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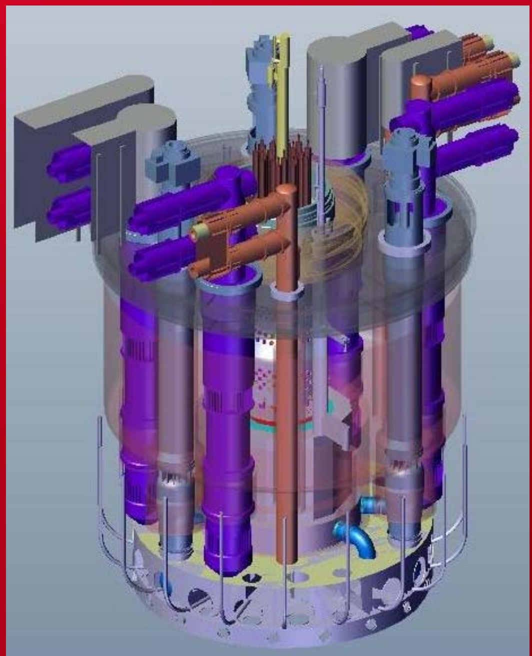

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ADVANCED SODIUM TECHNOLOGICAL

REACTOR FOR INDUSTRIAL DEMONSTRATION

# THE ASTRID PROJECT

## STATUS, COLLABORATIONS, LESSONS FROM FUKUSHIMA ACCIDENT

International Workshop on Prevention and Mitigation of Severe Accidents in Sodium-cooled Fast Reactors

11th-13th June, 2012, Tsuruga, Japan

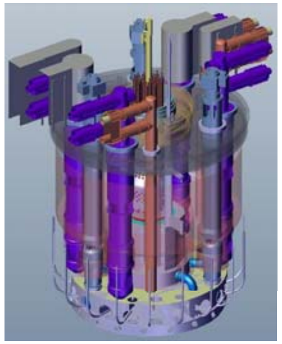
François Gauché

JUNE 12TH, 2012

# GEN IV FAST NEUTRON REACTORS AND CLOSED CYCLE

- Excellent use of uranium resource and ability to recycle plutonium without limitation (multirecycling).
    - Unlike the vast majority of reactors currently in operation or in construction worldwide, using only about 1% of natural uranium, fast neutron reactors are able to use more than 80% of the uranium resource. For instance, the current stockpile of depleted uranium available on French territory could feed the needs for electricity production at current rate for thousands of years.
- Ability to perform transmutation and burning of certain minor actinide
- Safety objectives equivalent to other reactors that are put into service at the same time
    - For ASTRID prototype, this means a safety level at least equivalent to 3rd generation reactors associated with the integration from design on of lessons learnt from Fukushima accident;
- Objective of good economic competitiveness for commercial use
    - Depending on the service that is rendered
- Objective of good guarantees in terms of proliferation resistance

# THE ASTRID PROGRAM

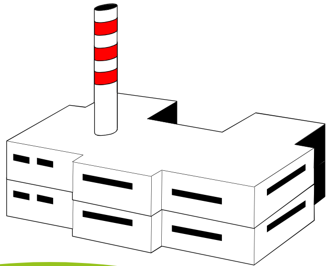


## ASTRID design studies

➔Industrial demo/prototype 600 Mwe
➔$4^{th}$ generation reactor
➔Irradiation tool

## Core fabrication workshop

➔MOX fuel
➔A few tons per year



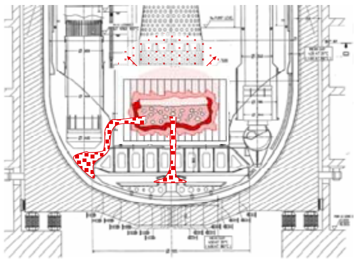
## Full scale component testing

➔ Refurbishment/Realization of large test sodium loops
➔ Refurbishment of zero power reactor MASURCA

**+ R&D**

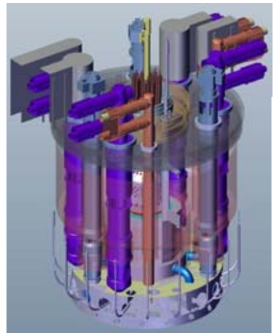
(including fuel cycle)

## Severe accidents experimental program



## Feasibility study for minor actinides bearing experimental fuel fabrication

# SCHEDULE FOR ASTRID AND LICENCING



Preliminary choice of options
Decision to continue
Decision to build
Fuel loading

2009 2010 2011 2012 2013 2014 2015 2016 2017

CONCEPTUAL DESIGN – 1
CONCEPTUAL DESIGN – 2
BASIC DESIGN
DETAILED DESIGN AND CONSTRUCTION

Start of discussions with Nuclear Safety Authority
Safety Orientations File
Safety Options File
Preliminary Safety Report
Public Enquiry

# CURRENT STATUS OF ASTRID

- Conceptual design Phase 1 started in 2010
- 1st important deadline: End of 2012. Studies are on schedule.
- Several partnerships signed: AREVA, EDF, ALSTOM, COMEX Nucléaire, TOSHIBA, BOUYGUES… Other discussions going on.
- More than 500 people working on the project (R&D and design)
- Safety Orientations Document to be submitted to French Nuclear Safety Authority by the end of June 2012.
- Check of Coherence of Safety Orientations with draft GIF Safety Design Criteria to be completed by the end of June 2012.
- Promising design options: core, energy conversion system, confinement, in-service inspection.
- Preparation of launch of Conceptual Design Phase 2 (2013-2014)
- Update of R&D program to meet ASTRID needs. Expression of interest toward international collaborations on specific items.

# ASTRID AND LESSONS FROM FUKUSHIMA ACCIDENT

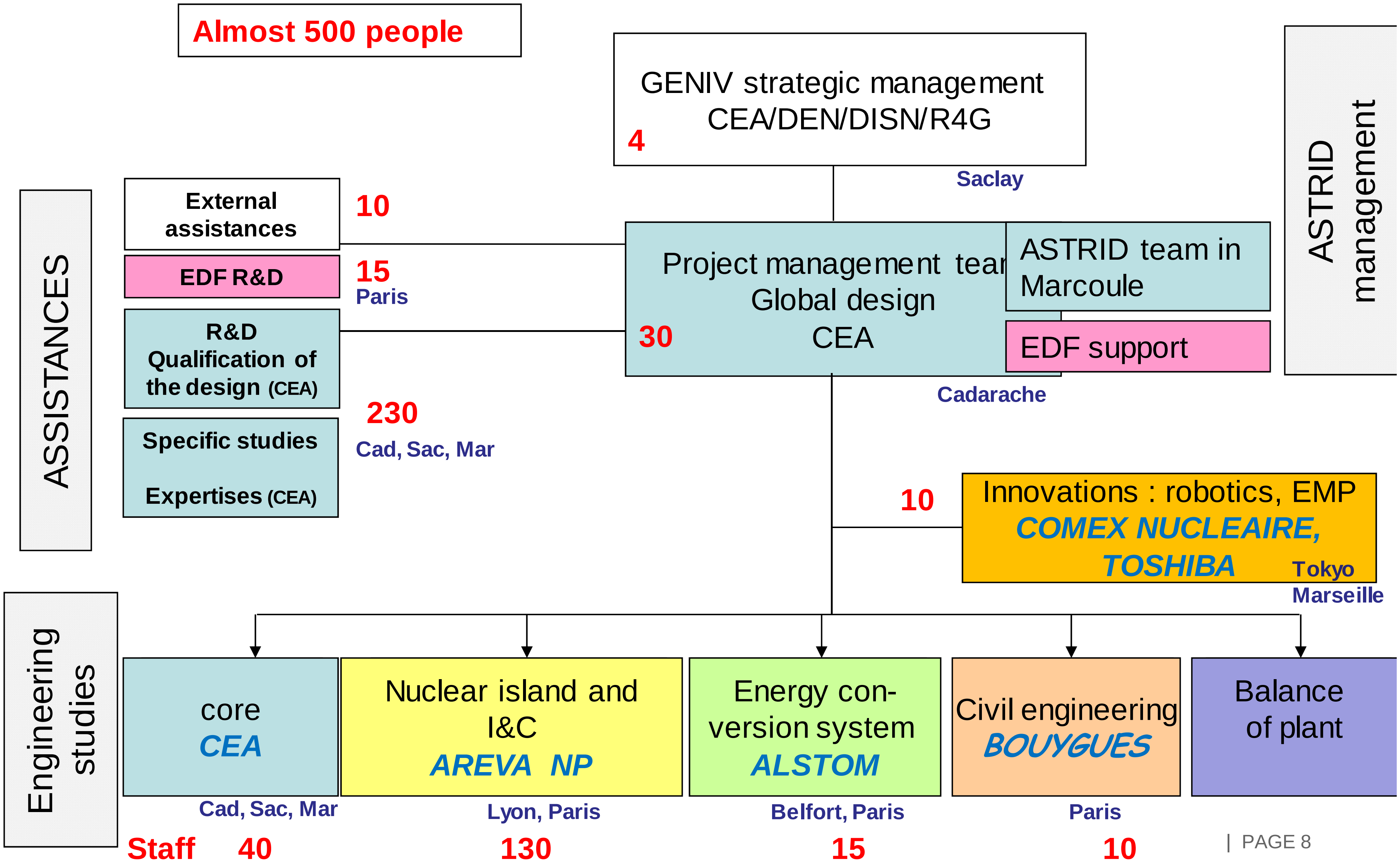
- ASTRID will take into account the lessons learnt from Fukushima accident from the design on.
- The design will build upon the advantages of pool-type, sodium-cooled fast neutron reactors, i.e. favourable intrinsic features to cool the reactor: large thermal inertia, diversified heat sink, natural circulation, ability to guarantee minimum sodium level.
- Safety objectives of ASTRID are derived from WENRA* statement "Safety objectives for new nuclear power plants". This document summarizes the highest standards, even in the case of Fukushima-like initiators. Former BDB or DEC events are to be considered in the design.
- As GENIV reactor, ASTRID will provide for significant improvement with regard to former SFR designs.

*Western European Nuclear Regulator's Association

# REMINDER: FAVOURABLE FEATURES OF SFRS

- The primary system is not pressurized.
- Power control by single rod position, no xenon effect, no need of soluble neutron poison.
- The intermediate (or secondary) system provides for an extra containment between the primary circuit and the environment.
- Large boiling margin of sodium (>300K).
- The large quantity of primary coolant provides for a high thermal inertia in case of loss of main heat sink.
- Good natural convection and circulation features allow to design passive, diversified decay heat removal systems.
- Collective dose on a pool type SFR is very low compared to PWR.

# ASTRID PROJECT INDUSTRIAL ORGANIZATION



# CONTENT OF THE 2012 & 2014 FILES

Government 2012 report

Pre-conceptual design

AREVA exemple

Conceptual design

## Management de Projet : Performances, Coûts, Délais, Risques

**Management de projet**
- Note de synthèse des performances
- Note d'ordre de grandeur des coûts
- Premier planning prévisionnel de réalisation

- Dossier de remontage des performances

**Plan préliminaire de Justification de la Définition**
- Notes de justification des options de conception
- Définition des besoins de R&D et de qualification
- Plan de développements technologiques
- Plan préliminaire de qualification

- Analyse des risques projet

- Notes de synthèse : descriptif, performances
- Note d'évaluation préliminaire des coûts
- Planning prévisionnel de réalisation

**Plan préliminaire de Justification de la Définition**
- Justification des choix de conception
- Justification en regard des performances
- Plan préliminaire de qualification

## Sûreté / Sécurité

**Sûreté**
- Contributions au Dossier d'Orientation de sûreté

**Sûreté**
- Stratégie vis-à-vis des agressions

**Sécurité / Malveillance / Protection physique**
- *Contributions aux dossiers Protection physique*

**Aspects réglementaires**
- Classement des équipements ESPN
- Démarche vis-à-vis des exigences ESPN

**Radioprotection**
- Stratégie de zonage radiologique
- Principes de mise en œuvre démarche ALARA

**Sûreté**
- Contribution AREVA au DOS
- Synthèse des analyses de sûreté
- Plans sectorisation feux

**Aspects réglementaires**
- Bilan fin AVP2 vis-à-vis des exigences ESPN

**Radioprotection**
- Notes de justification du zonage radiologique
- Étude préliminaire ALARA
- Schéma de l'architecture du réseau de surveillance

## Lots Techniques et Maquette 3D

- Supports de communication (Jeu de vues 3D)

- Plans guide de conception
- Maquette 3D (PDMS + CATIA)

**Installation générale**
- Remontage ilot nucléaire, plans CAO avec implantation des sous systèmes
- Plan masse de l'ilot nucléaire
- Plans guide GC

**Codes**
- Codes de référence du projet
- Critères de dimensionnement

**Principaux équipements, composants Circuits principaux et auxiliaires (Na; gaz; ventilation,…) Systèmes électriques, contrôle commande**
- Notes de calcul : dimensionnement neutronique, thermique, thermohydraulique, mécanique, …
- Etudes de faisabilité
- Etudes de transitoires
- Note de pré-design
- STB préliminaires

- Maquette 3D (PDMS + CATIA)

**Installation générale**
- Liste des salles
- Plans circulation matériels et personnels

**Principaux équipements, Circuits auxiliaires (Na; gaz; ventilation,…) Systèmes électriques, contrôle commande**
- Notes de calcul / fonctionnement consolidées
- Plans guides d'installation et d'interfaces
- Etude faisabilité et montage
- Liste capteurs et actionneurs

## Lots Transverses et Architecture d'ensemble

**ISIR**
- Scénarios d'inspection et de réparation

**Opérabilité**
- Stratégie de maintenance

**Environnement**
- Principes de minimisation des déchets et effluents

**Architecture fonctionnelle**
- Note d'architecture d'ensemble
- STB transverses
- Dossier des interfaces techniques et fonctionnelles

**Programme d'industrialisation**
- Etat des lieux du tissu industriel

**Etudes d'ensemble**
- Note de fonctionnement d'ensemble
- Définition des conditions de fonctionnement

**ISIR**
- Note descriptive des matériels d'inspection et de réparation

**Architecture fonctionnelle**
- Note d'architecture d'ensemble consolidée
- Dossier consolidé des interfaces techniques et fonctionnelles

**Opérabilité**
- Données d'interface pour évaluation des coûts d'exploitation/maintenance

**Etudes d'ensemble**
- Note de fonctionnement d'ensemble
- Définition des conditions de fonctionnement

**Environnement**
- Quantification et moyens de minimisation des déchets et effluents
- Plan de zonage déchets/ effluents

**Programme d'industrialisation**
- Schémas industriels de fabrication des composants principaux

**Matériaux**
- Dossiers matériaux et approvisionnement

**Chantier**
- Note de définition préliminaire des principes de montage

# CONCEPTUAL DESIGN PHASE 1: PREDICTIVE NUMBER OF DOCUMENTS

| | management | safety | Technical reports | Interfaces & general layout | Total |
|---|---|---|---|---|---|
| AREVA | 20 | 87 | 627 | 92 | 826 |
| CEA core | 11 | 20 | 102 | 6 | 139 |
| ALSTOM | 5 | 0 | 57 | 8 | 70 |
| COMEX | 5 | | 10 | 1 | 16 |
| Civil works | 7 | 0 | 53 | 10 | 70 |
| | | | | | |
| Total | 48 | 107 | 849 | 117 | **1121** |

More than 1,000 technical documents up to 2012

About 50,000 pages…

# STRONG IMPROVEMENTS IN SFR DESIGN FOR ASTRID 1/2

| Feedback of previous SFR | R&D directions | ASTRID Orientations |
| --- | --- | --- |
| **Core reactivity**<br>**Issue of sodium void coefficient**<br>**→ Safety** | Optimization of core design to improve natural behavior in case of abnormal transients.<br><br>Exploration of heterogeneous cores | CFV core (patented in 2010): innovative approach, negative overall sodium void coefficient.<br><br>Better natural behavior of the core, for instance in case of loss of cooling (e.g. due to loss of supply power) |
| **Sodium-Water reaction**<br>**→ Safety - Availibility** | - modular Steam Generators<br><br>- Reverse Steam Generators (sodium in tubes)<br><br>- Gas Energy Conversion System (nitroen in place of steam/water) | - Limitation of total released energy in case of sodium-water reaction<br><br>- Limitation of wastage propagation<br><br>- Design studies conducted by ALSTOM. No show stopper. |
| | | |

# STRONG IMPROVEMENTS IN SFR DESIGN FOR ASTRID 2/2

| Feedback of previous SFR | R&D directions | ASTRID Orientations |
| --- | --- | --- |
| Sodium fire<br>→ Safety | Innovation on sodium leak detection systems<br>R&D on sodium aerosols | Improvement of detection (patent of detection system integrated of heat insulation)<br>Close containement (limitation of available oxygen, inert gas) |
| Severe accidents<br>→ Safety | -Core catcher<br>-R&D on corium and sodium-corium interaction | Core catcher. Several locations are under study (in vessel, ex-vessel or between the two vessels). |
| Decay heat removal<br>→ Safety | -Reactor vessel auxiliary cooling system (extrapolability) | Combination of proofed DHR systems, RVACS |
| In-Service Inspection and Repair<br>→ Safety – Availibility | -Simplification of primary system design<br>-ISI&R is taken into account from design on<br>-New techniques : acousitc detection, LIBS, CRDS<br>-Signal processing<br>-TUSHT (ultrasound, high temperature), High temperature fission chambers, Optical Fibers, Flow meters for subassemblies<br>-Remote handling for inspection or repair<br>-Under sodium-viewing | |

# INTERNATIONAL COLLABORATIONS

- Russia
  - Material irradiations in BOR-60, Neutronics in BFS
  - Possibility of fuel irradiations in BN-600 ?
- India
  - Strong collaboration, several Implementing Agreement on going on safety, including severe accidents
- USA
  - Several STCs
  - Safety benchmark on CFV core
- Japan
  - Several STCs
  - EAGLE collaboration
- Europe
  - CP-ESFR project, SOFIA proposal
  - Next Framework program in preparation (2014-2020)
- Korea, China

# CONCLUSION

- The 1st phase of ASTRID conceptual design is almost complete. Important results have been achieved, so that ASTRID shows major improvements with regard to past SFR.
- The industrial collaboration around ASTRID is of outmost importance, provides innovation, and ensure industrial stakes are taken into account.
- Design studies are on schedule.
- It is essential to launch 2nd phase of conceptual design, to keep the momentum that has been gathered on R&D and design activities inside CEA and among its industrial partners.
- On the side of technical developments and experimental facilities, CEA is willing to develop international partnerships