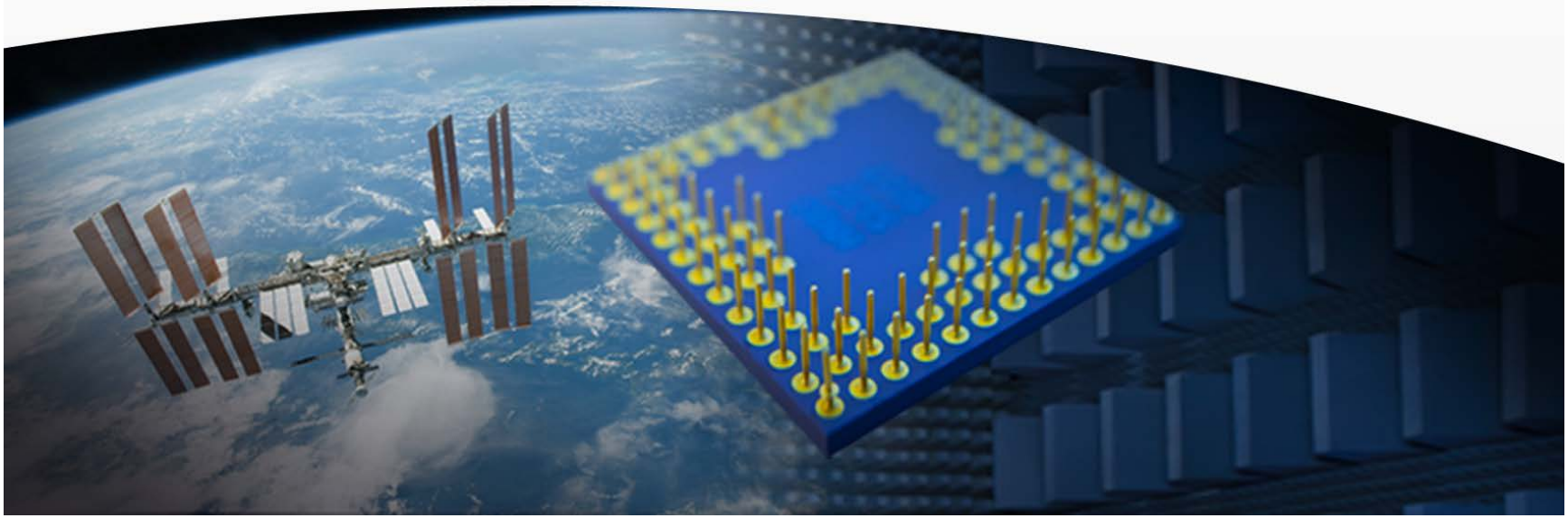


QUALITY ASSURANCE AND SAFETY AT A TID RADIATION TEST LABORATORY

Seville, 31.03.2016

Pedro Martin, *RadLab* Radiation Facility Supervisor

ALTER TECHNOLOGY

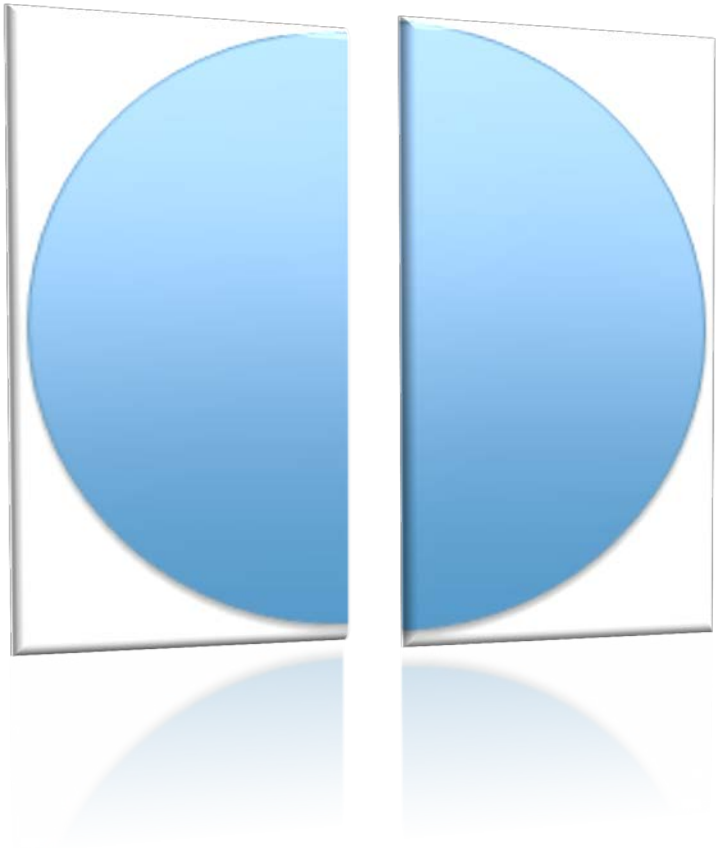
QUALITY ASSURANCE AND SAFETY

«Anything that can go wrong,
will go wrong».

?

QUALITY ASSURANCE AND SAFETY

Quality Assurance



Safety Assurance

QUALITY ASSURANCE. SUMMARY

Quality Assurance

RADIATION SOURCE AND DOSIMETRY (5)

TEMPERATURE (2)

TEST SAMPLES (2)

ELECTRICAL MEASUREMENT SYSTEM (2)

TEST FIXTURES (5)

BIAS CONDITIONS (1)

TIME INTERVALS FOR MEASUREMENT (1)

DOCUMENTATION (1)

ADDITIONAL ITEMS (1)

SAFETY. SUMMARY

PRECAUTIONS OUTSIDE OF THE FACILITY (1)

PRECAUTIONS IN CONTROL ROOM (8)

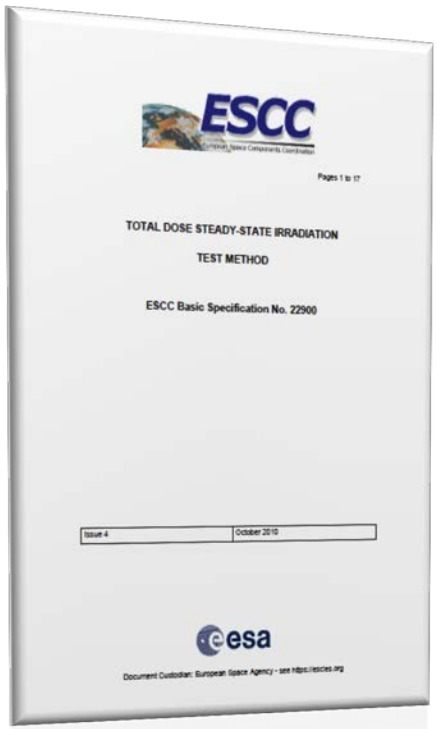
PRECAUTIONS IN IRRADIATION ROOM (5)

MORE SAFETY PRECAUTIONS (1)

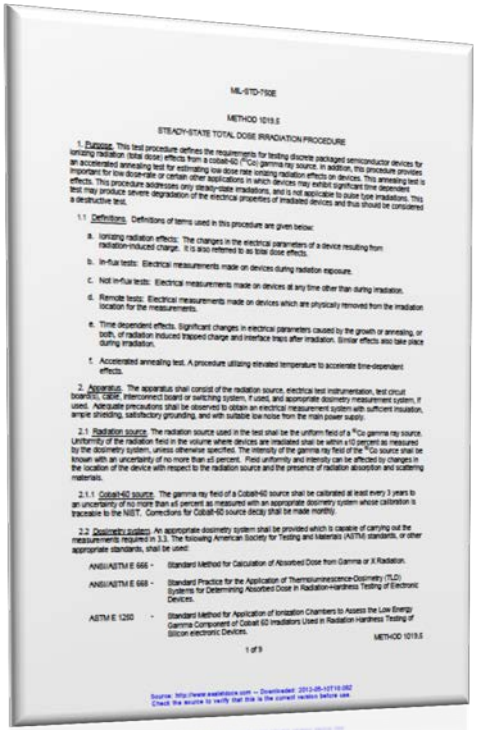
Safety Assurance

QUALITY ASSURANCE. INTRODUCTION

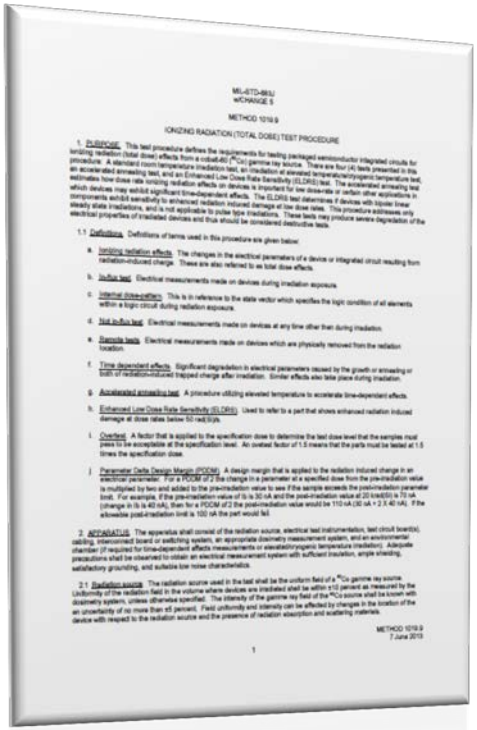
ESCC 22900 Iss.4



MIL-STD-750 TM 1019.5



MIL-STD-883 TM 1019.9



RADIATION SOURCE AND DOSIMETRY (1/5)

ESCC 22900 Requirement

«The radiation source used for the test shall be the field of a Cobalt 60 gamma source or an electron accelerator beam. Alternative sources that can be correlated to these sources may be used but, in the case of dispute, the Cobalt 60 or electron accelerator methods shall govern.»

- ❑ Radiation source:
  - ✓ Cobalt-60 gamma source;

    or
  - ✓ Electron accelerator.

Implementation

- ✓ Cobalt-60 gamma source

  +
- ✓ GBX200 Panoramic Irradiator.

Example at Alter Facilities

RADIATION SOURCE AND DOSIMETRY (2/5)

ESCC 22900 Requirement

«The dose at the device under test shall be measured to a resolution of better than 10% and the non-uniformity of the radiation field in the test area shall be a maximum of 10%. The field uniformity shall be verified if the geometry of the test setup is changed. (…) The test devices shall be exposed to within 10% of the specified radiation dose level(s).»

- ❑ Dose:
  - ✓ Resolution better than 10%.
  - ✓ Non-uniformity < 10%.
  - ✓ Within 10% of radiation levels.

Implementation

- ✓ Adequated equipment.
- ✓ Collimators & precise profiles.
- ✓ Exhaustive monitoring (RMS).

Example at Alter Facilities

3D Uniformity Profile

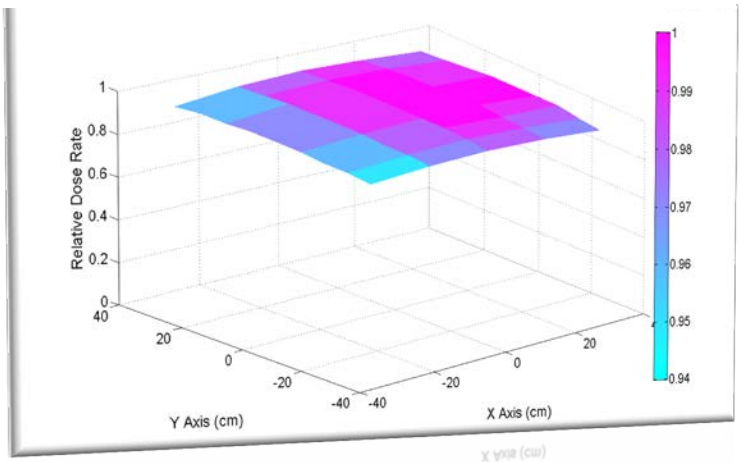


TABLE I
UNIFORMITY DATA IN RADLAB

Field size [cm x cm]	Dose Rate Uniformity [%]	
	Direct irradiation (~1100 rd(Si)/h)	With attenuator (~220 rd(Si)/h)
1 x 1	100.0	99.8
2 x 2	100.0	99.7
5 x 5	100.0	99.0
10 x 10	99.9	99.0
15 x 15	99.9	98.3
20 x 20	99.8	96.0
25 x 25	99.6	94.7
30 x 30	99.5	90.0

RADIATION SOURCE AND DOSIMETRY (3/5)

ESCC 22900 Requirement

«Unless otherwise specified in the test plan, there shall be a minimum of 3 exposures for which the increments in dose level(s) will be in ratios of 1/3, 1 and 3 times the radiation level of interest. The radiation level shall be specified in the test plan.»

- Multiple exposures:
  - ✓ Steps ≥ 3;
  - ✓ Ratios: 1/3, 1 & 3x Level of interest.

Implementation

- ✓ Always a TEST PLAN is carefully issued before starting the test with a detailed description of the dose steps in function of the level of interest and total dose.

Example at Alter Facilities

EXPERIMENTAL STEPS	1	2	3	4	5	6	7	8	9
PROCESS	Irrad	Irrad	Irrad	Irrad	Irrad	Irrad	Irrad	Ann	Ann
Dose [krad (Si)]	1	4	5	5	15	20	50	-	-
Cumulative Dose [krad (Si)]	1	5	10	15	30	50	100	-	-
Dose Rate [rad(Si)/h]	36	36	36	36	360	360	360	-	-
Exposure Time (h)	27.8	111.1	138.9	138.9	41.7	55.5	138.9	24	168
Temperature (°C)	25	25	25	25	25	25	25	25	100

EXPERIMENTAL STEPS	1	2	3	4	5	6	7	8
PROCESS	Irrad.	Irrad.	Irrad.	Irrad.	Irrad.	Irrad	Ann	Ann
Dose [krad (Si)]	10	10	5	25	25	25	-	-
Cumulative Dose [krad (Si)]	10	20	25	50	75	100	-	-
Dose Rate [rad(Si)/h]	36	36	36	Note 1	Note 1	Note 1	-	-
Exposure Time (h)	277.8	277.8	138.9	TBD	TBD	TBD	24	168
Temperature (°C)	25	25	25	25	25	25	25	85

RADIATION SOURCE AND DOSIMETRY (4/5)

ESCC 22900 Requirement

«The Dose Rate shall be specified in the Test Plan. (…) The gamma-ray dose rate of a Cobalt 60 source shall be calibrated in accordance with the requirements of ESCC Basic Specification No. 21500 to 5% or better. (…) The dose rate shall be held constant within 10% during a given radiation exposure. Dose rates shall be chosen in such a way that the errors in dose coming from timing errors and initial beam adjustment are kept below 5%.»

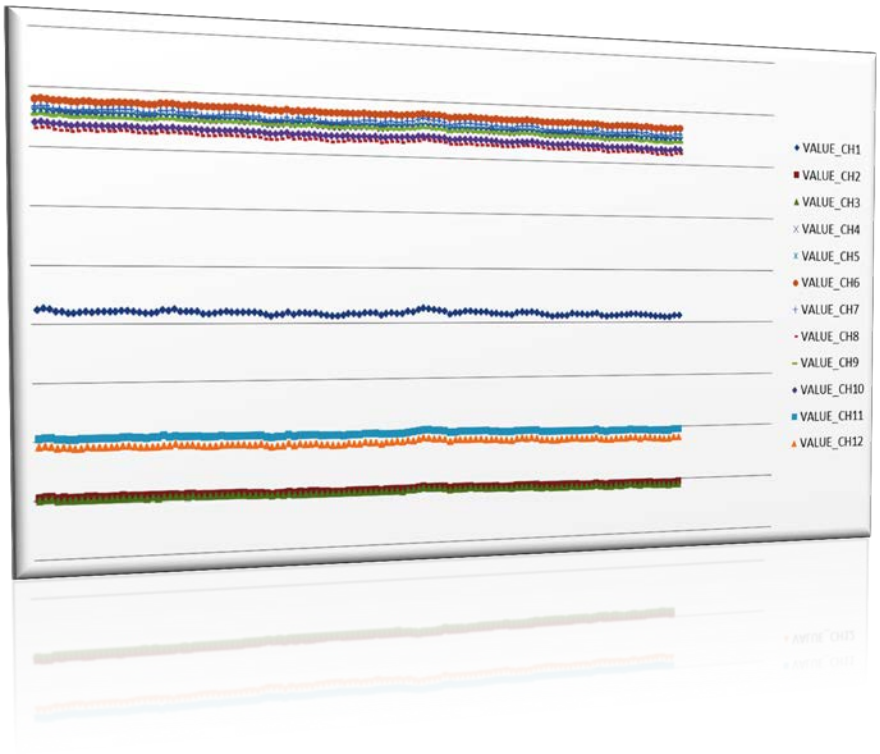
- ❑ Dose rate:
  - ✓ Specified in the Test Plan;
  - ✓ Calibrated to 5% or better;
  - ✓ Constant within 10%;
  - ✓ Timing errors < 5%.

Implementation

- ✓ Test Plan.
- ✓ Uncertainty ≈ 3.5%.
- ✓ RMS.

Example at Alter Facilities

12 Channels dose rate monitoring



RADIATION SOURCE AND DOSIMETRY (5/5)

ESCC 22900 Requirement

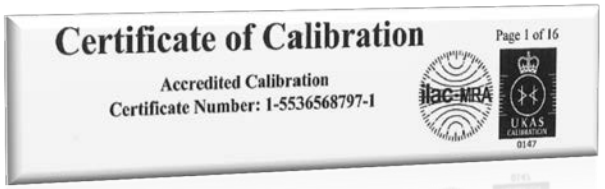
«Dosimetry shall be traceable to national standards. (…) Corrections for source decay shall be made once per month.»

- Dosimetry:
  - ✓ Traceable to national standards;
  - ✓ Monthly corrections for source decay;

Implementation

- ✓ Dosimetry equipment traceable to MRA.
- ✓ Monthly to daily corrections for source decay.

Example at Alter Facilities



TEMPERATURE (1/2)

ESCC 22900 Requirement

«The devices under test shall be irradiated in an ambient temperature of +20±10°C which shall not vary by more than 3°C during the irradiation exposure.»

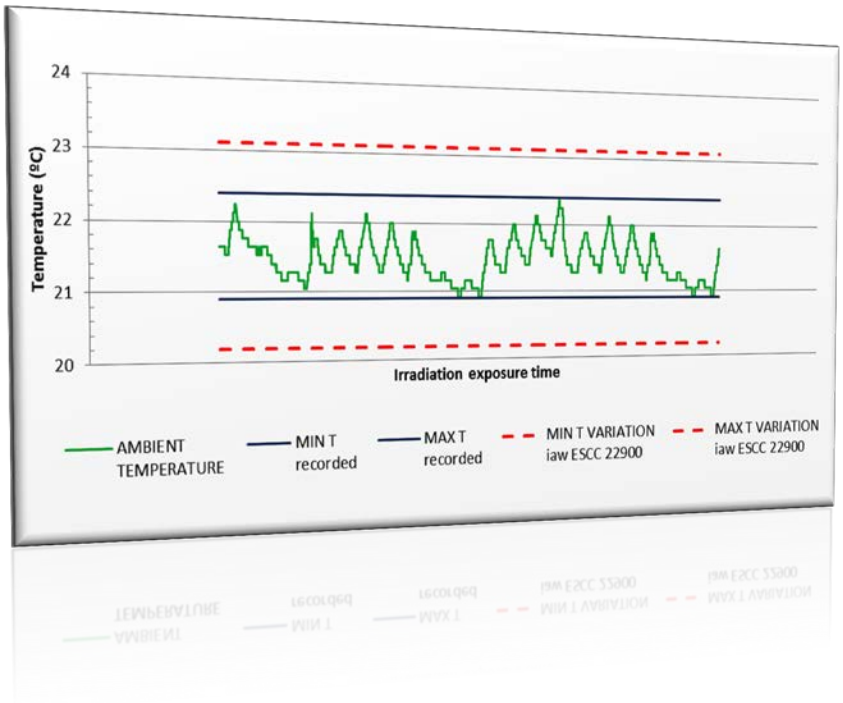
- Temperature:
  - ✓ Irradiation room = 20ºC ± 10ºC;
  - ✓ Variation ≤ 3ºC during irradiation;

Implementation

- ✓ Air-conditioning system.
- ✓ TPH Monitoring system.
- ✓ TPH Alarms system.

Example at Alter Facilities

Temperature data recorded during the irradiation exposure of a TID test.



TEMPERATURE (2/2)

ESCC 22900 Requirement

«The electrical measurements shall be performed at the temperature specified in the Detail Specification for Electrical Measurements at Room Temperature. If the devices are transported to and from a remote electrical measurement site, the temperature of the test devices during transport shall not be allowed to increase by more than 10°C with respect to the temperature of the irradiation environment.»

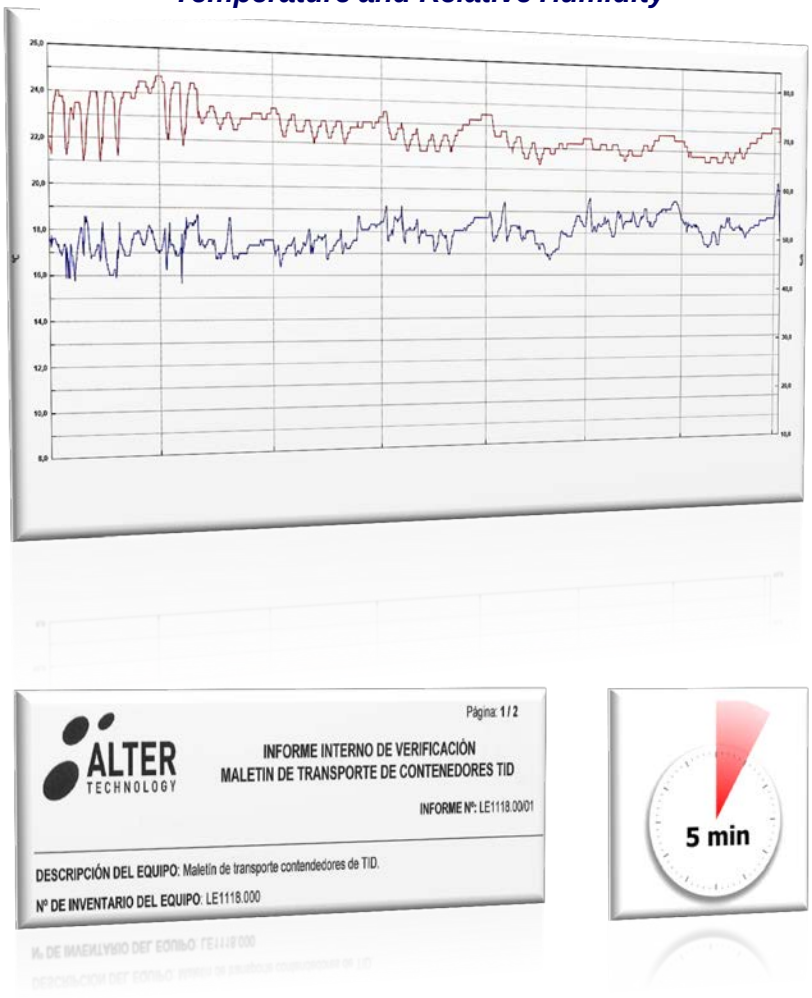
- Temperature:
  - ✓ Electrical Meas. 22ºC ± 3ºC;
  - ✓ Increase ≤ 10ºC during transport.

Implementation

- ✓ TPH Monitoring + Alarms.
- ✓ Calibrated carrying briefcase.
- ✓ Minimised duration of transport.

Example at Alter Facilities

Temperature and Relative Humidity



TEST SAMPLES (1/2)

ESCC 22900 Requirement

«Test specimens shall be surrounded by equilibrium material which will minimise dose enhancement from low-energy scattered radiation by producing charged-particle equilibrium. For equilibrium, the use of a container of at least 1.5mm Pb with an inner lining of at least 0.7mm Al is recommended.»

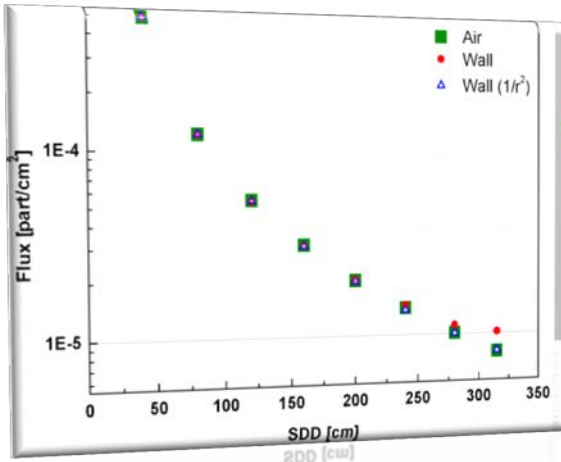
- ❑ Test samples:
  - ✓ Surrounded by equilibrium material;
  - ✓ Pb-Al container for equilibrium.

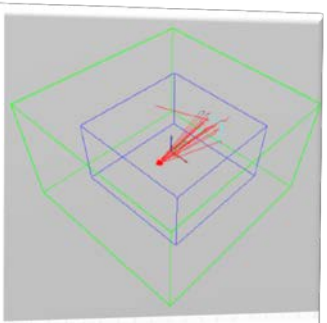
Implementation

- ✓ Dedicated TID containers with Al + Pb + Build-up.
- ✓ Monte-Carlo Simulation.

Example at Alter Facilities

Filter Boxes





Photon track and data obtained by simulation

Monte Carlo Simulations performed by Dr. Praena

TEST SAMPLES (2/2)

ESCC 22900 Requirement

«One sample shall be designated an "unirradiated control". (…) Immediately after selection, each individual sample device shall be serialised to facilitate pre-and post-irradiation data identification and comparison. The system of marking shall be such as to ensure that the samples are clearly identified»

- Test samples:
  - ✓ One unirradiated control sample;
  - ✓ Serialization.

Implementation

- ✓ 1 control + 1 setup samples.
- ✓ All test samples are serialised by the test engineer.

Example at Alter Facilities

Samples serializated prior to TID testing

ELECTRICAL MEASUREMENT SYSTEM (1/2)

ESCC 22900 Requirement

«Precautions shall be taken to obtain an electrical parameter measurement system which, by use of sufficient insulation, ample shielding, satisfactory grounding etc. shall yield suitably low levels of interference from mains power supplies and other sources of noise and leakage. The magnitude of interference from each of these items shall be sufficiently small so as not to affect any electrical measurement. All instruments used for the electrical measurements shall have the stability, accuracy and resolution required for accurate measurement of the electrical parameters of the test devices as given in the Detail Specification.»

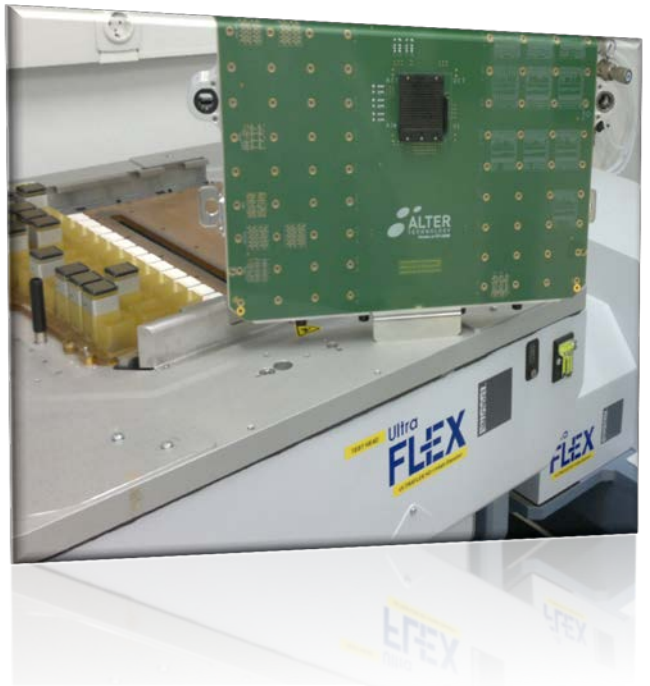
- ❑ Electrical measurement system:
  - ✓ Low levels of interference;
  - ✓ Stability, accuracy & resolution.

Implementation

- ✓ All ATN capabilities are available!
- ✓ SW internal process validation

Example at Alter Facilities

Electrical measurements equipment



ELECTRICAL MEASUREMENT SYSTEM (2/2)

ESCC 22900 Requirement

«Any parts of the system required to operate within the irradiation chamber shall be insensitive to the required accumulated test doses or be shielded until that condition is achieved.»

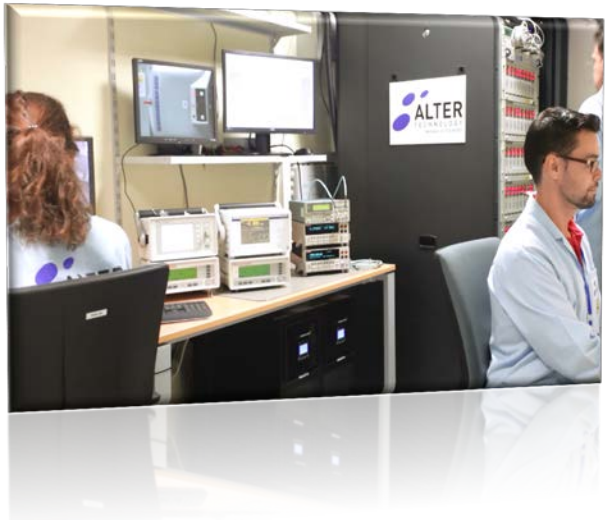
- Electrical measurement system:
  - ✓ Insensitive instruments;

    or
  - ✓ Properly shielded.

Implementation

- ✓ A complet set of electrical equipment and cables are installed at the facility.
- ✓ Safe areas availables in the irradiation room to place in-situ sensitive equipment.

Example at Alter Facilities



TEST FIXTURES (1/5)

ESCC 22900 Requirement

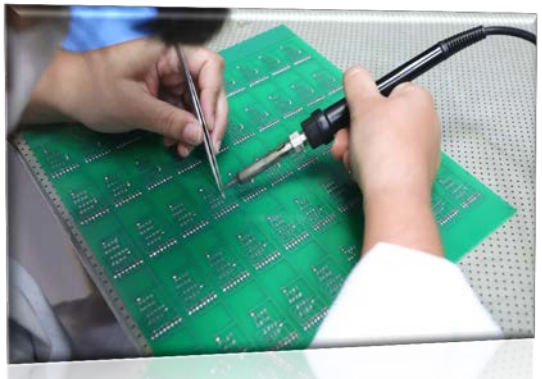
«Devices to be irradiated shall be mounted on test circuit boards together with any associated circuitry necessary for application of bias during irradiation or for in-situ measurements. Other than devices under test, components that are placed on the board(s) shall be insensitive to the required accumulated test doses or be shielded so that that condition is achieved. For these tests, the device terminals shall be electrically connected as prescribed in the Test Plan and/or Detail Specification.»

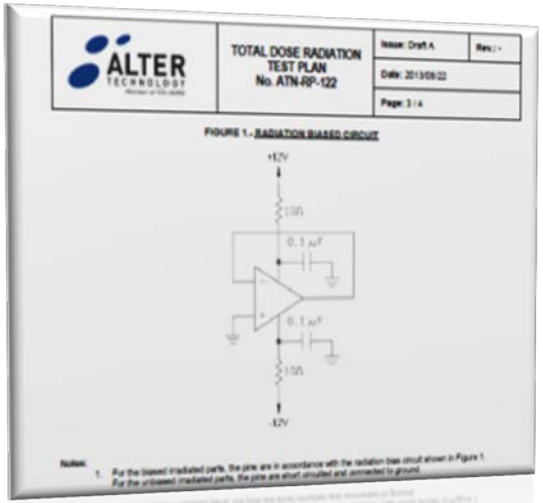
- ❑ Test Circuit Boards:
  - ✓ Contain: DUTs + biasing circuitry;
  - ✓ Biasing circuitry → Insensitive;
  - ✓ Circuit → Test plan.

Implementation

- ✓ PCBs are designed by the TID Engineer iaw test plan and validated before use.

Example at Alter Facilities





TEST FIXTURES (2/5)

ESCC 22900 Requirement

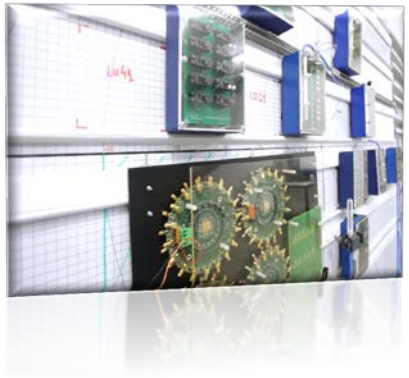
«The geometry and materials of the completed board(s) shall allow uniform irradiation of the devices under test. If the radiation beam is unidirectional then, unless otherwise specified, the beam shall be perpendicular to the diffusion face of the semiconductor chip.»

- ❑ Test Circuit Boards:
  - ✓ Geometry → Uniform irradiation;
  - ✓ Beam ⊥ Diffusion face of the semiconductor;

Implementation

- ✓ PCBs are designed following validated geometry templates.
- ✓ PCBs are placed in dedicated irradiation areas.

Example at Alter Facilities



TEST FIXTURES (3/5)

ESCC 22900 Requirement

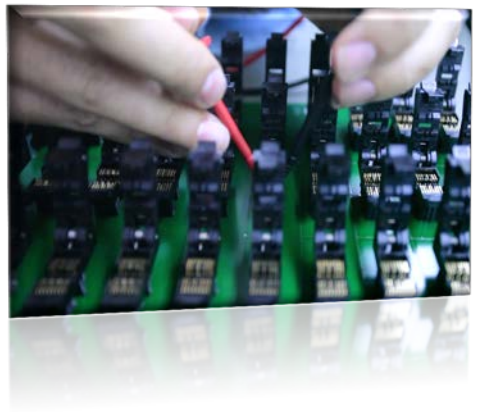
«Design and construction practices shall be used to prevent damage by oscillation, and to minimise external noise pick-up and leakage currents and to obtain accurate measurements of device parameters.»

- ❑ Test Circuit Boards:
  - ✓ Prevent damage by oscillation.
  - ✓ Minimise external noise pick-up
  - ✓ Minimise leakage currents

Implementation

- ✓ PCBs are double checked after manufacturing and before use with setup samples.
- ✓ Electrical measurements are performed with and without PCB.

Example at Alter Facilities



TEST FIXTURES (4/5)

ESCC 22900 Requirement

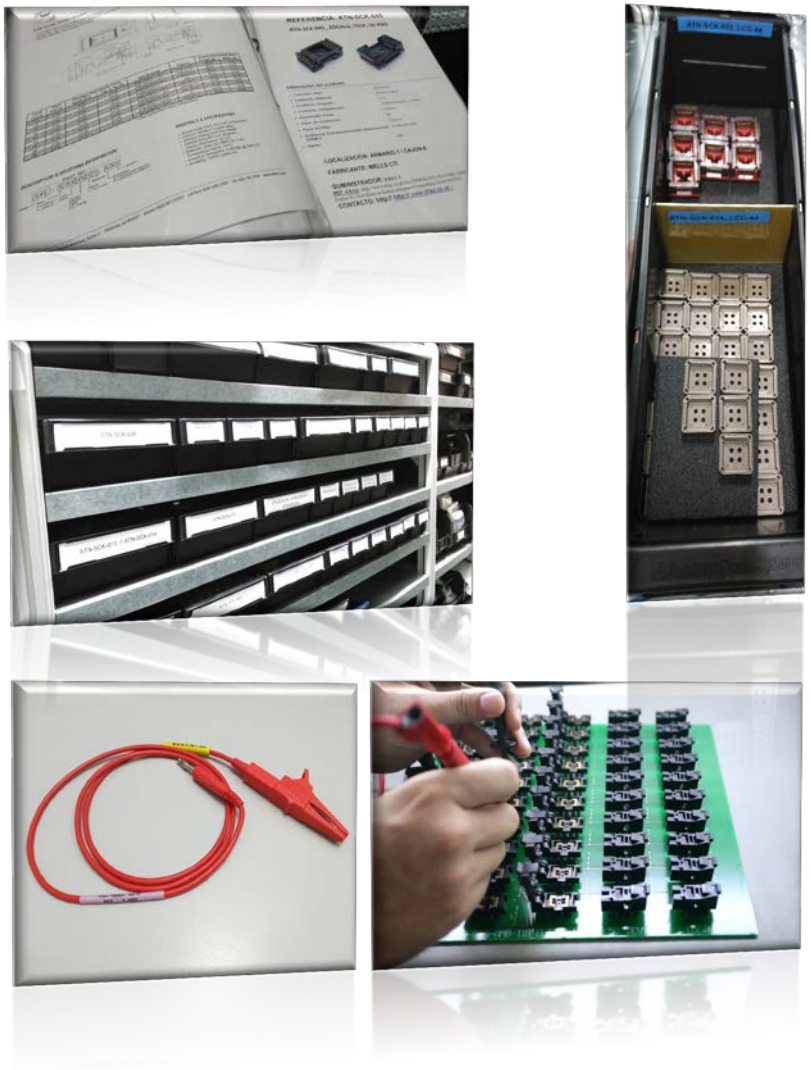
«Only sockets which are radiation-resistant and do not exhibit any significant leakages (relative to the devices under test) shall be used to connect devices and associated circuitry to the test board(s). Similar precautions shall be taken in respect of cabling and switching systems. All equipment used repeatedly in radiation fields shall be checked periodically for physical and/or electrical degradation.»

- ❑ Sockets, cabling & switching systems:
  - ✓ Radiation-resistant;
  - ✓ Checked periodically.

Implementation

- ✓ ATN sockets technical database.
- ✓ ATN cables technical database.

Example at Alter Facilities



TEST FIXTURES (5/5)

ESCC 22900 Requirement

«To assess interference and leakage, a circuit board shall be connected to the entire system, with no test devices installed, all sources of noise and interference operative, but no radiation field applied. The current as measured for the specified bias between any 2 terminals on each empty socket shall not exceed 10% of the lowest current value given in the specification of pre-irradiation values.»

- ❑ Circuit Board:
  - ✓ Evaluated without test devices and without radiation.
  - ✓ The measured current ≤ 10% lowest pre-irrad current value

Implementation

- ✓ ATN circuit board validation process.

Example at Alter Facilities

BIAS CONDITIONS (1/1)

ESCC 22900 Requirement

«While connected to the bias fixture, the biasing condition for the test devices, including the values of voltage and duty cycle, shall be maintained and monitored to remain within 10% of the conditions specified in the Test Plan and/or the Detail Specification. If these limits are exceeded the test shall be void. The specified bias shall be maintained at all times on each device until removal of the device except for the periods required for electrical parameter measurements. Devices to be annealed shall be mounted on boards providing the same bias condition as used for irradiation.»

- ❑ Biasing conditions:
  - ✓ 10% Tolerance;
  - ✓ Maintained at all times;
  - ✓ Irradiation = Annealing.

Implementation

- ✓ Check & Monitoring of the biasing conditions (RMS).
- ✓ RMS. Biasing Alarm system.

Example at Alter Facilities

TIME INTERVALS FOR MEASUREMENT (1/1)

ESCC 22900 Requirement

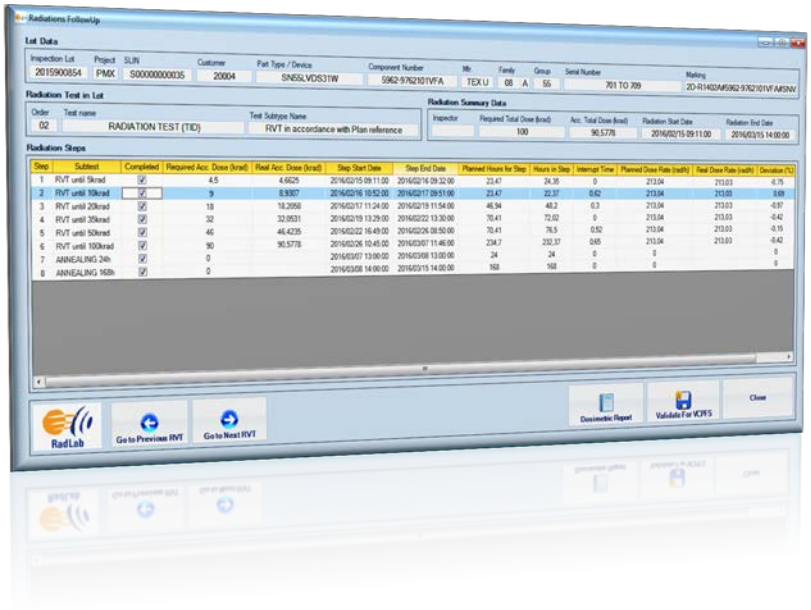
«The time interval from the completion of an exposure to the start of the measurement of parameters shall be a maximum of 1 hour. The time interval from the completion of an exposure to the start of the next exposure shall be a maximum of 2 hours.»

- ❑ Time interval:
  - ✓ Irrad. stop → ≤1h →Meas. start;
  - ✓ Irrad. stop → ≤2h →Irrad. start;

Implementation

- ✓ Dedicated TID Engineer.
- ✓ Manual and Automatic step schedule planning.
- ✓ RMS. Dose alarm system.

Example at Alter Facilities



DOCUMENTATION (1/1)

ESCC 22900 Requirement

«For each irradiation test to be performed, 2 sets of documents are required: (a)A Test Plan (prior to irradiation testing) defining the detailed requirements of the irradiation test programmes for the specific components to be tested.

(b)A Test Report giving the actual test conditions and test results.

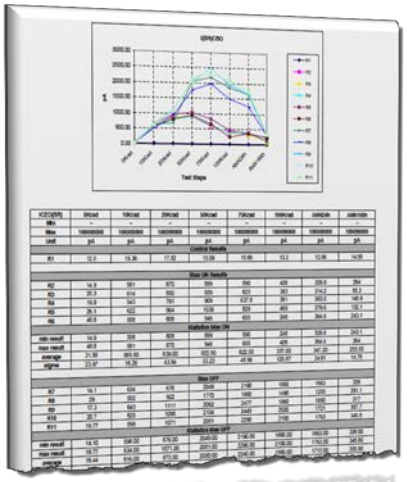
The Test Plan and Test Report shall be presented in accordance with the respective format and completion notes provided in the ESCC forms section of ESCIES.»

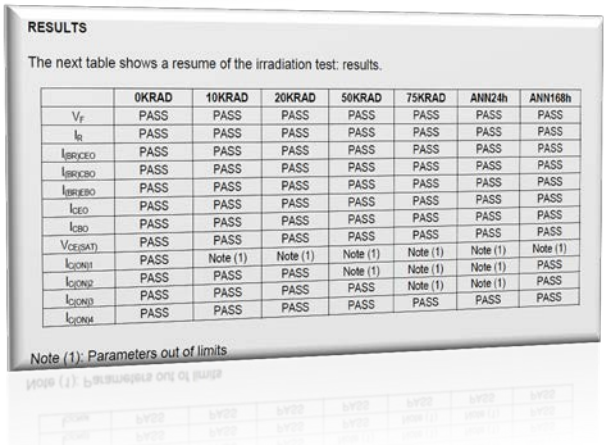
- ❑ Documentation:
  - ✓ Test Plan;
  - ✓ Test Report;

Implementation

- ✓ TID Test Plan: ATNF140.
- ✓ TID Test Report: ATNF141.

Example at Alter Facilities





RESULTS

The next table shows a resume of the irradiation test: results.

	0KRAD	10KRAD	20KRAD	50KRAD	75KRAD	ANN24h	ANN168h
V_F	PASS	PASS	PASS	PASS	PASS	PASS	PASS
I_R	PASS	PASS	PASS	PASS	PASS	PASS	PASS
$I_{BR(CEO)}$	PASS	PASS	PASS	PASS	PASS	PASS	PASS
$I_{BR(CBO)}$	PASS	PASS	PASS	PASS	PASS	PASS	PASS
$I_{BR(EBO)}$	PASS	PASS	PASS	PASS	PASS	PASS	PASS
I_{CEO}	PASS	PASS	PASS	PASS	PASS	PASS	PASS
I_{CBO}	PASS	PASS	PASS	PASS	PASS	PASS	PASS
$V_{CE(SAT)}$	PASS	PASS	PASS	PASS	PASS	PASS	PASS
$I_{C(ON)1}$	PASS	Note (1)	Note (1)	Note (1)	Note (1)	Note (1)	Note (1)
$I_{C(ON)2}$	PASS	PASS	PASS	Note (1)	Note (1)	Note (1)	PASS
$I_{C(ON)3}$	PASS	PASS	PASS	PASS	Note (1)	Note (1)	PASS
$I_{C(ON)4}$	PASS	PASS	PASS	PASS	PASS	PASS	PASS

Note (1): Parameters out of limits

MORE REQUIREMENTS?

Not considered explicitely

Example at Alter Facilities

- ❑ Interlaboratory comparisons.
- ❑ External & Internal Audits.
- ❑ International accreditations.
- ❑ Handling of the test samples (ESD).
- ❑ Calibration of the equipment.
- ❑ Quality Manual.
- ❑ Quality surveys.
- ❑ Technical responsibles.
- ❑ Personnel Training.
- ❑ Internal test procedures.
- ❑ Internal checklists.

MORE REQUIREMENTS?

Not considered explicitely

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Example at Alter Facilities

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- Calibration of the equipment.
- Quality Manual.
- Quality surveys.
- Technical responsibles.
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- Internal test procedures.
- Internal checklists.

Example at Alter Facilities

AENOR ER Calidad Aeroespacial OP-0021/2003

AENOR ER Empresa Registrada UNE-EN ISC 9001 ER-0603/1997

AENOR Gestión Ambiental UNE-EN ISO 14001

CERTIFIED IQNet MANAGEMENT SYSTEM

ISO 17025

ISO 17025 (RADLAB)

ALTER

– ONLY LAB CERTIFIED IN EUROPE –

DEFENSE LOGISTICS AGENCY

DLA SUITABILITY

ALTER

– ONLY LAB CERTIFIED OUT OF USA –

SAFETY. SUMMARY

PRECAUTIONS OUTSIDE OF THE FACILITY (1)

PRECAUTIONS IN CONTROL ROOM (8)

PRECAUTIONS IN IRRADIATION ROOM (5)

MORE SAFETY PRECAUTIONS (1)

Safety Assurance

SAFETY (1/15)

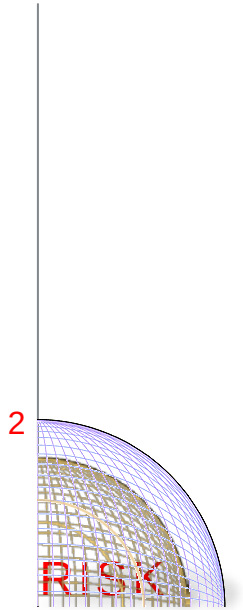
Rectricted access to control room through **biometric fingerprint**.

[control room]

SAFETY (2/15)

The irradiator only can be activated using its corresponding **key** in the console.

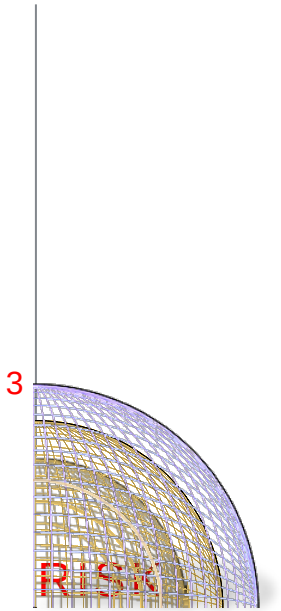
[control room]



SAFETY (3/15)

Acoustic signal and light indicator of the radiation in the console.

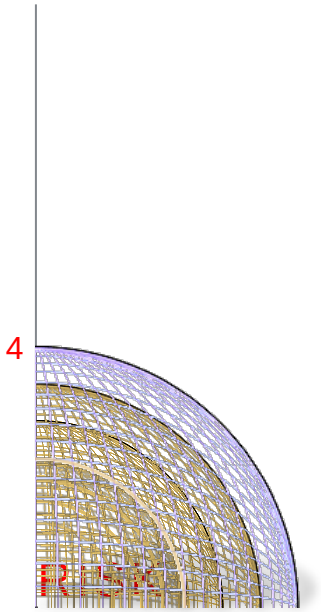
[control room]



SAFETY (4/15)

Audible and visible alarms provided by the area monitor.

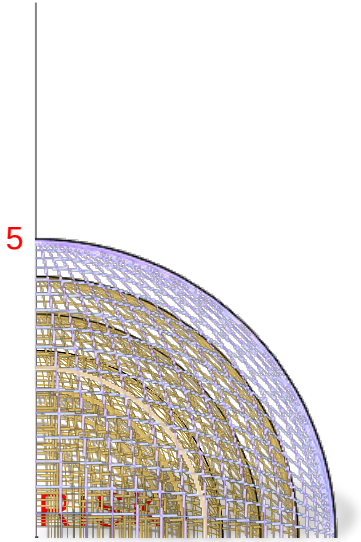
[control room]



SAFETY (5/15)

Source position indicators.
A **red lamp** placed on the head of the irradiator but visible in the **LCD monitor** of the control room connected to the bunker cam.

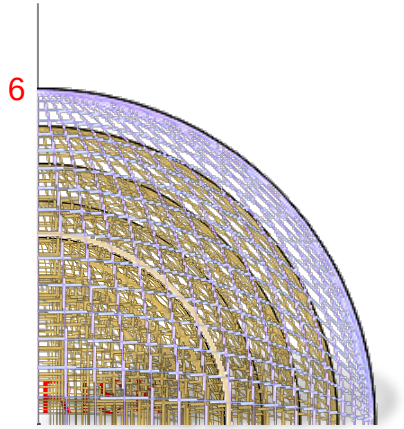
[control room]



SAFETY (6/15)

A **red indicator rod** that protrudes through the cover of the head of the irradiator and is visible in the LCD monitor of the control room connected to the bunker cam.

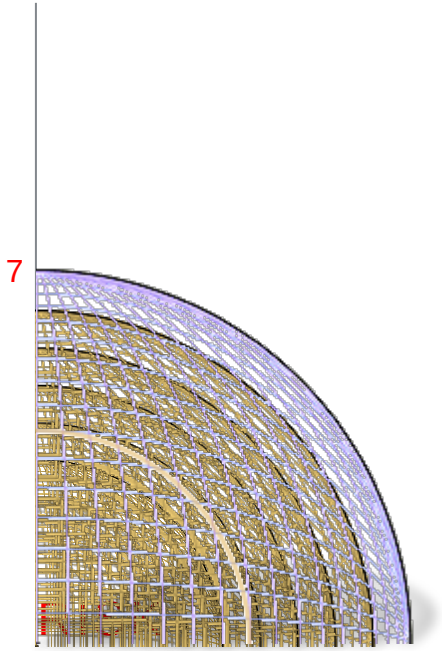
[control room]



SAFETY (7/15)

A **red/green lamp** above the entrance door to the bunker.

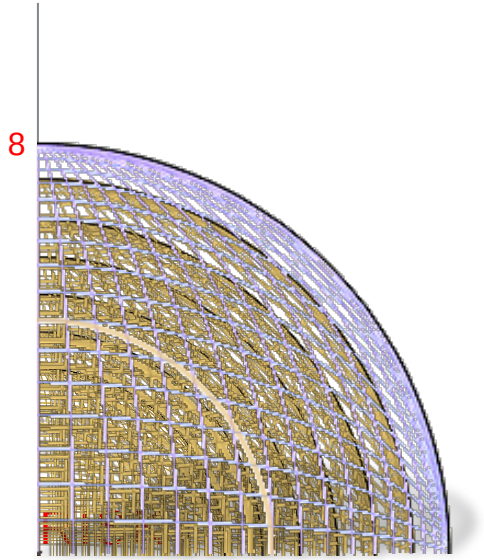
[control room]



SAFETY (8/15)

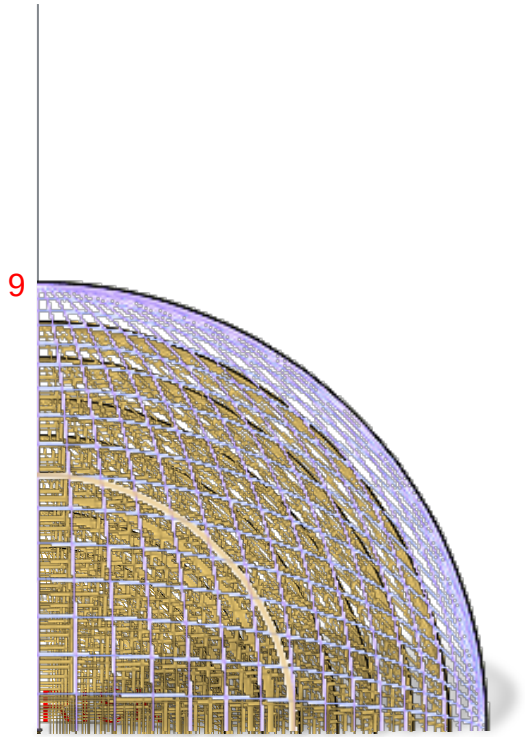
Interlock switch which prevents opening the entrance door to the bunker when the area monitor detects radiation.

[control room]



SAFETY (9/15)

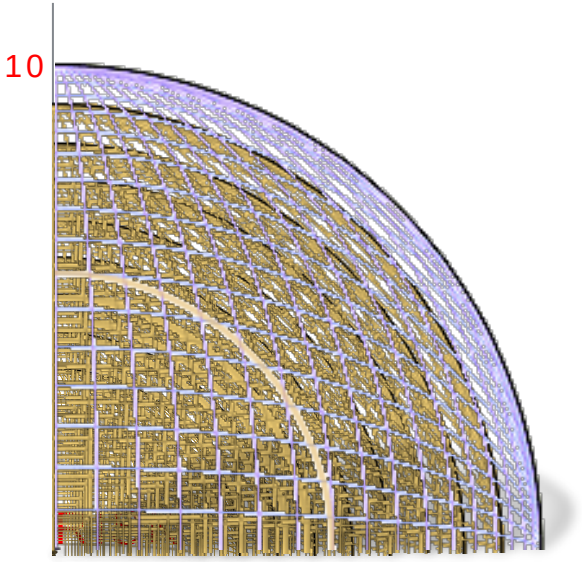
Open door sensor which retracts the source if the door to the bunker is open. [control room]

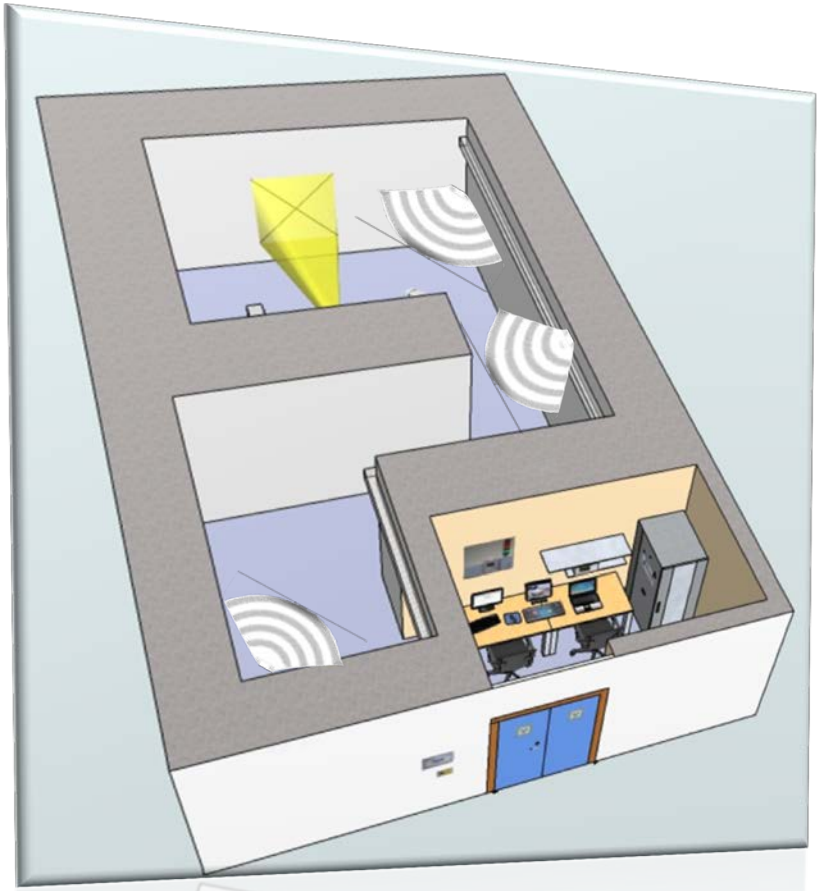


SAFETY (10/15)

Three **motion sensors** across the corridor to irradiation room connected to the irradiator to switch off in case of any presence.

[irradiation room]

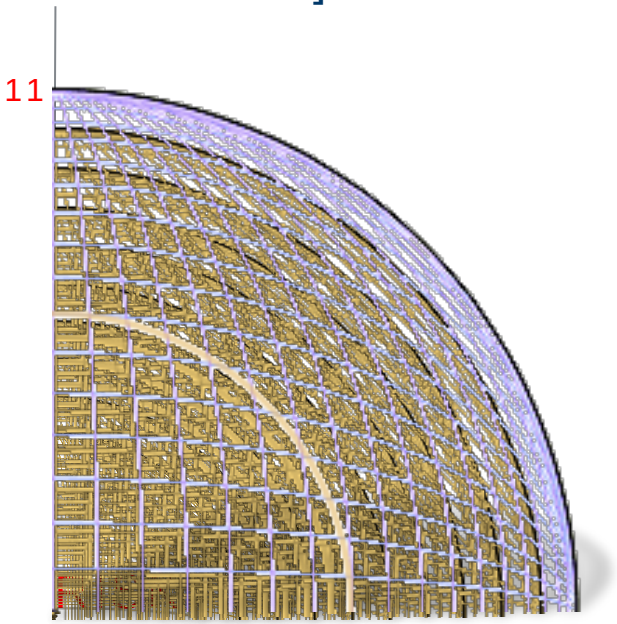




SAFETY (11/15)

A **red indicator rod** that protrudes through the cover of the head of the irradiator.

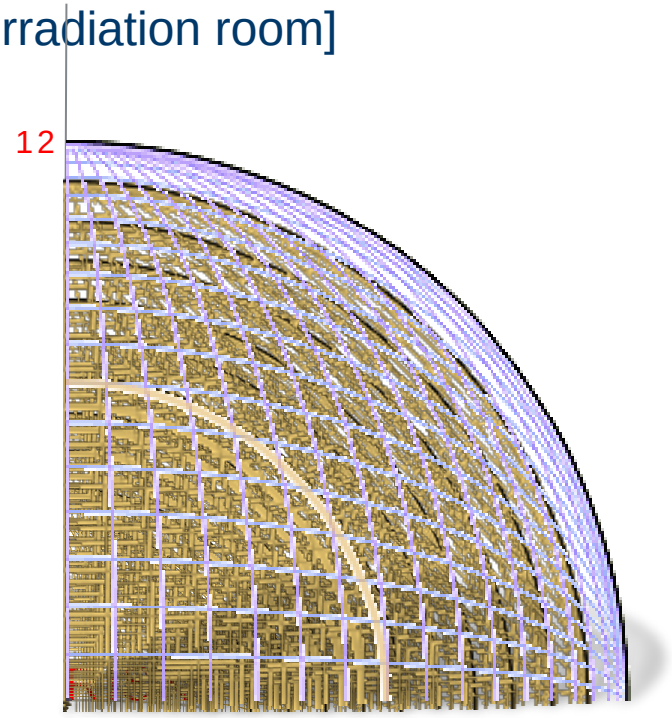
[irradiation room]



SAFETY (12/15)

Source position indicators.
A **red lamp** placed on the head of the irradiator.

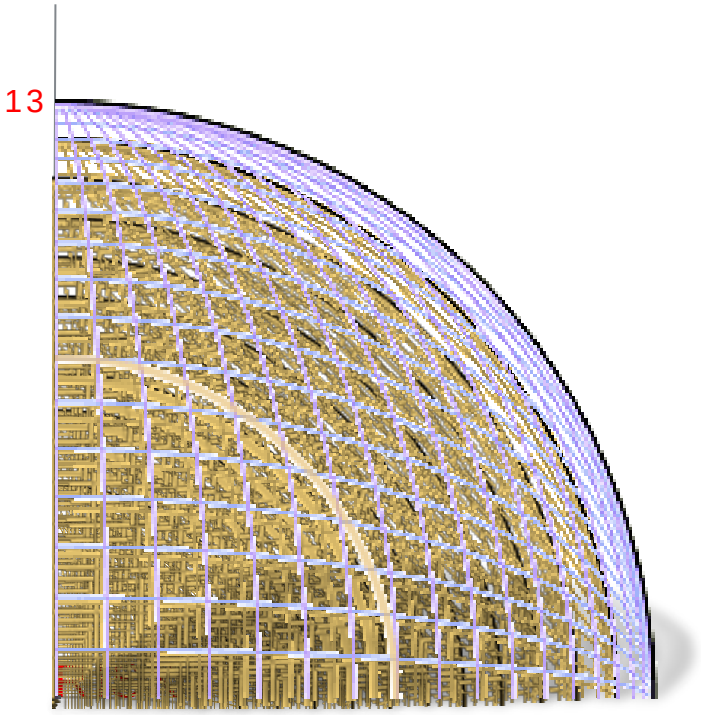
[irradiation room]



SAFETY (13/15)

Active dosemeters
(gamma survey meters) with visual and acustic alarms.

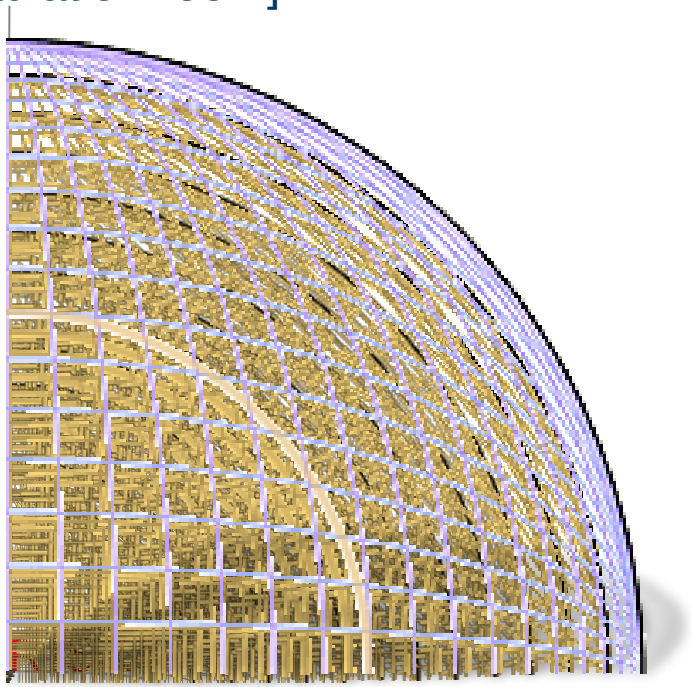
[irradiation room]



SAFETY (14/15)

You will never enter alone!
Two authorized ATN people are required as minimum to work at RadLab.

[irradiation room]



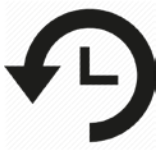
SAFETY (15/15)

Six **Emergency-stop pushbuttons** placed in strategic positions.

A **manual source lock** to block the source in the fully shielded position.

A **wall switch** located in the irradiation room. Once the wall switch is activated, the door must be closed within 60 seconds.

A **built-in delay circuit** delays the exposure of the source and activates a warning signal.



QUALITY ASSURANCE AND SAFETY

«Anything that can go wrong, will go wrong».

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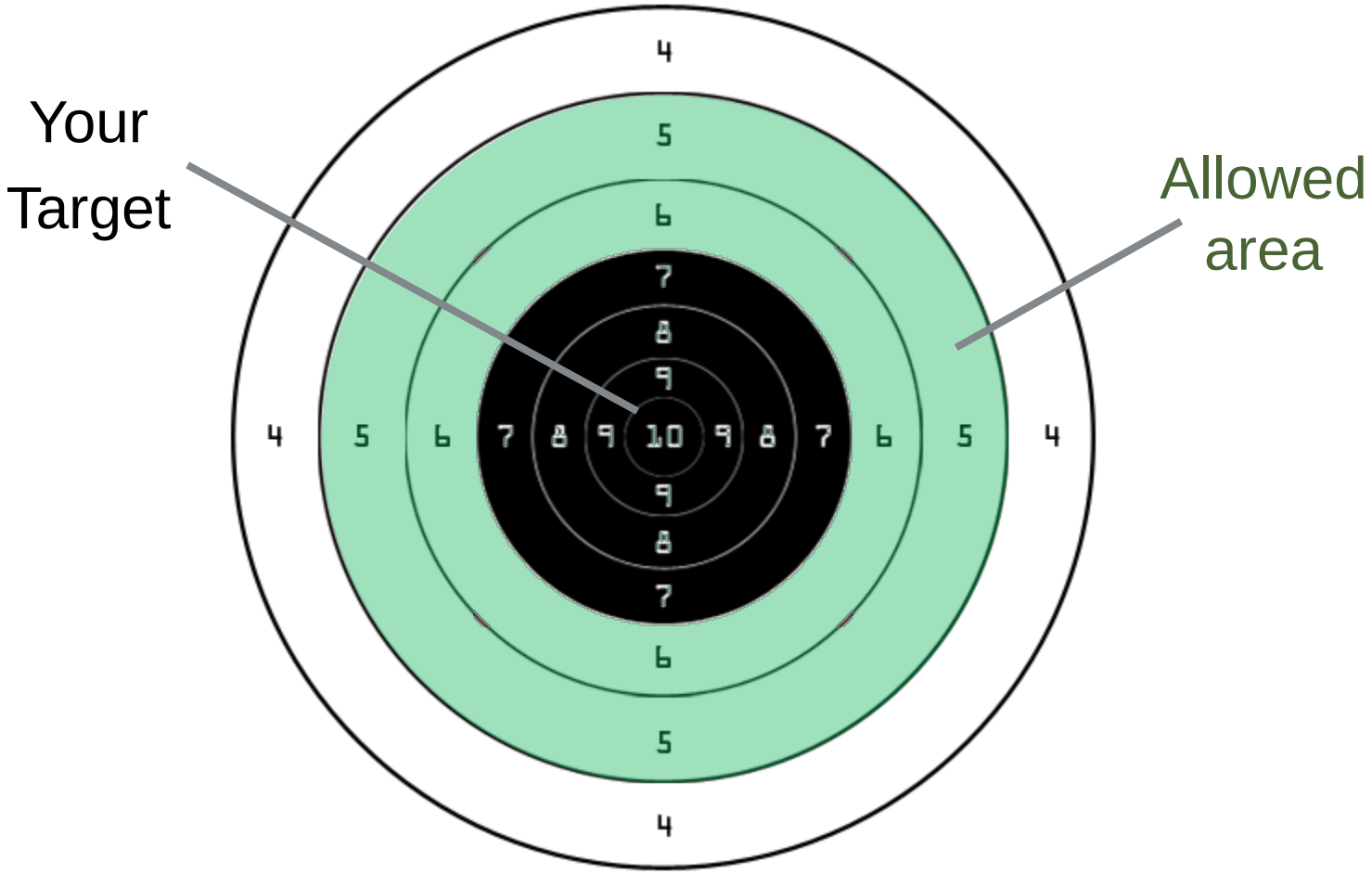
QUALITY ASSURANCE AND SAFETY

If you aim high…

QUALITY ASSURANCE AND SAFETY

… even if you fail, you probably will meet the requirements.



THANK YOU!