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FRAMATOME'S LESSONS LEARNED ON MULTI-UNIT PSA

PSAM14 Conference

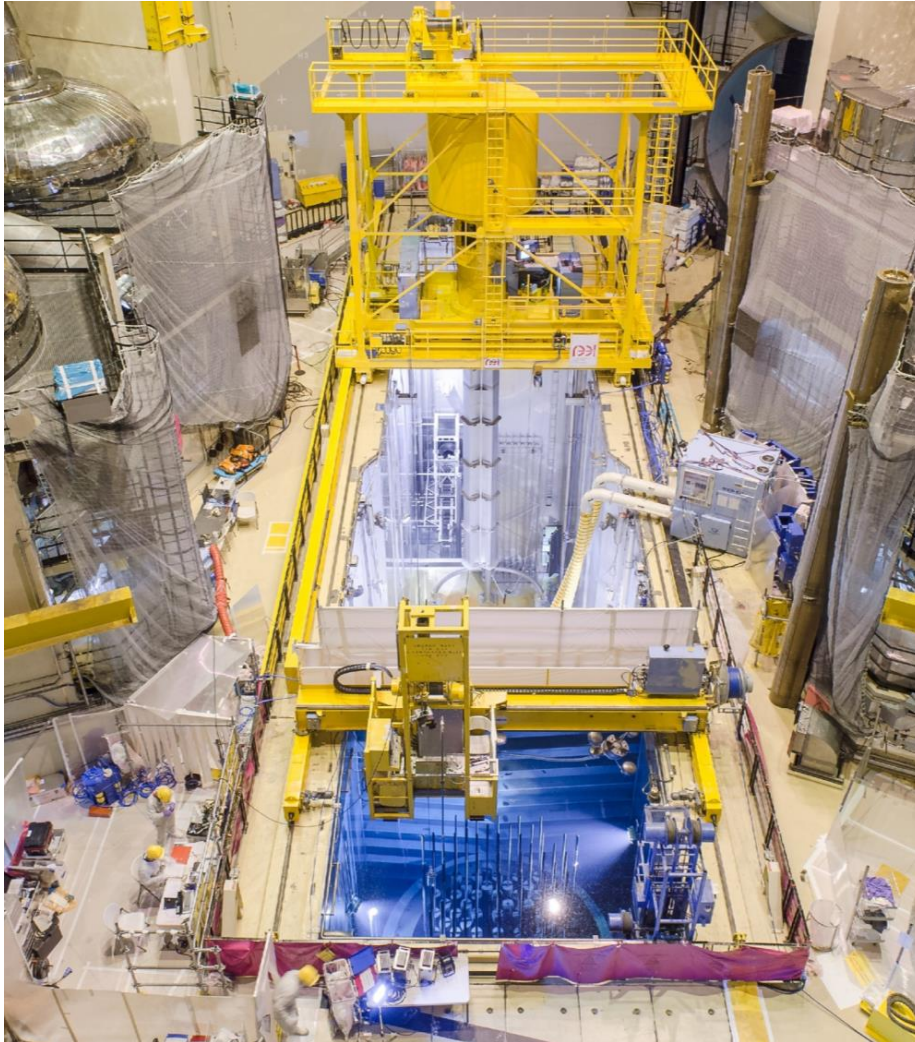Presenter: Jean-Yves Brandelet, PSA Specialist
Other authors:
Hervé Brunelière, Pierre Lacaille

UCLA Luskin Conference Center, Los Angeles, 18th September 2018

1. **ABOUT FRAMATOME**

2. FRAMATOME'S LESSONS LEARNED ON MULTI-UNIT PSA

3. CONCLUSION

About Framatome

- **Framatome (formerly AREVA NP) is a major international player in the nuclear energy market.**

- **The company designs, manufactures, and installs components and fuel for nuclear power plants and offers a full range of reactor services.**

- **Framatome is owned by the EDF Group (75.5%), Mitsubishi Heavy Industries (MHI – 19.5%) and Assystem (5%).**

Framatome Key figures
(July, 2018)

Finland, Olkiluoto unit 3 - EPR Reactor

14,000 employees worldwide

3,3 billions annual revenue
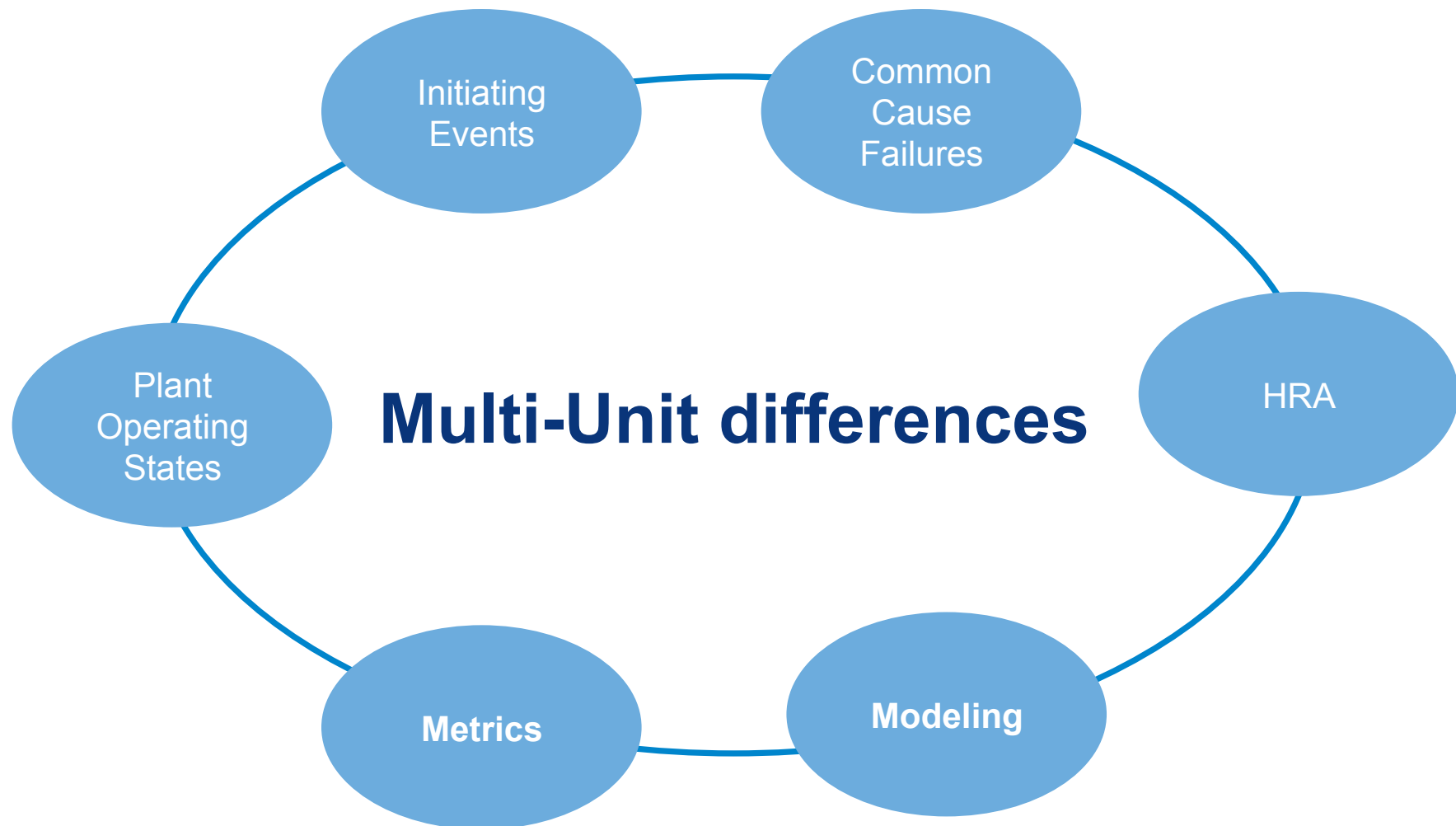
58 locations

14 billions backlog

- **June 29, 2018, Taishan Nuclear Power Plant Unit 1 has been successfully connected to the Chinese grid**

- **This is the first EPR reactor worldwide to be producing electricity.**

China, Taishan units 1&2 - EPR Reactor

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3. CONCLUSION

- **PSA considers in most cases only one reactor, and Multi-Unit accidents are not systematically studied**

- **The Fukushima Daiichi accident reinforced the importance of Multi-Unit risk assessment**

  > **Occurrence of Multi-Unit accident sequences involving unusual challenged to systems, structures, components and human resources is possible**

- **International community is willing to expand current PSAs to account for multi-unit accident**

- **Framatome is currently developing a Multi-Unit PSA level 1 and investigate the problematics specific to it**

Differences between single unit and Multi-Unit PSA

Initiating Events

Common Cause Failures

Plant Operating States

Multi-Unit differences

HRA

Metrics

Modeling

p.7

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Multi-Unit PSA modeling

- **The Multi-Unit PSA level 1 under development at Framatome considers a two-units site, with two identical reactors. It is based on an existing detailed single unit PSA model**

- **Main steps of the Multi-Unit modeling:**
  - ◆ Duplication
 - ◆ Multi-Unit Event Trees modeling

Multi-Unit PSA modeling

- **First step of the construction of the Multi-Unit PSA model: duplication of the existing PSA model, inside a single model. This allows having one PSA model containing two single units PSA.**
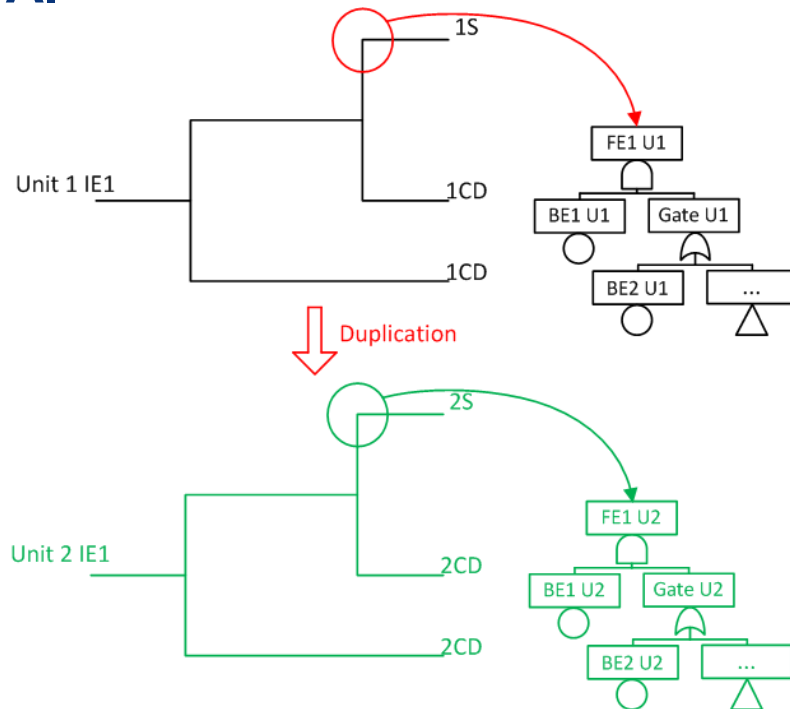
Event Trees, Fault Trees, Basic Events, parameters,… are duplicated from unit 1, and renamed for unit 2

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Multi-Unit PSA modeling

- **Second step of the construction of the Multi-Unit PSA model: creation of "multi-unit Event Tree". This allows assessing the states of both units.**
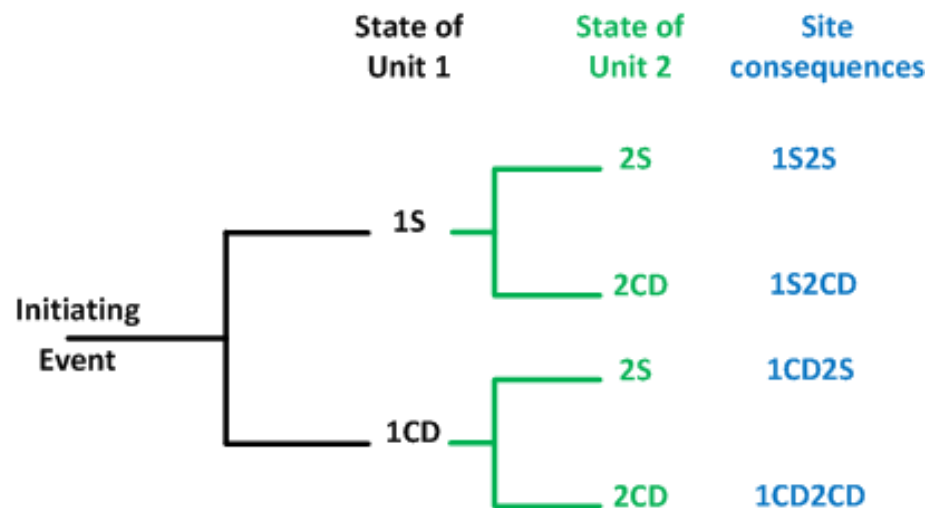
Knowing the state of each unit, the consequence at the site level can be defined and the SCDF can be assessed

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- **Duplication method:**
  - ◆ Conventional PSA software does not allow automatically duplicating a PSA model.

    > A manual export/import is to be performed
    > Very time consuming

  - ◆ The export/rename/import process also generates some bugs. These bugs cannot be automatically detected, thus their identification and correction was manually performed.

  - ◆ The identification length of basic event, fault trees, gate… is limited, and some identifications of the existing PSA model already reached this limit.

    > The single unit PSA was not build having in mind the possibility to duplicate it. For future PSA model, it is recommended to anticipate this need, and to define an appropriate naming rule allowing adding a character to identify the considered unit

Lessons learned

- **Multi-Unit Event Trees**

    - ◆ The multi-unit Event Trees lead to numerous and complexes sequences to be evaluated. → very long calculation times

    - ◆ This modeling may be appropriate for 2 units, but becomes unmanageable for a site with more units
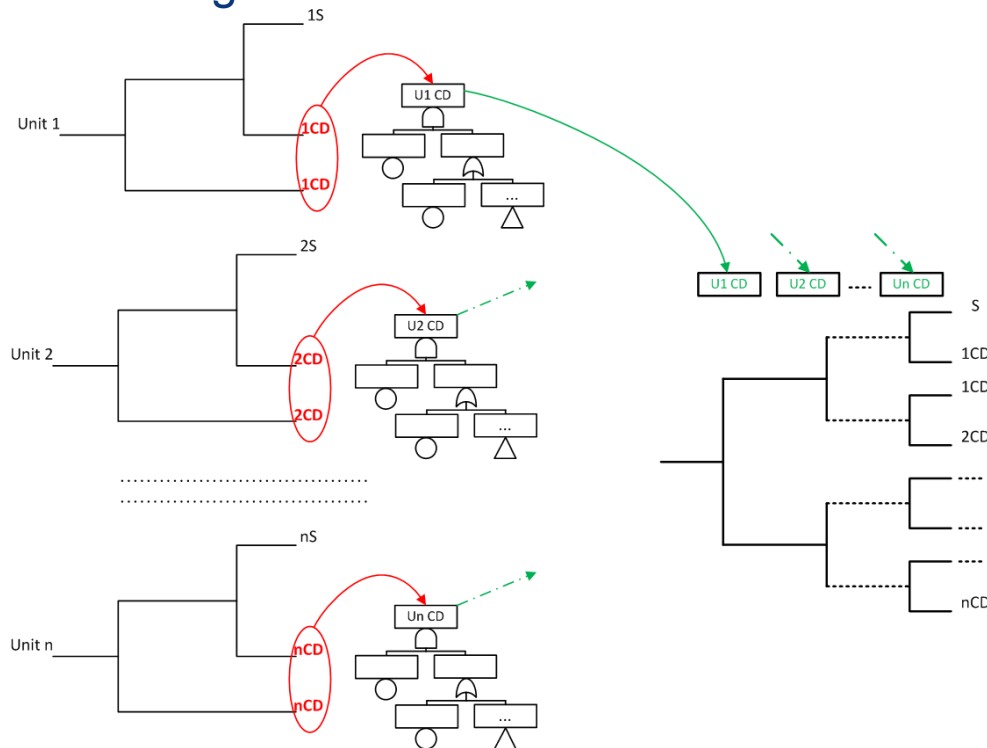
    > An alternative modeling is necessary

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Multi-Unit Event Trees / alternative modeling

◆ It aims at converting Event Trees into Fault Trees and at eventually building a new Event Tree allowing counting the number of units in core damage

- This modeling can be applied for a site with a large number of units.

- Few sequences → the calculation time is drastically reduced.

- The converting process may be complex, depending on the Event Tree structure.

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Conclusion

- **The modeling of a multi-unit PSA model should anticipate calculation time**

- **An automatization of the duplication process and of the converting process would simplify the modeling task**

- **Future PSA single unit model, should anticipate the need to duplicate them, and consequently define an appropriate naming rule**

- **The following points must be investigated by Framatome:**
  - Development of a multi-unit PSA level 2, and level 3
  - Development of a methodology to take into account accident sequences involving reactor building accident and spent fuel pool accident
  - Development of a methodology allowing taking into account different accident progression on various unit (investigation on dynamic PSA)

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