# SPACE Validation on a Steam Generator Tube Rapture Experiment with SMART-ITL Facility

# AGENDA
## PRESENTATION

1 Introduction (NPPs - SPACE - SMART100 - Objectives)

2 Methodology (4 Steps)

3 Results & Discussion

4 Conclusion

# Introduction

## ❖ **NPPs** (Nuclear Power Plants):

- Evaluation of Nuclear Power Plants performances during accident conditions has been the main issue of the research in nuclear fields during the last 40 years.

- Safety and performance analysis codes validation is required and important work that should be performed to obtain reliable results for simulating the NPPs behaviors during the **steady state** or **transients**.

## ❖ **SPACE** (Safety and Performance Analysis CodE for nuclear power plants):

- Firstly, it has been developed for the safety analysis of operating PWRs and the design of advanced water reactors.

- Secondly, it adopts advanced physical modeling of two-phase flows, mainly two-fluid three-field models that consists of gas, liquid, and droplet fields.

- Thirdly, Nuclear Safety and Security Commission (NSSC) approved the use of the SPACE for licensing applications of Korean PWRs in 2017.

- Finally, it has been improved continuously to extend its application for the Design Extension Conditions (DECs).

# Introduction

❖ **SMART100** (System Integrated Modular Advanced Reactor):

- It was upgraded from the standard design of SMART and developed by Korean Atomic Energy Institute (KAERI).

- It adopts a helically coiled steam generator, and internal pressurizer inside the Reactor Pressure Vessel (RPV).

- It has fully Passive Safety Systems (PSSs)
  - Passive Safety Injection System (PSIS)
  - Passive Residual Heat Removal System (PRHRS)
  - Automatic Depressurization System (ADS).

❖ **Objectives** are to:

- Validate SPACE based on the steam generator tube rapture experiment with SMART-ITL facility.

- Predict and identify the capability of SPACE for analyzing thermal hydraulics in integral reactors.

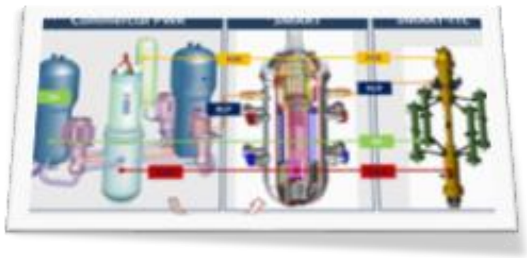
# Methodology

## ❖ **Step 1** (Review, Verify, and Identify the Design Data and Characteristics of SMART-ITL)

- SMART-ITL is an integral test loop facility that has been constructed by KAERI and finished its commissioning tests in 2012, to observe and understand the thermal hydraulic phenomena that occur in the systems of SMART during normal operation or transients.

- It has been designed to preserve and represent the same height ratio, time scale, pump head and pressure drop of the reference plant SMART.

| Design Parameter | Ratio (SMART/ITL) |
|---|---|
| Length | 1/1 |
| Time | 1/1 |
| Pump head | 1/1 |
| Pressure drop | 1/1 |
| Diameter | 1/7 |
| Area | 1/49 |
| Volume | 1/49 |
| Core power | 1/49 |
| Flow-rate | 1/49 |



**Comparison Figure**

## Methodology

### ❖ **Step 1** (Review, Verify, and Identify the Design Data and Characteristics of SMART-ITL)

- The basic design of SMART-ITL is to provide core cooling capability during all Design-Basis-Accidents (DBAs) without additional operational actions for at least 72 hours as same as the reference reactor.
- It has new passive safety featured components and systems:

**4-trains**

**PSIS** (CMT - SIT)

**Connected** to RPV, provides heat removal from the core without AC power or operator action and supplies borated water into the RCS to prevent core uncover.

**4-trains**

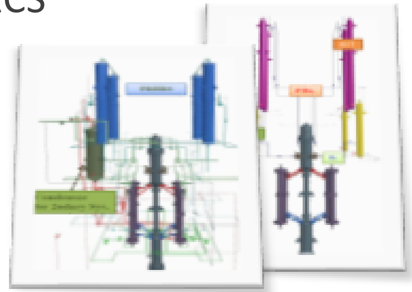
**PRHRS** (ECT - HX - MT)

**Connected** to the secondary system and removes the RCS heat by natural circulation

**2-trains**

**ADS**

**Connected** to the upper part of the reactor closure head and rapidly depressurizes the RCS



**PSSs Figures**

# Methodology

## ❖ **Step 2** (Steady State Condition)

- The steady state condition of this SGTR been applied on 25% of full scaled thermal core power of SMART-ITL, the full thermal core power in SMART PPE design equals 365 (MWth). Therefore, the thermal core power with SMART-ITL was equal:

$$\frac{365}{49}(25\%) = 1.862\ (MWth)$$

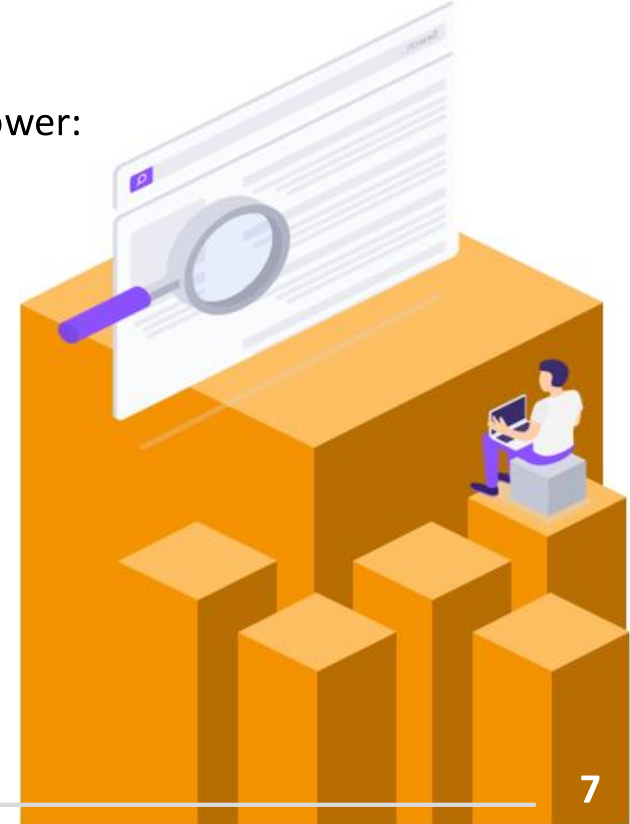
- Steady-state reference and target ratios for the primary and secondary systems of 25% Core Power:

○ **Primary System**

| Parameter | Ratio (SMART/ITL) |
|---|---|
| Core power ($MW_{th}$) | 1/196 |
| Operating pressure (MPa) | 1/1 |
| Flow-rate (kg/s) | 1/196 |
| Core inlet temp. (°C) | 1/1 |
| Core outlet temp. (°C) | 1/1 |

○ **Secondary System**

| Parameter | Ratio (SMART/ITL) |
|---|---|
| Flow-rate (kg/s) | 1/196 |
| Feedwater pressure (MPa) | 1/1 |
| Feedwater temp. (°C) | 1/1 |
| Main steam pressure (MPa) | 1/1 |
| Main steam temp. (°C) | 1/1 |



## ❖ **Step 3** (Sequence of Events and Set Point/Trip Signal)

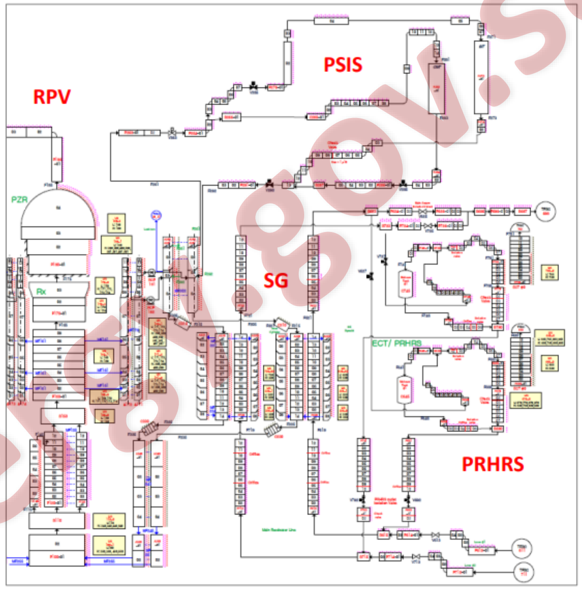
- There are multi reactor trip signals for SGTR accident which are **Low Pressurizer Pressure (LPP)** and **Low Pressurizer Water level (LPL)**, both of them have the same sequences but the only major difference between them is the time delay of actuation signal response and we have followed the **LPL** set point.

| SOE | Set point / Trip signal |
|---|---|
| Break | - |
| Reach LPL | LTPZR = 45% = 2(m) |
| Reactor trip signal | LPL + 1.1 s |
| CVCSIAS | LPL + 1.45 s |
| PRHRAS | LPL + 1.45 s |
| CMTAS | PRHRAS + 1.45 s |
| CVCS stop | CVCSIAS + 1.45 s |
| CMT injection start | CMTAS + 1.45 s |
| PRHRS IV open | PRHRAS + 5 s |
| MSIV and FIV close | PRHRAS + 5 s |
| SITAS | PTPZR = 1.78 MPa + 1.45 s |
| SIT injection start | SITAS + 1.45 s |
| ADS #1 open | CMT level < 31% |
| ADS #2 open | SIT level < 14% |
| Reach safety shutdown condition | RCS temp. = 215 ºC |

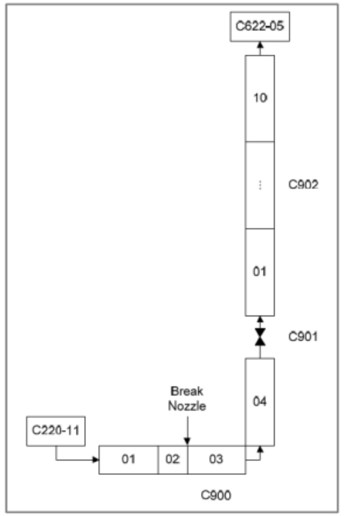
# Methodology

## ❖ **Step 4** (Nodlization and Break Line Modeling)

- All the PSSs that includes (PSIS - PRHRS - ADS) have been modeled and added in SPACE, and on operation mode during the simulation.

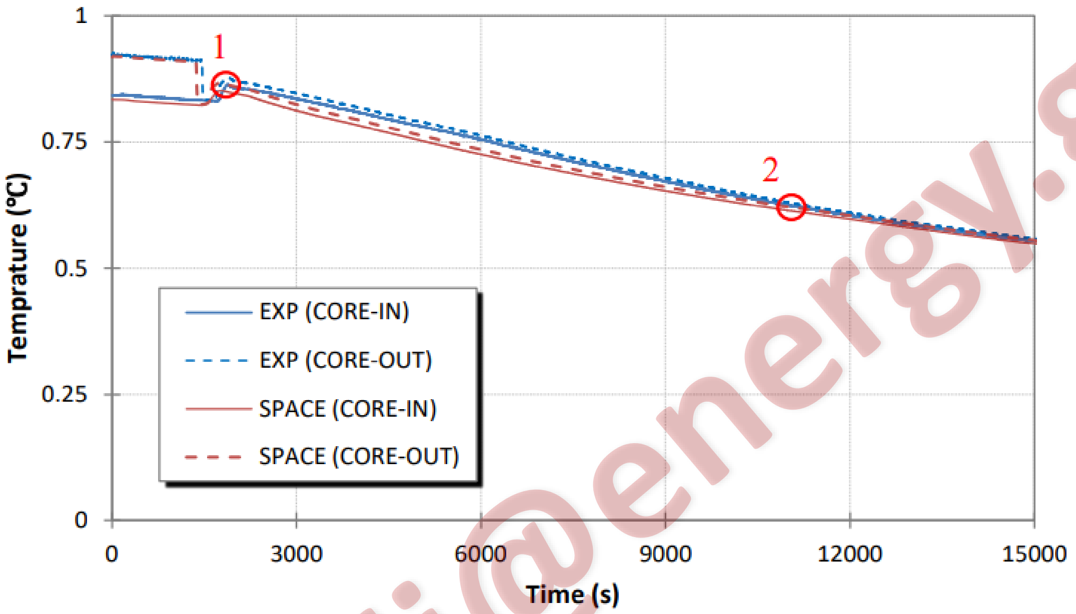



- The SGTR was modeled by an opining valve, break nozzle, and two pipe components that directly connected the primary side of steam generator and main steam line.



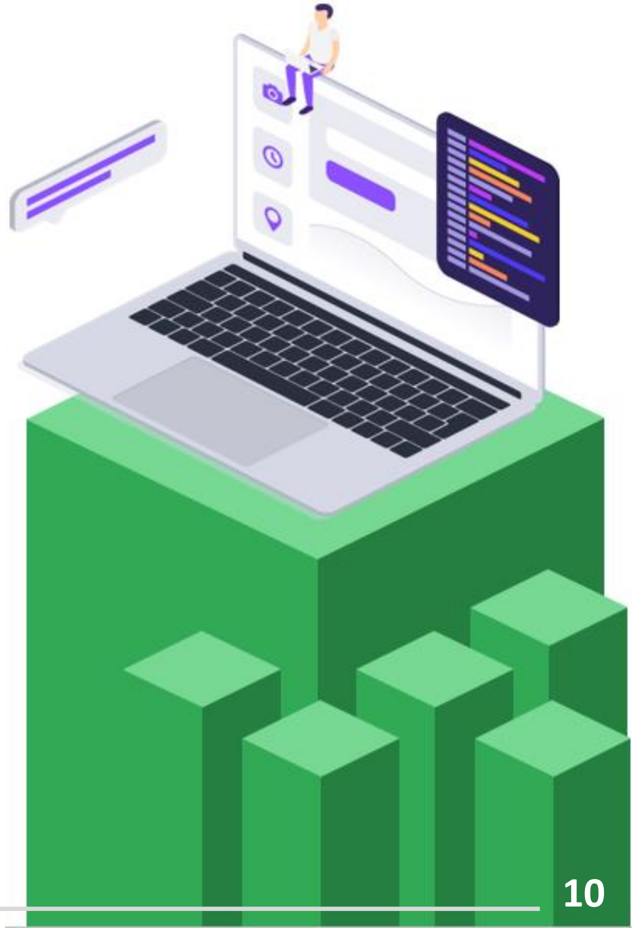

## ❖ Core Inlet and Outlet Temperature

- When the steam generator raptured is occurred and the reactor trip signal is actuated due to the LPL:



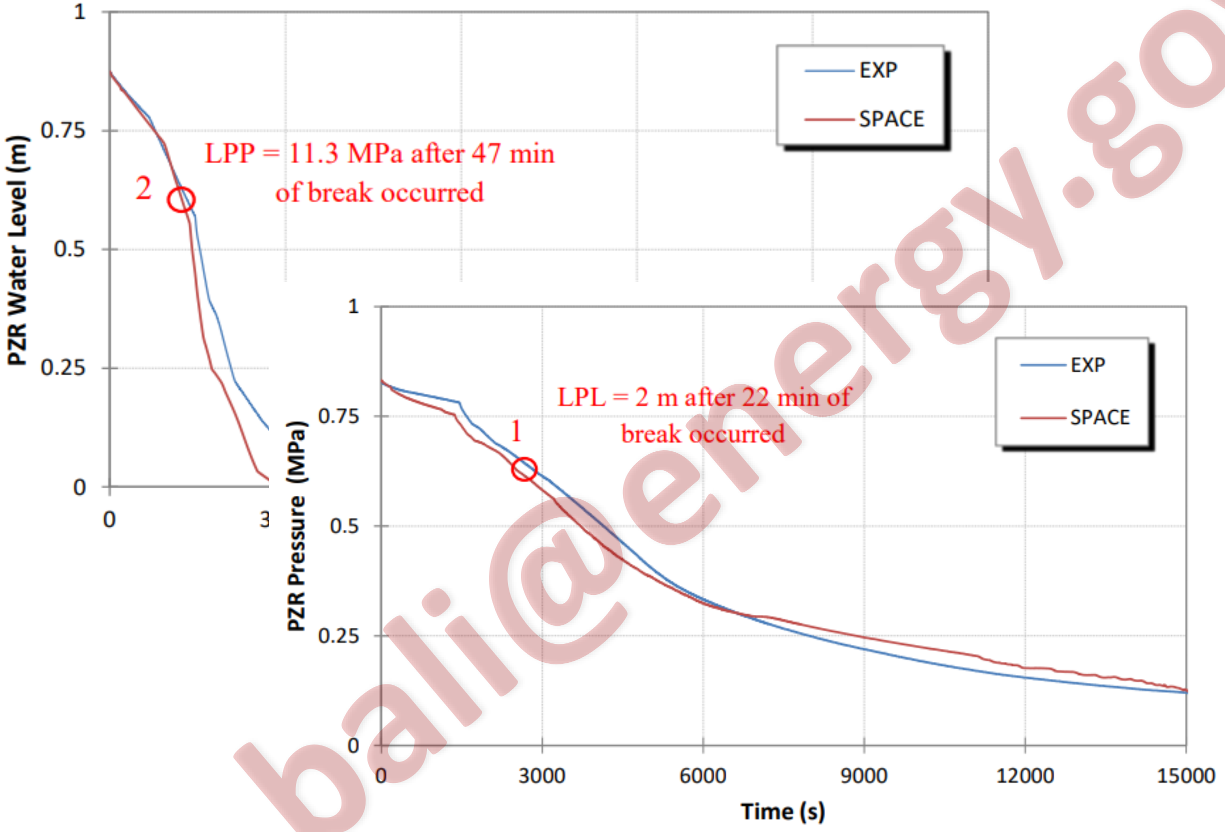

- (1) The core inlet and outlet temperatures started decreasing due to the dropped of core power. This means the capacity of thermal power to heat up the RCS is decreased due to the start injection of CMTs and removing heat by PRHRSs.

- (2) The RCS reached the safety shutdown condition when temperature was 215 (C) at time of almost 3.1 (hr)

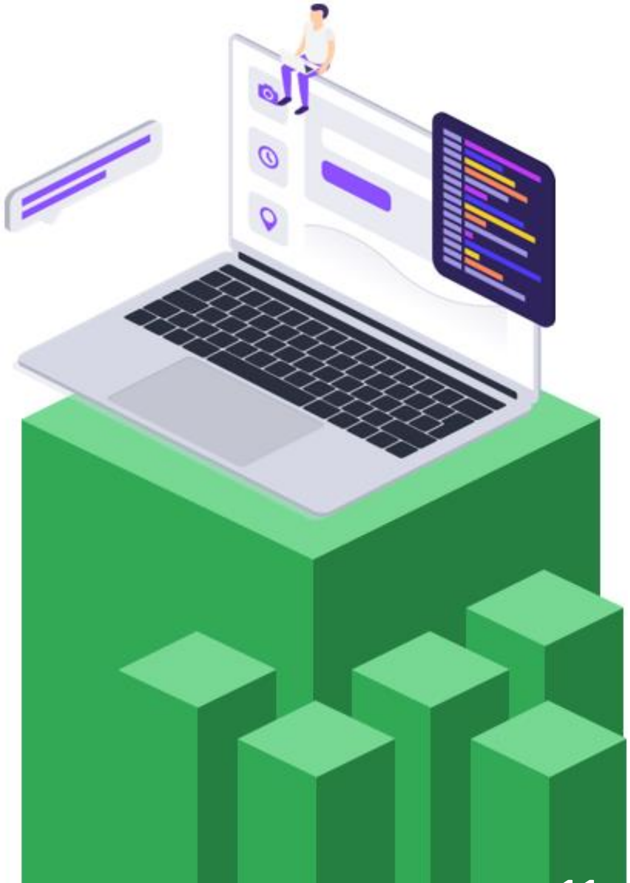


## ❖ PZR Pressure and Water Level

- The PZR pressure and PZR water level started decreasing gradually and immediately after SGTR occurred:

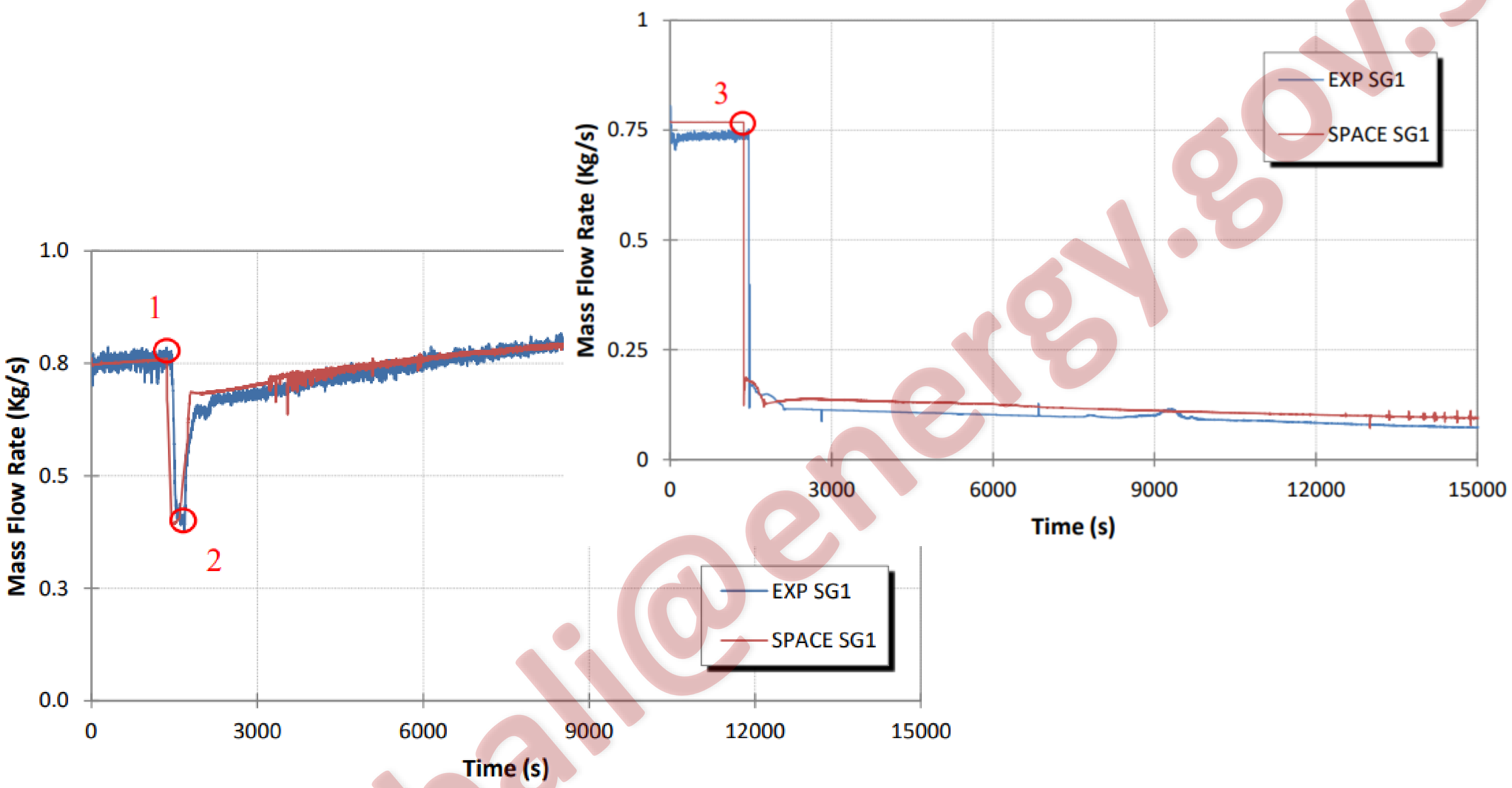



- (1,2) The PZR pressure took longer time than the PZR water level to reach the set point with 25 minutes different in between.

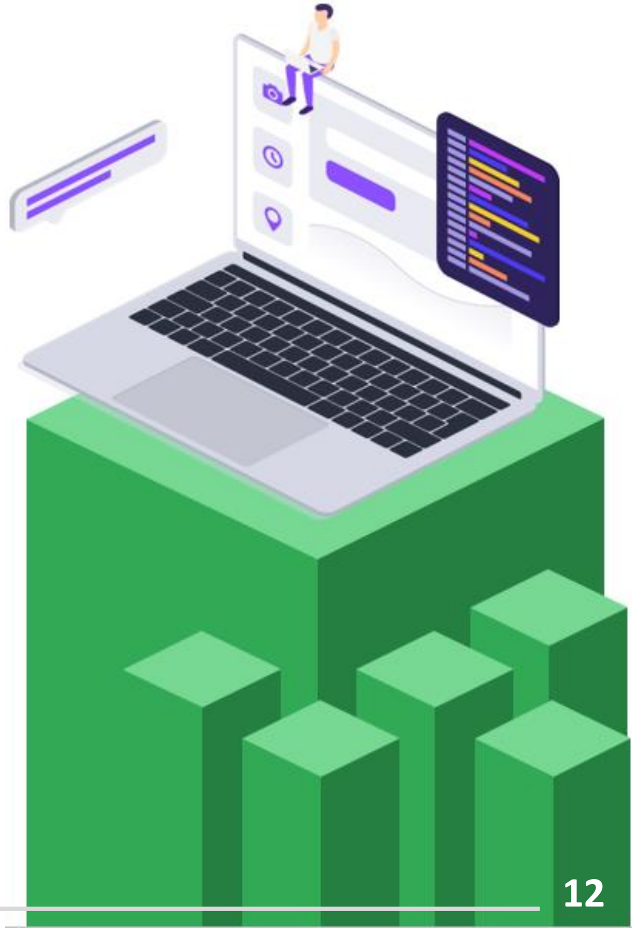


## Results & Discussion

### ❖ Primary and Secondary SG Flow Rate




- (1,3) the SG primary and secondary flow-rate dropped rapidly after the trip signal.
- (2) Primary SG mass flow-rate started to increase again due to the PSIS especially the CMTs injection



# Conclusion

## ❖ Firstly

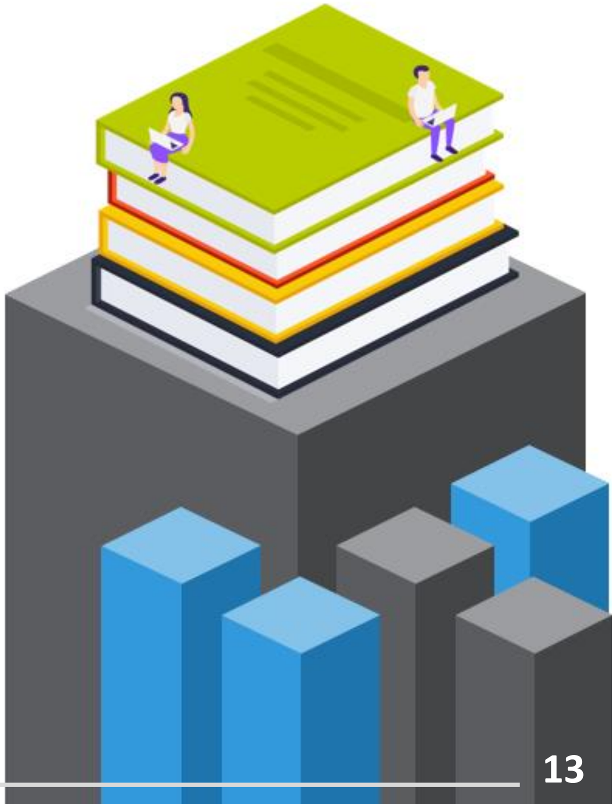
- SPACE analysis and validation on a steam generator tube rapture experiment with SMART-ITL facility has been performed.

## ❖ Secondly

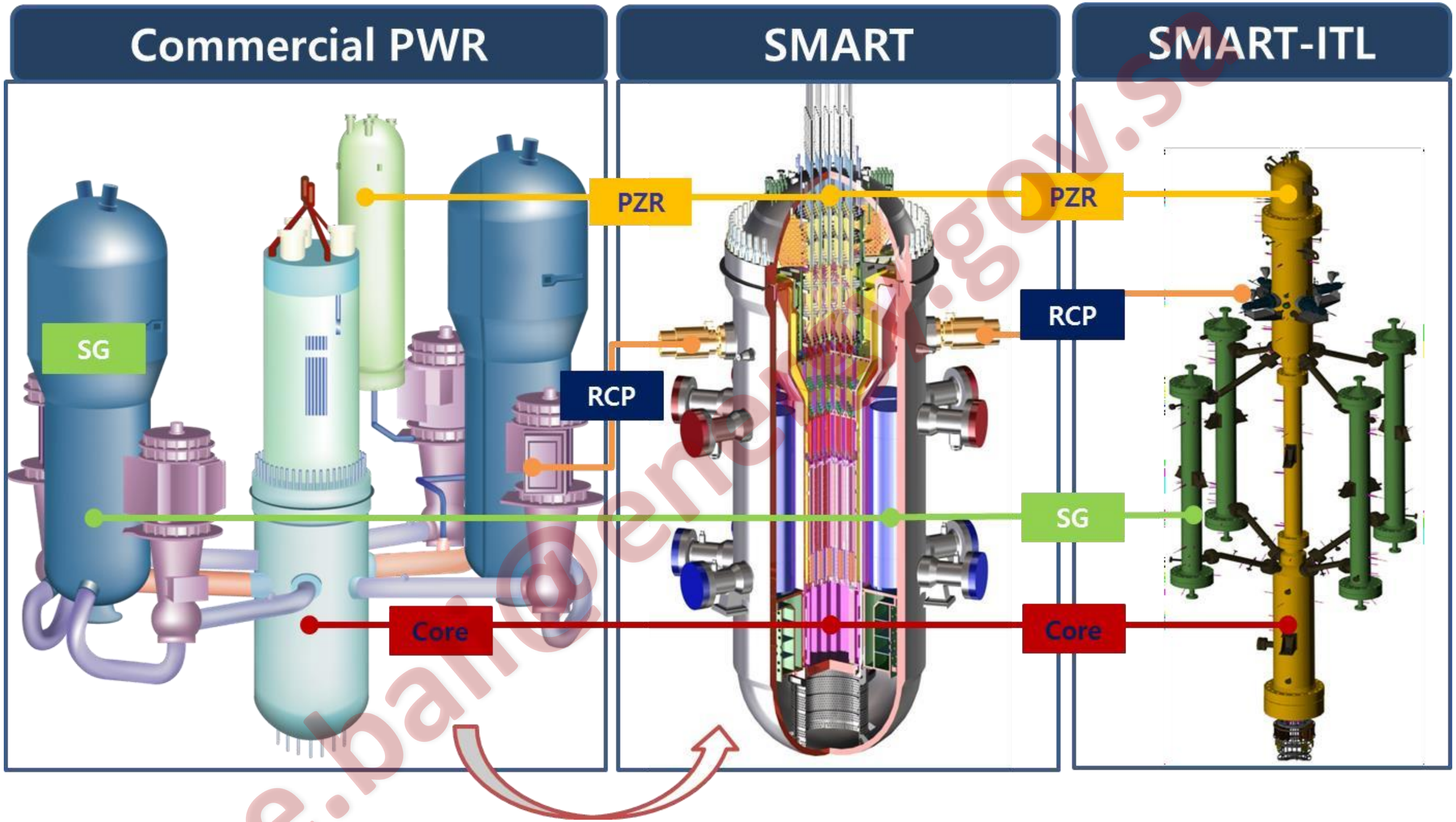
- Development of certain physical models of SPACE has been modified and added to the code for simulating the thermal hydraulic behavior of SMAERT-ITL.

## ❖ Finally

- The validation results show that, overall the thermal hydraulic behaviors of parameters were predicted well. Therefore, SPACE has the capability for analyzing thermal hydraulics in integral reactors specially SMART100



# THANK YOU



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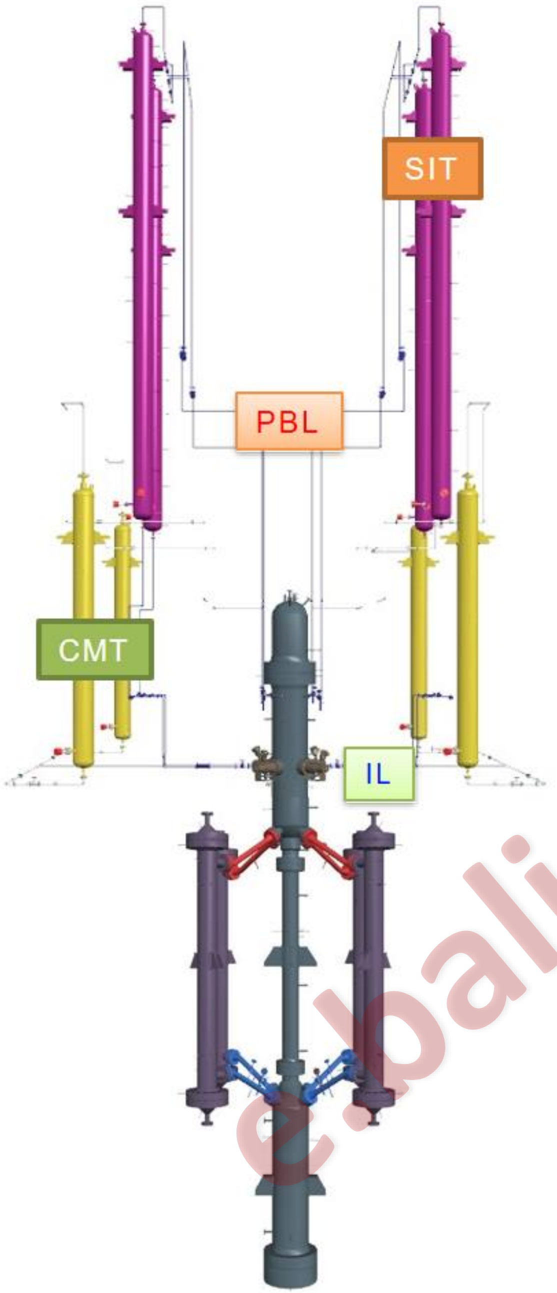
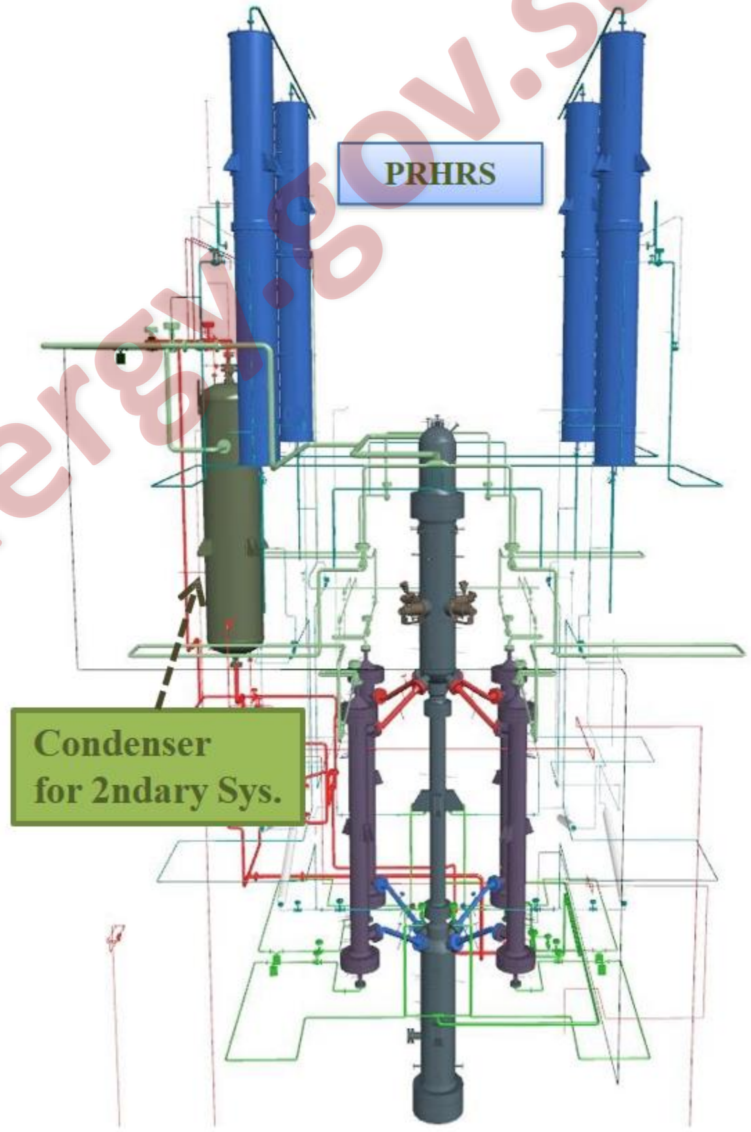
- PSIS




- PRHRS



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