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STATUS OF THE ASTRID CORE AT THE END OF THE PRE-CONCEPTUAL DESIGN

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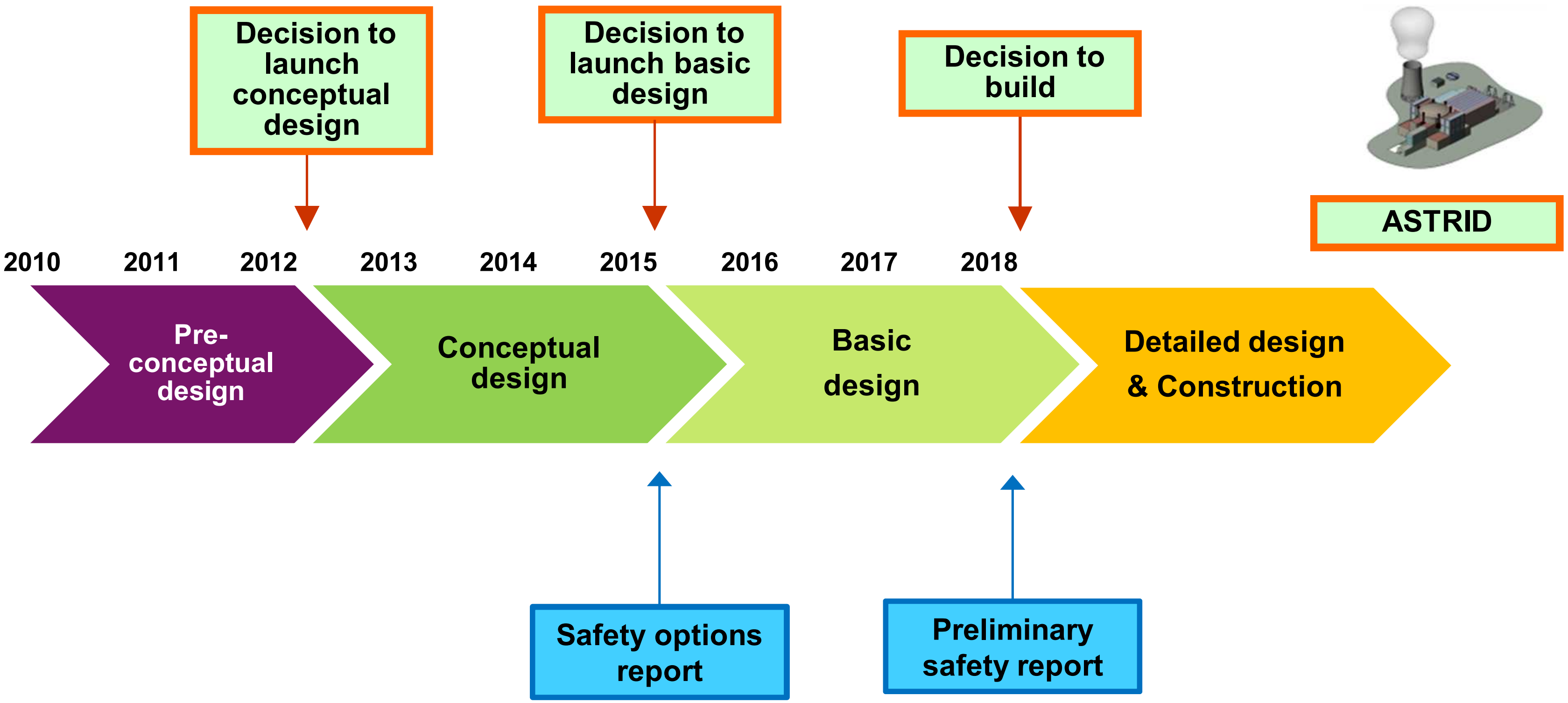
FR 13, Paris, France 4-7 March 2013

CONTENT

ASTRID MASTER SCHEDULE

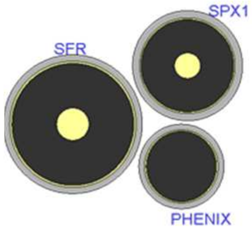


CFV* CORES

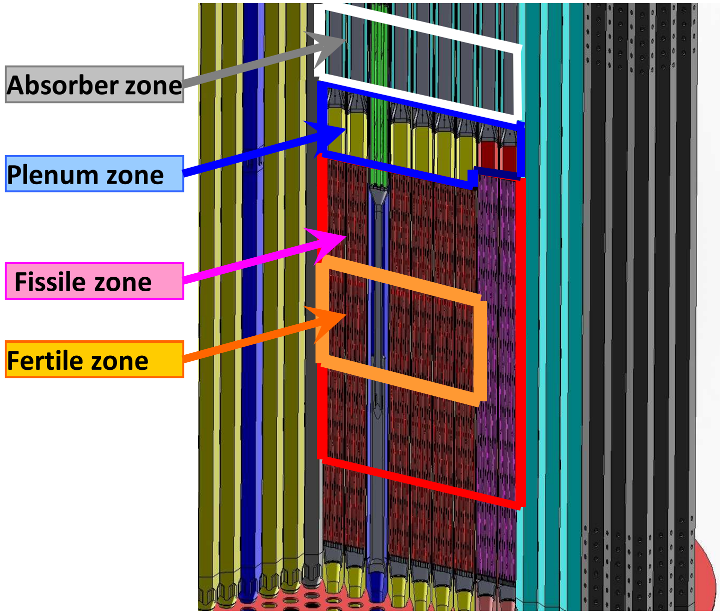
« Low Void Effect Core »

CFV CORE LAYOUT (DESIGN OPTIONS)

Research of :
- small burn-up reactivity excess
- low sodium void effect



2011 : version v1 of the CFV concept - promising safety improvement



2012 : version v2 of the CFV concept with the aim of optimising this concept with respect to the ASTRID safety objectives :
- increase safety margins in the events of unprotected loss of flow or loss of heat sink situations,
- increase safety margins in the event of an accidental control rod withdrawal,

Low Sodium void worth

The option chosen to achieve this goal in version v2 of the CFV core was to decrease the fuel temperature at full rated power

CFV v1 AND CFV v2 CORES DATA

	CFV-1500MW-v1	CFV-1500MW-v2
Number of fuel sub-assemblies (Inner zone / Outer zone)	291 (177 / 114)	355 (241 / 114)
Number of pins / sub-assembly	217	271
CSD/ DSD number	12 / 6	12 / 8
S/A pitch (cm)	17.5	17.17
Inner zone / outer zone fissile height (cm)	60 / 90	60 / 90
Inner fertile zone / lower axial blanket (cm)	20 / 30	20 / 30
Inner zone / outer zone Na plenum (cm)	40 / 30	40 / 30
Average PuO_2 enrichment (vol%)	21.6	22.7
Initial Pu loading (t)	4.9	5.8
Mass of Pu (t) per year	1.15	1.18
Circumscribed diameter of the core (cm)	340	367
Loss of reactivity per day (pcm/EFPD)	4.3	3.6
Core average power density (W/cc)	234	204
Maximum linear power (W/cm)	484	317
Average burn-up (GWd/t)	78	77
Conversion ratio	-0.02	-0.02
Sodium void worth at EOC ($)	-0.5	-0.6
Coolant Pressure drop across pin bundle (bar)	2.6	1.7

Neutronic calculations were performed with CEA's reference code ERANOS

SAFETY ASSESSMENTS

UNPROTECTED TRANSIENTS

To investigate the core capabilities, 5 main unprotected transients were calculated with the CFV cores and a SFRV2 core for comparison :

- ULOF (Unprotected Loss of Flow) sequences :
  - total loss of power without reactor scram,
  - coast down of all the primary pumps without reactor scram while the secondary coolant pumps remain operational,
  - failure of a pump – diagrid connection without reactor scram,

- A sequence of ULOHS (Unprotected Loss Of Heat Sink) where the secondary pumps are tripped and the steam generators dry out without reactor scram,

- Conditions involving CRW (Control Rod Withdrawal) with or without detection.

Hypothesis for comparison : halving time for the primary pumps is 10 s or 24s

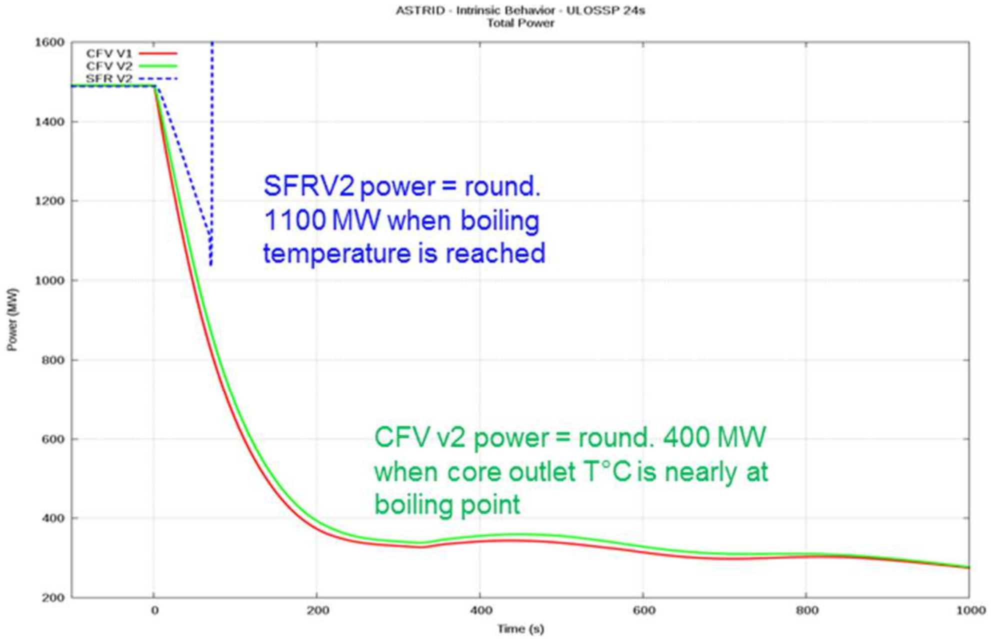
All results presented are given for the hot S/A

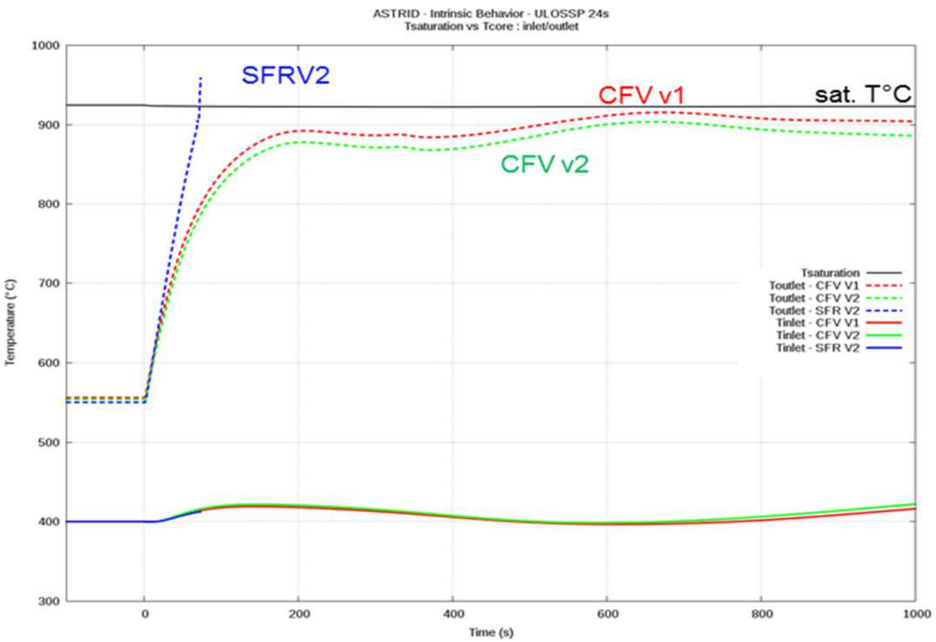
ULOF / TOTAL LOSS OF POWER

These results are given without uncertainties

For this transient, the CFV v2 core does not provide the gain expected with the selected design options.

It is recommended that the linear power is to remain above a certain value.

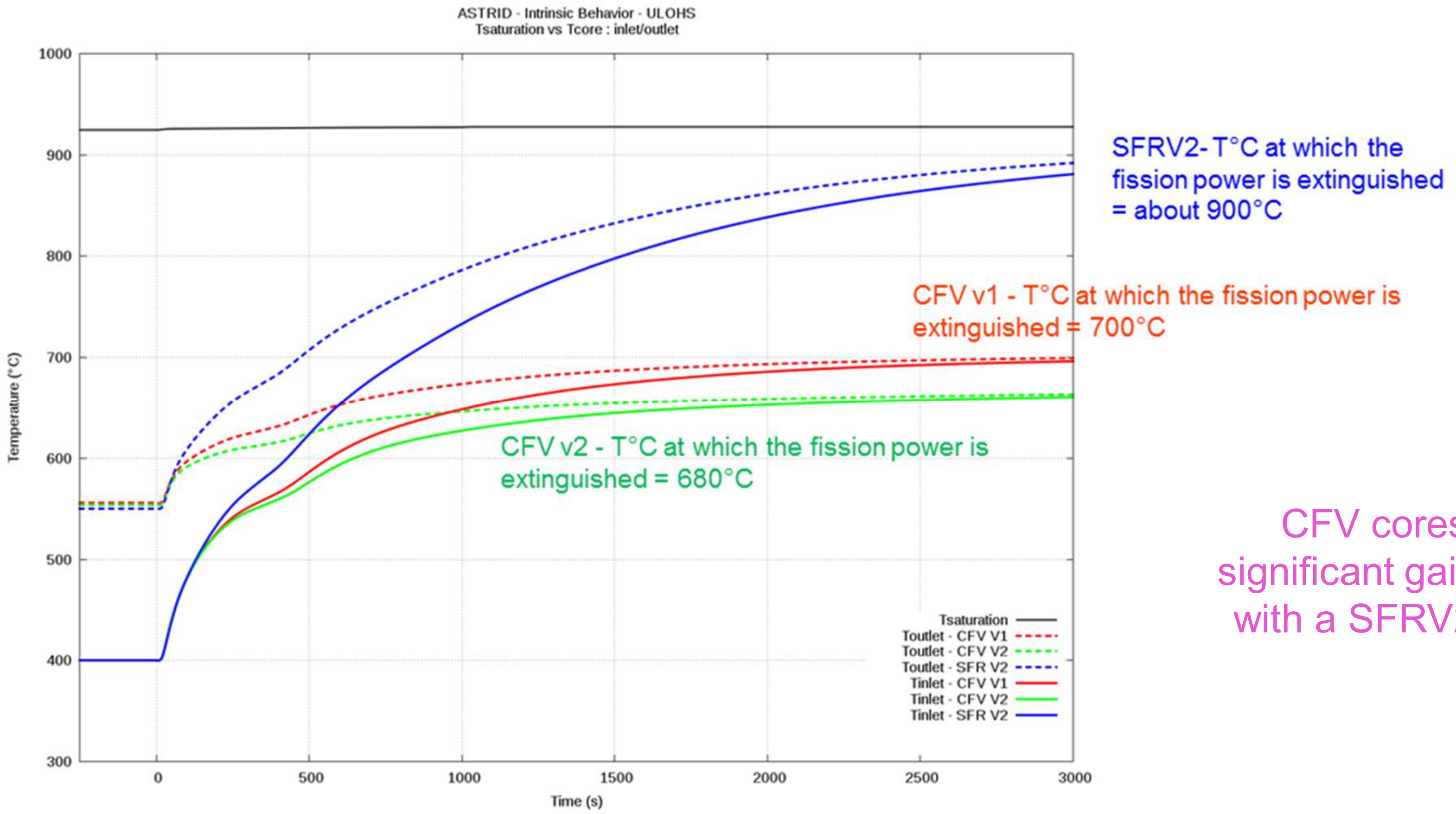




Improved behaviour under degraded conditions

A robust margin will be ensured by an additional safety measure (hydraulic or thermal passive actuation)

ULOHS (Unprotected Loss Of Heat Sink)



CFV cores show a significant gain compared with a SFRV2-type core

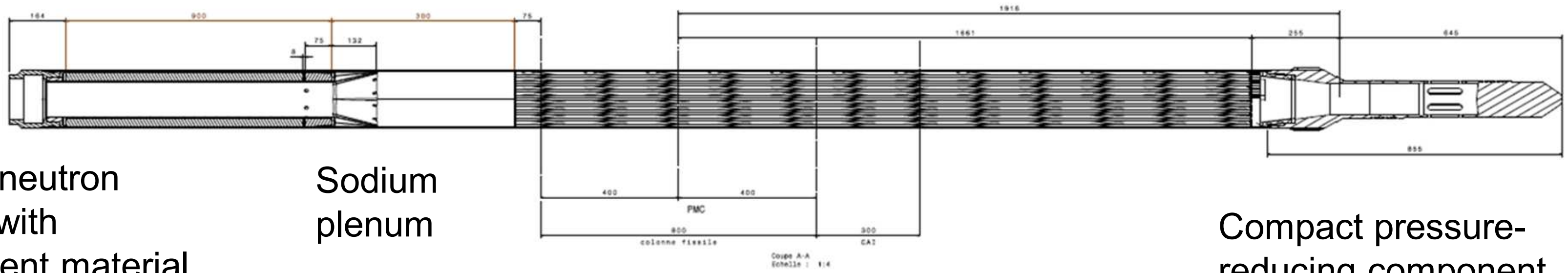
The need for additional safety measure will be investigated according to the maximum temperature compatible with the resistance of the primary circuit structures over several days.

SUB ASSEMBLIES DESIGN

and

CORE MONITORING

FUEL SUB-ASSEMBLIES



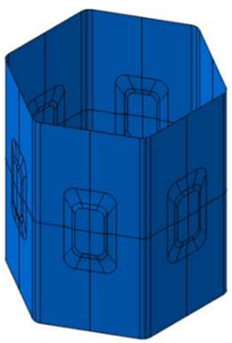
Upper neutron shield with absorbent material (B_4C) - <u>removable design is being studied</u>

Sodium plenum

No upper axial blanket

Compact pressure-reducing component

Total length : 4,5 m

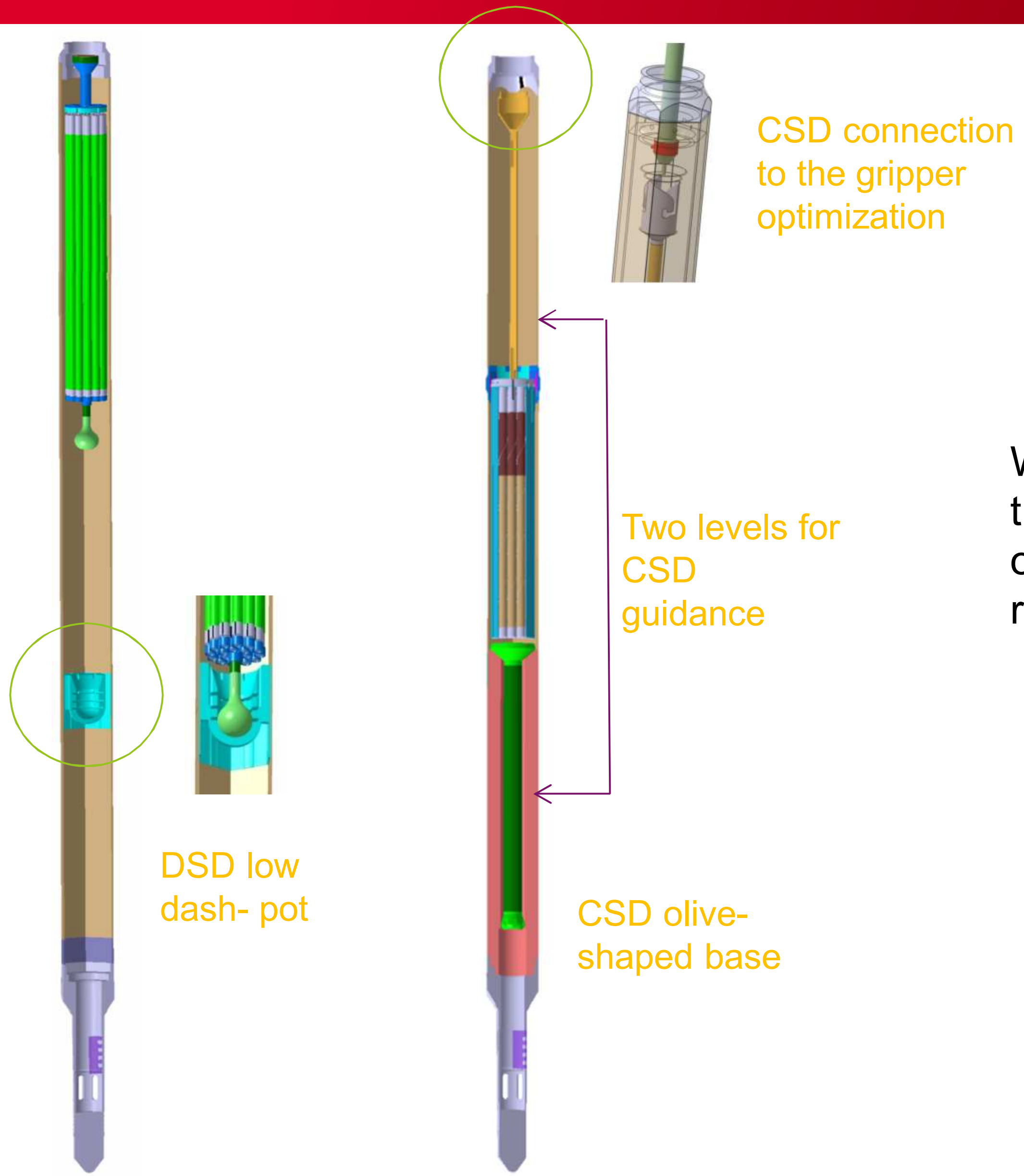


The risk of core compaction related to dynamic stress (earthquakes, pulse loads) was studied.

The stiffness of the plates and the plasticity of the sub-assembly spike will be optimised

~~core restraint~~

ABSORBER SUB-ASSEMBLIES



With the aim of reducing the height of the sub-assemblies, innovative options for the control and shutdown rods are under investigation.

Gain of 0,5 m on sub-assembly above diagrid length

REFLECTOR SUB-ASSEMBLIES AND NEUTRON SHIELDING

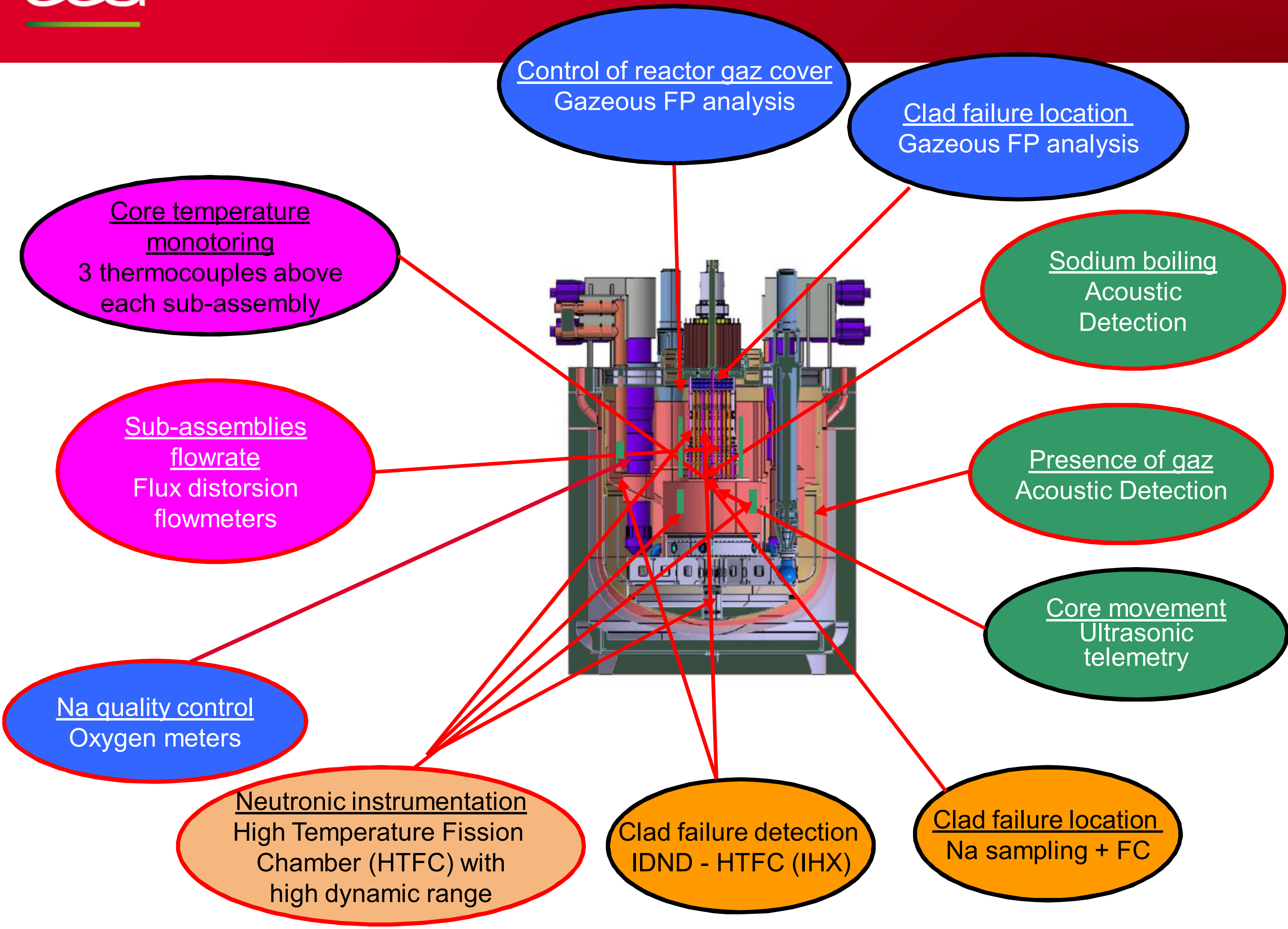
Many combinations of materials for reflectors and neutron shielding are studied :

- for the reflector sub-assemblies: SiC, MgO, $MgAl_2O3$ or $^{11}B_4C$.
- for the lateral neutron shielding: natural B_4C or alternative materials on a hafnium or steel base.

Criteria :

- Limitation of secondary sodium activation,
- Limitation of tritium source term in the reactor
- Protection of primary system structures

CORE MONITORING



temperature of the sub-assembly from the handling arm and ultrasonic identification system

QUALIFICATION REQUIREMENTS

QUALIFICATION REQUIREMENTS

In 2012, the various qualification requirements for the CFV core were analysed in the following fields: neutronics, thermohydraulics and core mechanics, fuel sub-assemblies and absorbers, core materials, core instrumentation, and safety.

This analysis involved:

- evaluating the feedback,
- identifying the lack of information in experimental databases,
- identifying the needs for computer codes validation

On the basis of this information, a preliminary qualification plan was established. The objective was to identify the qualification requirements that make it possible to differentiate between a CFV-type core concept and a homogeneous core concept (SFRV2 type), or potentially located on the critical path of the ASTRID master schedule.

The level of qualification is considered to be similar for both the CFV and SFR V2 core concepts.

CONCLUSION AND FUTURE WORK

CONCLUSION

The pre-conceptual design phase confirmed the safety potential of the CFV cores and the CFV concept is retained for conceptual design phase.

Its potential will have to be consolidated by :

- characterising the core behaviour in all the operating conditions (categories 1 to 4 and severe accident prevention situations).
- selecting and designing the additional safety measures in relation to prevention and mitigation situations.
- reinforcing the studies related to severe accident mitigation situations.

FUTURE WORK : TOWARDS THE ASTRID CFV CORE version 3

During the conceptual design phase, a technical-economic optimization of the CFV core will be pursued, including a goal of reducing the core overall radial dimensions.

Sub assemblies design will continue in order to validate innovative options.

The objective at the end of conceptual design phase is to define an exhaustive list of reference options for the core protection and monitoring system by determining the chosen technologies and by defining the level of diversification, the overall performance expected and its location in the reactor block.

This will give the version 3 of ASTRID CFV core.

The analysis of the needs for qualification will be completed.

THANK YOU FOR YOUR ATTENTION

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