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THE SIGNIFICANT COLLABORATION OF JAPAN AND FRANCE ON THE DESIGN OF ASTRID SODIUM FAST REACTOR SINCE 2014

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Introduction

After 6 years of Conceptual Design phase (called AVP Phase), the ASTRID Project has entered in January 2016 in its Basic Design Phase. Since the beginning (2010), the management of ASTRID project was organized around a strong involvement of industrial partners in the reactor design [1].

Since 2014, a partnership with Japanese nuclear institutes and industries is effective on two main items: ASTRID reactor design studies and R&D in support of Sodium Fast Reactors (SFR) [2]. This French-Japanese collaboration on ASTRID Program and Sodium Fast Reactor has been set up in two steps: the signature of a General Arrangement between CEA and the representatives of MEXT and METI on May 5th, 2014; in a second step, an Implementing Arrangement was signed the same year on August 7th by CEA, AREVA NP, JAEA, MHI and MFBR.

This collaboration of a significant level is foreseen to run at least up to the end of 2019. At the beginning, the collaborative work (input data, planning and deliverables) was divided in 29 Task Sheets covering ASTRID design (3 Task Sheets) and R&D (26 Tasks Sheets). Since 2016, the contribution of JAEA/MHI–MFBR to the ASTRID reactor engineering studies has increased, passing from three to twelve Design Task Sheets. Therefore the cooperation between CEA, AREVA NP, JAEA, MHI-MFBR is fruitful and it has been complemented by all parties since July 2017 by an additional contribution to enlarge Japanese involvement in a process called "Joint Evaluation" to prepare a future potential Common Design.

This paper aims at a brief overview of involvement of JAEA/MHI–MFBR in the ASTRID design studies through these Design Task Sheets, covering in particular at the early beginning the design of an active decay heat removal system and of a passive reactor shutdown system based on a Curie point electromagnet system. In addition, some Task Sheets are focusing on thermal-hydraulic and thermo-mechanical studies related to the primary vessel.

Japan's contribution to ASTRID program is very significant. Except CEA (which acts as the industrial architect of the project), JAEA-MHI-MFBR became in 2015 the 2nd largest contributor to the ASTRID program - behind Framatome - in terms of involved staff and related financial contribution. It means that ASTRID project has to adapt its project management to integer this important partnership.

After a brief recall of the ASTRID context and the genesis of this collaboration, this paper aims at a presentation of the significant involvement of JAEA / MHI – MFBR in the ASTRID design studies through the "Design Task Sheets" and through the "Joint evaluation".

ASTRID Project partnership

As defined in the French Law of 28 June 2006 on the sustainable management of radioactive

materials and waste, CEA's Nuclear Energy Division is responsible for the ASTRID project.

For the Basic Design phase, CEA has renewed the bilateral partnerships for this new step, reflecting the determination of the different partners to be involved in the ASTRID project. As shown in Fig. 1, it was settled of 14 bi-lateral partnerships connected to CEA at the beginning of the Basic Design phase.

Fig. 1: Set of ASTRID Partnership

Since beginning of the project, CEA acts as the Project manager from the definition of the main functional requirements to the assembly of the 3D mock up including performance control, configuration and interface management between elementary products. Since the AVP phase, the project management is entirely based on a Product Breakdown Structure (PBS), which is in constant evolution.

Japan and France cooperation in the nuclear SFR field before ASTRID Project

Japan and France have been involved for a long time in the peaceful use of nuclear energy and dispose of many nuclear power plants to produce electricity. Each of the two countries has been developing the technology of Sodium Fast Reactors for several decades. Japan operates JOYO and MONJU and France has operated RAPSODIE, PHENIX and SUPERPHENIX. Collaborative R&D arrangements have been existing for a long time, based on a mutual interest in the respective design and related safety approach. Indeed, even if Japan chose the concept of a loop type reactor when France considers a pool type, cross-analyses have brought to light many similarities in design, technology, materials, fuel, safety approach... It has been the subject of exchange of company employees between SFR reactor and the detachment of CEA sodium specialists on MONJU site. Several common publications can illustrate these fruitful exchanges [3], [4], [5], [6].

The ASTRID Project partnership with Japan

The history and the ruling of the ASTRID Project partnership with Japan have been extensively explained in [2]. This chapter will just recall the main milestones.

First exchanges on a possible involvement of Japan in the ASTRID project took place in 2010, but no further action was engaged because the priority for France was to structure ASTRID project which had just been launched.

In 2013, Japan and France initiated the discussion for an entry in the ASTRID project. Five working groups were created: 1/Definition of the terms of the agreement and of its principles of governance, 2/ASTRID design activity, 3/R&D on severe accidents, 4/R&D on fuel, 5/Other R&D items (Na technology, ISI&R, Instrumentation).

Fig. 2: Preparatory meeting of the design activity at Tokyo, June 2014

In 2014, these discussions led to a two-level partnership:

The "General arrangement", which establishes the main principles of collaboration; the signatories are the Japanese Ministry of economy, trade and industry (METI) and Ministry of education, culture, sports, science and technology (MEXT) on Japan side, and the CEA by delegation of the French government. It was signed on May 5th, during the visit of the Japanese Prime Minister in Paris.

The "implementing arrangement", signed by JAEA, MHI, its subsidiary Mitsubishi FBR Systems (MFBR), AREVA (now Framatome) and CEA. It specifies in detail the principles and the governance of the R&D and design activities, the intellectual property and rights of use, the transfer of information to third parties, the rights after 2019 etc. At the starting point, 29 Task Sheets were approved, three for ASTRID design and 26 for R&D.

Fig. 3: First face to face meeting at Lyon, September 2014

The Executive Committee is responsible for proposing the creation of new implementing arrangements, follow their progress and solve the related difficulties (face-to-face meeting every semester). The Joint Team is in charge of the day-to-day control of design and R&D work (monthly meeting). This organization is fully embedded and coherent with the organization set-up with the other partners of the ASTRID project.

Collaborative works on design studies related to ASTRID

In the design field, Japanese team first contributed directly to the ASTRID Preliminary Design phase on three topics coherently with the ASTRID Master Plan. They concerned the design of:

- An active decay heat removal system,
- a control rod system with Curie point electro magnets,
- and a seismic isolation system for the Reactor Building.

Design activities increased sharply during the year 2016 from three Task Sheets to nine, then to ten in 2017. Up to now, the current list of design activities is as follows:

- Astrid Active Decay Heat Removal System (DHRS),
- Curie Point Electro Magnet (CPEM) for diversified Astrid control rods,
- Seismic Isolation System (SIS) of the Astrid Nuclear Island (Benchmark),
- Fabricability and thermo-mechanical calculations of the Astrid Above Core Structure (ACS),
- Fabricability studies of the Astrid Polar Table,
- Contribution to propose technical solutions of the Astrid Core Catcher,
- Transient evaluation and benchmark of Astrid plant,
- Thermomechanical analyses of Astrid main and inner vessel,
- Evaluation of Astrid Core characteristics and core shielding,
- General discussions on the Astrid reactor system, for preparation of future Design Task Sheet or Joint Evaluation.

An overview of the technical progress of these design Task Sheets can be found in [7].

Reinforcement of the collaboration: Common view of a future SFR

In the frame of the Franco-Japanese the first collaborative agreement on ASTRID signed in 2014 has been reinforced by a bilateral collaboration agreement on nuclear energy including a specific chapter dedicated to the ASTRID signed the 21st of March 2017 (see Fig. 4). This agreement is setting the framework to start deeper bilateral discussion. As specified in this signed collaborative agreement: "*This discussion aims at:*

- Deepening the exchanges in order to define more clearly a common technical design of the ASTRID demonstrator, especially the means to integrate adjustments of French and Japanese technology to the current design study carried out since 2010;

- Identifying a potential new collaboration framework relating to the know-how and experience of both partners, ensuring a fair and appropriate management of the Intellectual Property and taking into account the reflection carried out by the French part on a new

organization for the next coming steps of this project;
- Identifying in France and in Japan, facilities that shall be used to proceed to the validation of the design and R&D works.
Both partners will make all possible efforts to achieve their discussion at the end of 2018, or sooner if possible, in order to settle the new phase of their collaboration."

Fig. 4: Picture of Ms Ségolène Royal and Mr Hiroshige Sekō signing the 21st of March 2017 the New Fr-Jp collaboration agreement on Nuclear Energy

The project organization is performed in two steps:

- It started with a series of Face-to-Face meetings performed during the first semester of 2017 to understand the fundamental specifications from each part and the technical points of convergence and those to be further discussed for a deeper exchange and explanation.
- According to this first step of evaluation, Working Groups were created to be able to achieve a better common view for a SFR common design reactor.

These Working groups are presented in Fig. 5.

Group N°	Subject Name
WG1	Top Level Requirements
WG2	Core & Fuel
WG3	Reactor Shutdown
WG4	CDA Mitigation
WG5	Reactor structure / Primary system (HFD)
WG6	Secondary / tertiary systems
WG7	DHRS
WG8	Fuel Handling
WG9	Containment
WG10	System Consistency & Costs
WG11	Joint road map for common SFR technological qualification
WG12	Joint road map for common SFR numerical simulation

Fig. 5: Table of the joint Working Group items

Each of them was composed of a board of specialists coming from CEA / Framatome / JAEA / MHI-MFBR.

Each of these working groups (except WG10) had to respect the following rules:

- They have to initiate their starting time with a Workplan accepted by all parts.
- They have to perform several regular meeting by visio-conference (see Fig. 6).
- They have to perform regular Progress of Technical Work report to the WG10 plus a final written synthesis at the end of 2017; and the same process is reproduced for 2018.

The objective is to confirm by each working group the requirements and expectation for ASTRID project and SFR simulation program for extrapolation to future commercial SFR. Conclusions of this joint study have to be reported to the respective national government board.

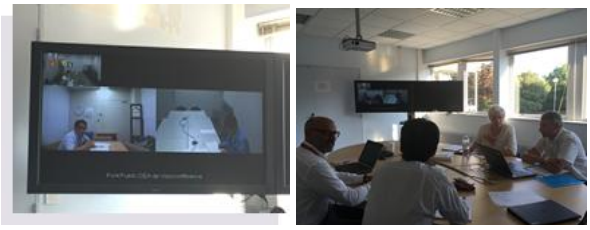

Fig. 6: The efficient use of the video conference system to exchange at 10 000 km distance

ACKOWLEDGMENTS

Many people are involved in this collaboration and it was impossible to put all of them as co-authors. Nonetheless, the authors would like to thank all persons involved in the different Task Sheets, coming from ASTRID project team, Project and Engineering teams from Japan (JAEA / MHI - MFBR) and France (FRAMATOME).

NOMENCLATURE

ACS:	Above Core Structure
ASTRID:	Advanced Sodium Technological Reactor for Industrial Demonstration
AVP1/2:	Conceptual design studies, phase 1/2 of ASTRID project
BD:	Basic Design
CEA:	French Atomic Energy Commission
CFD:	Computational Fluid Dynamic
CPEM:	Curie Point Electro-Magnetic system
DHRS:	Decay Heat Removal System
FBR:	Fast Breeder Reactor
GEN IV:	Fourth Generation Reactor
HFD:	High Frequency Design
ISI&R:	In-Service Inspection & Repair
JAEA:	Japan Atomic Energy Agency
JSFR:	Japan Sodium Fast Reactor
METI:	Japanese Ministry of economy, trade and industry
MEXT:	Japanese Ministry of education, culture, sports, science and technology
MHI:	MITSUBISHI Heavy Industry
MFBR:	Mitsubishi FBR Systems
PBS:	Product Breakdown Structure
R&D:	Research and Development
SASS:	Self Actuated Shutdown System
SFR:	Sodium Fast Reactor
SIS:	Seismic Isolation System
SPX:	Superphenix (*French SFR*)
TH:	Thermal Hydraulic
TS:	Task Sheet
WG:	Working Group
3D:	Three-Dimensional

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