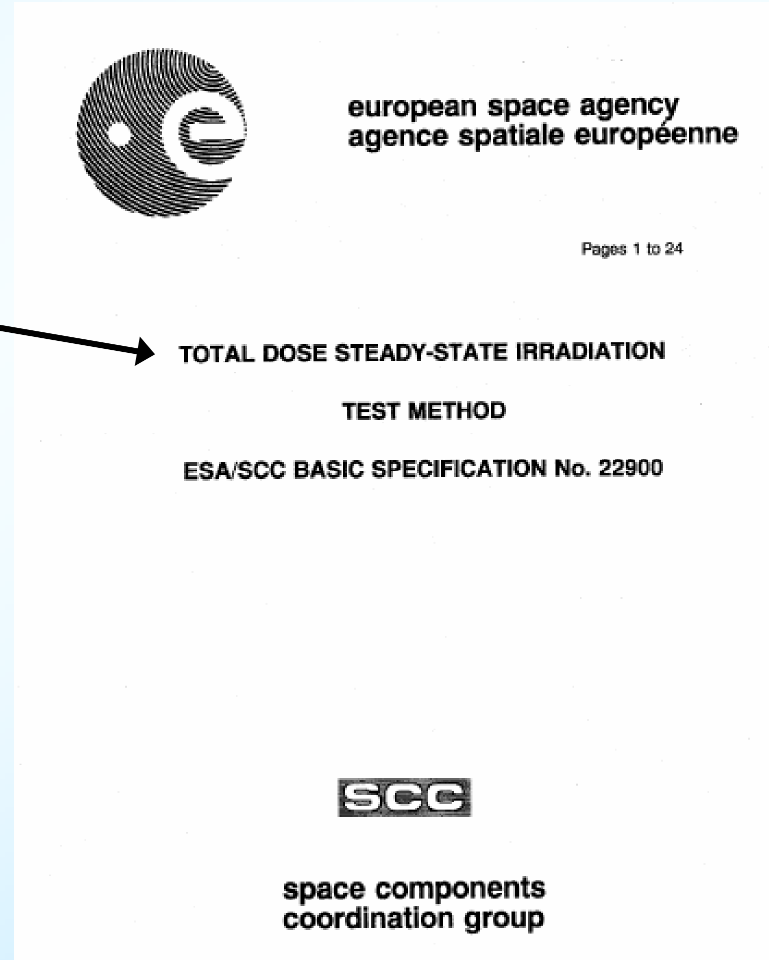
Activities for both TID (Total Dose) and SEE (Single Event Effects).



TID - COMPONENT CHARACTERISATION

Procedure:

- Total Dose Steady State Irradiation Test Method ESA-SCC no.22900



european space agency
agence spatiale européenne

Pages 1 to 24

TOTAL DOSE STEADY-STATE IRRADIATION

TEST METHOD

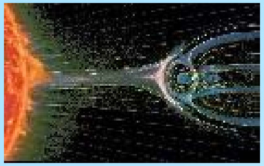
ESA/SCC BASIC SPECIFICATION No. 22900

SCC

space components
coordination group

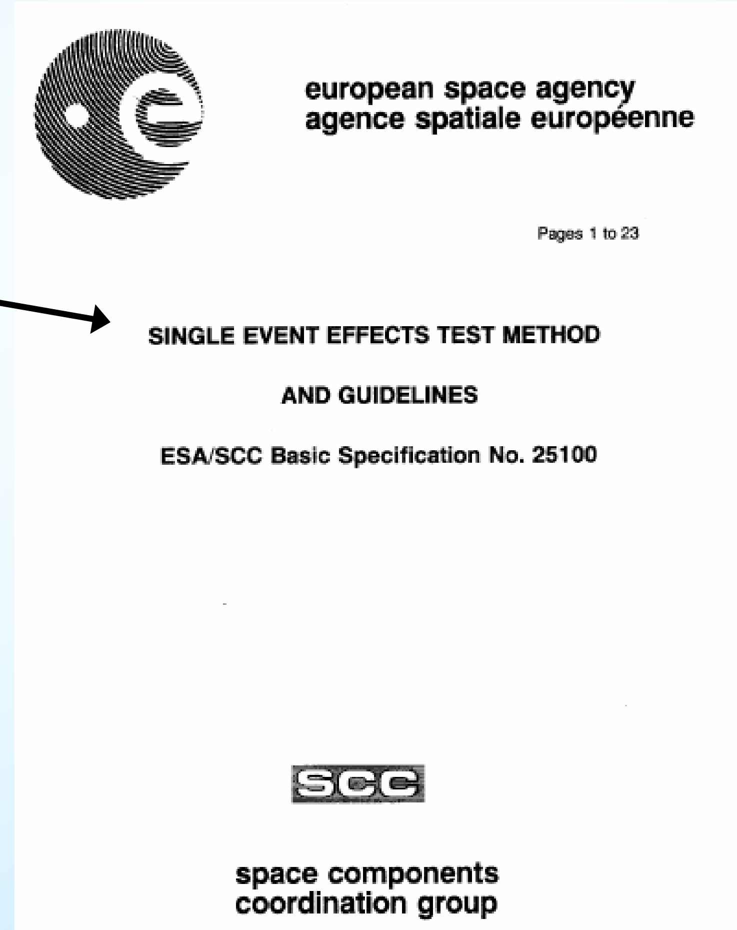
Test requirements:

- Radiation source: Cobalt 60 gamma source
- Radiation dose rate
  - standard rate: 3.600 to 36.000 rad hr^{-1}
  - low rate: 36 to 360 rad hr^{-1}
- Test set-up
  - bias condition
  - in situ testing/remote testing
- Annealing



SEE - COMPONENT CHARACTERISATION

Test procedure:
•Single Event Effect Test Method and Guideline
ESA SCC 25100



european space agency
agence spatiale européenne

Pages 1 to 23

SINGLE EVENT EFFECTS TEST METHOD

AND GUIDELINES

ESA/SCC Basic Specification No. 25100

SCC

space components
coordination group

Test requirements:

•Radiation Source: particle accelerator

heavy ions/protons

•Radiation test plan: select ions, define test set up

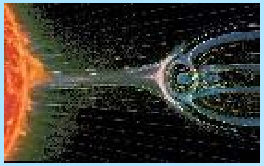
This type of test is expensive:

remote, expansive facilities

test set up development

special problems: parts de-lidding and

in vacuum operation



RADIATION ANALYSIS

INPUTS from customer:

- Environmental specification
- Product Assurance Plan

INPUTS from project leader:

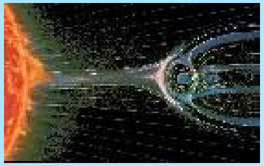
- EEE part list
- Design description

Radiation analysis (TID & SEE) may highlight:

- non compliance
- need of countermeasures
- need for component characterisation

Important to <u>start in the early phase of the project</u>

1) to avoid redesign, 2) to procure appropriate EEE components, 3) not to overdesign box



TID: REQUIREMENTS on EEE COMPONENTS

From COSMO PRODUCT ASSURANCE PLAN

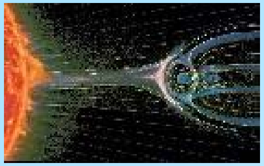
For total dose radiation, part types shall have a resistance of 15 Krad minimum unless otherwise specified in the Cosmo Skymed project. On the basis of the data available, each part type shall be identified as belonging to one of the following four categories, depending on the sensitivity level:

- **Category 1** : includes all the parts having a radiation resistance **higher than 100 Krads**. It includes also insensitive parts (resistors, capacitors, inductors, etc.).

- **Category 2** : includes all the parts having a radiation resistance **between 50 Krads and 100 Krads**. A detailed report with the test results on the relevant electrical parameters is required, in order to demonstrate the suitability of the parts for use.

- **Category 3** : includes all the parts having a radiation resistance between **15 Krads and 50 Krads**. For these part types, a lot-by-lot radiation test is required. The above test can be waived in case sufficient data are available to demonstrate that the radiation test results are not variable from lot to lot, and that **the radiation sensitivity is higher than 1.5 times the received dose.**

- **Category 4** : includes all the parts having a radiation resistance **lower than 15 Krads**. As stated above, these parts cannot be used.



TID COMPUTATION: DOSE - DEPTH CURVE

Input parameters:

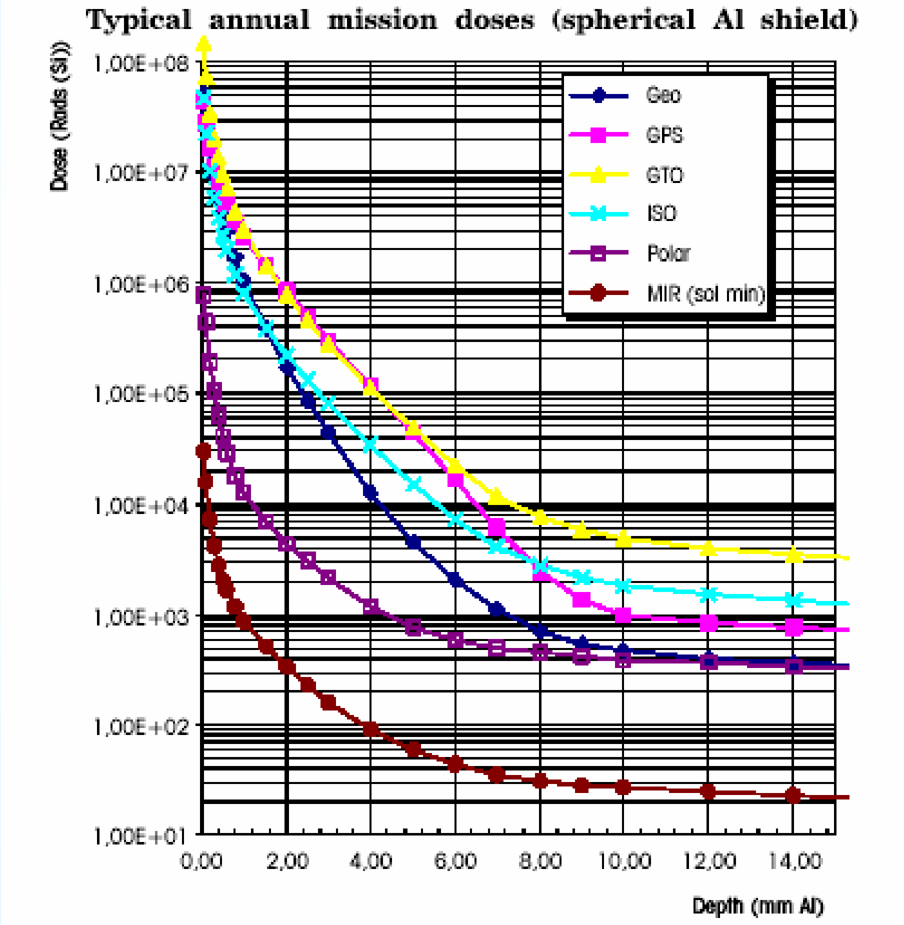
satellite orbit
space weather condition (solar min/max, flares)
mission duration

Output:

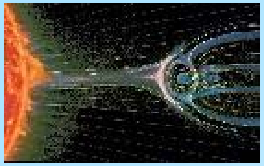
Dose-depth curve: dose at the center of an Al sphere of a given thickness

Tool:

Spenvis (http://www.spenvis.oma.be/spenvis/)



Usually the dose-depth curve is reported in the Environmental Specification Document



TID COMPUTATION: DOSE AT COMPONENT

Input parameters:

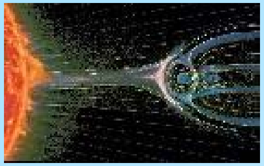
- dose-depth curve
- satellite shielding in Al equivalent
- geometry of the electronic unit
- material density
- location of component

Output:

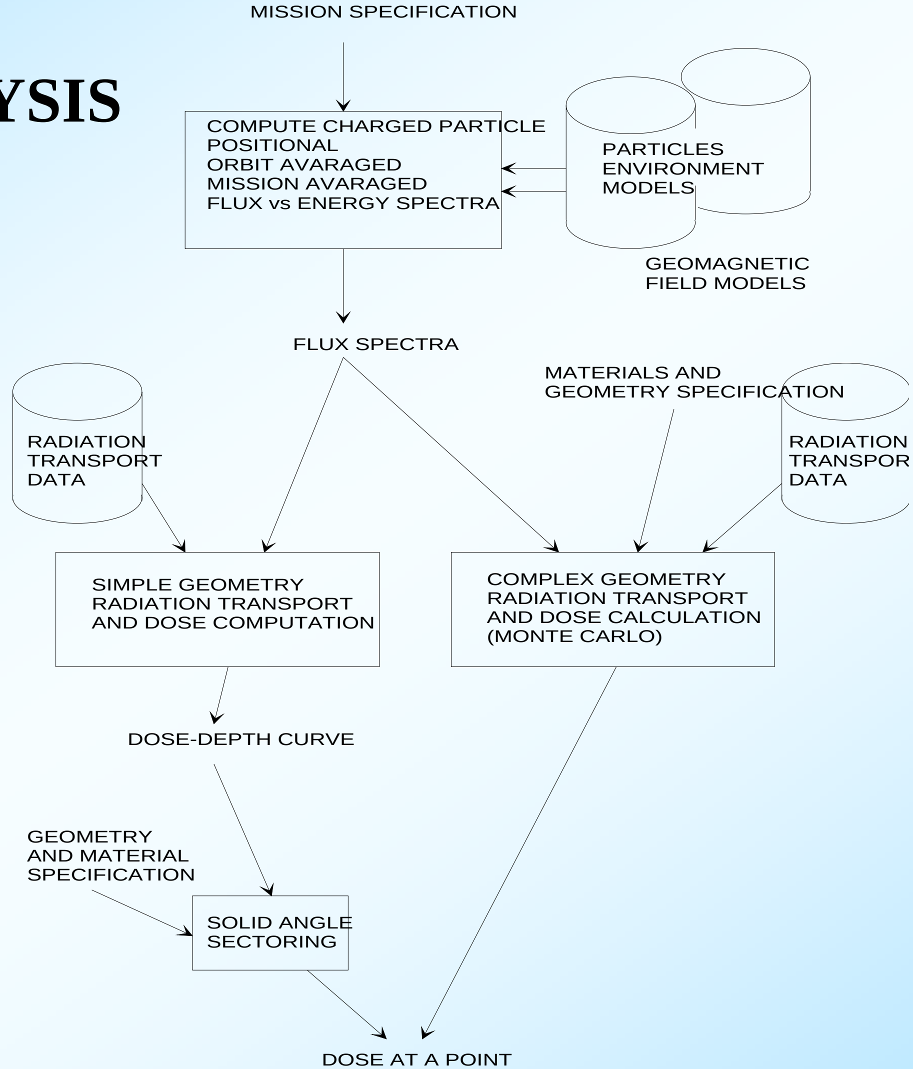
- dose received at target components

Tool:

- ESABASE- DOSRAD

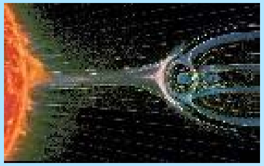


RADIATION ANALYSIS TOOLS



Esabase - Dosrad

Montecarlo



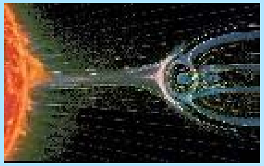
TID: COUNTERMEASURES

If the component tolerated dose < 1.5 x RECEIVED DOSE ?

Countermeasures:

- modification of device/PCB placement
- add on spot shielding
- increase box walls

More accurate analysis can be performed with other tool than ESABAE/DOSRAD (Montecarlo)



SEE: REQUIREMENTS on EEE COMPONENTS

Three main classes are identified, according to the following definition**:**

LET_{th} > 37 MeV·cm^2/mg for SEU
LET_{th} > 100 MeV·cm^2/mg for SEL

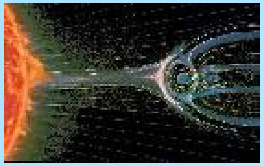
The EEE parts are considered not sensitive to heavy ions/protons induced phenomena, no further actions will be done. The component can be used as is no analysis is required.

12 MeV·cm^2/mg < LET_{th} < 37 MeV·cm^2/mg for SEU
12 MeV·cm^2/mg < LET_{th} < 100 MeV·cm^2/mg for SEL

The EEE parts are considered sensitive to heavy ions but not to protons induced phenomena. The rate of the event on components must be calculated and their effects on the circuit and on the equipment must be evaluated.

LET_{th} <12 MeV·cm^2/mg

The EEE parts are considered sensitive to heavy ions and to protons induced phenomena. The rate of event on components must be calculated as the sum of the SEP rate induced heavy ions and the one induced by protons. The effect of SEP on circuit and on equipment must be evaluated.



CREME96 - Cosmic Ray Effects on Micro-Electronics

Create numerical models of the radiation environment in near-Earth orbits.
Evaluate the resulting radiation effects on electronic system in spacecraft.

Input parameters:

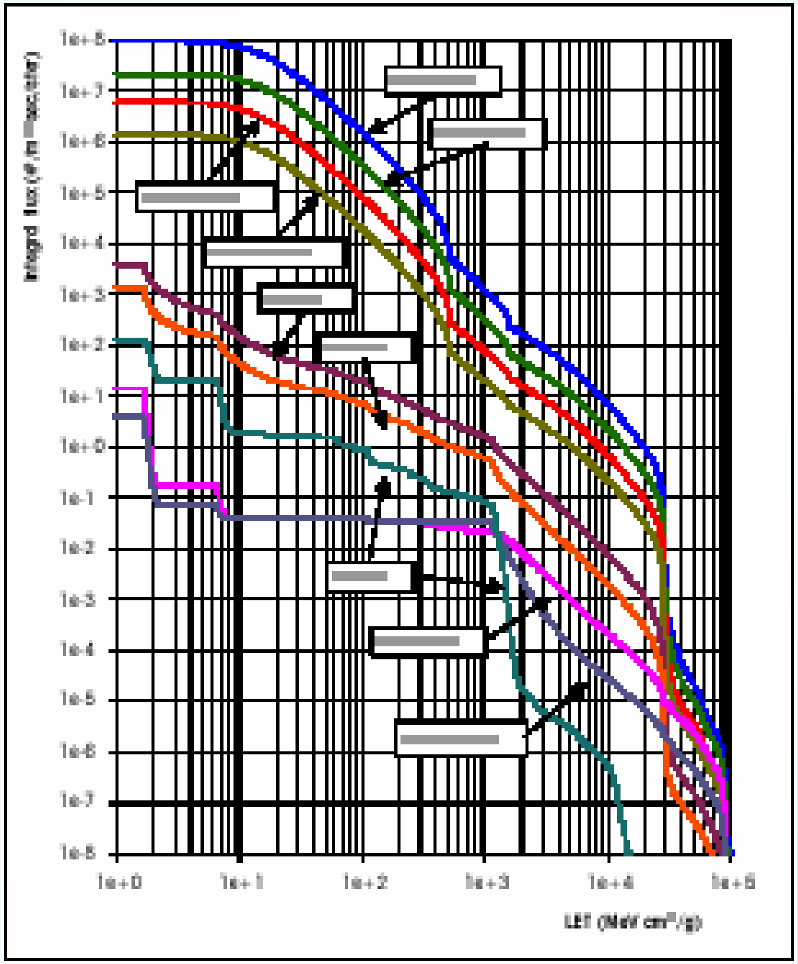
- orbit of the satellite
- Space weather condition(solar min/max,…)
- Satellite shielding
- Component characteristics

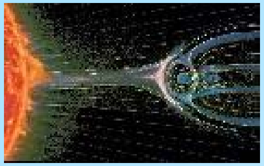
Output:

- LET spectrum
- Predicted SEE rate

Tool:

- CREME96 (http://creme96.nrl.navy.mil/)





Alenia SPAZIO
A FINMECCANICA COMPANY

SEE: MITIGATION TECHNIQUES

Single Event Upset

TRM - Triple Redundant Module
Error detection & correction code
Scrubbing

Single Event Transient

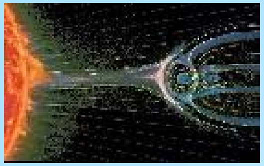
Circuital analysis to verify the impact of transient on the performance: add filtering

Single Event Latch-up

Latch up protection circuit (current limitation)
Technology Immune

Single Event Burn-out / Gate Rupture

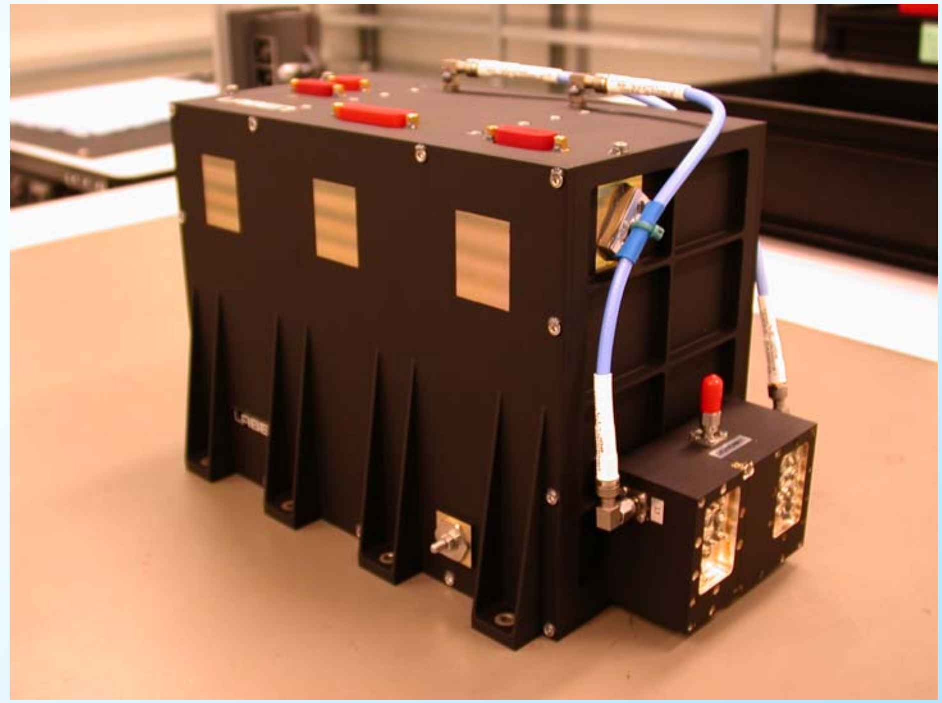
De-rating rules



LAGRANGE™

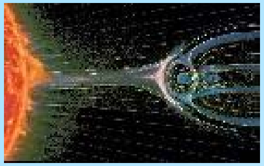
Laben GNSS Receiver for Autonomous Navigation Geodesy and Experiments

LAGRANGE receiver development started in 1998 with Laben internal funds;
first prototype developed
in 1999 with Italian Space Agency contribution for demonstrative flight on SAC/C satellite.



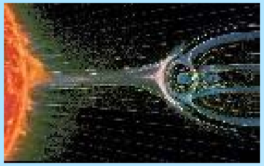
LAGRANGE is today on board the following missions:

- RADARSAT-2 (1 PFM, 1 FM)
- COSMO (1 EQM, 1 PFM, 5 FM’s)
- GOCE SSTI (1 EQM, 2 FM’s)
- LAGRANGE for Radio Occultation (1PFM)



LAGRANGE Main Characteristics

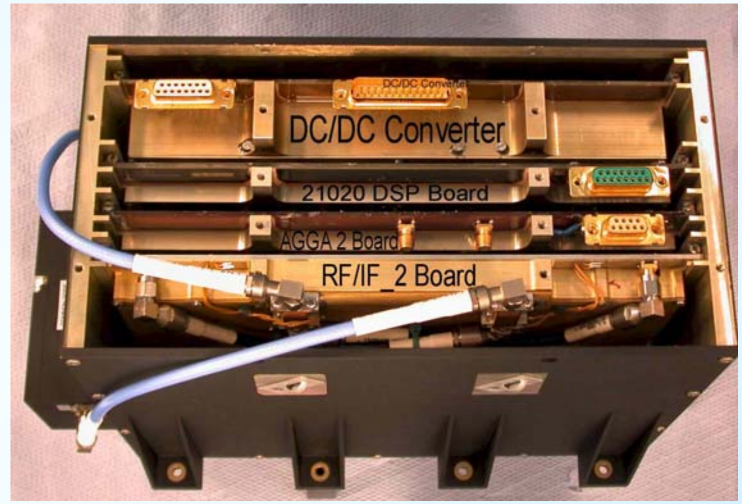
Receiver Type:	Integrated GPS/GLONASS receiver for spaceborne applications (navigation and scientific experiments)
Channels:	Up to 12 dual frequency channels
Frequency Band:	GPS L1: 1575.42 MHz GPS L2: 1227,6 MHz
Observables:	L1CA, L1P & L2P Code phase L1CA & L2P Carrier phase L2-L1 delta range Instantaneous Doppler Time



LAGRANGE Composition

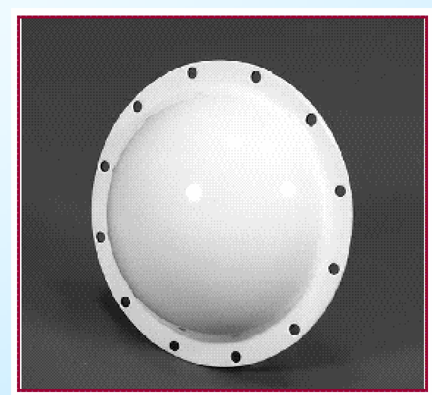
Receiver Unit:

Power Supply Module DC/DC
Processor Module 21020DSP
AGGA 2 Module AGGA2
RF/IF Module RF/IF_2
Motherboard



Antenna:

Diplexer (externally allocated)
Interconnection Cables



LAGRANGE RF/IF Module

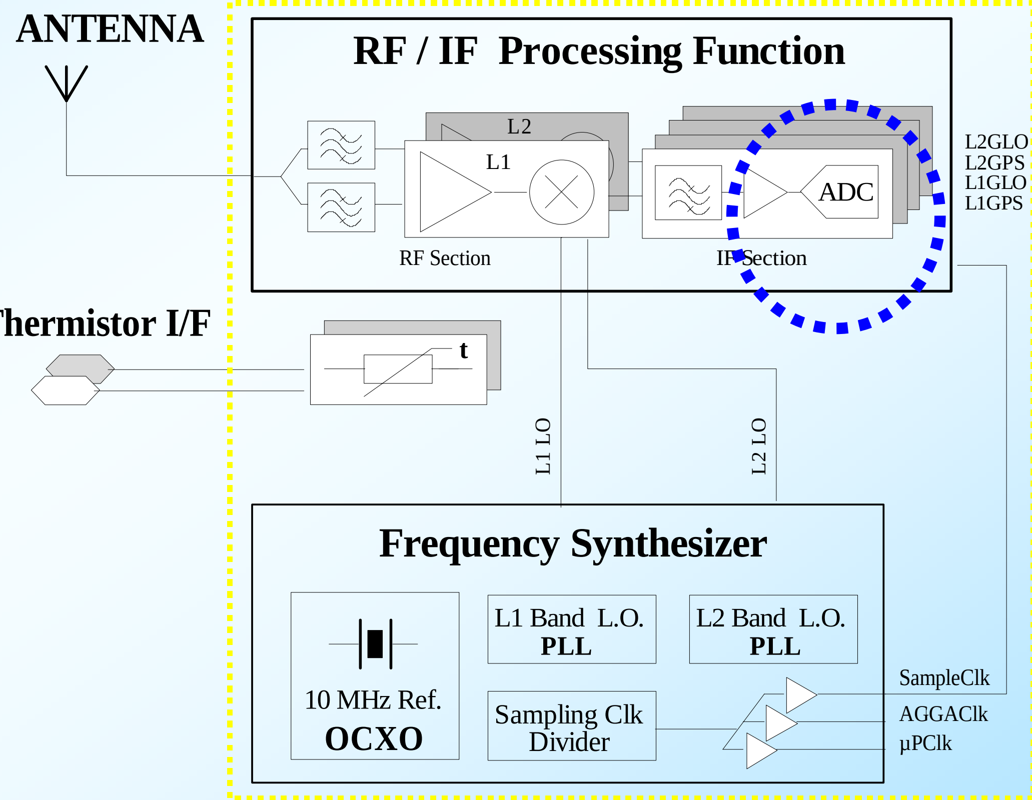
Overall Noise Figure < 3dB

AGC dynamic range 30 dB

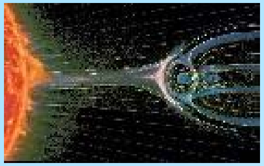
GPS Channels (L1, L2) group delay distortion <4 nS OFTR*

GLONASS Channels (L1,L2) group delay distortion <3 nS OFTR*

*Over Full Temperature Range



ADC is a fundamental component for the RF/IF processing function

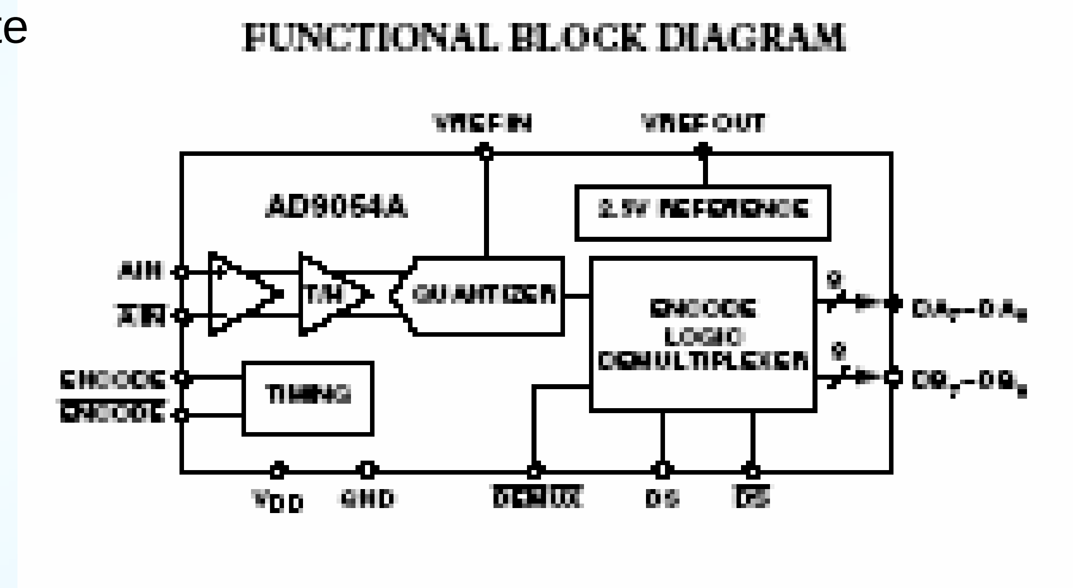


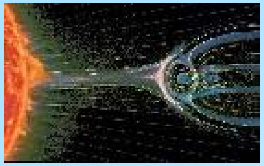
ADC - A/D CONVERTER

AD9054 from Analog Device was selected

FEATURES:

- 200 MSPS Guaranteed Conversion Rate
- 135 MSPS Low Cost Version Available
- 350 MHz Analog Bandwidth
- 1 V p-p Analog Input Range
- Internal 2.5 V Reference and T/H
- Low Power: 500 mW
- 5 V Single Supply Operation
- TTL Output Interface
- Single or Demultiplexed Output Ports



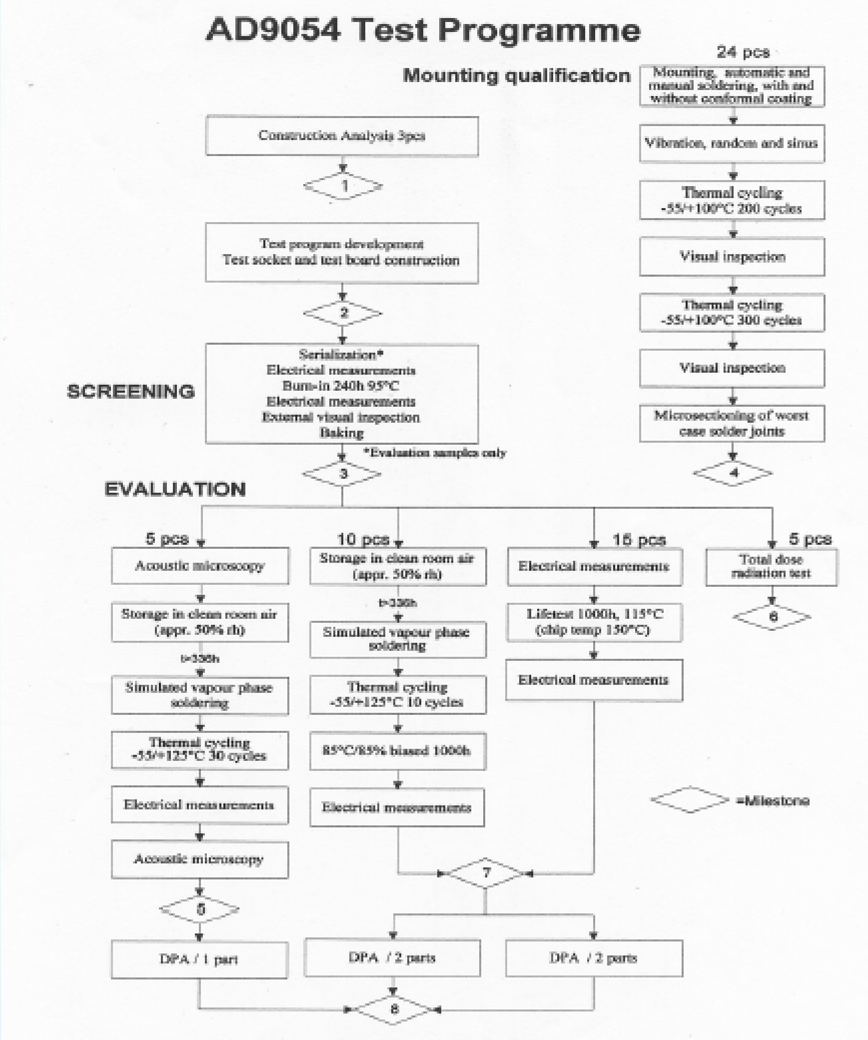


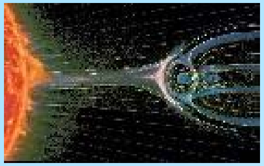
AD9054 QUALIFICATION

The AD9054 from Analog Device is a COTS (Commercial Off The Shelf) component.

It is encapsulated in a 44 pin plastic leaded quad flat package.

The device was evaluated and qualified for METOP program, used in RADARSAT.





AD9054 Radiation Test Results

TID

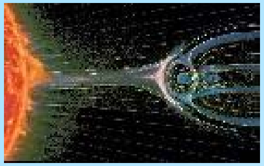
- No functional & parametric changes up to 20 Krad(Si)

SEE

- No SEL up to LET=55 MeV/mg/cm^2

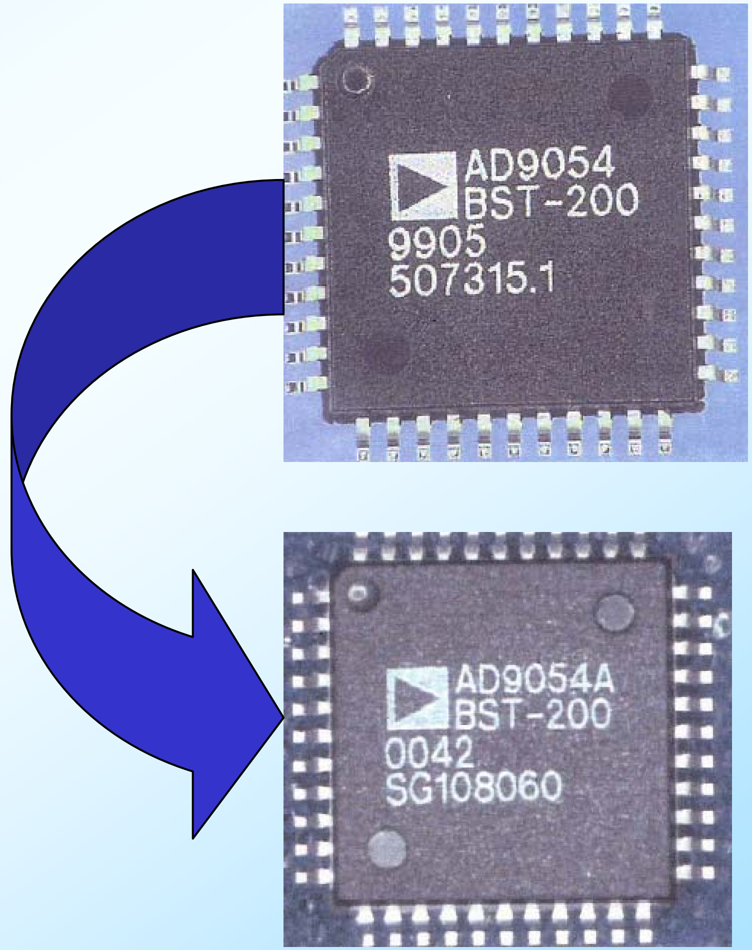
During the procurement of a second lot of the A/D converter the device AD9054 was no more available

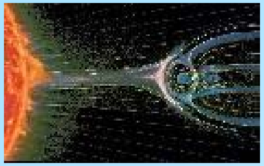
AD 9054A is the replacement.



AD9054A is a pin-for-pin replacement for AD9054

- The AD9054A was designed to be a drop in replacement for AD9054
- AD9054A also offers a more “user friendly” mode for Data Sync (used for encode rates >100MHz)
- The AD9054A uses polysilicon fuses to calibrate linearity for improved manufacturing yields
- The AD9054A pinout and electrical specifications are identical to the AD9054 except for minor items.



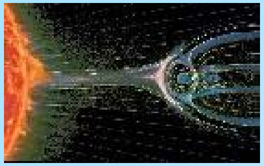


AD9054A is a pin-for-pin replacement for AD9054

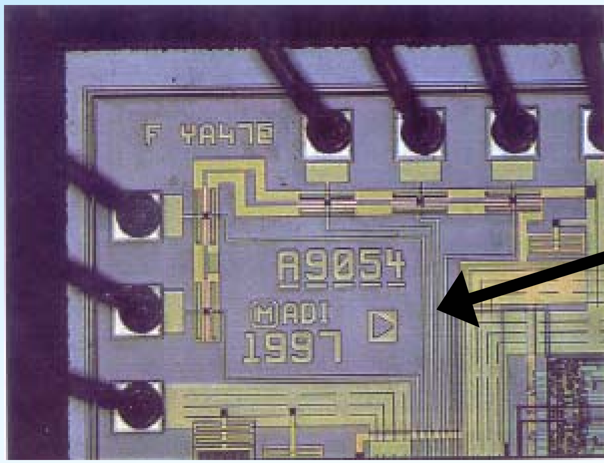
These are the information that we got from Analog Device

"The redesign of the AD9054 to the AD9054A was fairly major as a complete new layout was done and the incorporation of trim capability to correct for linearity errors was added. The change was considered a major change by ADI. The process remained the same however."

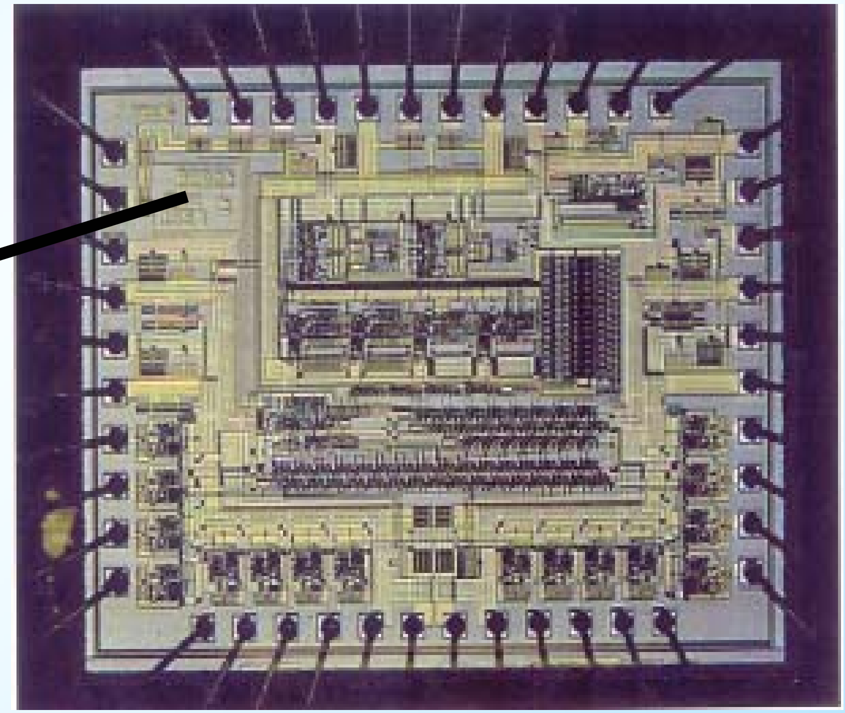
"The change from the AD9054 to the AD9054A will change the radiation tolerance of the device.
The AD9054 is all bipolar structures which is more radiation tolerant.
The AD9054A had some CMOS structure added which effect the linearity of the part.
Since CMOS is less radiation tolerant it is my guess that the AD9054A would not hold up in a space type application. However, Analog Devices makes no claims or warranties with respect to radiation tolerance, or lack thereof, on the AD9054A.
The performance of the AD9054A has not been tested or measured to our knowledge"



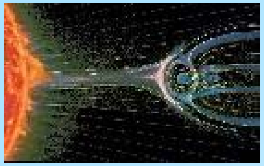
AD9054 - PHOTO of the CHIP



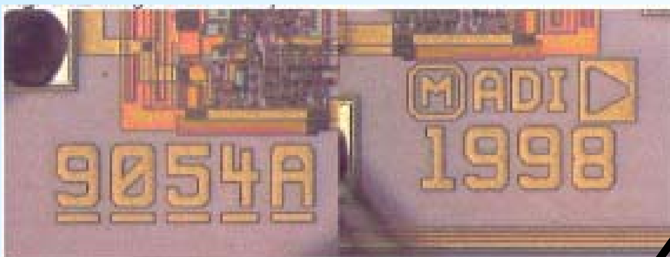
Die Marking



Complete layout of the chip

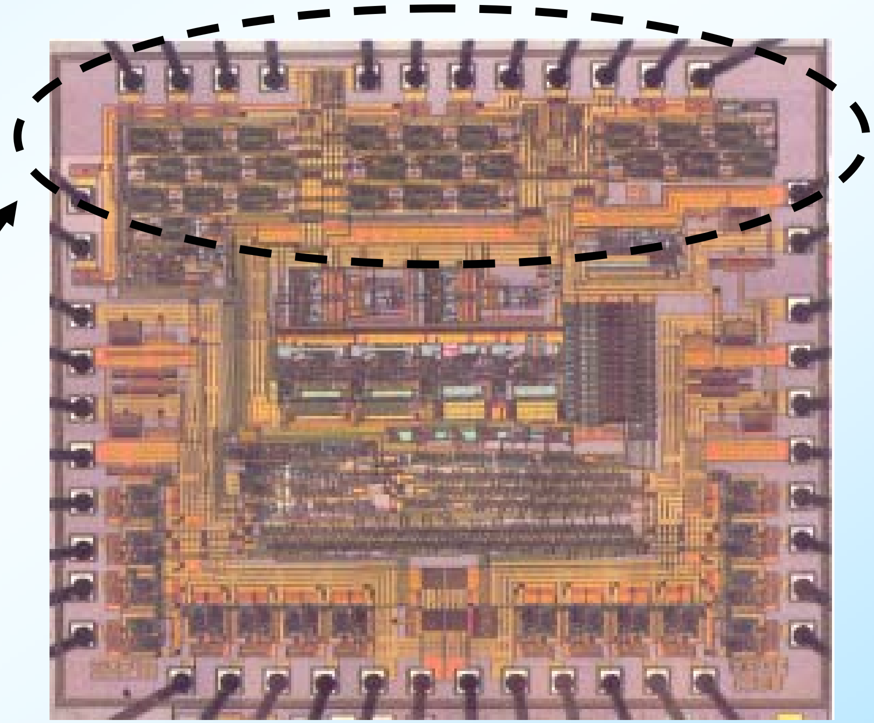


AD9054A - PHOTO of the CHIP

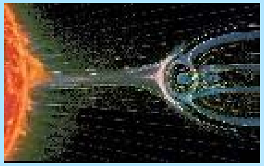


Die Marking

These are the added functions



Complete layout of the chip



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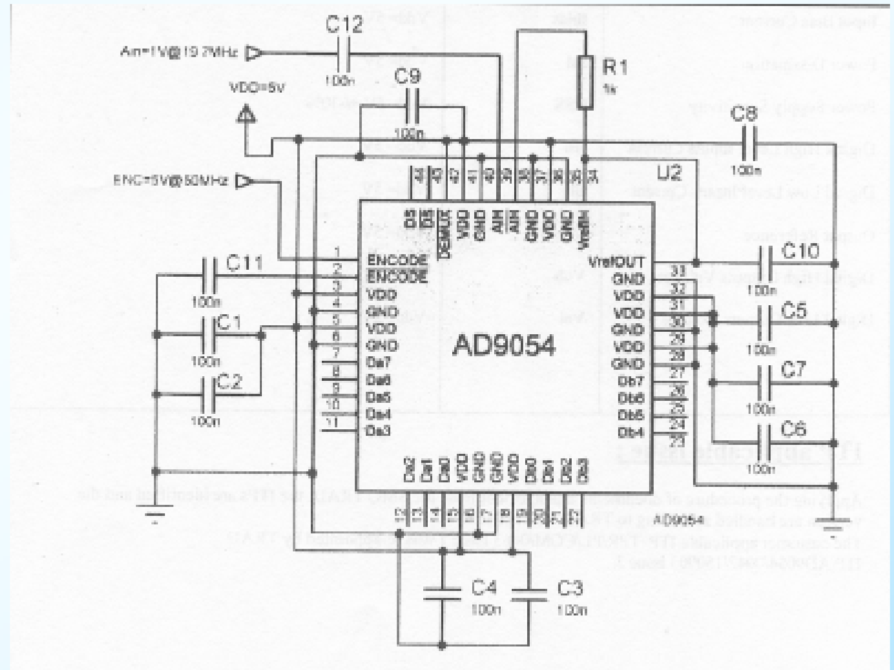
AD9054A RADIATION TEST ACTIVITIES - TID

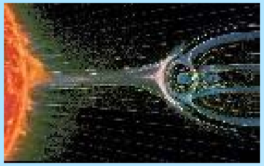
Total Dose Test Plan

- Number of parts: 5+1
- Source:Cobalt 60
- Total dose limit: 20 Krad(Si)
- Level of measurement: 0, 5, 10, 15, 20 Krad(Si)
- Dose rate: 0.22 Krad(Si)/h
- Annealing: 24 hours @ 25°C
- 13 electrical parameters have been tested (SNR, INL, DNL,…)



Total Dose Test results

- **All parts are in specification at total dose**



AD9054A RADIATION TEST ACTIVITIES - SEE

Two separate runs are foreseen:

1) SEL

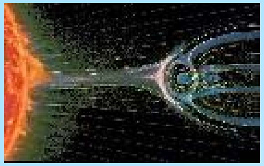
then (if SEL results are acceptable)

2) SEU

Test Facility: Universite de Louvain (UCL) - ESA had assured Laben get allocated 2-3 hours
of beam time in order to conduct these tests on two parts

Ions used: 84Kr17 & 132Xe26 for a LET respectively of 34 and 55,9 MeV.cm^2/mg

The use of a tilt angle allows for additional effective LET values

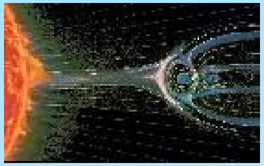


AD9054A RADIATION TEST ACTIVITIES - SEL

Run	Ion	Energy Mev	LET MeV/(mg/cm^2)	Range µm	Tilt Deg	Eff LET MeV/(mg/cm^2)	Test Tme s	Flux #/(cm^2.s)	Fluence #/cm^2	SELs
1	Kr	316	34	43	0	34	304	8251	2.51E+06	0
2	Kr	316	34	43	45	48.08	334	7490	2.50E+06	0
3	Kr	316	34	43	45	48.08	295	8498	2.51E+06	0
4	Xe	459	55.9	43	0	55.9	384	6523	2.50E+06	0
5	Xe	459	55.9	43	45	79.5	316	7932	2.51E+06	0
6	Xe	459	55.9	43	45	79.5	276	9069	2.50E+06	0

OK: No SEL detected for LET values < 80 MeV/(mg cm2)

SEU test foreseen in the next month



CONCLUSIONS

The usage of COTS devices for space application is a must when dealing with
- high performances
- short developing time and low cost

- Radiation effects on components and systems are an increasing concern to industry
  - scaling of technology decreases TID sensitivity but increases SEE sensitivity

- Implementation of a proper Radiation Assurance helps in anticipating problems

- Other example of COTS: DRAM for solid state mass memory