RHA : THE RADIATION HARDNESS ASSURANCE

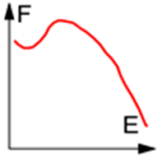
FOR SPACE ELECTRONIC EQUIPMENT

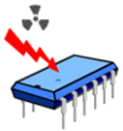
TABLE OF CONTENTS

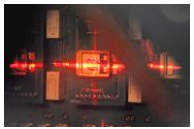
Introduction

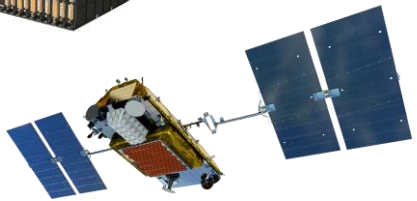
/// RHA : The process used by the space industry to electronic systems

- To guarantee that the spacecraft will survive the space radiation
- Applicable to the complete design lifetime of the spacecraft from the parts and materials to the complete satellite
- Includes all skills involved :
  - Space environment
  - Particle transport
  - ASIC / equipment / system design
  - Device testing









- Failure in space in not an option !

RHA = Radiation Hardness Assurance

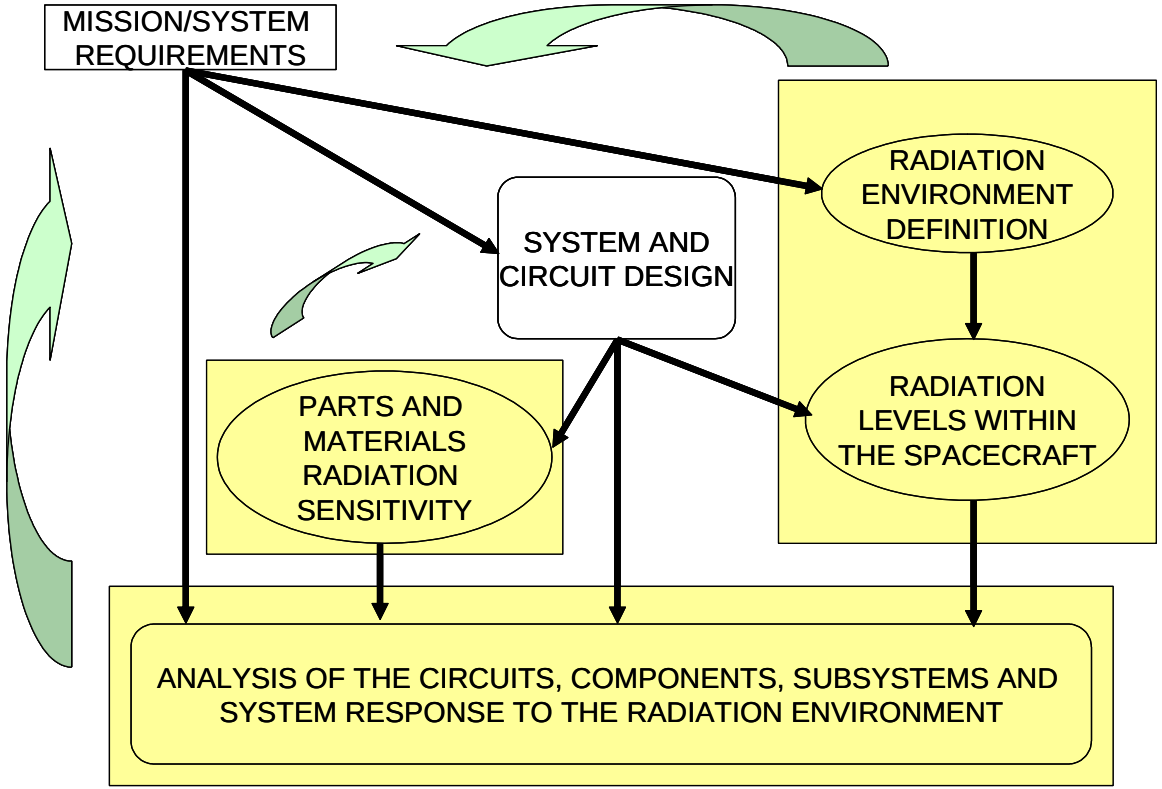
Date: 15/06/2021
Ref: BVS ABR space radiation workshop – 18 June 2021
Template: 83230347-DOC-TAS-FR-008

RHA process overview

/// Interaction between activities

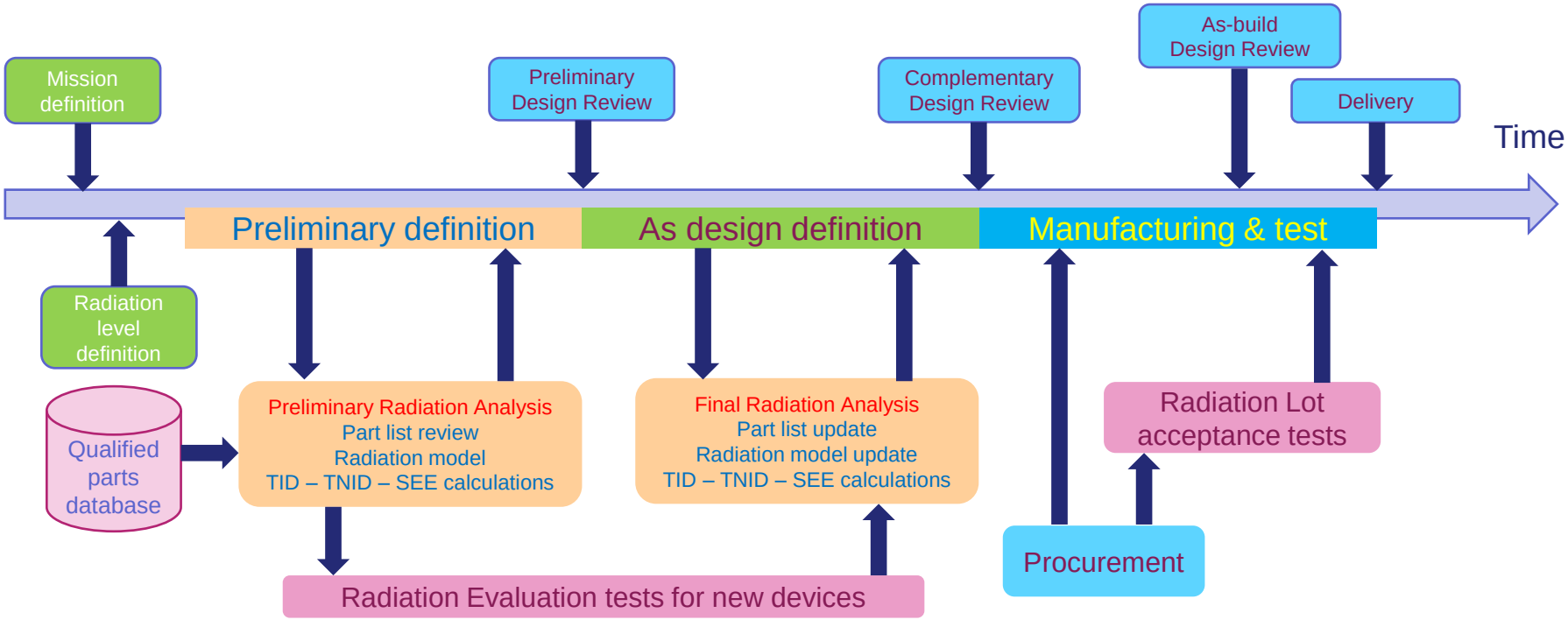
/// It is an iterative process

/// From ECSS-Q-ST-60-15C



RHA process overview

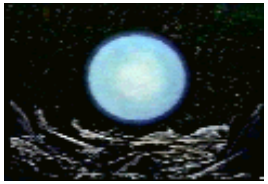
/// Timeline . . .



Date: 15/06/2021
Ref: BVS ABR space radiation workshop – 18 June 2021
Template: 83230347-DOC-TAS-FR-008

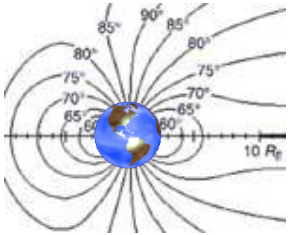
Space environment

/// Irradiation sources considered in space :



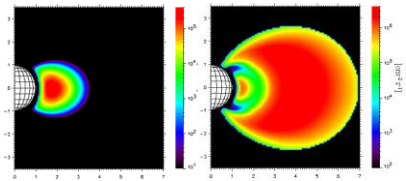
- Galactic cosmic ray (Ions from z = 1 to 92)
  - Heavy Ions coming from the universe with extremely high energy (max 3e20 eV ~ 50J) !
- Solar protons (quiet and flare)
  - Solar wind and flare

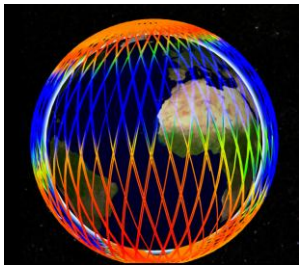
- Trapped particles
  - Electrons and protons trapped in the Earth magnetic field

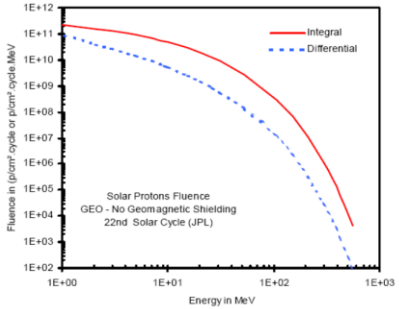


/// Spectrum calculation

- Model based on multiple space missions
- Free tools are available
  - SPENVIS (BIRA-IASB / ESA)
  - OMERE (CNES)
  - CREME 96 (NASA)





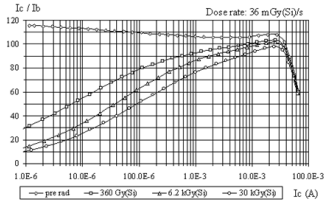


Date: 15/06/2021
Ref: BVS ABR space radiation workshop – 18 June 2021
Template: 83230347-DOC-TAS-FR-008

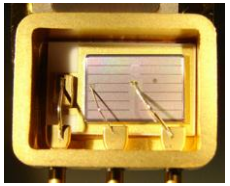
Component behaviour

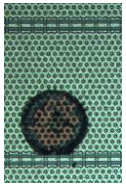
/// Effects on electronic devices :

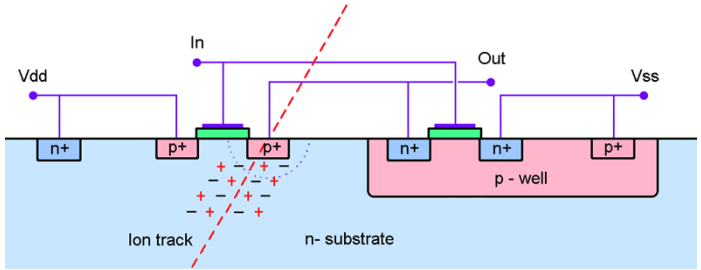
- Total dose : Device parametric drifts due to ionising effects and displacement damages

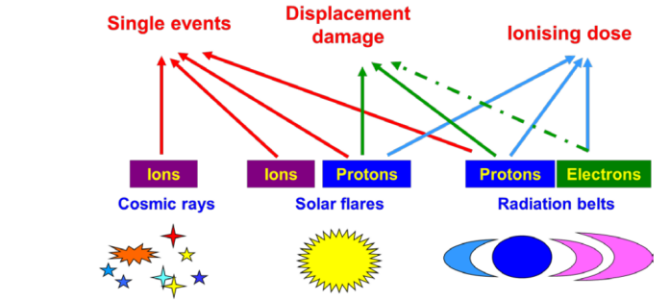


- Single Event Effect (SEE) : Transient effect due to one particle
  - A complete family of events : SEU, SET, MBU, SEFI, SEL, SEB, SEGR, SEDR
  - Some events are destructive (i.e. devices burnout) => impact on reliability
  - Some events are non-destructive (i.e. data corruption) => impact on availability









(courtesy of CNES)

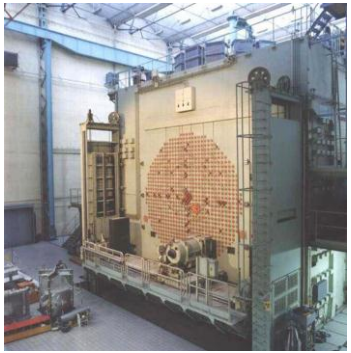
Date: 15/06/2021
Ref: BVS ABR space radiation workshop – 18 June 2021
Template: 83230347-DOC-TAS-FR-008

Part selection

SPACE AND MIL STANDARDS

/// Part selection based on testing under irradiations

- All components used in our equipment are evaluated/qualified vs radiation's effects
- Testing process follow standards : ESCC22900; ECSS25100; MIL-STD-750; MIL-STD-883; . . .
- Up to testing the flying wafer lot !



/// Each basic effect is assessed :

- Total ionising Dose (TID) : Done with Co60 sources
  - Dose rate : 0,36 to 3,60 Gy(Si)/hour

- Total Non-Ionising Dose (TNID) : Done with protons or neutrons
  - Accelerator able to cover energy from 20 to 200 MeV
  - Neutron reactor : i.e. BR1 at SCK-CEN

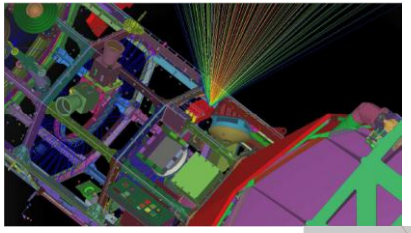
- Single Event Effect (SEE) : use accelerators (cyclotron)
  - Accelerator able to cover LET from 1 to 60 MeV/mg/cm²

Particle Transport

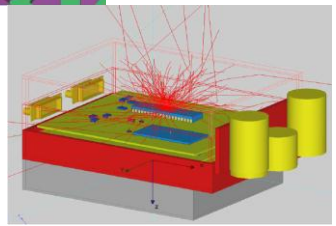
/// Goal : Total dose calculation

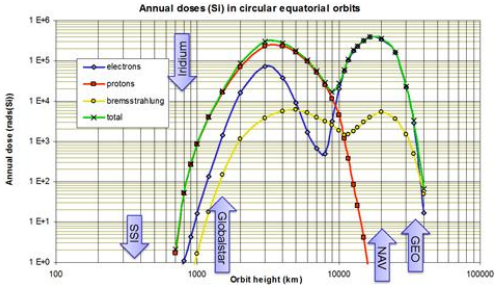
/// Transport calculation through the equipment / satellite

/// Use of commercial tools : NOVICE or FASTRAD



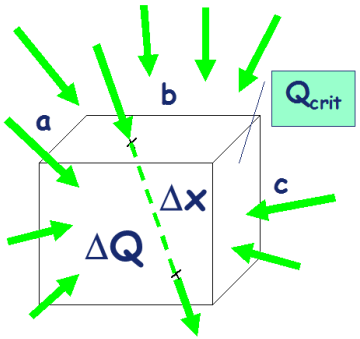
- Able to do ray-racing or Monte-Carlo algorithm
- Targeted for industrial applications (not so complete as GIANT 4)
- Shielding optimisation feature
- User friendly





/// Goal : SEE rate calculation

- Compute the event rate in a given orbit
- Based on CREME (Cosmic Ray Event in Micro Electronic) algorithm
- Free tools : SPENVIS website or OMERE



$$n_{seu} = \int_{L_{\min}}^{L_{\max}} \pi . \varphi(L) . A . P[x \geq x_{crit}(L)] dL$$

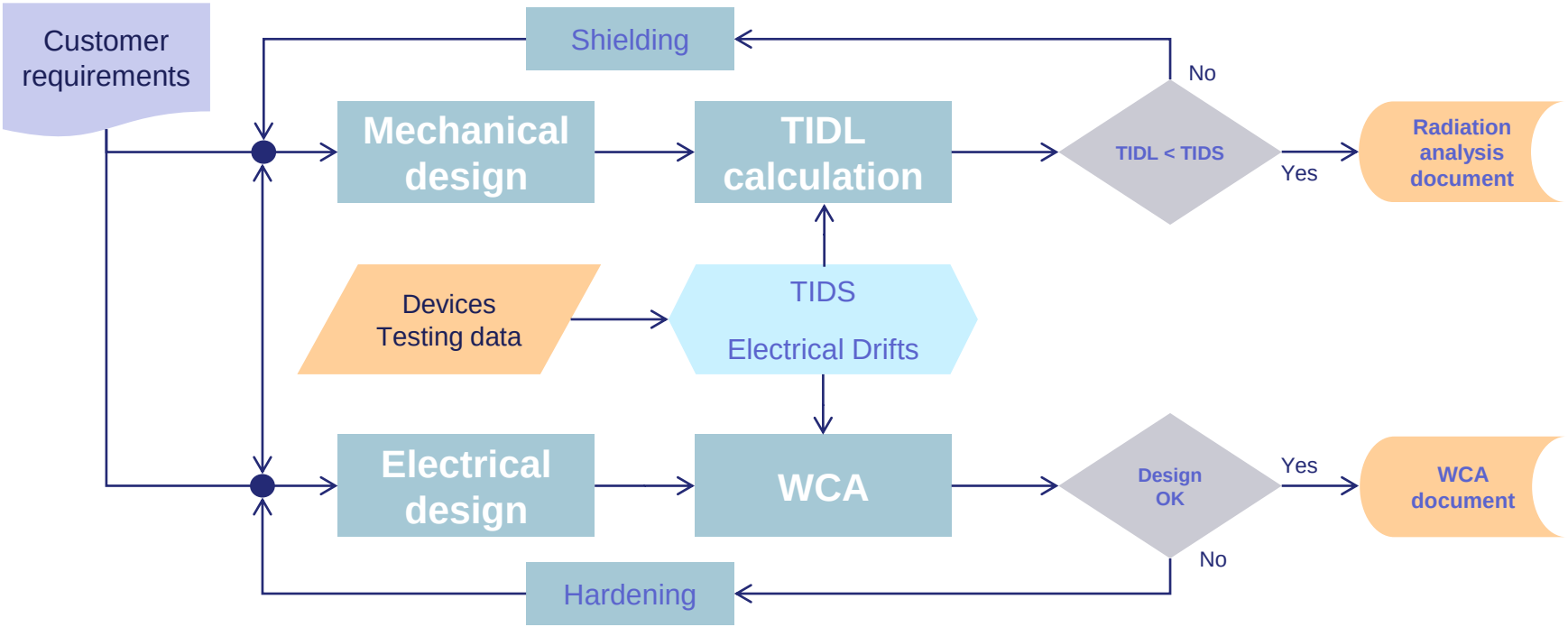
Date: 15/06/2021
Ref: BVS ABR space radiation workshop – 18 June 2021
Template: 83230347-DOC-TAS-FR-008

Electrical & Mechanical design

TIDL = dose received
TIDS = device sensitivity dose
WCA = worst case analysis

/// Electrical & Mechanical design are done in close relation

- Dual loop between dose calculation, worst-case electrical analysis, mechanical design and hardening

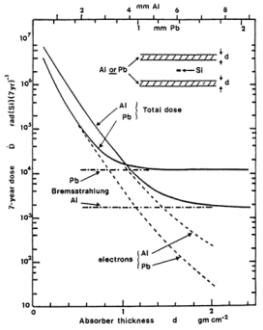


Date: 15/06/2021
Ref: BVS ABR space radiation workshop – 18 June 2021
Template: 83230347-DOC-TAS-FR-008

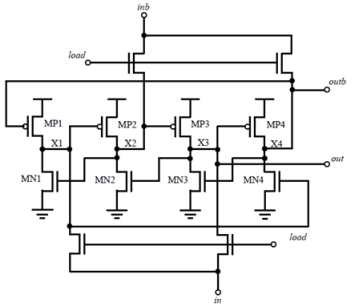
Hardening the system

/// Multiple solutions exist to make the design compliant . . .

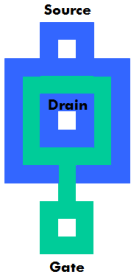
- Shielding
  - Take care of bremsstrahlung coming from electron stopping



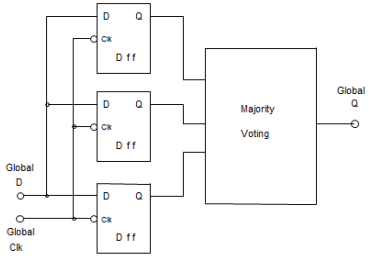
- Hardening by electrical design
  - Robust schematic solutions (DICE cell, filtering, gain compensation, . . .)
  - Redundancy



- Hardening by physical design (Layout in ASIC)
  - Edgeless transistors, guard ring, . . .



- Hardening by software



- And, . . . Do not forget to discuss the specification . . .

Date: 15/06/2021
Ref: BVS ABR space radiation workshop – 18 June 2021
Template: 83230347-DOC-TAS-FR-008

Conclusions

/// Space Industry follow RHA process
to certify the electrical design vs space radiations

/// This process need to master various disciplines

- Space environment
- Particle transport
- Device testing
- Equipment/system design

/// Failure is not an option !

/// The process is robust

- Failure due to ionising radiation are uncommon
- Satellites survive many years more than planned
  - Sign that margin exist !