



**FUSION
FOR
ENERGY**

Radiological and Environmental Monitoring System

Market Survey - System Description

Giovanni Piazza

F4E Project Manager for REMS

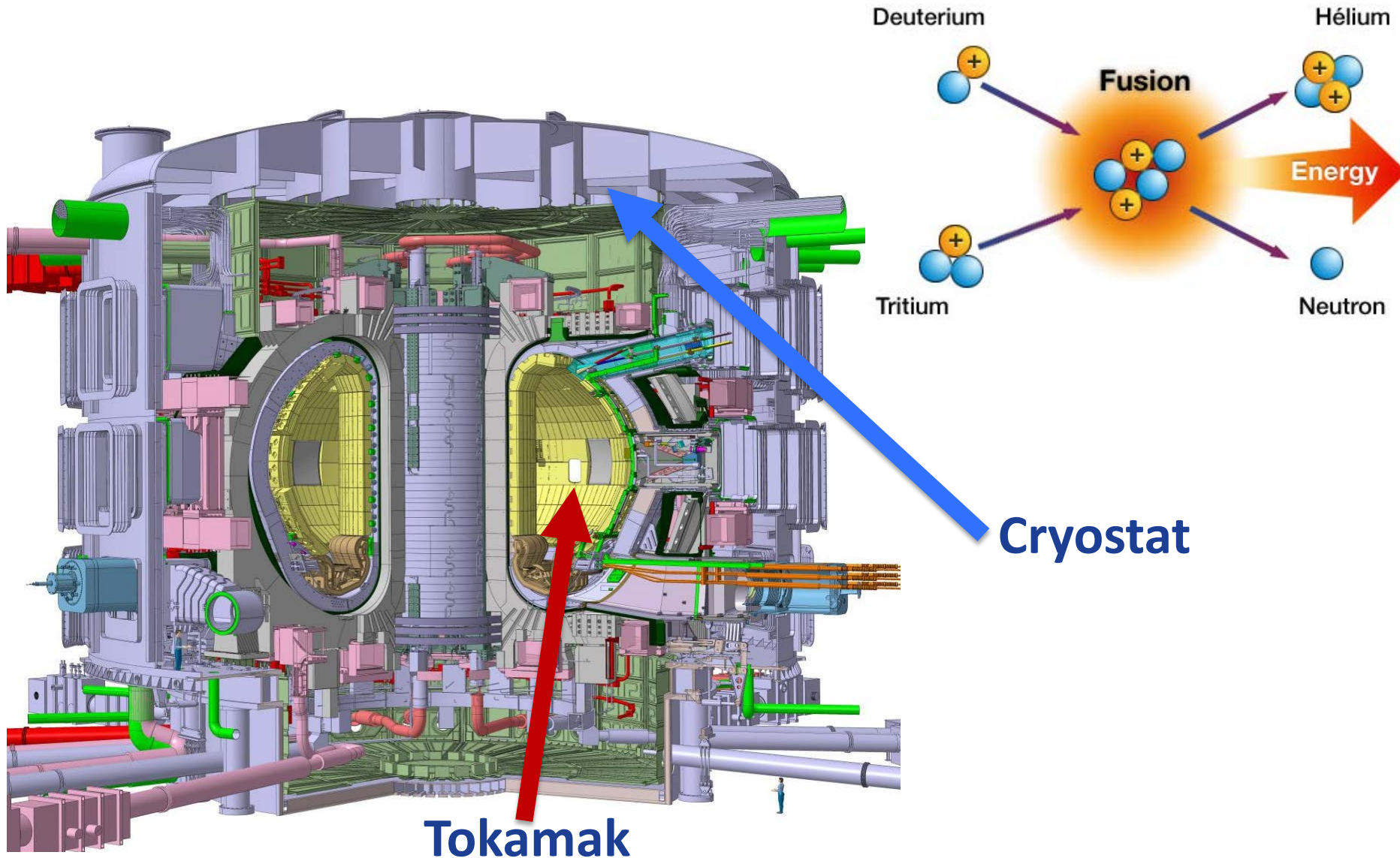


Aim of the presentation is to inform potentially interested suppliers on:

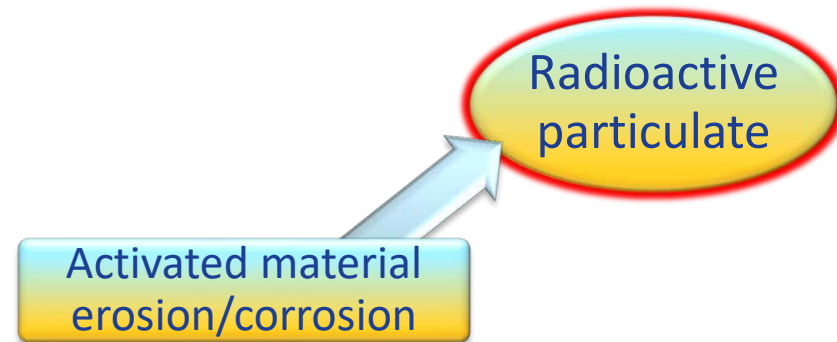
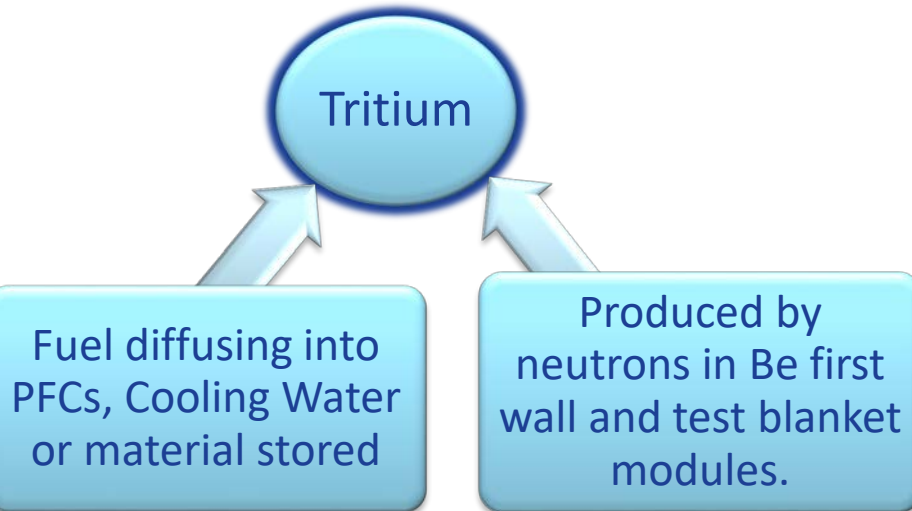
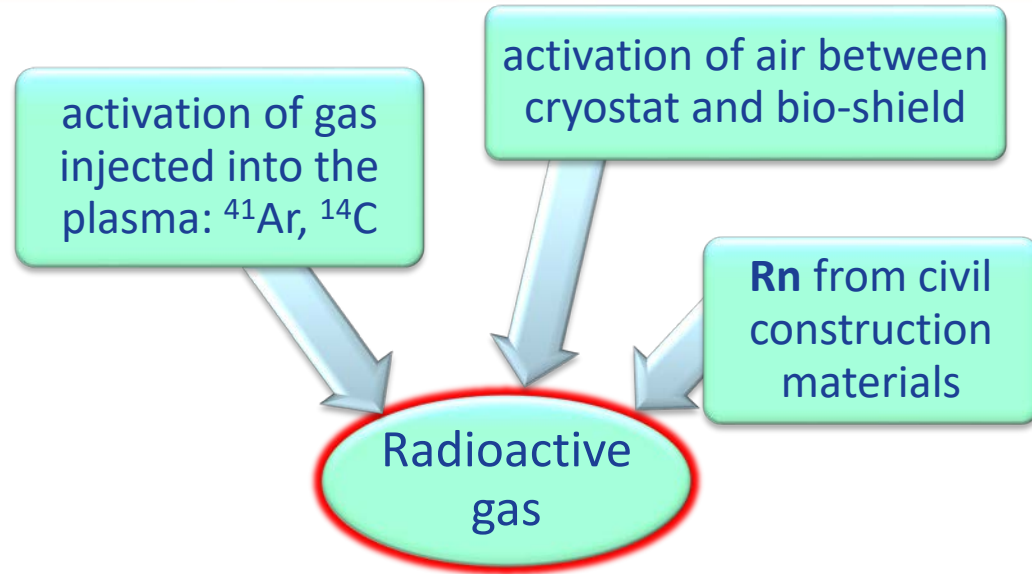
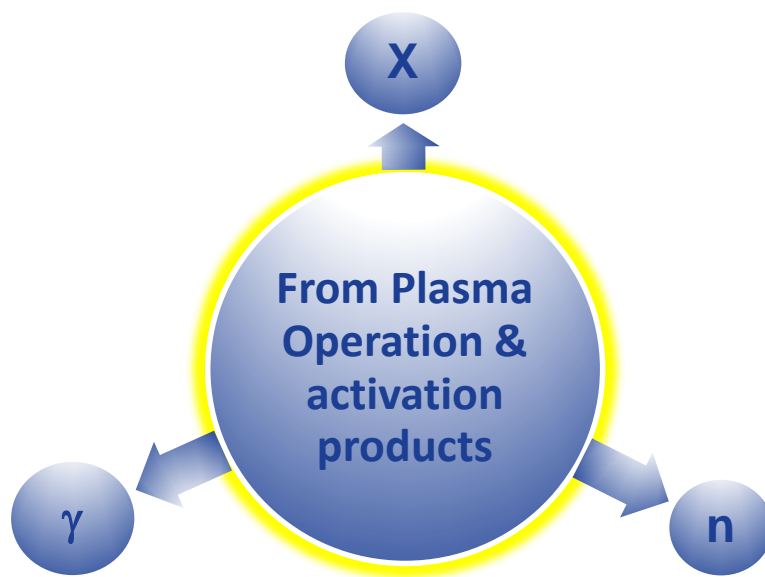
- Function of the ITER Radiological and Environmental Monitoring System (REMS)
- Scope of the whole F4E procurement package*;
- F4E procurement strategy with the planned Supply contracts:
 - First Plasma;
 - Tokamak Complex for Nuclear Operation;
 - Hot Cell Complex for Nuclear Operation;

** Any proprietary instrument shown in this presentation has to be considered only as a proposal coming from the Preliminary Design and not as a final choice. The Manufacturer and/or supplier of each type of equipment may change and will be fixed at the time of contract award.*

Overview of REMS: Nuclear Fusion



Overview of REMS: Radiological Hazard



Isotopes produced from activation in :

- In-vessel component structural material:

W-alloys: $^{187/185/185m/181}\text{W}$ and $^{188/186/188m}\text{Re}$.

Cu-alloys: $^{64/62/66}\text{Cu}$, $^{60m/62/60}\text{Co}$ and ^{65}Ni .

316 LN: $^{54/56}\text{Mn}$, ^{55}Fe , ^{52}V , ^{51}Cr , and $^{58/58m/60m/57}\text{Co}$.

Cooling water :

$^2\text{D}(n,\gamma)^3\text{T}$;

$^{17}\text{O}(n, \alpha)^{14}\text{C}$ and $^{18}\text{O}(n,n'\alpha)^{14}\text{C}$;

$^{16}\text{O}(n,p)^{16}\text{N}$ ($T_{1/2} = 7.12\text{s}$, γ -source);

$^{17}\text{O}(n,p)^{17}\text{N}$ ($T_{1/2} = 4.12\text{ s}$ n-source).

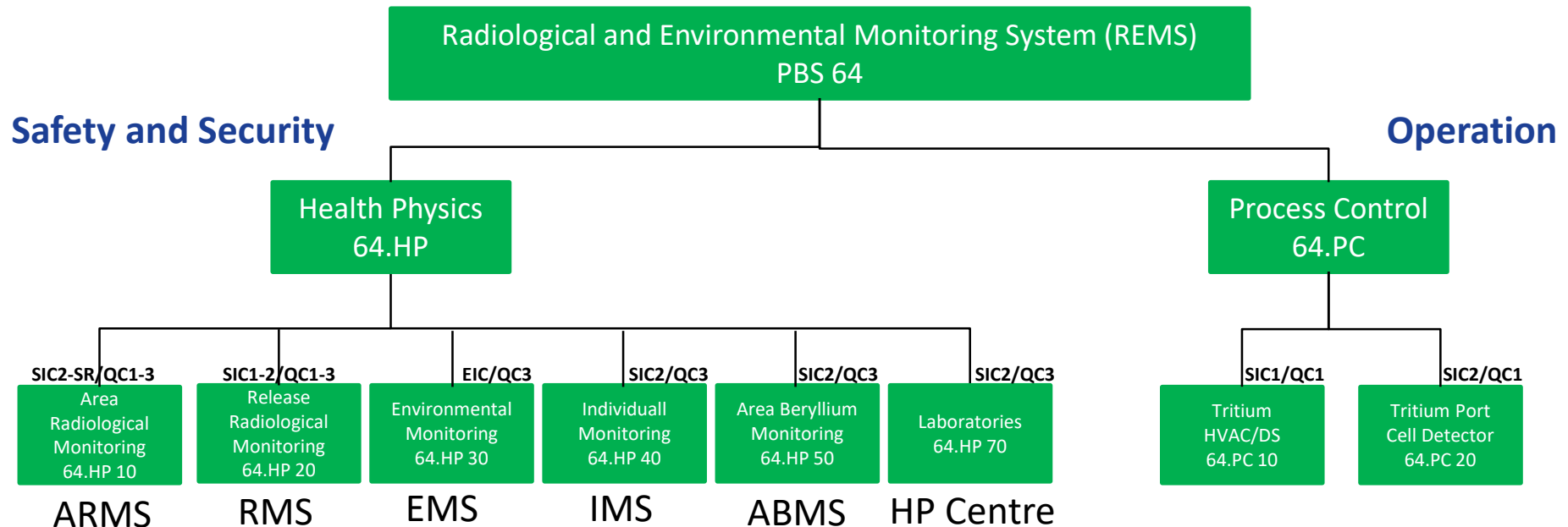
Overview of REMS: Functions

The Radiological and Environmental Monitoring System provides:

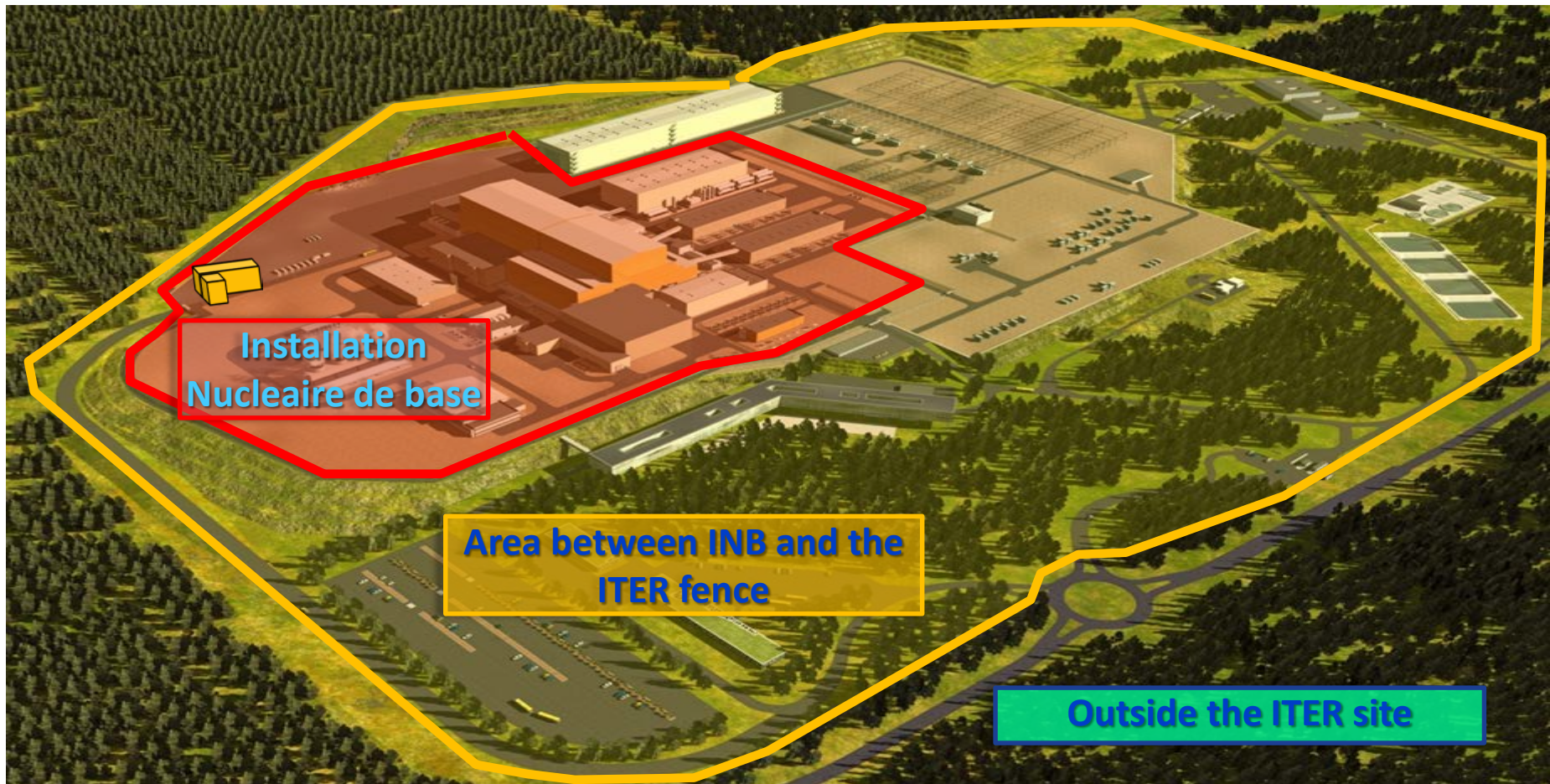
**Health and Radiological monitoring
of Workers**

**Area and environmental monitoring
for Public (including Be)**

by assisting in the protection from ionizing radiation during the whole life of ITER from construction to operation and decommissioning.



Overview of REMS



- REMS Plant-wide functions are integrated, status monitored and recorded centrally at the HP Centre.
- Information is provided to the CODAC and the Central Safety Systems. No actuators in REMS scope

Stationary, mobile and portable radiation/contamination monitors and samplers inside the ITER facility rooms

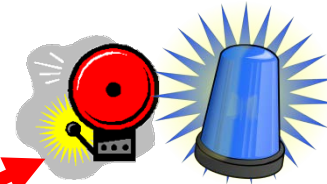
Check rad. levels within ITER rad. zoning limits

white
Blue
Green
Yellow
Orange
Red

unregulated zone ($< 80 \mu\text{Sv}$ in one month)
 supervised zone ($< 7.5 \mu\text{Sv}$ in one hour)
 controlled zone - not specially regulated ($< 10 \mu\text{Sv/h}$)
 controlled zone - specially regulated ($< 100 \mu\text{Sv/h}$)
 controlled zone - specially regulated ($< 100 \text{mSv/h}$)
 controlled zone - human access forbidden ($\geq 100 \text{mSv/h}$)



Detect accident/incident



**Local rad. Warning
in rad. contr. areas**

**Local warning on
malfunctioning.**



**Inform HP-C
& Operator in
CSS (M/B-up)
and CODAC**



**Data to CODAC
for archiving**



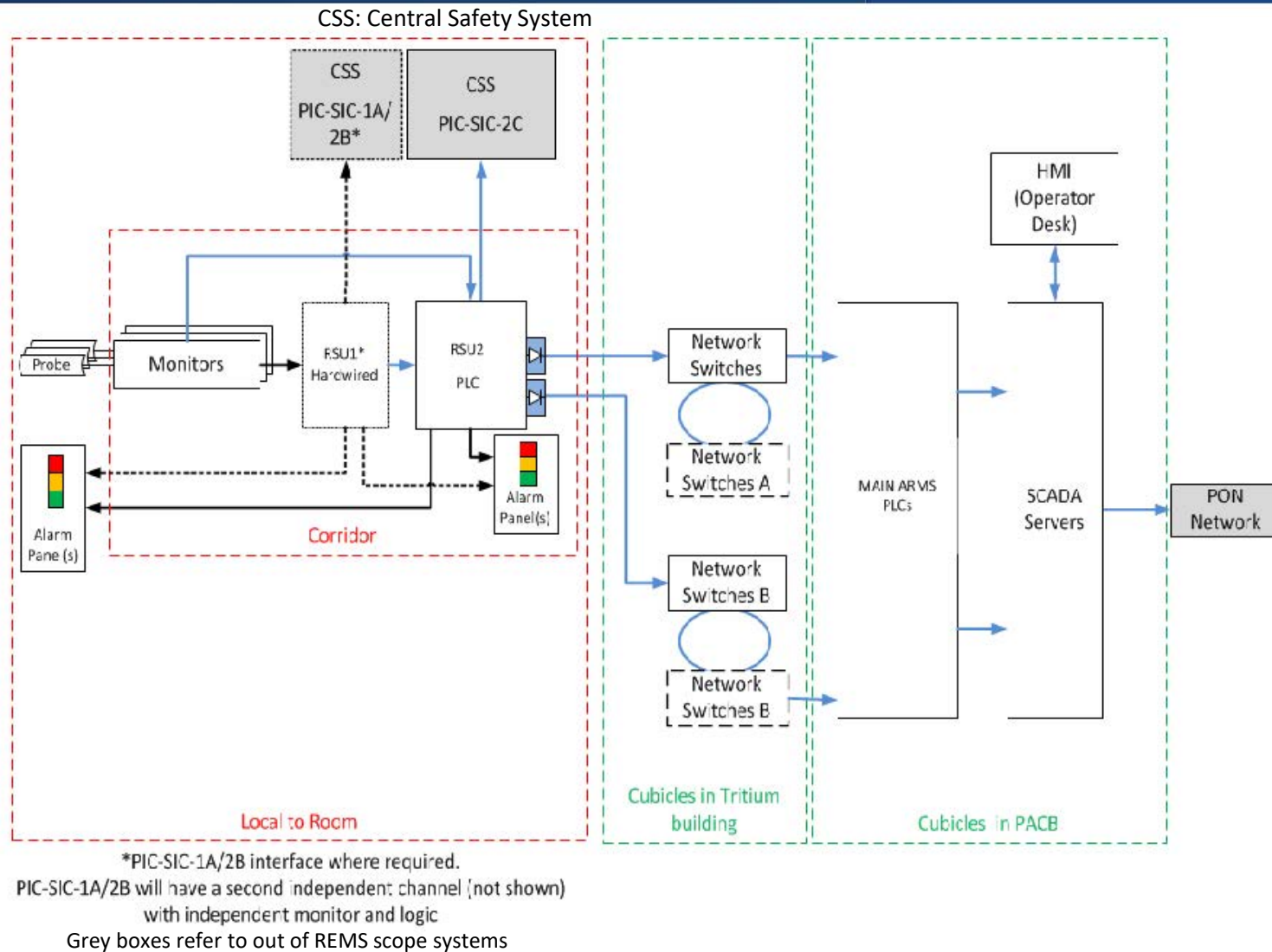
Inform CSS to allow/block access



**Monitor radiation hazard during
operation and decommissioning
and efficiency of confinement**

ARMS: Architecture

- In the architecture the local alarms presented to the workers are processed locally to the room.
- This is done in the Radiological Synthesis Units (RSU), typically located in the corridors or airlocks (lower radiological and magnetic exposure).



Stationary Be samplers inside the TAPB.

Beryllium zone	Atmospheric concentration ($\mu\text{g}/\text{m}^3$)	Access and control conditions
Beryllium non-controlled zone	< 0.01	<ul style="list-style-type: none"> no plausible risk of presence of Be, no access limitation.
Beryllium controlled zone	$0.01 < [\text{Be}] < 0.2$	<ul style="list-style-type: none"> no dispersion risk for Be aerosols, vapour and dusts, possible presence of Be, in concentrations above the detection limits of monitoring equipment, access limited to Be-qualified personnel, stay times and possible safeguards adapted to the risk of exposure, depending on the operations to be performed.
Beryllium zone with respiratory protection	> 0.2	<ul style="list-style-type: none"> presence of contamination and/or potential to exceed the limits for Be controlled zone. Access limited to especially qualified Be-staff. Confined and ventilated zone requiring use of respiratory protection gear.

Check that Be concentrations levels in air are within ITER Be-zoning limits

Check efficiency of Be confinement



Detect accident/incident



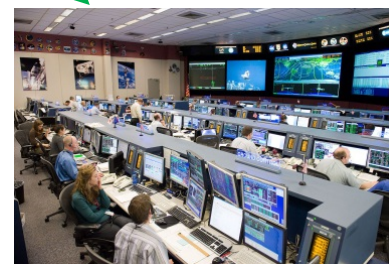
Local warning



Assess the potential volumetric Be concentration in air to allow/block access



Data to CODAC for archiving



Inform HP-C & Operator in CSS (Main/Back-up) and CODAC



- Gas effluent characterisation to demonstrate compliance with authorized emission levels
- Planned points of exhaust:

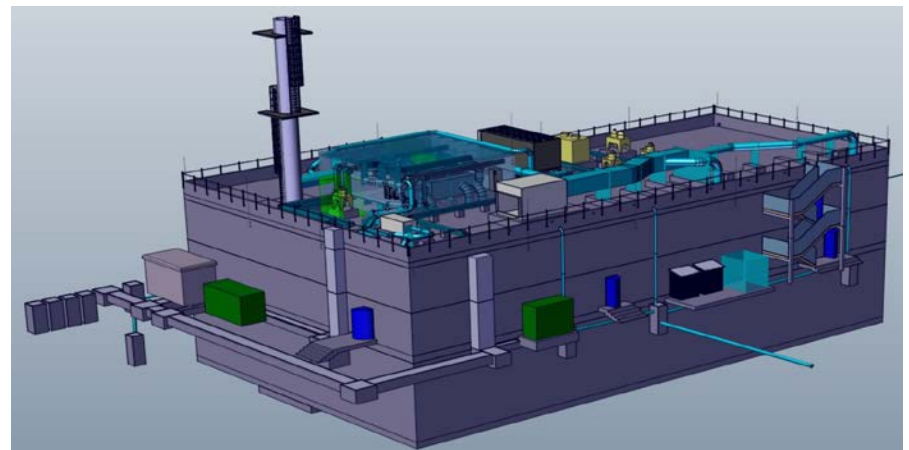
Non-SIC and SIC stacks in TKC for:

- β & γ emitters (Tritium, ^{14}C , ^{41}Ar , radioactive dust & corrosion products)
- Beryllium



Stack in TAPB for:

- Beryllium.



RMS: Gaseous Release at the Stack (TKC)

SIC DUCT

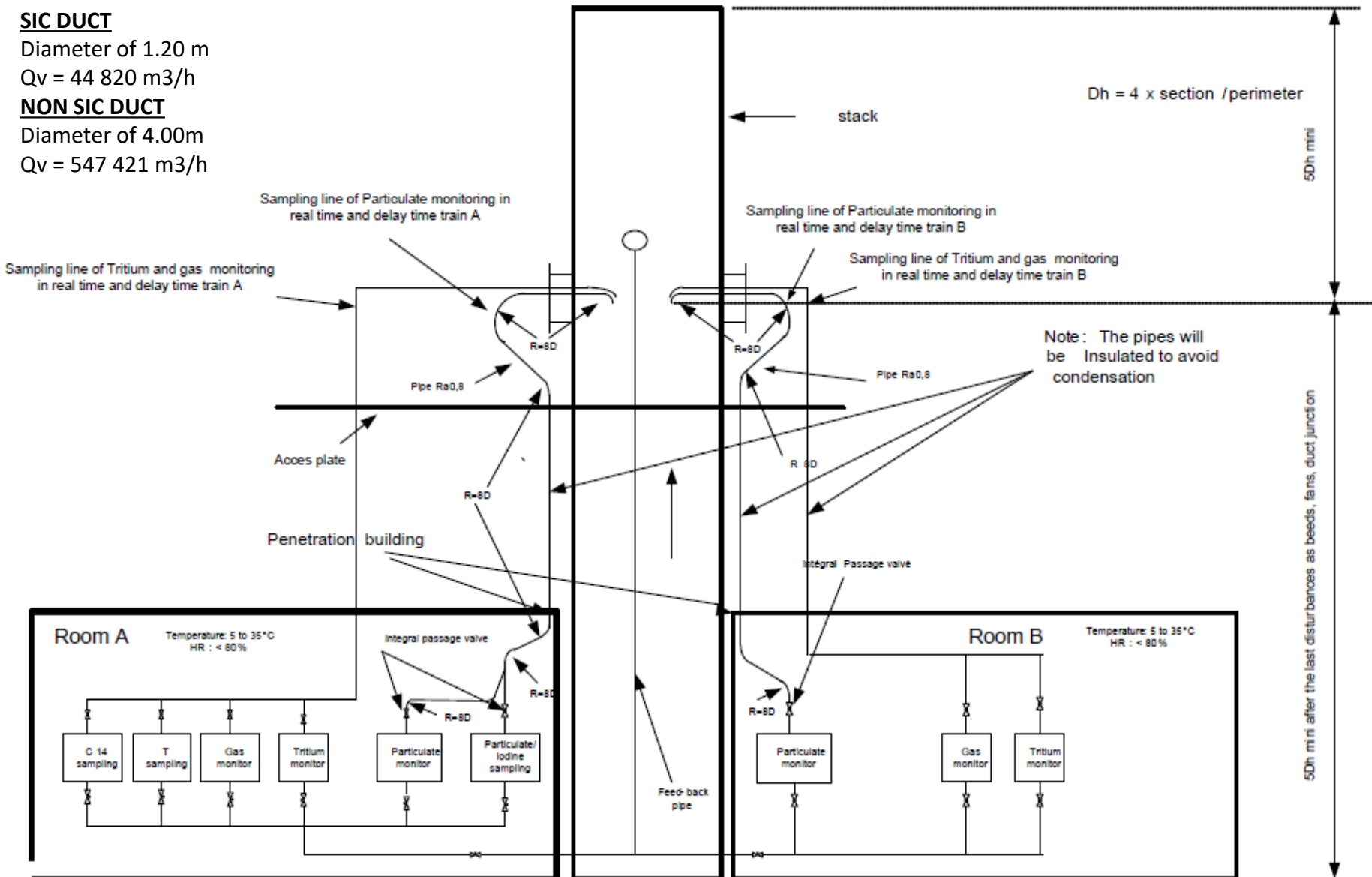
Diameter of 1.20 m

$Q_v = 44\,820 \text{ m}^3/\text{h}$

NON SIC DUCT

Diameter of 4.00m

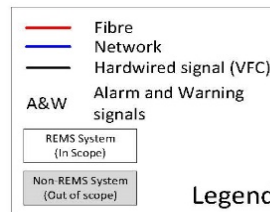
$Q_v = 547\,421 \text{ m}^3/\text{h}$



RMS: I&C Architecture

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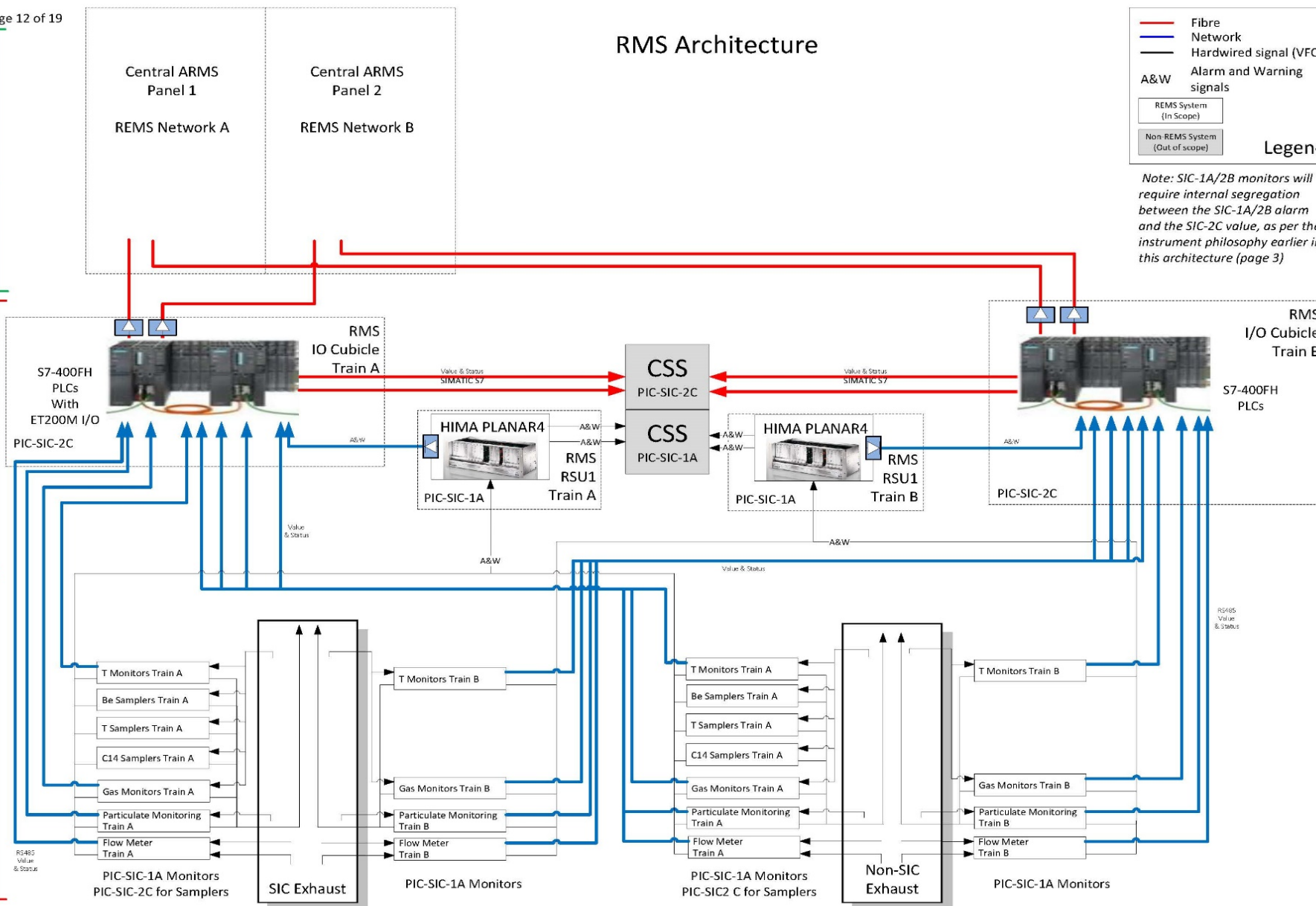
RMS Architecture



Note: SIC-1A/2B monitors will require internal segregation between the SIC-1A/2B alarm and the SIC-2C value, as per the instrument philosophy earlier in this architecture (page 3)

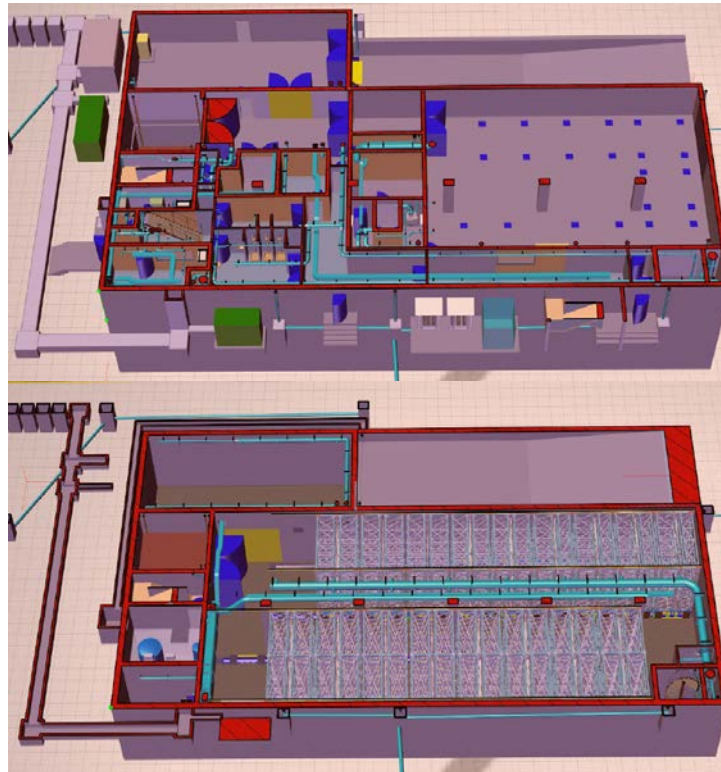
SR System

Hardwired PIC-SIC-1A System/loop and Networked PIC-SIC-2C System/Loop



Fixed Particulate detector:

- Samplers trap Be particulate on a filter through iso-kinetic sampling from a duct. Duct flow (10-100 l/min) is measured directly and recorded by the instrument.
- Periodic analysis of filter performed off-line in the HP labs (spectrometry):



TAPB L1 level:

TAPB B1 level:

Stack height: **14.1 m** above roof.

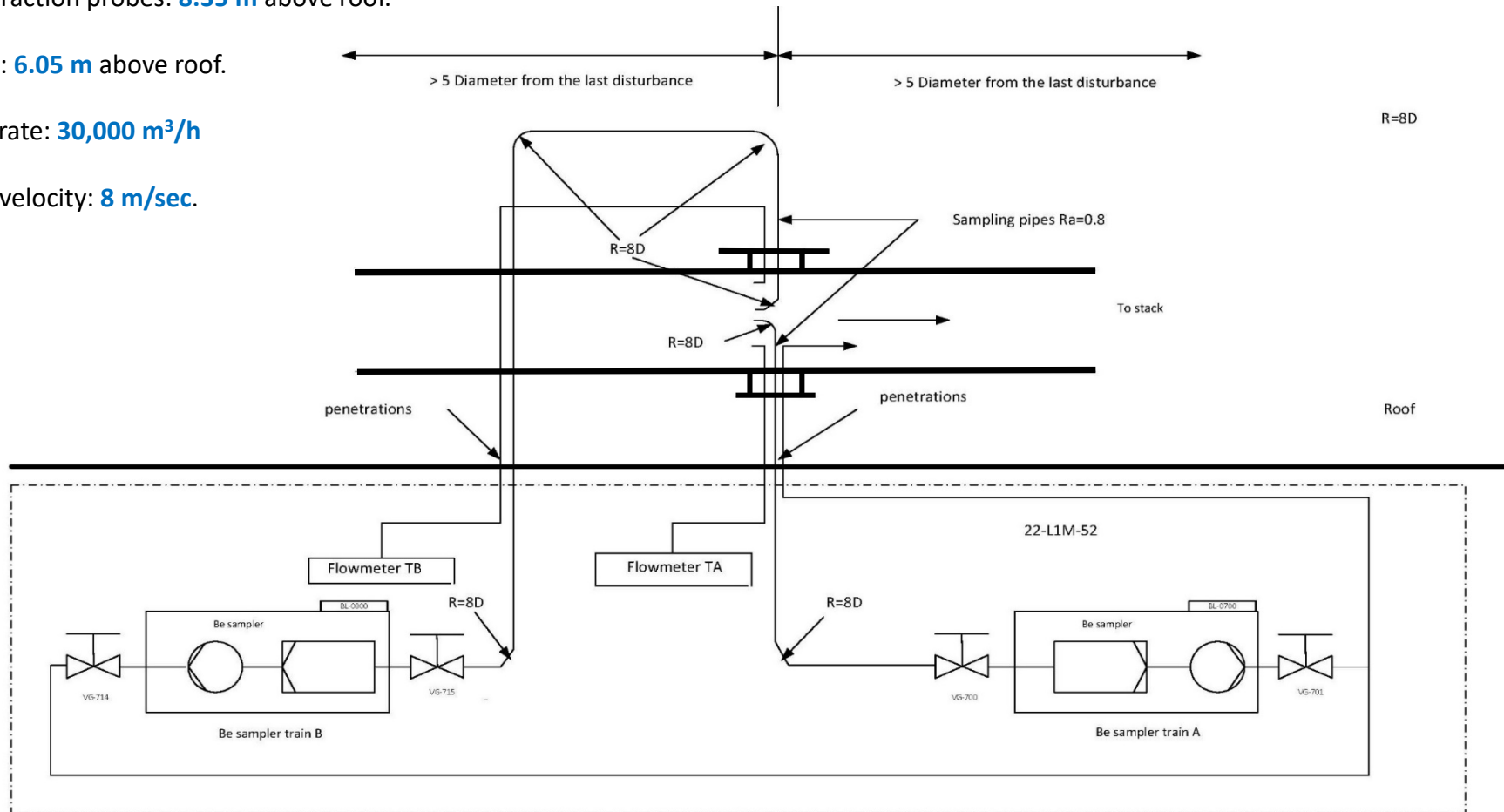
Stack diameter: **1.15 m**.

Sample extraction probes: **8.35 m** above roof.

Pitot tubes: **6.05 m** above roof.

Stack flow rate: **30,000 m³/h**

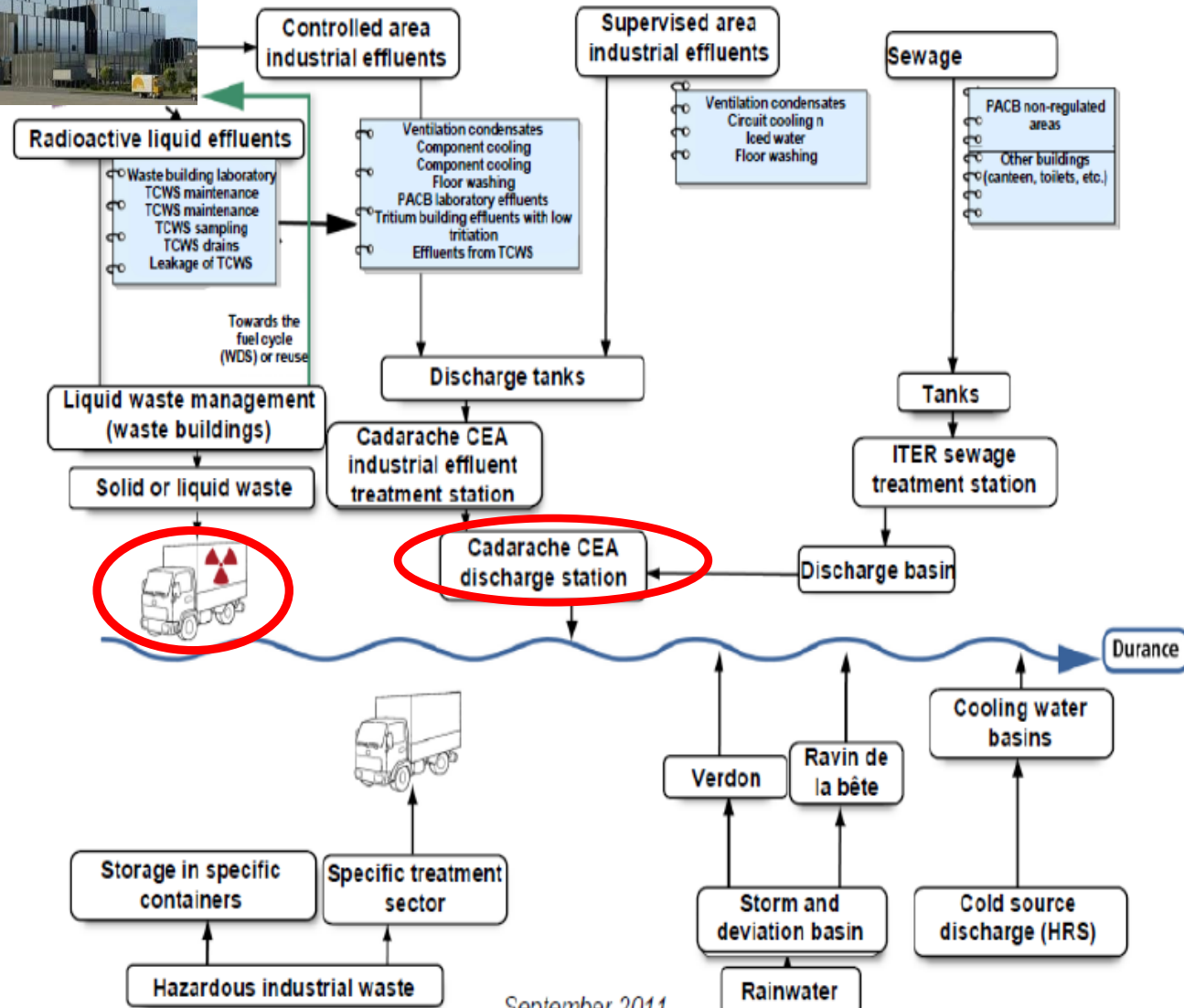
Centerline velocity: **8 m/sec**.



Release monitoring TAP building

Release Monitoring Sub-system (RMS):liquid

Liquid release:
Sampling + analysis
in laboratories

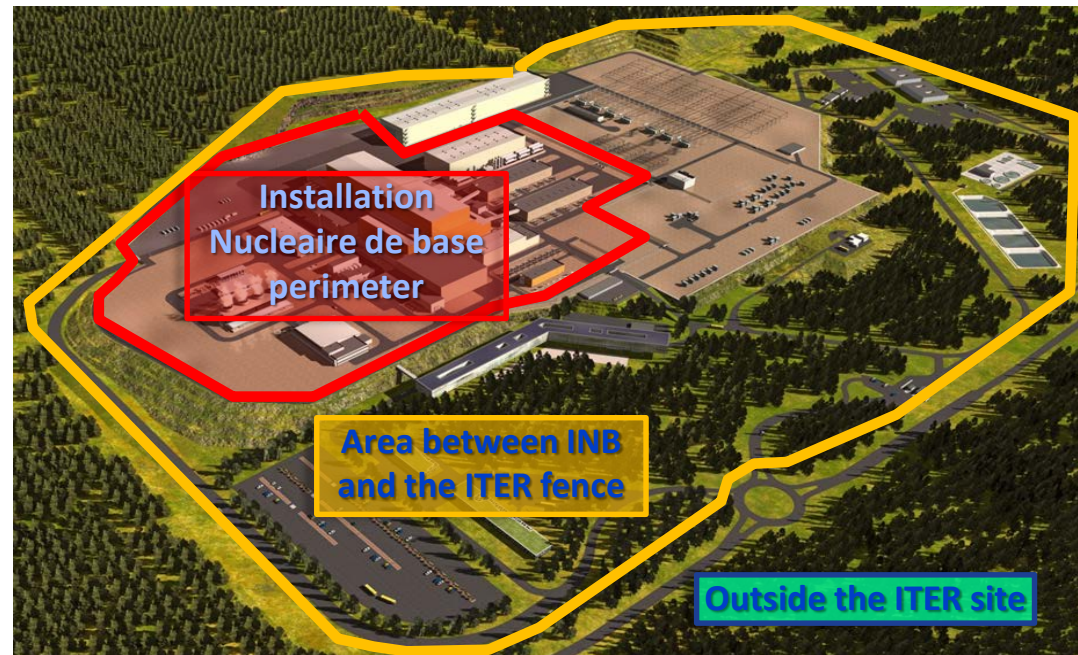


Check toxicity of water from
basins before discharge into
environment : **fish test**



Inside the INB perimeter and between INB perimeter and ITER fence;

- a) γ background
- b) Neutrons
- c) Tritium (HT, HTO)
- d) Radioactive particulate
- e) Beryllium
- f) Groundwater and Rainwater
 - ^{14}C , HT/HTO,
 - β , γ emitting particulate
 - Chemicals, Toxic



Outside the ITER site.

1. γ background
2. α , β , γ emitting particulate, Be
3. ^{14}C gas, HT/HTO
4. Rainwater
5. Meteorology (wind speed/direction, temperature, humidity and pressure).

The sampling portable devices :

- Air samplers Be particulates,
- Air samplers radioactive aerosols



- Tritium in air sampling,
- Carbon 14 in air sampling,



1) Personnel dosimetry:

- a) **Internal**: to monitor and record internal contamination (inhaled, ingested and absorbed radiological isotopes (i.e. dust of ACP, Tritium and beryllium):
 - a) In-vivo measurements (whole body counting based on x-ray and γ , emission);
 - b) Radiotoxicological analysis (excreta monitoring)

- a) **external** to monitor and record x, γ, β and n radiation exposure:
 - a) passive such as:
 - Optical Stimulated Luminescence (OSL),
 - Thermo-Luminescence Dosimetry (TLD),
 - Radio Photo Luminescence (RPL)
 - b) active such as Electronic Personal Dosimeters.

Dosimetry



Passive dosimeter



Electronic dosimeter with dosimeter reader

Contamination checking



2) Contamination checking:

- a) **Personnel and small items**: to avoid spreading of contamination inside the controlled areas, contamination checking is installed at interface of potentially contaminated areas;
- b) **Floors**: routine inspection programme for floor contamination inside and outside controlled areas;
- c) **Movement of other materials** inside controlled areas: contamination will be checked by portable devices and smear tests will be performed;
- d) **Movements of radioactive material outside ITER site**: check of all packages containing nuclear material. Contamination will be checked by portable devices and smear tests will be performed. Fixed monitors located at the INB fence entrance and exit will monitor workers and vehicles.

Portables

- X, beta gamma dose and dose rate,
- Neutron dose and dose rate,
- Alpha, beta gamma surface contamination,
- Tritium in air concentration,

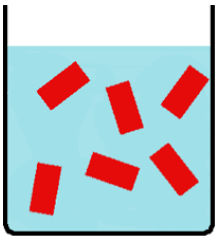


Support to the HP operations

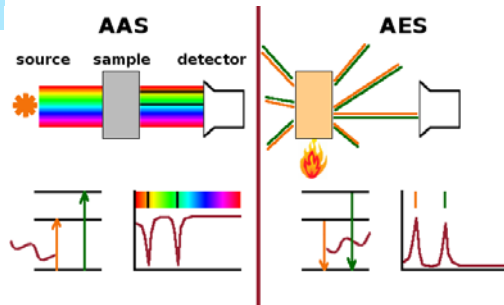
Beryllium laboratory

(40,000-60,000 samples/y)

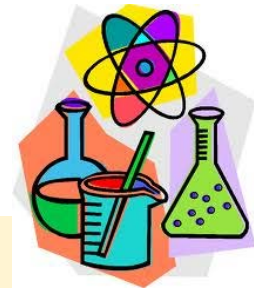
Be sample preparation



Be analysis



HP laboratory



Capability:

Gaseous/liquid/particulate releases;

Airborne/surface contamination;

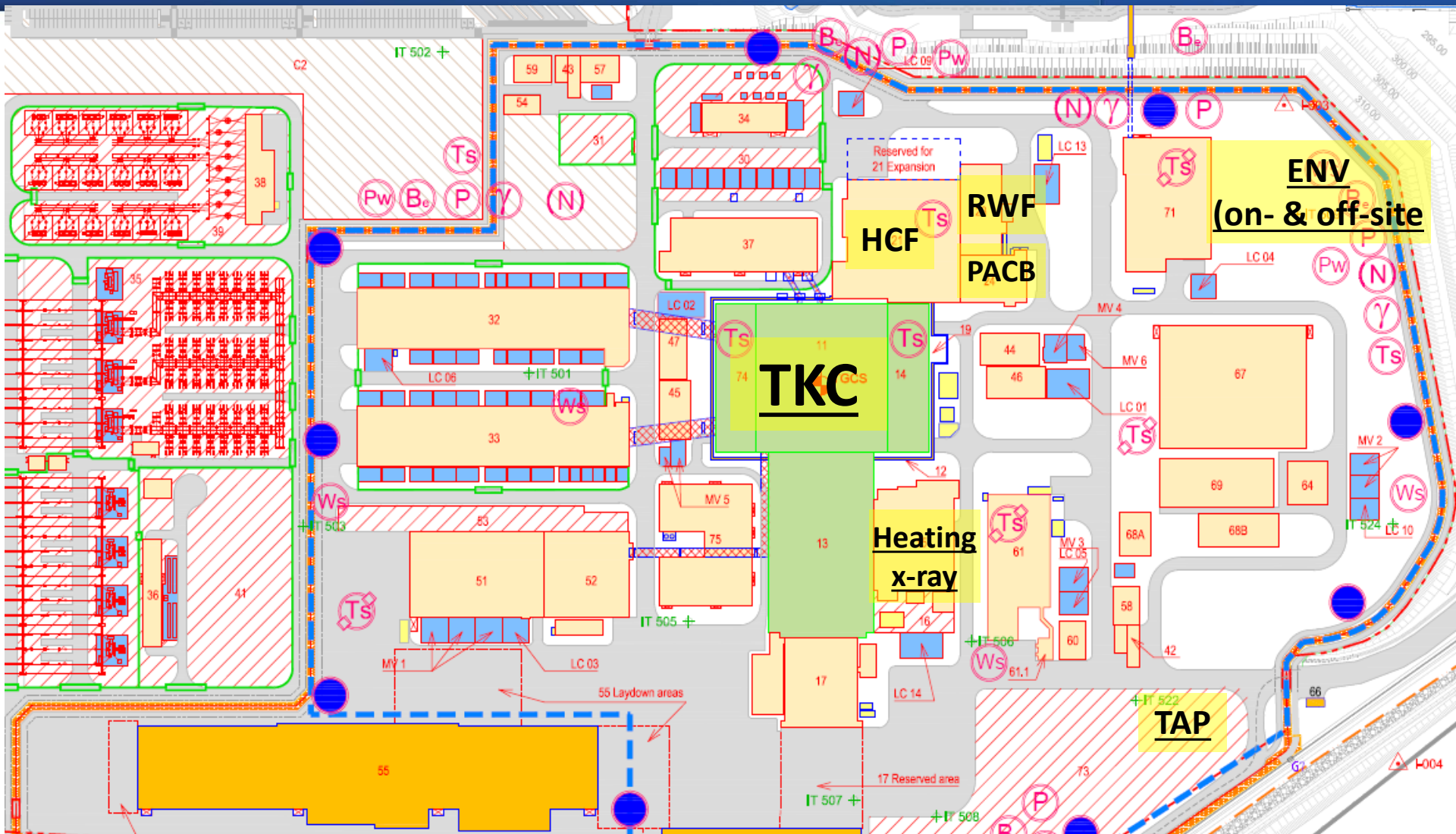
Background radiation

Radioactive sample preparation

β , γ counting laboratory

Tritium analysis laboratory

REMS Interfaces



REMS scope is broad, impacted by safety requirements and interfaces, e.g. :

- Due to the unknowns on the actual final scope (Building design not available), it was decided to split the REMS Procurement scope in parts to be implemented depending on the available information on interfaces.

PART 1: DESIGN (started in 2013)

- REMS Design:
 - Preliminary and Final Design of TKC, HCC, TAPB
 - ✓ PD for TKC completed (06/2017) : ARMS, ABMS (no TAPB), RMS, IMS, EMS, PC
 - ✓ PD TAPB ABMS completed (12/2018).
 - ✓ PD for Hot Cell Complex (HCC) not performed yet.
 - ✓ Final Designs not performed yet.

PART 2, 3 & 4: REMS PROCUREMENT/ASSEMBLY/INSTALLATION/SAT/COMMISSIONING

- “First Plasma” REMS: on going.
- Tokamak Complex REMS: see attached MS Word document.
- Hot Cell Complex REMS: planned early 2024 Call for Tender.

Stationary radiation
monitoring inside the rooms of
ITER facility

ARMS

- **88** γ -dose rate monitors
- **14** n-dose rate monitors
- **69** T in air monitors
- **33** T in air samplers
- **3** C-14 air samplers
- **9** Part. air monitors
- **14** Part. Air samplers
- **11** Rad. Gas monitors
- **128** signaling units
- **46** RSU (Siemens S7)
- **130** Conn. Points for mobile equip.
- **34** Electrical Distribution Boxes
- **280** sampling & outlet lines (20 m each)
- **9** Control cubicles
- **1** Plant control system
- **4** Workstation

Stationary Be monitoring
inside the rooms of ITER facility

ABMS

- **19** Be air samplers
- **38** sampling & outlet lines (20 m each)

Process
Control

Stationary monitoring of:

- Tritium HVAC/DS
- Tritium Port Cell Detector

- **124** T monitors
- **46** Logic modules 2/3
- **388** sampling & outlet lines (20 m each)
- **47** Radiological Synthesis unit (SIEMENS S7)
- **16** Electrical Distribution Boxes
- **4** REMS cubicles

RMS

Stationary monitoring of:

- **Gaseous effluents** at releases (radiological and Be)
- **Liquid effluents** prior to discharge (rad. and chem.)

- **6** T monitors
- **4** Rad. particulate monitor and samplers
- **4** Gas monitors
- **2** Gas monitors
- **2** Sampling lines with isolation valves (35 m each)
- **2** Radiological Synthesis unit (HIMA PLANAR R4)
- **2** Electrical sub distribution boxes
- **1** T sampler (bubbler)
- **1** C-14 sampler (bubbler)
- **1** Beryllium sampler
- **2** Radiological Synthesis unit (SIEMENS S7)
- **2** γ -detectors viewing liquid waste transfers to CEA

REMS: Instrumentation Scope

- Personnel dosimetry;
- Bioassay system;
- Contamination checking;
- Portable and mobile monitors

IMS

- **1500 + 50** Worker dosim. integr. ($\beta/\gamma/x$) + (n)
- **750** Worker Electr. dosim. ($\beta/\gamma/x$)
- **2** Electr. dosim. reader
- **1** Plant control system
- **200** Zoning dosim. integr. (γ/n)
- **2** Whole body counter
- **2** T exhalation monitor
- **15** Hand & Foot monitors
- **2** Whole body personnel contamination monitors (β/γ)
- **2** γ -portal monitors (personnel control)
- **2** Tool contamination monitors
- **1** Vehicle monit. INB entrance/exit (β/γ)
- **30** Mobile γ -dose rate monitors
- **50** Mobile T in air monitors
- **4** Mobile radioactive gas monitors
- **25** Mobile β/γ - particulate continuous air monitors
- **20** Mobile T in air samplers
- **5** Mobile C-14 air samplers (bubbler type)
- **25** Mobile Rad. particulate
- **25** Portable T in air monitors
- **18 + 5** Portable dose rate monitors ($\beta/\gamma/x$) + (n)
- **6** Portable radio-nuclide identification instruments
- **10** Portable contamination survey monitors (β/γ)
- **2** Portable contamination floor monitors (β/γ)

Radiological and chemical monitoring **outside ITER Buildings:**

- INB perimeter;
- INB-fence area
- Outside ITER

EMS

- **22** dosimeter integrators (β/γ)
- **20** dosimeter integrators (n)
- **8** Dose rate monitors (β/γ)
- **8** Dose rate monitors (n)
- **13** T samplers
- **8** Particulate samplers
- **8** Be samplers
- **8** Rainwater-pluviometers
- **10** Groundwater- sample taking equipment
- **10** Industrial water- sample taking equipment
- **2** Offsite monitoring station
 - Gamma dose rate monitor (**1**)
 - Tritium sampler (**1**)
 - C-14 sampler (**1**)
 - Radioactive particulate (**1**)
 - Beryllium particulate (**1**)
 - Pluviometer (**1**)
 - Rainwater droplet size (**1**)
 - Weather station (**1**)
- **5** NOx gas analysis instruments
- **1** EMS cubicles
- **1** EMS Plant Control System
- **1** Working station (PC)
- **2** Laboratory equipped vehicles.

Health physics laboratories and
offices

Laboratories

- **4** Surface wipe (smear) counters for β/γ emitters (automated or manual)
- **4** counters low-level counter (automated sample counting for air samples, dried liquids on planchet etc.) for β/γ emitters
- **4** Liquid scintillation counter (for all the bubbler sampler analyses)
- **2** Liquid scintillation counter (low-level) (for special sample analyses)
- **4** Gamma-ray spectrometer (lab-based) (germanium detectors)
- **2** Portable, electrically-cooled germanium spectrometer
- **10** Portable liquid scintillation counters (for field use to assess contamination)
- **3** Total gamma detector
- **2** Shielded cabinet for storage or radioactive sources
- **3** Liquid sample collection bottles
- **1** Gamma irradiator for onsite instrument calibrations
- **3** ICP-MS
- **11** Fume hood
- **1** Cabinets for chemical products
- **1** Cabinets for samples storage
- **12** Bench/cupboards
- **1** Set of equipment for sample preparation (calcination furnace, drying chamber, centrifuge, cutting mills, oxydizer, sieving machine, balances, freeze drying device, distillation system)
- **1** REMS cubicles
- **2** Electrical sub distribution boxes

- The ITER REMS design is based on industrially available or manufacturable components in order to increase the reliability and reduce the costs;
- A “trade and alternative analysis” was performed to confirm that most of the described monitors are commercially available solutions which match ITER requirements;
- A new Value Engineering study is included in the REMS TKC contract scope to further optimise the design in terms of both system efficiency and cost reduction (both procurement and operational)

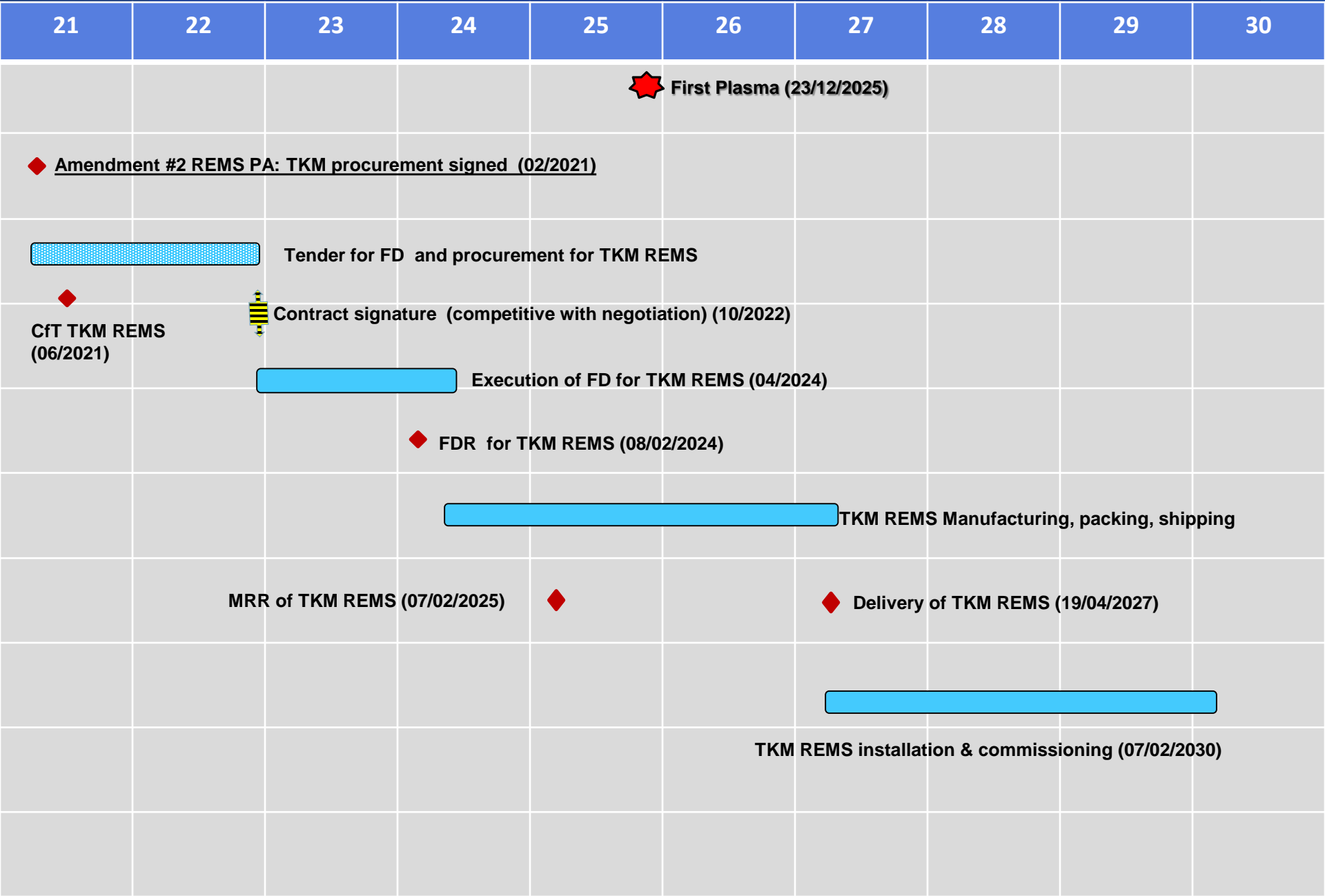
Type of monitor	Qualification available?	Comments
<u>Seismic qualification</u>		
<ul style="list-style-type: none"> • γ monitors, • β/γ particulate monitors, • gas monitoring, • particulate sampling 	Yes	
<ul style="list-style-type: none"> • tritium monitors, • tritium samplers, • neutron monitors 	No	
<p>Although suppliers are experienced with this type of process, such type of qualification may imply modifications of the equipment and a longer qualification time.</p>		

Type of qualification	Qualification available	Comments
<u>Electromagnetic and Radiation field qualification</u>		
Neutron Monitor:	Yes	Good operation under <u>22 mT for the processing unit</u> and <u>300 mT for the detector</u> .
Low range γ monitors	Yes	Good operation under <u>28.5 mT for the processing unit</u> and <u>30 mT for the detector</u> .
High range γ monitors (GIM206):	No	Failed operation under <u>30 mT</u> for the processing unit but good operation under <u>300 mT</u> for the detector. Returns to good operation when magnetic load is removed.
Junction Box	Yes	Good operation with load of <u>28.5 mT</u> .
Noble Gas Monitor (NGM209K)	No	The monitor falls into a degraded mode under a 30 mT magnetic field, however returns operational after the test.
Tritium Monitor (Bionix)	No	Tests did not demonstrate good behaviour and operation of the equipment except at 30 mT. The equipment operational after the test with a manual reset
<ul style="list-style-type: none"> As such, the equipment requires being <u>carefully located</u> within the TKC and with the possibility of adding <u>magnetic shielding</u>. The REMS design is feasible with some location modifications to take into account high magnetic load areas. 		

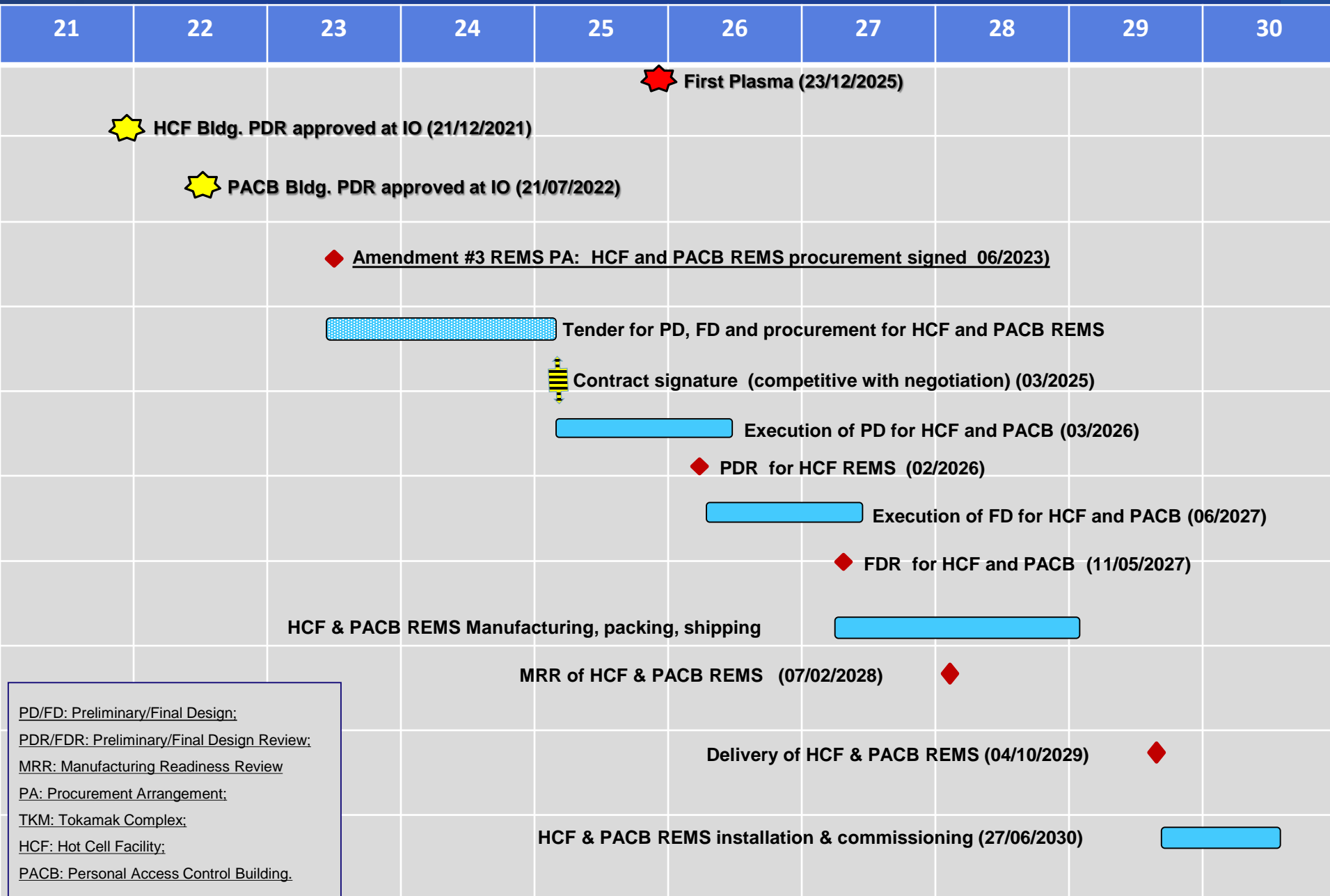
Radiological Environmental Monitoring System (REMS)

19	20	21	22	23	24	25
<div> <div>◆</div> <div>Amendment #1 PA for REMS Design to procure 1st Plasma monitors signed (15/10/2019)</div> </div>						
<div> <div> <div></div> <div>Tender for FD and procurement of “1st Plasma” monitors</div> </div> <div> <div>◆</div> <div>Call for Interest sent (20/01/2020)</div> </div> </div>						
<div> <div> <div> <div></div> <div>Contract signature (26/03/2021)</div> </div> <div> <div></div> <div>Final Design</div> </div> </div> </div>						
<div> <div> <div>◆</div> <div>Final Design Review (30/01/2022)</div> </div> </div>						
<div> <div> <div>Manufacturing, packing, shipping</div> <div></div> </div> </div>						
<div> <div> <div>Manufacturing Readiness Review (15/03/2022)</div> <div>◆</div> <div>Delivery of “1st Plasma” Monitors (05/2023)</div> <div>◆</div> </div> </div>						
<div> <div> <div>Installation & commissioning of 1st Plasma Monitors (10/06/2024)</div> <div></div> </div> </div>						
<div> <div> <div>First Plasma (23/12/2025)</div> <div>★</div> </div> </div>						

Radiological Environmental Monitoring System (REMS)



Radiological Environmental Monitoring System (REMS)



PD/FD: Preliminary/Final Design;
PDR/FDR: Preliminary/Final Design Review;
MRR: Manufacturing Readiness Review
PA: Procurement Arrangement;
TKM: Tokamak Complex;
HCF: Hot Cell Facility;
PACB: Personal Access Control Building.