# ASTRID - An original and efficient project organization

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**Abstract**.

CEA is the contracting authority and industrial architect of ASTRID Project, an industrial prototype of 4th generation Sodium Fast Reactor. This reactor of 600 eMW is integrating French and international SFRs feedback, especially in domains of safety, operability and ultimate wastes transmutation. The project is funded for basic design phase (2016-2019) through an agreement between the French Government and CEA within the scope of the "investments for the future" program. The industrial network is made of bilateral agreements between CEA and fourteen industrial partners. The main keys of success are the followings:

- Industrial companies chosen in their core area of excellence,
- Partnerships with co-funding and involvement in strategic decisions rather than commercial contracts,
- Strong, flexible and efficient R&D program in support of ASTRID design international agreements with Europe, Japan, Russia, India, USA, China,
- Early discussions with regulatory authorities,
- Strategic and Operational managements, Technical control with Engineering System tools and 3D mock-up consolidation.
- CEA has created a specific entity: Astrid Project Unit (CPA for Cellule Projet ASTRID in French): in charge of creating and ruling an efficient project management. It acts as the industrial architect of the project.

**Key Words**: ASTRID - Engineering System – Project management – Generation IV

## 1. Introduction

Sodium-cooled Fast Reactors (SFR) is one of the Generation IV reactor concepts selected to secure the nuclear fuel resources and to manage radioactive waste. In the frame of the French Act of 28 June 2006 on sustainable management of radioactive materials and wastes, French Government entrusted CEA (French Commission for Atomic Energy and Alternative Energy) to conduct design studies of ASTRID (Advanced Sodium Technological Reactor for Industrial Demonstration) prototype [1] [2]. After a first period of studies and R&D jointly performed by the CEA, EDF and AREVA to investigate a range of innovative solutions, the project itself was launched in late 2009 and a project team (ASTRID Project Unit: CPA) was set up in the first half of 2010. Funding was granted through an agreement between the French Government and CEA within the scope of the "investments for the future" program published in the Official Journal on 11 September 2010 [3].

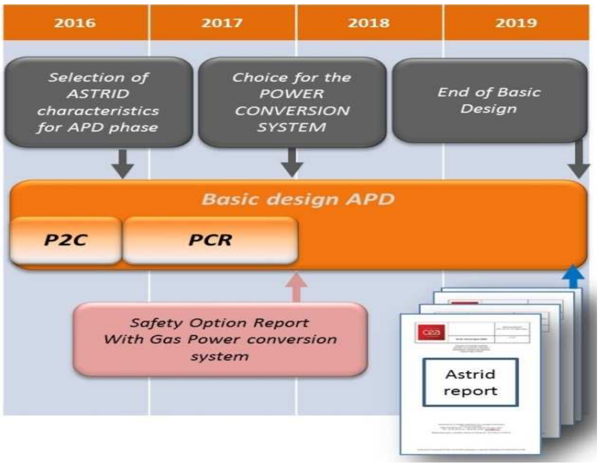
After 6 years of Pre-Conceptual Design and Conceptual Design phases (AVP), the Project is involved since January 2016 in Basic Design. It is a four years duration phase with different milestones at the project level and also with the relevant ministry. Conceptual Design phase was closed by obtaining the main award of the French Society of Nuclear Energy (SFEN) rewarding the great scientific contribution for the AVP of ASTRID. It also highlights the quality of the organization in partnership which was naturally extended for the Basic Design.

At the end of the Conceptual Design phase, it was decided to consider as reference the power conversion systems (PCS) in Brayton gas cycle in order to benefit from the use of a gas (pure nitrogen) non-reactive with sodium. The first two years of the Basic Design phase are dedicated to design and integrate this power conversion system in the ASTRID layout.

Until October of 2016, the Project activity was mainly dedicated to a Confirmation of Configuration Phase (P2C) whose objectives were to revisit and optimize the different technical options considered as the reference configuration during the Conceptual Design phase. The P2C phase was achieved in October 2016 by a review which defined the new reference configuration for the Basic Design studies.

From November 2016 to the end of 2017, the objective of the Consolidation Phase (PCR) is to raise gas PCS integration studies at the same level that was achieved for Water/steam PCS at the end of 2015. A go/no go decision for Gas PCS integration will be organized at the end of 2017. The choice will include technical and cost considerations but also public acceptance requirements.

ASTRID Project current driver schedule for the Basic Design phase is shown in *FIG. 1*, considering a 4 years period which could be extended after 2020.




## 2. Project organization

### 2.1. General organization with the engineering companies

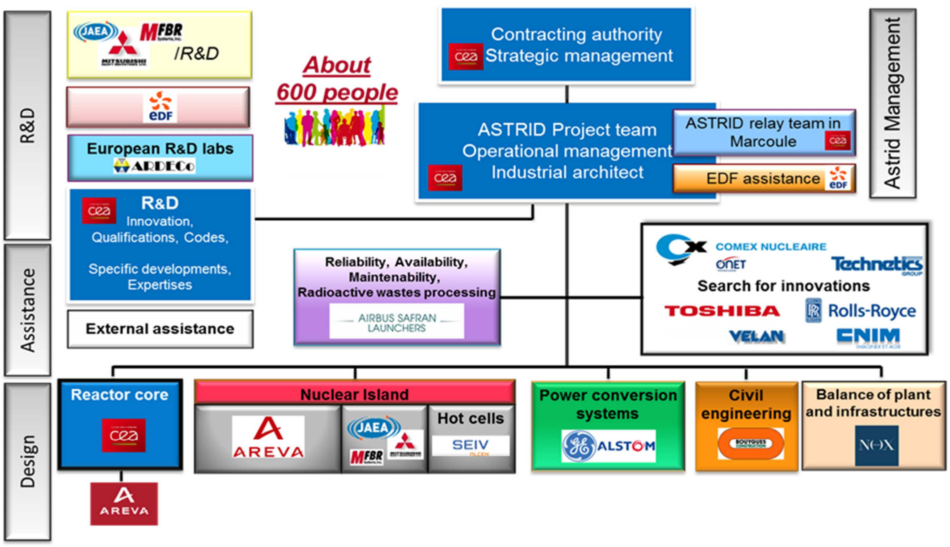
The project is organized according to the following principles:

- The CEA is the project owner: This role is confirmed by the CEA's funding via the above-mentioned agreement to launch the Basic Design.
- As project owner, the CEA is responsible for drafting the safety reports and maintains dialogue with the French nuclear safety authority (ASN).
- The CEA set up partnerships with industrial companies to carry out the Basic Design.

- The CEA chose to assume the role of architect engineer itself instead of using a prime contractor. For this reason, the CEA defined the different project engineering packages and then distributed them among the engineering partners.
- The CEA also decided to ensure the engineering studies of the reactor core during the pre-conceptual design phase until the basic design phase.

The project is divided into different engineering packages which are entrusted to its industrial partners within the scope of bilateral collaboration agreements for this Basic Design phase. The relationships with the different partners in charge of the engineering packages are detailed in the management specifications (with each partner providing their own management plan in response) according to the RG aero 0040 standard.

In 2017, the ASTRID project employs about 600 people and is including 13 confirmed partners plus one still under discussion. The multi-partnership organization and management has not been modified for the Basic Design phase (see *FIG. 2.*)

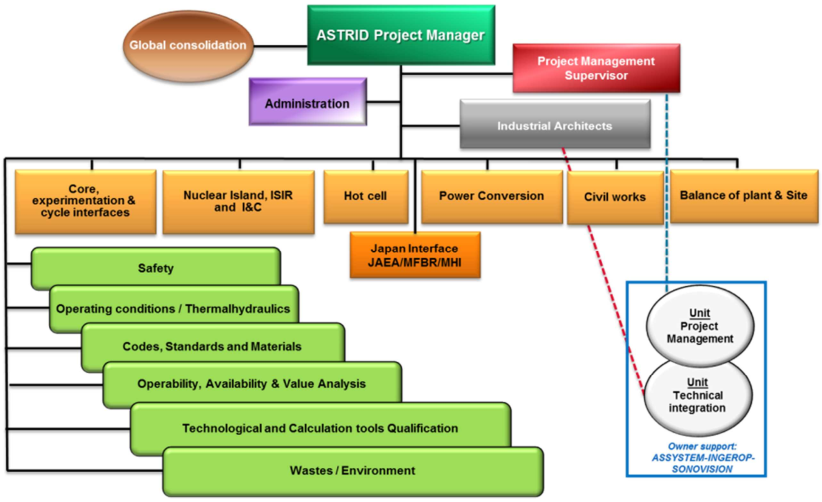



As project owner, the CEA ensures the strategic and operational management of the project. It is also responsible for drafting the safety reports and maintaining dialogue with the French Nuclear Safety Authority (ASN). In order to integrate the safety and availability objectives as best as possible while retaining as much flexibility to take into account innovative solutions during the design phase, the CEA has chosen a concurrent engineering design approach. This approach covers the product definition, the manufacturing processes and all other processes required during the reactor life cycle such as operation and in-service inspection. With this type of management system, cross-disciplinary units (R&D, modelling, operation, maintenance, etc.) can work towards the same objective in parallel right from the start.

## 2.2. Organization within the project team

The operational management of the project is ensured by the ASTRID Project Unit (CPA) working within the Reactor Studies Department (DER) at the CEA/Cadarache Centre. This unit is leaded by a Project Manager who relies on a support team which includes (*see FIG.3.*):

- A deputy-manager,
- Industrial architects, in charge of the technical integration and engineering coordination. They rely on an external support for integration and configuration management tasks,
- A project management supervisor responsible for organization, risk control, schedule and cost tracking; he relies on a responsible of quality management and an external support,
- Cross-disciplinary package leaders responsible for the major issues of ASTRID,
- Product package leaders responsible for managing the different engineering packages,
- A JAEA liaison officer, to ensure the interfaces between CEA and JAEA/MFBR/MHI,
- A secretary.




In collaboration with its industrial partners, the ASTRID Project Unit also set up three groups of experts to cover the following themes throughout the design phase:

- Safety, with the ASTRID safety group (GSA) which is responsible for elaborating the project's safety approach and communicating the safety requirements to the designers,
- Operation, with the ASTRID operators group (GEA) which is responsible for analyzing the design options in relation to the future operation of the plant,
- Malevolent acts, with the ASTRID technical protection group (GTPA) which is responsible for analyzing the constraints associated with this issue and integrating them into the design.

The ASTRID Project Unit also signed a number of commercial contracts for technical support in various fields: project management and technical integration, training, value analysis, cost assessment.

## 2.3. Partnerships

In compliance with the above act and the “investments for the future” program, the CEA set up partnerships with French and foreign companies which are also investing in the project on both a technical and financial level. These partnerships are bilateral contracts between the CEA and the relevant industrialist. All of the partnerships around ASTRID, established during the Conceptual Design phase, were renewed (except for the one with Rolls Royce, which is still under discussion), with some changes or modification of the scope. To date, about 600 people are working on the ASTRID project and half from our industrial partners. The project remains open to other partnerships, whether French or foreign.

#### *2.3.1. Industrial partnerships:*

The main scopes for the Basic Design are recalled below for each industrial partner:

- AREVA: the only European manufacturer with know-how in the design of sodium-cooled fast reactors is in charge of the engineering aspects of the nuclear island, I&C, industrialization of the sodium-gas compact exchanger.
- EDF: Operation and project management drawback, R&D activities and technical assessments to support the ASTRID project. EDF provides the CEA Project Owner Team with support through its direct involvement in its team, as well as providing a team based in Lyon to deal with safety and technology matters. It contributes its skills and its expertise as an operator of Pressurized Water Reactors (PWRs) and Sodium Fast Reactors (SFRs).
- SEIV: Hot cell design.
- CNIM: Industrialization and fabricability of large components, gas cycle heat exchangers, seismic pads.
- BOUYGUES: Civil engineering, seismic pads.
- NOX (ex JACOBS France): General layout and site infrastructure.
- GENERAL ELECTRIC (ex ALSTOM): Tertiary energy conversion system.
- VELAN: Sodium isolation valve for secondary circuits.
- TOSHIBA: Secondary circuit electromagnetic pump.
- AIRBUS SAFRAN LAUNCHERS: Operability, waste management processes.
- JAEA / MHI / MFBR: *see §2.3.2 The partnership with Japan.*
- ONET TECHNOLOGIES: Inspection carrier system, concept of innovative rod mechanism.
- TECHNETICS: Insulation seals for rotating plugs.

It should be noted that the responsibility for the engineering of the core and associated subassemblies is carried over to the CEA through the core design engineering and is not formalized through a specific endorsement.

#### *2.3.2. The partnership with Japan [6]:*

In the framework of the Implementing Arrangement of August 7$^{th}$, 2014 signed between Japan Atomic Energy Agency (JAEA), Mitsubishi Heavy Industry (MHI) Mitsubishi Fast Breeder Reactor System (MFBR), AREVA and CEA, contribution, of ASTRID Design activities increased sharply during the year 2016 from three Task Sheets “Design” to nine. In particular, the evaluation activities by the Japanese party of the technological solutions selected by the project could lead, in a second time, to proposals for improvement. The current list is as follows:

- Task Sheet D1: Active Decay Heat Removal System (DHRS),
- Task sheet D2: Curie Point Electro Magnet (CPEM) for diversified control rods,
- Task Sheet D3: Seismic Isolation System (SIS),

- Task Sheet D4: Fabricability and thermomechanical calculations of the Above Core Structure (ACS),
- Task sheet D5: Fabricability of the Polar Table,
- Task Sheet D6: Contribution to design the Core Catcher,
- Task Sheet D7: Transient evaluation of Astrid plant,
- Task sheet D8: Thermomechanical analyses of main and inner vessel,
- Task Sheet D12: General discussions on the Astrid reactor system, in the scope of the Joint Team, to have discussions for preparation of future Design Task Sheet or Joint Evaluation.

Furthermore, twenty six “R&D” Task Sheets are also carried out in the same framework.

The practical organization is the following: The executive committee is responsible for proposing the creation of new implementing arrangements, follow their progress and solve the related difficulties. The joint team is in charge of the day to day control of design and R&D work and of the definition and the follow-up of “joint evaluation” on important subjects for GEN IV SFR. This organization is fully imbedded and coherent with the organization set-up with the other partners of the ASTRID project.

Japan contribution to ASTRID program is significant and important. Except CEA (which acts as the industrial architect of the project), JAEA-MHI-MFBR became in 2015 the 2$^{nd}$ largest contributor to ASTRID program - behind AREVA NP - in terms of involved staff and financial contribution. It means that ASTRID project has to adapt its project management to cope with this important partnership.

Some regular video conferences are carried out to follow the work in progress and punctuated by Face to Face meetings. The Steering Committee is programmed every semester, and it allows an overview of the progress of work and current status of this fruitful collaboration.

## 2.4. R&D activities

The ASTRID project aims at integrating a number of innovative options to meet the objectives of the Generation IV reactors while fulfilling its specifications. It is therefore relying on an important R&D program at the CEA – SFR R&D. This was launched in 2006 as part of the three-party framework agreement with EDF and AREVA, to provide in due time the data required to qualify the ASTRID options. A progress report on all the actions performed is provided on a monthly basis.

Since 2007, the CEA has also been setting up a series of international partnerships to consolidate and develop its R&D efforts. These partnerships make it possible to share the development costs and the use of heavy experimental infrastructures.

The section below briefly describes these partnerships and their objectives.

On a European level, the SFR technology and the ASTRID prototype are covered by 1) the SNE-TP roadmap (Sustainable Nuclear Energy Technology Platform, www.snetp.eu) which aims at building a European research platform in the field of fission, 2) the European Sustainable Nuclear Industrial Initiative (ESNII) which is the industry’s equivalent to SNE-TP, and 3) the European Energy Research Alliance (EERA, http://www.eera-set.eu).

On an international level, the CEA is a key player in the Generation IV International Forum (http://www.gen-4.org/) which federates 13 countries interested in sharing R&D efforts on six different systems including the SFR, as well as on transmutation, safety and technology issues. This International Forum – via its Risk and Safety Working Group – is actively involved in harmonizing standards and safety references.

The CEA is also involved in a number of IAEA activities within the scope of the Technical Working Group on Fast Reactors (TWG-FR), and the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO). These groups provide the opportunity to discuss the safety and technological developments of fast reactor systems, while sharing feedback from the construction, operation and dismantling phases of SFRs.

In parallel to these institutional collaborations, the CEA has signed a series of bilateral partnerships with R&D organizations involved in SFR development, such as Rosatom (Russia), the Indira Gandhi Centre for Atomic Research (IGCAR, India), Bhabha Atomic Research Centre (BARC, India), the Japan Atomic Energy Agency (JAEA), the Department of Energy (DOE, United States) and the Chinese Experimental Fast Reactor (CEFR).

Furthermore, in the framework of the Implementing Arrangement of August 7$^{th}$, 2014 signed between Japan and France, twenty six R&D Task Sheets are ongoing.

### 2.5. Interfaces outside the CEA

Considering the feedback from the other projects run by the CEA Nuclear Energy Division (DEN) and the issues related to ASTRID, the CEA has maintain ed regular contact with the following entities very early in the process since they play an important role in ensuring the smooth progress of the project:

- French National Assessment Committee (CNE). The strategic objectives and preliminary technical orientations of the project were presented to the CNE several times in the pre-conceptual design.
- French Nuclear Safety Authority (ASN). Discussions with the French regulator started as early as 2010 to present the project's safety objectives, the project's positioning in terms of the WENRA directives, the expected reactor performance, and the preliminary design data. A safety orientations document (corresponding to a very preliminary version of the safety options file) was sent to the ASN mid-2012 and the safety evaluation group (“Groupe Permanent”) approved in mid-2013 safety objectives and principles of ASTRID. This approach makes it possible to integrate the safety objectives as early as possible into the design, and to develop the technical solutions required to meet these objectives on the basis of a common vision.
- Senior Defence & Security Official. A similar approach is currently underway to integrate the security issues (theft, physical protection and malevolent acts) as early as possible into the design, and to draft an equivalent security file associated with each safety file.

## 3. Innovative industrial set-up

The innovative nature of this industrial set-up is due to several aspects:

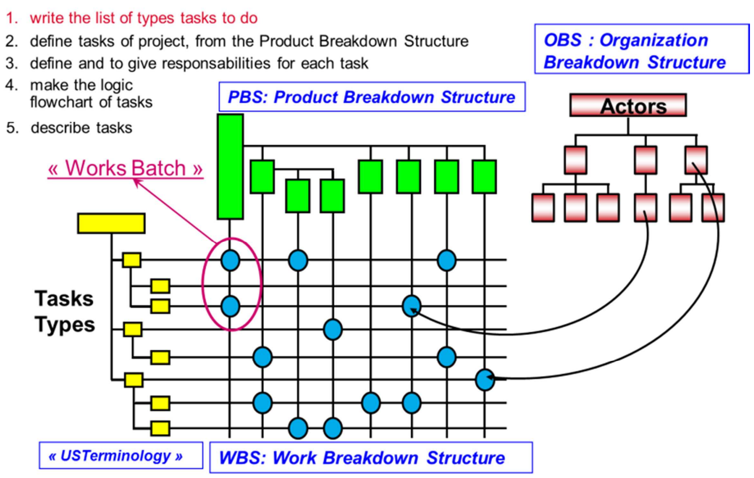
- The design is not ensured by a single engineering company but several different engineering companies at the same time, with each having been chosen to work in its core field of excellence. This requires an industrial architect to ensure the technical coordination and integration of the different parts of the project.

- The signing of collaborative agreements with the different engineering companies rather than standard commercial contracts. This aspect has enabled the co-funding of studies by the industrial parties, which is additional proof of their desire to make this project a success.
- Continuation of R&D activities in parallel to the design studies carried out by the engineering companies. This guarantee of innovation demands highly efficient and flexible R&D (capable of integrating its activities in association with the key project milestones for the choice of options) that can be adapted to reorient or develop additional programs in relation to the project's needs.

## 4. Engineering & management methods [4] [5]

ASTRID develops the **System Engineering**, in particular with the implementation of the requirements, traceability, Product and Functional Breakdown Structures, interface data management, technical data management, configuration & evolution management, **Work Breakdown Structure (WBS) of ASTRID program.** Furthermore, the future implementation of a Product Life Management (PLM) tool is assessed.

The WBS provides an exhaustive and codified structure of the project, applicable to all the actors of the project and is an essential tool of System Engineering. It defines interfaces between different tasks and actors, for each level of responsibility in the Project (Contracting Authority, Engineering Partners, R&D support…), from the Product Breakdown Structure, the logic and planning of the Project and the organization of actors. This process is schematized in the *FIG. 4.* below:




The WBS allows to:

- Structure the projects (pilot, responsibilities, means allocated, logic of interlocking, deliverable, conditions of completion,…) on a single shared support,
- Detect / highlight the possible gaps in the organization of the program (ex: tasks not allotted in the network Customer/Supplier). It avoids forgetting tasks,
- Check the satisfactory completion of the whole tasks of the program,
- Establish in details the level of depth of the studies at the end of 2019.

**3D Mock up**: Exchanges for the general installation and the architecture of the buildings are done via a 3D Mock up.

**Transversal analyses** are done on the design to take into account transversal needs such as: physical protection, organizational and human factors, codes and standards aspects, wastes, environmental aspects, operability availability, operating conditions.

**Studies are undertaken in close cooperation** with many partners in all technical areas of work. Each company brings its expert testimony in terms of design and construction to produce a global layout.

## 5. Efficiency and key to success

### 5.1. Communications

#### *5.1.1 Scientific communication & publications*

Several project presentations have already been given to a non-CEA public:

- French Nuclear Energy Society (SFEN) during conferences held in Paris, Marseille, Grenoble, Marcoule, Lyon and Aix-en-Provence,
- Various conferences, such as the International Conference on Advanced Power Plants (ICAPP), the International Young Nuclear Congress (IYNC), the International Conference on Fast Reactors and Related Fuel Cycles (FR) organized by IAEA. ASTRID Project Team has already produced several scientific papers in these conferences.

#### *5.1.2. Internal and external communication*

According to partners request and in coherence with the CPA Communication strategy, CPA decided to launch an **e-Newsletter** on the ASTRID project main progress. Its goal is to inform CEA's interested members and partners about ASTRID main topics, technical steps or options selection. Partners are highly invited to submit subjects of interest within their perimeter of study. The newsletter is only circulating by an electronic way, at a four time basis per year, but as often as needed according to ASTRID project activity.

Seminars, project reviews and workshops organized by CPA are also an essential axis of internal and external communication.

### 5.2. Multi-level management and involvement in strategic decisions of engineering companies

On such a far-reaching project with a complex industrial set-up, project management requires the proactive participation of the entire project owner team, each member of the project assuming his responsibilities within his assigned scope, even if in the end, the project manager and program manager make the final decisions. The project organization of ASTRID has three levels of decisional meetings:

- **Strategic management** level: This meeting is named COPIL (COmité de PILotage) and is a regular meeting carried out twice a year, at n+1 level between the CEA program level (CEA/DISN/R4G) and its corresponding level on the partner side. This meeting is a reporting of the progress of the general progress of the partnership contract, including a financial report and treats strategic topics as governance, collaboration agreements and intellectual property.

- **Operational management** level is set by the technical monthly meeting organized between the partner and the corresponding work-package leader. This meeting is devoted to report technically the progress of work.
- **Technical control** level: The interface meetings are ruled by the ASTRID architects to guaranty the correct exchange of interface data between two partners involved in the same item, or to register some decoupling values allowing each partners to progress correctly.

### 5.3. R&D management

In order to assess the progress of R&D actions, to check their correspondence with the project needs and to ensure their reorientation or possible prioritisation, regular meetings are organised with the different technical work package leaders and with the relevant project managers. Furthermore, a joint planning approach is used by the prototype investment project team and the R&D support team. This guarantees that the qualification needs and related deadlines are taken into account on both sides, while taking into consideration the schedules for regulatory procedures and engineering design studies.

## 6. Conclusion

The ambitious objectives of ASTRID require the implementation of innovating engineering and management methods which go beyond the current feedbacks; and significantly different compared to the former projects. This paper describes the industrial set-up implemented through the series of collaboration agreements with the different project partners, thereby making it possible to take into account the interests of the industrial parties at a very early stage and to integrate recent feedback from other projects. Close coordination between the prototype construction project and the R&D support programs will also contribute to the success of the project. Lastly, the CEA as project owner is managing the ASTRID project in a collaborative approach based on a series of concrete organizational methods. This organization will function up to the end of the basic design.

## Acknowledgments

The authors wish to thank all ASTRID partners :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