RA-10: a New Argentinian Multipurpose Research Reactor

H. Blaumann, A. Vertullo, F. Sánchez, F. Brollo, J. Longhino

Nuclear Engineering Department
National Atomic Energy Commission
Argentina

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Present nuclear facilities: RR + NPP

Reactor	Type	Location	Main Application
RA-0	RA-1 critical facility	Córdoba University	Human resources for nuclear industry Promote nuclear energy applications
RA-4	Siemens SUR 100 critical facility	Rosario University	
RA-1	UO2-graphite fuel rods, water cooled and moderated, tank reactor, 40 kW	Buenos Aires /CNEA	Long term material irradiations, nuclear instrumentation testing, training
RA-6	MTR, pool type, 1 MW	Bariloche/CNEA	Teaching/BNCT/NAA
RA-3	MTR, pool type, 10 MW	Buenos Aires/CNEA	RI production
Atucha I	PHWR	Lima/NASA	357 Mwe
CNE	CANDU	Embalse/NASA	648 Mwe

Current nuclear projects

NPP	TYPE	POWER
Atucha II	PHWR	745 MWe
CNE+	life extension and power upgrade	656 MWe
CAREM 25	prototype for an Argentinean PWR reactor	25 MWe
RA-10	multipurpose RR	30 MW

Argentinian Research Reactors

REACTOR	POWER	LOCATION	CRITICALITY
RA-6	500 kW	Argentina	1982
RP-10	10 MW	Perú	1988
NUR	1 MW	Algeria	1989
ETRR-2	22 MW	Egipt	1997
OPAL	20 MW	Australia	2007

Why the RA-10 project?

- To provide a replacement for the RA-3 reactor (1967)
- To increase the RI production for supporting the local and regional future demand
  - 2500 Ci/w molybdenum-99
  - increase the production of lutecium-177 and iridium-192 and to try the generation of new RI such us bismut-213
  - with the Brazilian RMB might be relevant keys for LA self sufficiency in the supply of RI ensuring a natural back up
- To consolidate the national capabilities related to nuclear fuel production
  - to implement facilities for testing new fuel elements developments including miniplates, MTR and NPP fuel elements.
  - to implement facilities for materials testing focused on radiation damage and corrosion evaluation

Why the RA-10 project?

- To offer to the scientific and technological system new capabilities based on neutron techniques
  - to develop thermal and cold neutrons facilities for the applications of neutronic techniques to nuclear technology, material science and biology.

Steps in the project launching

- Potential stakeholders meetings (2009)
- Project inclusion in the CNEA 2010-2019 strategic plan
- Project approval by the government: «Design, construction and commissioning of an Argentinian multipurpose reactor: RA-10»
- Project officially started in CNEA (june 2010)

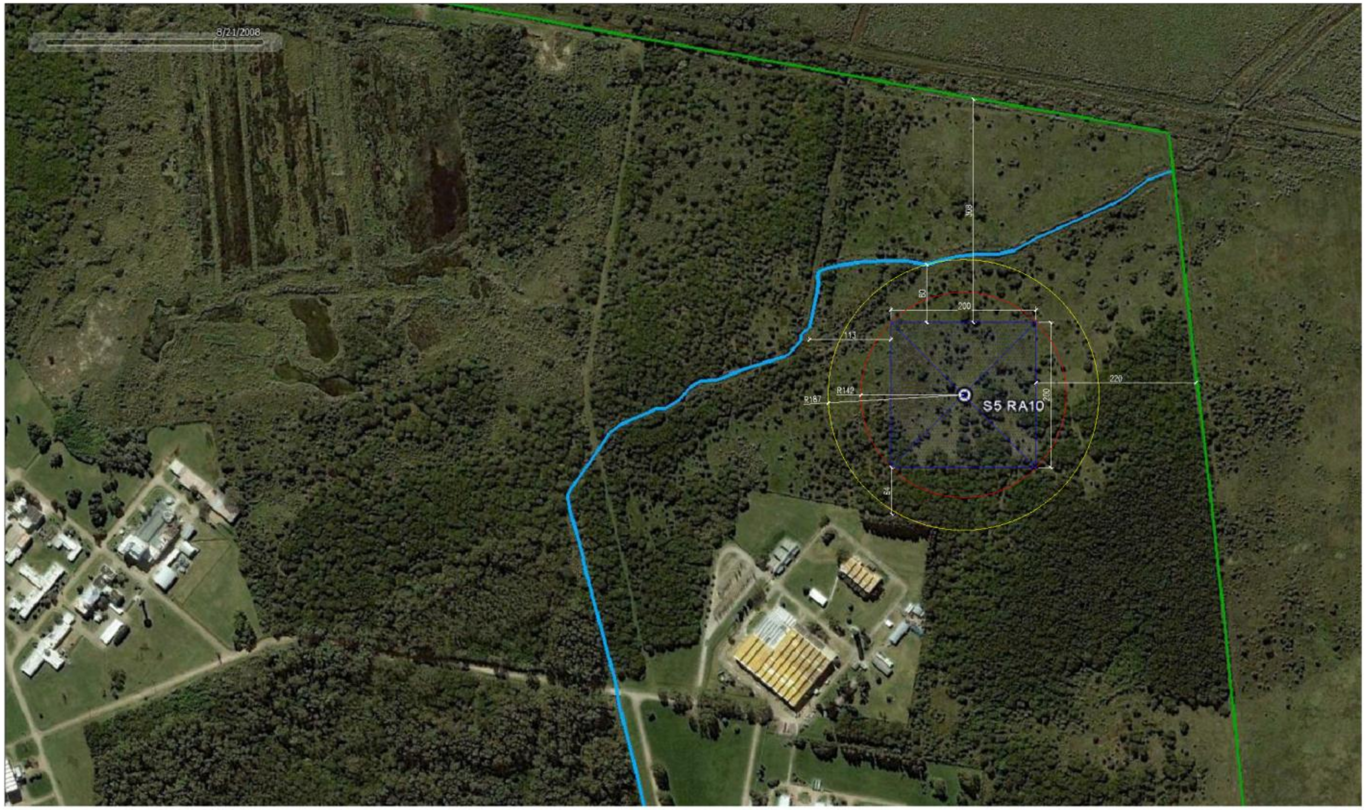
Reactor Site

- Ezeiza Atomic Center (Buenos Aires)

- Related facilities:

    - Spent fuel elements storage facility
    - Hot cells
    - Fission plant (molybdenum production)
    - Solid waste storage facility
    - Liquid effluent treatment plant
    - Ezeiza International Airport

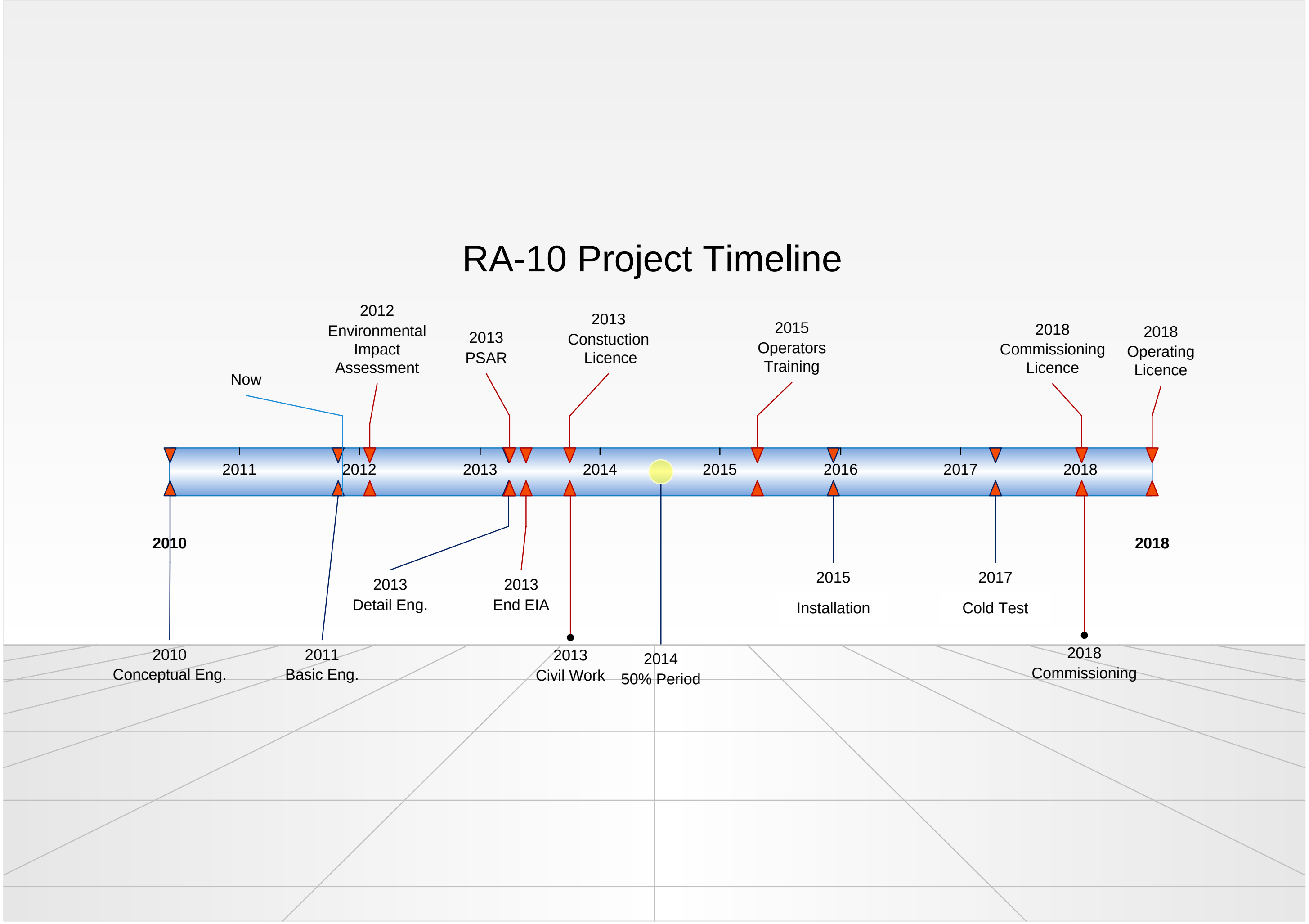
Reactor Site



Project advance

- **Conceptual design**:
  - Requirements specification related to reactor applications
  - Design criteria
  - SSCs classification
  - Reactor Systems
  - General Layout
- **Basic design**:
  - contract for the provision by INVAP (and CNEA)
- **Licensing**:
  - licensing basis (siting, design criteria, SSCs casification, initial events listing, safety features description)

RA-10 Project Timeline



CNEN-CNEA agreement

- The Brazilian and Argentinian presidents signed a **Nuclear Cooperation Declaration** where they agreed to **intensify efforts** for implementing **the joint development** of a **multipurpose research reactor project** (August 3, 2010)

- The Argentinian and Brazilian National Nuclear Energy commissions, **CNEA** and **CNEN** formalized **an agreement** for a **joint developmen**t of their **own projects:** the Brazilian RMB and the Argentinian RA-10 (January 31, 2011)

Design goals and project main guidelines

- A multipurpose facility suitable for RI production, material and fuel irradiation, neutron techniques and silicon doping.

- Based on LEU fuel elements

- Based on Argentinian Safety Regulations and IAEA Standards
  - Systematic approach to Safety Managment (following IAEA NS-R-4, 2005)
  - Dynamic interaction between Design and Safety Analysis

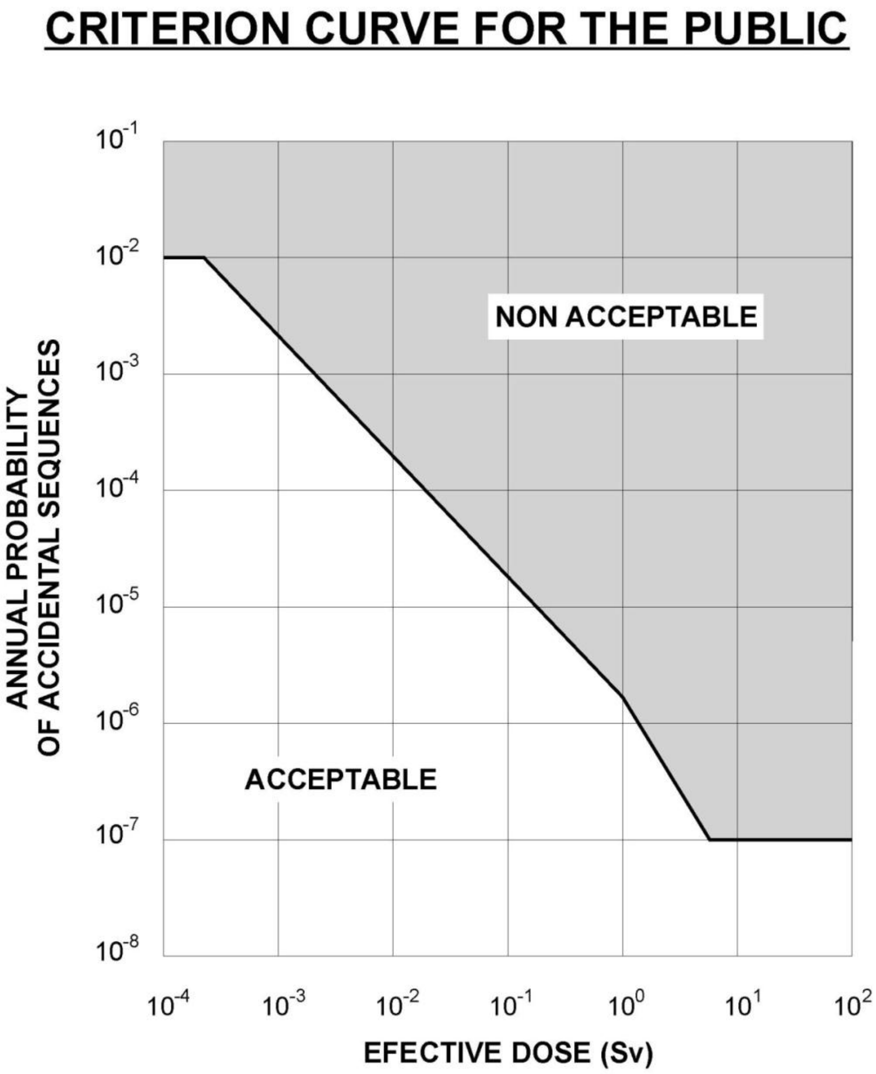
Safety regulations (risk-oriented)

- The Argentinian regulation does **not foresee restrictive conditions for general cases**. Instead, it is based on **performance or risk-oriented**. This means that it should be guaranteed, for all **postulated accidental sequences** that the **risk on the public** (radiological individual risk) is sufficiently low.

- For each **accidental sequence** a **probability** (annual ocurrence) and a **resulting dose** (effective dose in a representative person) are evaluated.

Safety regulations (risk oriented)

- Each **sequencial accident** is represented by a **dot** in this figure.
- For the plant to be **acceptable**, **none** of these dots must be located in the **non-acceptable** zone



Safety regulations: prescriptive conditions

- The **activation channels** of the shutdown systems must be **redundan**t, and if it is possible, **diverses** and designed on at least a **2oo3** logic.
- The **failure probability** of the **safety systems** must be determined by the **failure tree** technique or equivalent. The **failure rate** per demand for each safety system must be **lower than 10^{-3}**
- The **global power reactivity coefficient** must be **negative** for all anticipated operational ocurrance and accidents
- The **cooling system** must be designed in such a way that in any operational situation **ONB is not achieved** at any point.
- Specific **suggested** values (ARN **guide**) for core, experiments and control rods reactivity, shutdown margin, normal and emergency core cooling conditions, fuel storage conditions, etc.

Design objectives: RI production

Application	Spectrum	Flux	Irradiation conditions	Section	Length	Positions
Mo-99	Thermal	1.0-1.5 x10^{14}	* Continuous loading	5.2cm (diam.)	30cm	* 10 positions (up to 8 miniplates each one)
Ir-192 (Industrial)	Thermal	1.0-1.5 x10^{14}	* 2-3 cycles	5.2cm (diam.)	12cm	1
Ir-192 (medicinal)/ Lu-177	Thermal	>2 x10^{14}	* 2-3 cycles	5.2cm (diam.)	12cm	4

Design objectives: materials irradiation

Application	Spectrum	Flux	Irradiation conditions	Section	Length	Positions
Structural materials irradiation	Fast	>3 $x10^{14}$ (E>0.1 MeV)	Rig	5cm (diam.)	12cm	2
MTR miniplates and fuel elements irradiations	Thermal	>1 $x10^{14}$		8x8 cm	65cm	1
RPV material irradiation	Fast	$1x10^{14}$ (máx), E>0.1MeV	Rig	5cm (diam.)	12cm	1

Design objectives: NPP fuel irradiation

Application	Spectrum	Flux	Irradiation Conditions	Section	Length	Positions
NPP fuel elements irradiation	PWR	1-1.3 $x10^{14}$ (base mode) up to 2.5 $x10^{14}$ (power ramp mode)	* Loop	10cm (diam.)	40cm	1

Design objectives: NPP fuel irradiation

Burnup build-up tests	Transient tests	Selfshielding tests
• base irradiation at constant power	• power ramp with slope 10-50 W/cmmin	• constant power
• 2 or 3 fuel rods	• 1 fuel rod	• up to 7 fuel rod
• up to 500 W/cm	• 300 to 500 W/cm	• 200 W/cm.
• 3 to 5%	• up to 10%	• up to 10%
• up to 60000 Mwd/tonU		• 2000 Mwd/tonU
• 3 FPY		• 2 FPM

Design objectives: neutron beams

Application	Spectrum	Flux	Irradiation conditions	Section	Positions
Cold source	Thermal		D_2, cryogenic power < 5 kW	10 lts	1
Cold beams	E< 0.01 eV	$>10^9$ (neutron beams hall)	in-pile guide		2
Cold beams	E< 0.01 eV	$>4\ 10^9$ (reactor face)	in-pile guide		1
Thermal beams	E<0.1 eV	$>10^9$ (neutron beams hall)	in-pile guide		2
Thermal beams	E<0.1 eV	$>10^{10}$ (reactor face)	in-pile guide		1

Design objectives: other facilities

Application	Spectrum	Flux	Irradiation Conditions	Section	Length	Positions
NTD	Thermal	1×10^{13}-4×10^{13}	With rotator and flatter devices	15.24(2) / 20.32(2) / 25.4(1) cm (diam.)	60cm	5
NAA	Thermal+ Epithermal	2×10^{14}	Pneumatic device	3cm (diam.)	12-30cm	1
NAA	Themal	1×10^{13} - 2×10^{14}	• Pneumatic device	3-5cm (diam.)	10cm	12
Under water NR	Thermal	> 1×10^{8}	L/D>150	15cm (diam.)	-	1
Surveillance programme	Reactor	Maximum flux in the reflector Tank	capsule	<5cm (diam.)	12cm	3

General characteristics

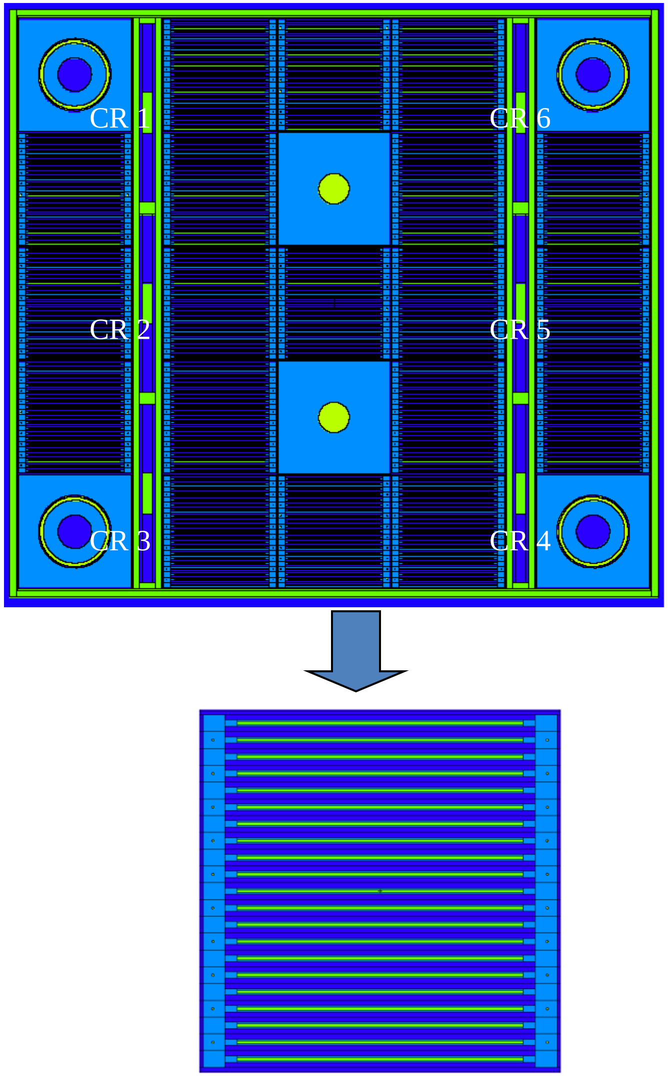
- Open pool type
- 30 MW power
- Low enrichment MTR fuel elements
- D_2O reflector
- H_2O moderator - coolant
- Upward coolant direction
- 2 independent shutdown systems: hafnium plates and D_2O reflector tank emptying
- 26 days continuous operation cycle

Core description

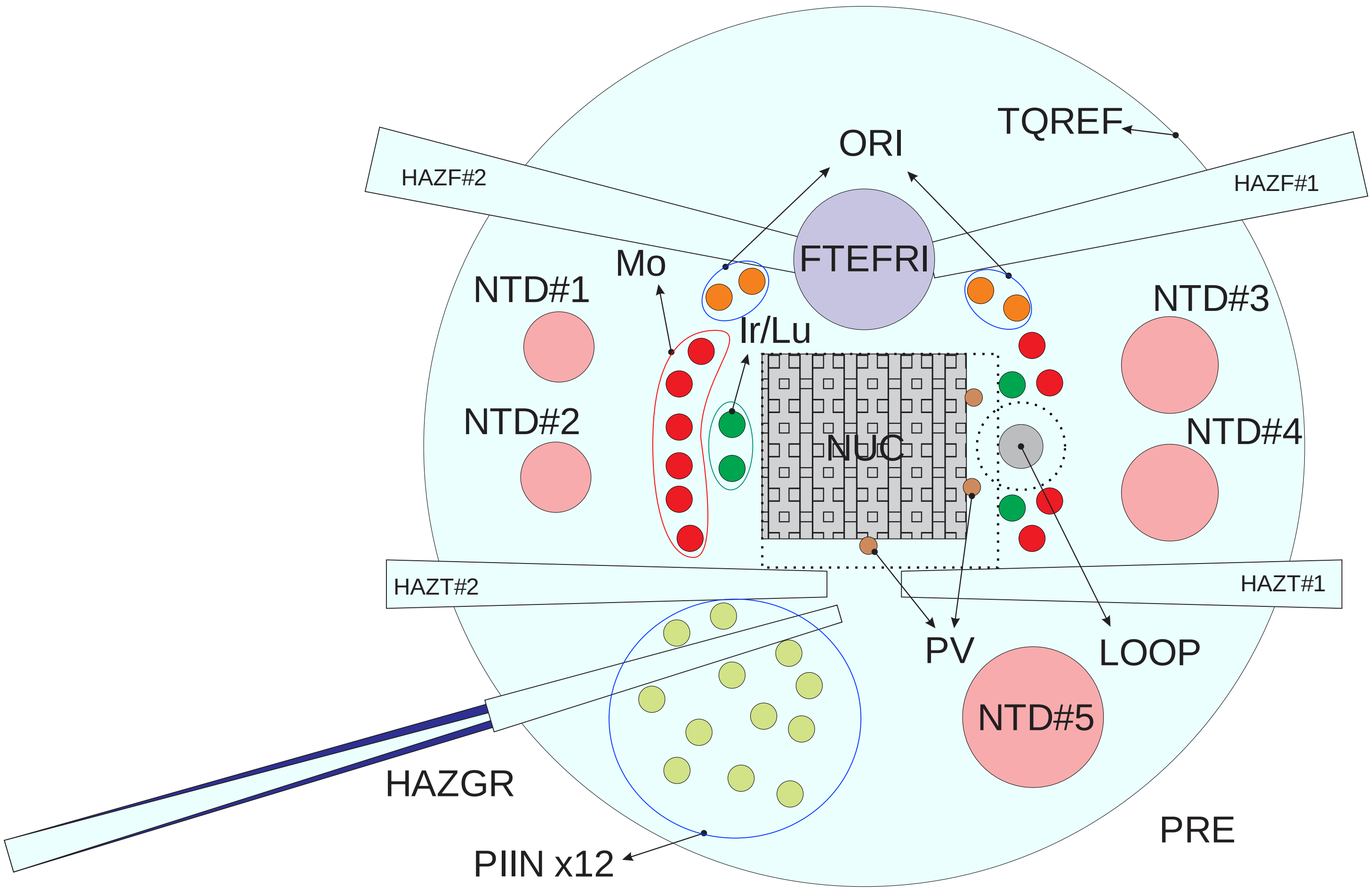
- **Compact core with internal irradiaton positions:**
  - 19 fuel elements in a 5x5 arrange
  - 2 central positions
  - 4 lateral positions

- **Fuel elements:**
  - MTR type
  - 21 fuel plates, 1.45 mm thickness
  - $U^{3}Si^{2}$, 0.71 mm thickness meat
  - 565 U^{5} g
  - 20 cadmium wires

- **Control rods:**
  - 6 hafnium plates



Reflector facilities arrangement



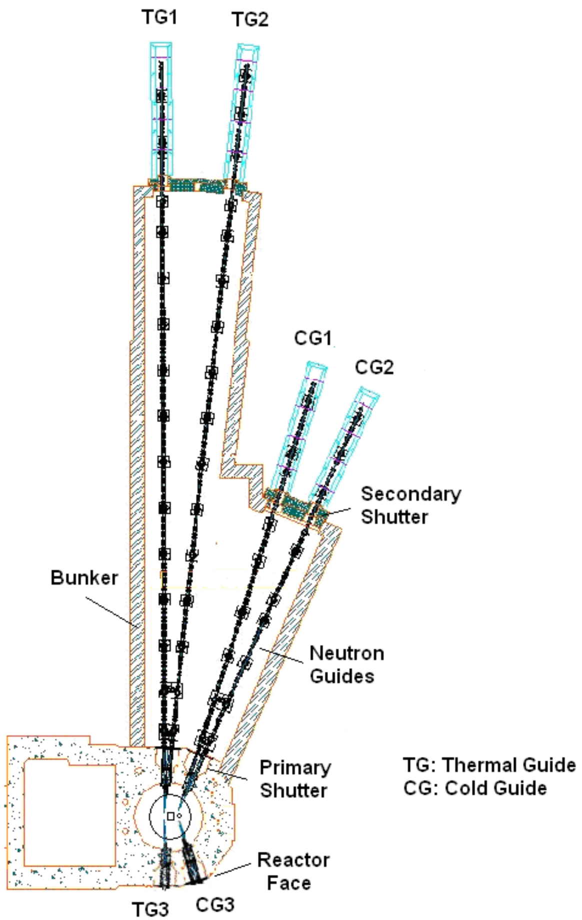
In-core facilities performance

IRRADIATION POSITION	THERMAL FLUX	EPITHERMAL FLUX	FAST FLUX
CENTRAL	$1.1x10^{14}$	$3.2x10^{14}$	$3.5x10^{14}$
LATERAL	$2.1x10^{14}$	$1.5x10^{14}$	$1.2x10^{14}$

Estimated performance for RI production

RI facility	Blanket geometry	Irradiation period	Final Activity
Mo 99	LEU miniplates	5 days	3000 Ci/w (6- day-Curies)
Ir 192 (med)	wires	1 cycle	120 Ci/cm (10 Ci/cm seeds)
Lu 177	foils	1 cycle	90 Ci/g
Ir 192 (ind)	foils	1 cycle	1900 Ci/g (500 Ci/g)

Neutron beams performance



BEAM TYPE		POSITION	NEUTRON FLUX (n/cm²/sec)
Thermal	TG1, TG2	neutron beams hall (50 mts from reactor core)	3 $x10^9$ ($1x10^9$)
	TG3	reactor face	3 $x10^{10}$ (1 $x10^{10}$)
Cold	CG1, CG2	neutron beams hall (50 mts from cold source)	6 $x10^9$ (1 $x10^9$)
	CG3	reactor face	6 $x10^9$ ($4x10^9$)

Preliminar instrument proposal

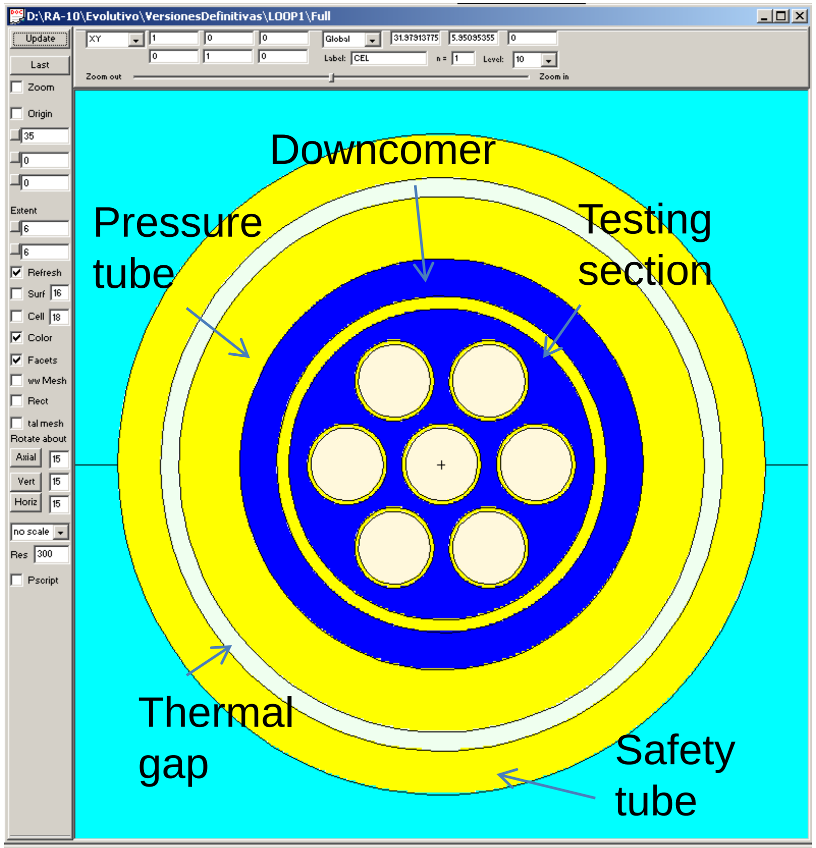
	NEUTRON BEAMS HALL	REACTOR FACE
COLD NEUTRONS	Small angle neutron diffractometer	NR
	Triple axis spectrometer	
	Reflectometer	
THERMAL NEUTRONS	High resolution powder diffractometer	High intensity powder diffractometer
	Strength analysis diffractometer	
	PGNAA	

Loop performance

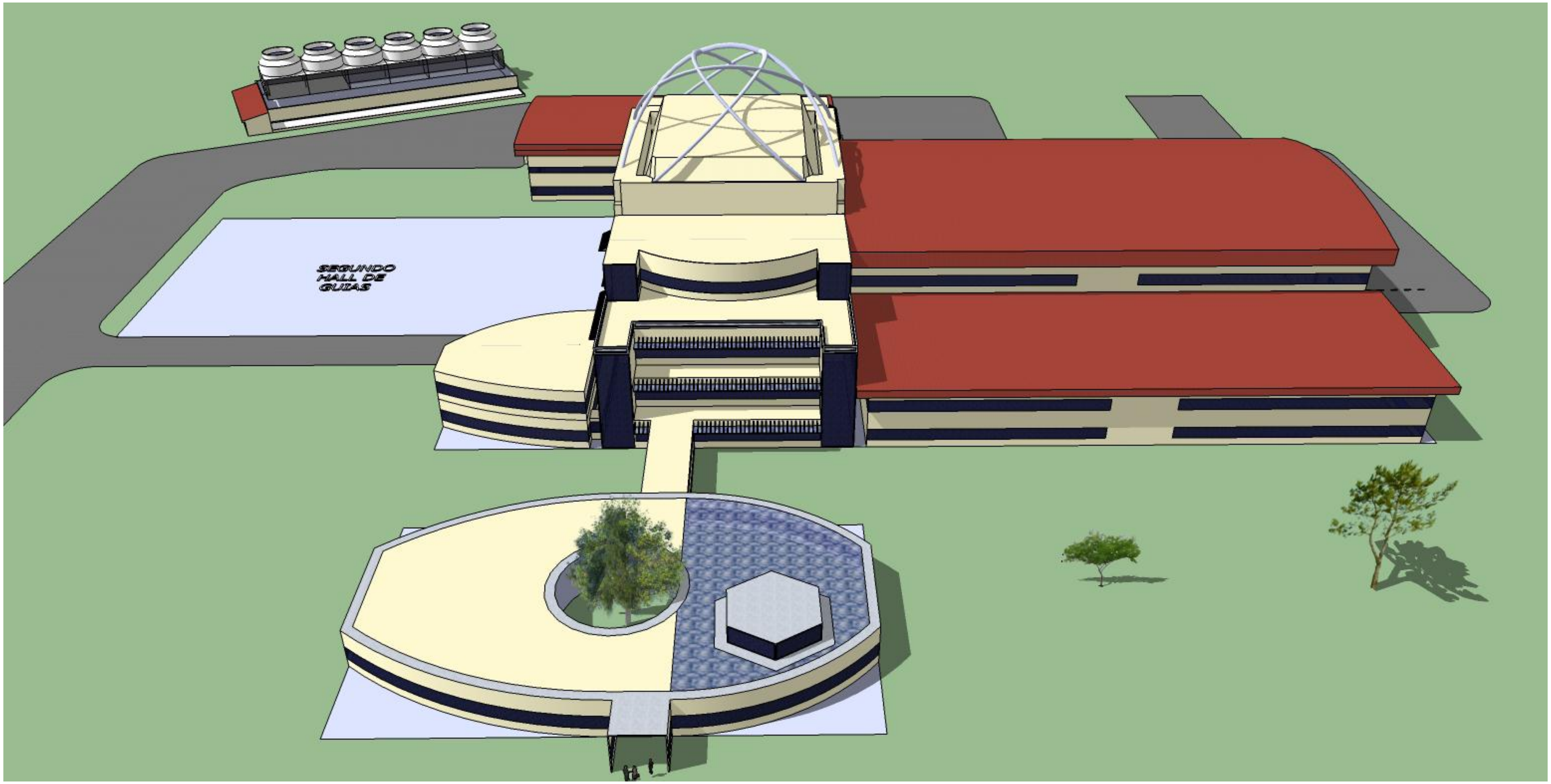
Test section: 7 UO2 fuel rods, 40 cm length
Coolant: H2O, 18 MPa y 350 °C
Structural material: SS

E %	Thermal	Epithermal	Fast
0.85	41%	37%	22%
5	23%	40%	37%

E %	0.85	5
Total power (kW)	57	145
Average lineal power (W/cm)	218	560



RA-10 facility view

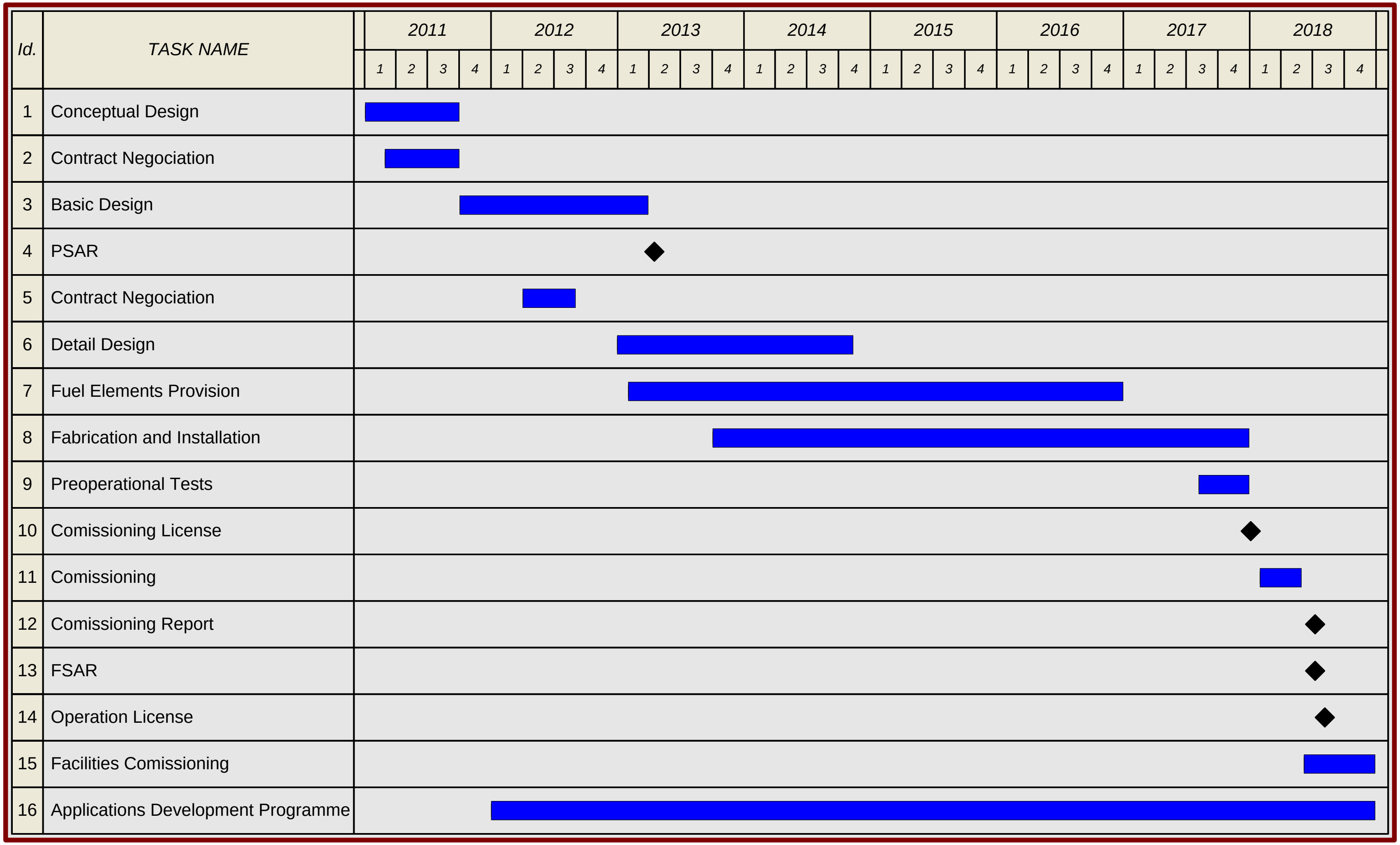


Conclusions

- The RA-10 project has completed its initial, planning and conceptual stage.
- The proposed design meets the stated objectives.
- The reactor performance must be ensured in the next basic engineering stage, while completing the safety analysis.

Thank you

RA-10 Project Schedule



SSCs classification

Reactor Protection System	A
First Shutdown system	A
Long Term Cooling system	(A/C)
Emergency core cooling system	C
Second Shutdown system	(A/C)
Confinement Ventilation and Insulation system	(A/C)
Core	A
Reflector Tank	A
Reactor Pool and internal components	A
Service Pool and components	A
Reactor Block	A
Radiation Monitoring System	A
Neutron Beams	A
Biological shildings	A
Cold Neutron Source Vessel	A

A: Safety SSCs

B and C: Safety related SSCs

Risk management

Event	Mitigation plan
Budget reduction	To support the project on a wide stakeholders spectrum
Social oposition during contruction	To promote an active and comprehensive comunication plan
No licensing	To implement a Licensing Plan for assuring the inclusion of local regulations and IAEA standards for all the project stages To foresee engineering features that might provide from licensing requirements and evaluate its impact in the project

Methodology for safety clasification of SSCs

BASIS:

- Defence in Depth Criteria
- Safety function identification
- Consequences of SSCs failure
- Probability of SSCs to be demanded to fulfill a safety function
- Elapsed time after a PIE occurrence in which the actuation of a SSCs is required

ITERATIVE SCHEME SEQUENCE:

1. Postulation of initiating events
2. Safety functions identification (Application of Defence in Depth Criteria)
3. Safety functions Class asignment
4. Requirements per class asignment
5. Safety function groups identification
6. Refinement of class assignment (to Item 3)

Classes for safety classification of SSCs

Class A
SSCs which failure could provoke unacceptable consequences when required
SSCs which failure could provoke unacceptable consequences and there is no class A SSCs to cope with
Any mitigatory SSCs required to reach a controlled state following a DBE or AOE

Class B
SSCs controlling and limiting relevant process variables
Those SSCs whose failure demands the actuation of a Class A SSCs

Class C
Those SSCs that contributes to ensure class A or B SSCs reliability
Any auxiliary or process SSCs performing mitigation function after a BDBE

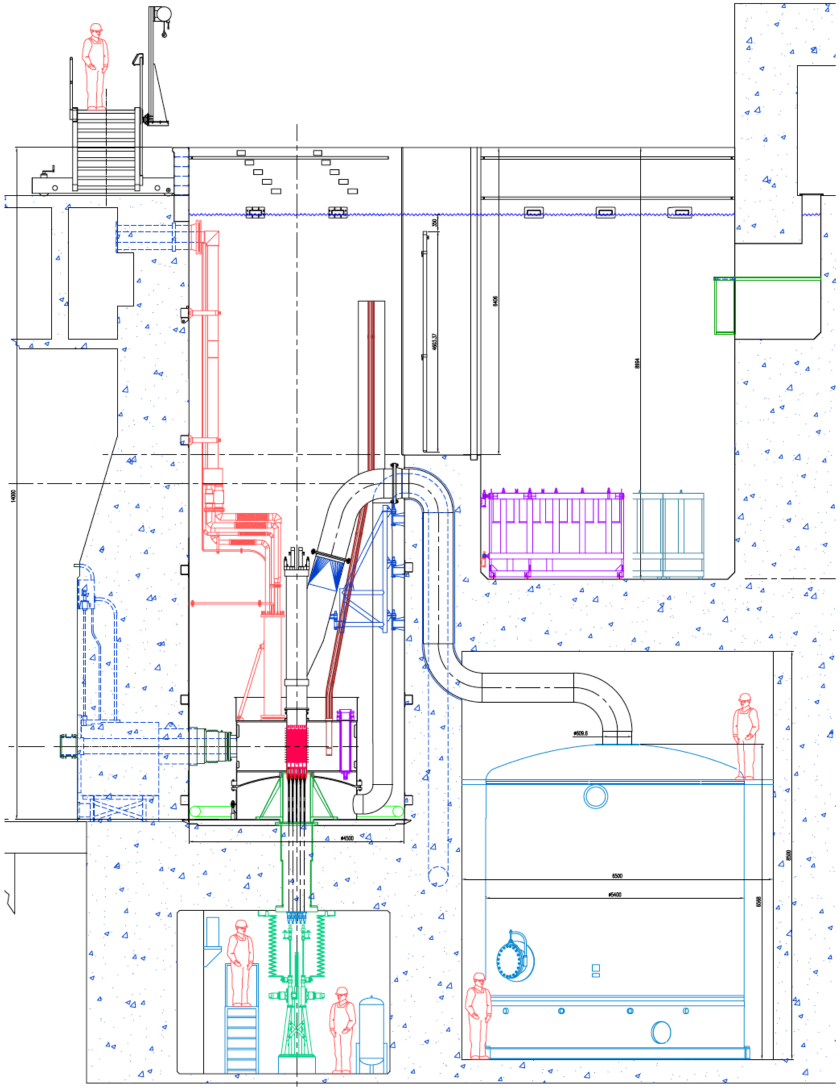
Classes Requirements:

- At Function level
- At System Design level
- At Equipment Performance level
- At Quality Assurance, Verification and Mantainance level

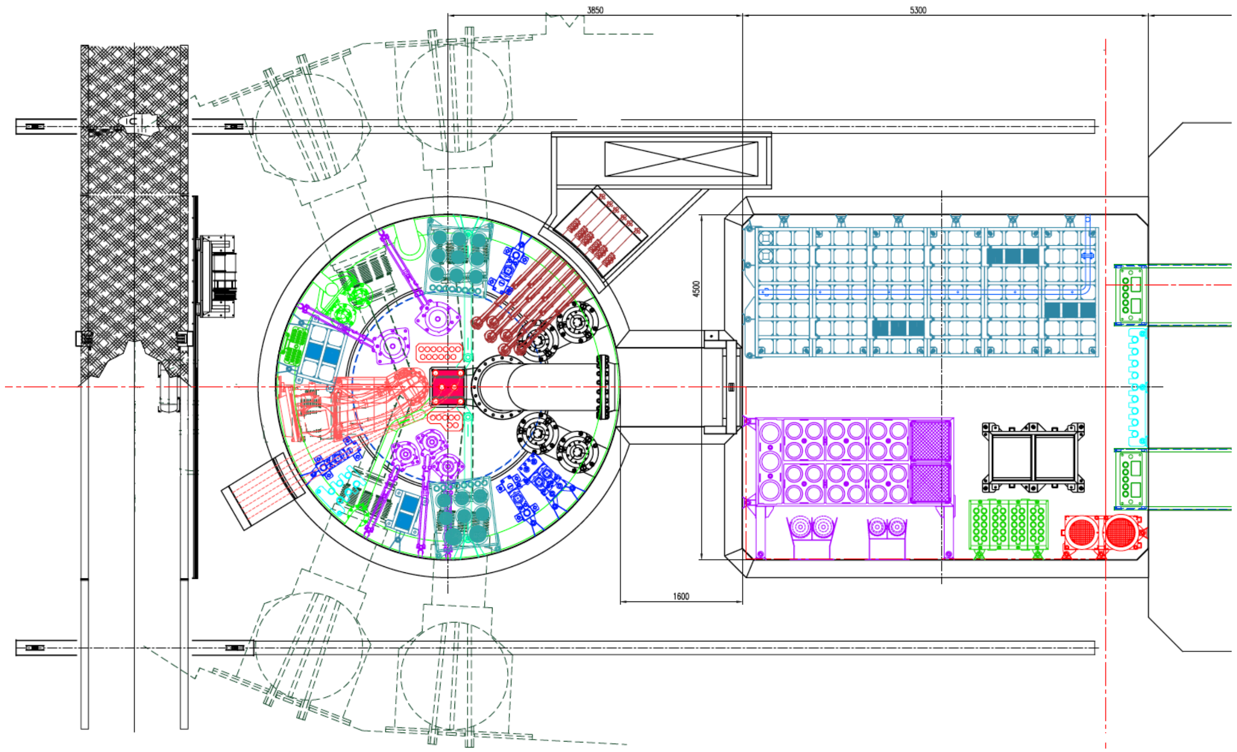
Table of safety Classification of SSCs

Structures, systems and components	Safety Class
Reactor Protection System	A
First Shutdown system	A
Long Term Cooling system	(A/C)
Emergency core cooling system	C
Second Shutdown system	(A/C)
Confinement Ventilation and Insulation system	(A/C)
Core	A
Reflector Tank	A
Reactor Pool and internal components	A
Service Pool and components	A
Reactor Block	A
Radiation Monitoring System	A
Thermal Neutron Beams	A
Cold Neutron Beams	A
Biological shildings	A
Cold Neutron Source Vessel	A
Control and regulation System	B
Primary circuit	B
pH /Conductivity Control system	C

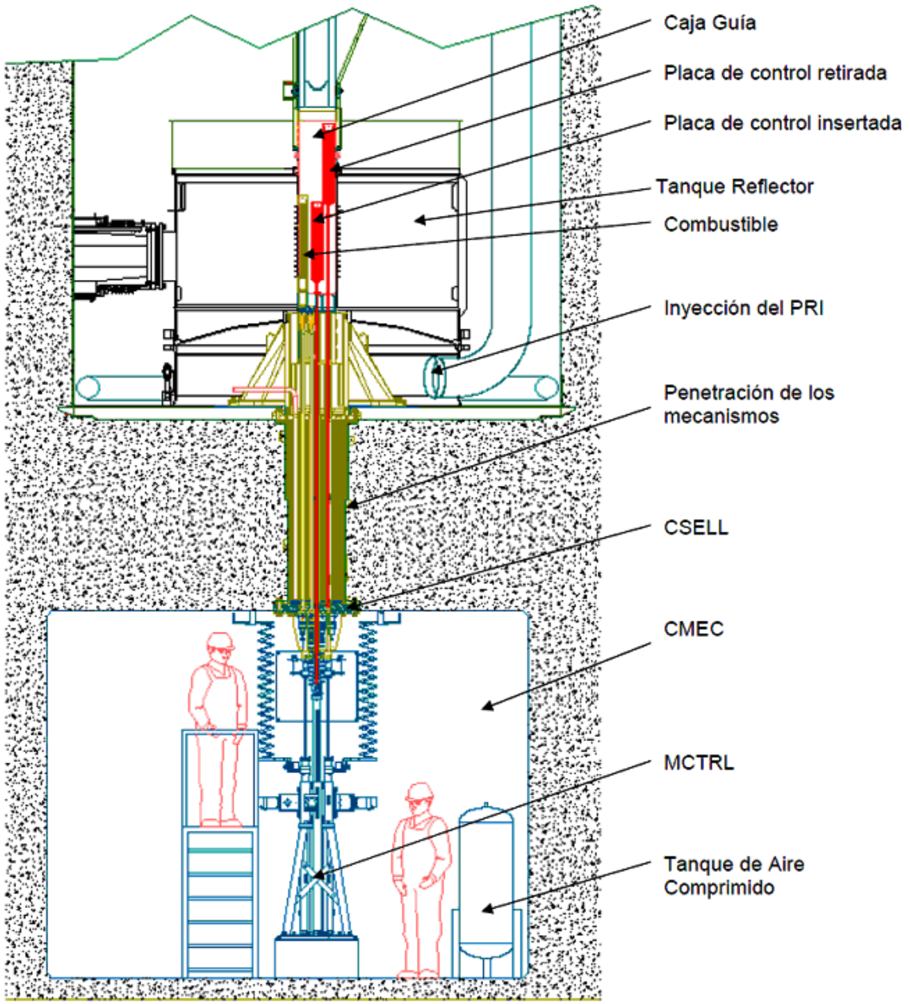
Reactor pool and services pool



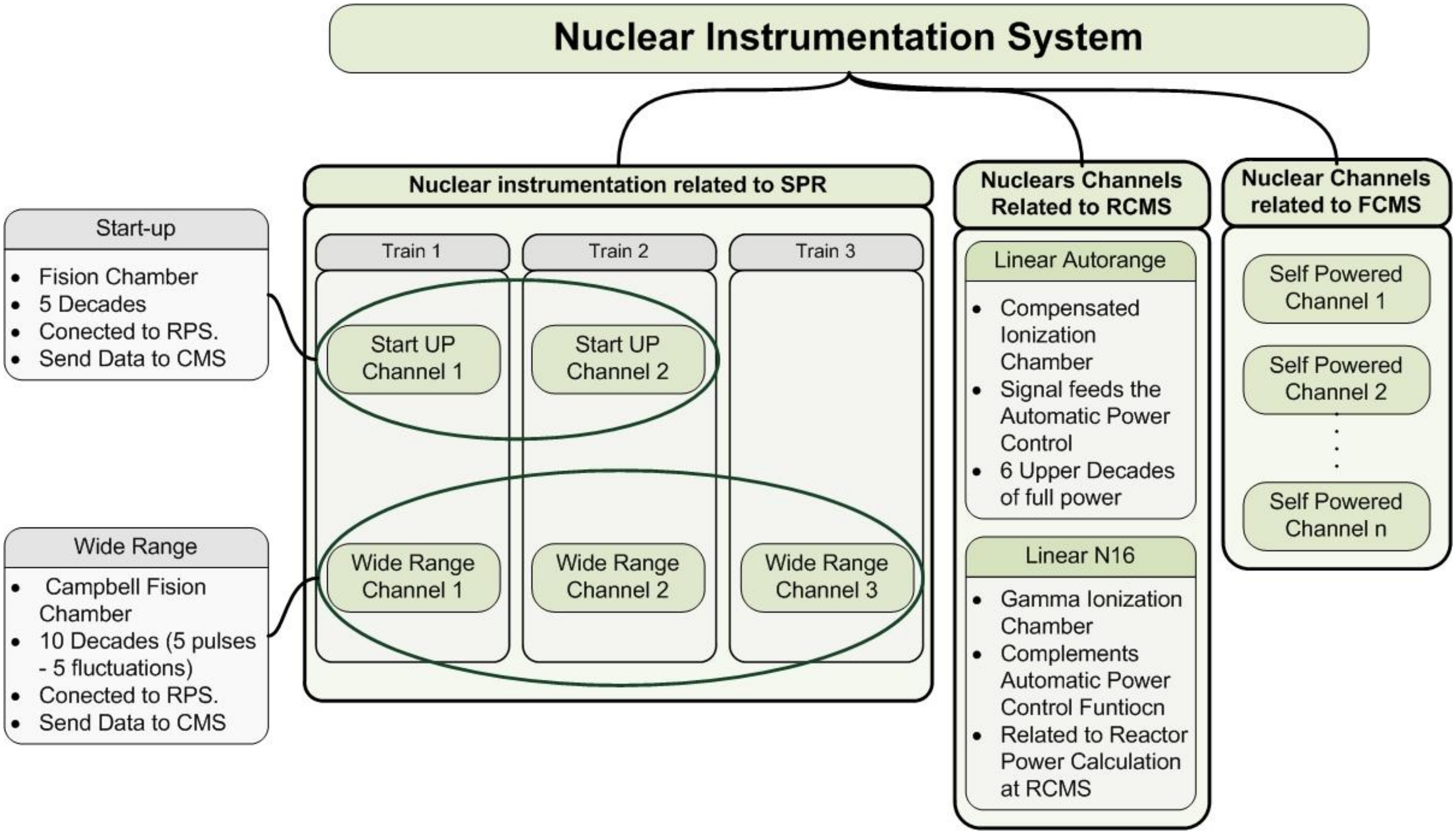
Reactor pool and services pool



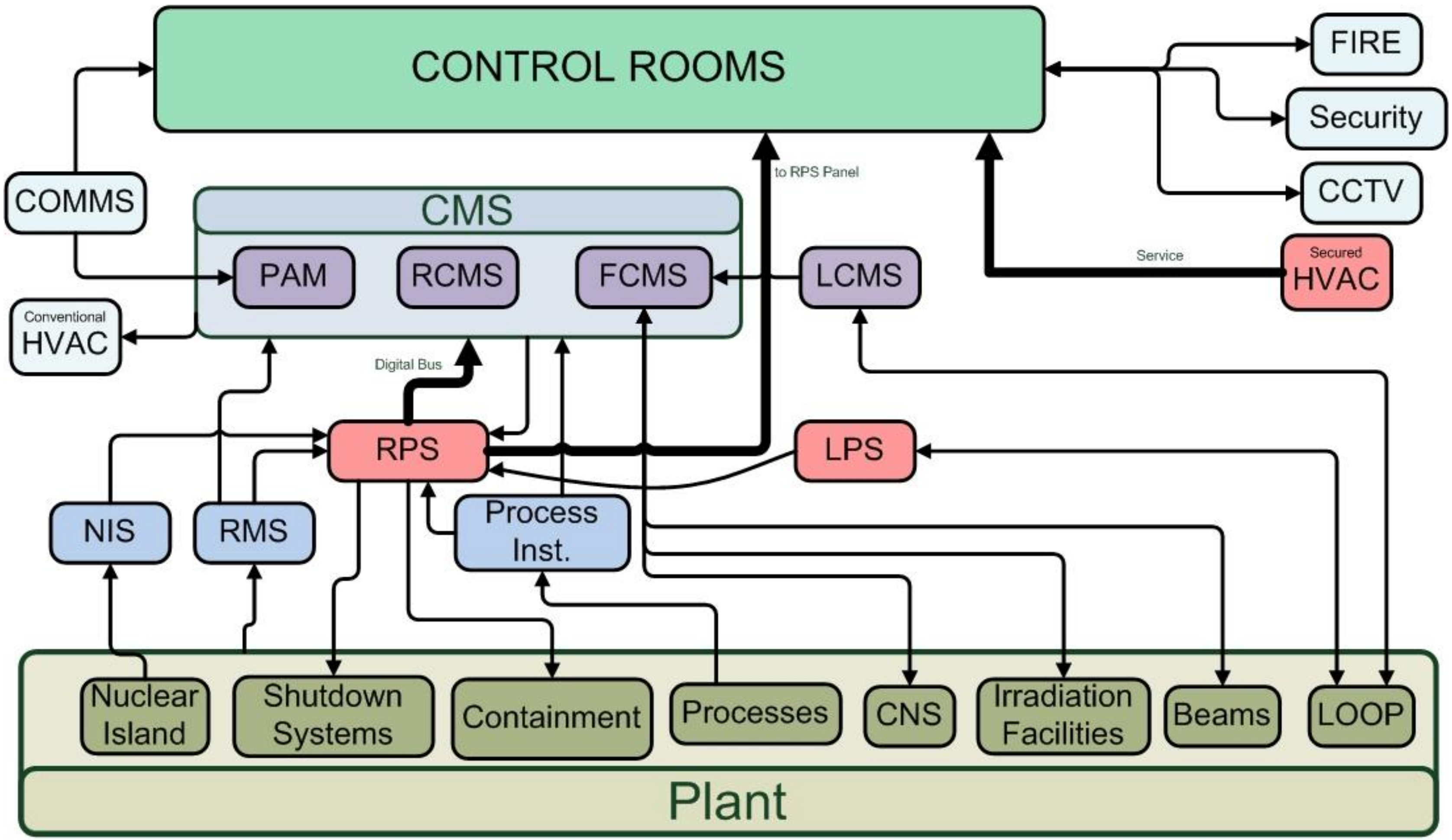
First shutdown system



I&C: neutronic instrumentation system



I&C: RPS, RCMS, FCMS



NIS: Nuclear Instrumentation System
RMS: Radiation Monitoring System
RPS: Reactor Protection System
PAM: Post Accident Monitoring
RCMS: Reactor Control and Monitoring System
FCMS: Facilities Control and Monitoring System

CMS: Control and Monitoring System
LCMS: Loop Control and Monitoring System
LPS: Loop Protection System
HVAC: Heat, Ventilation and Air Condiotining
CCTV: Close Circuit TV
COMMS: Communications System

CNS: Cold Neutron Source