

# ***INGENIA NUCLEAR: UPM-CDIO Project in Nuclear Engineering Education***

**V.J. Casas et al. (Grupo INGENIA 2019-2020)**

MASTER IN INDUSTRIAL ENGINEERING

E.T.S. de Ingenieros Industriales

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## What ‘INGENIA’ course is?

- Course within in “**Master in Industrial Engineering Program at UPM**”
- 12 ECTS : 5hours/week – 2 semesters
- INGENIA is based on the CDIO (Conceive Design Implement Operate) initiative, which has been also adopted by other Universities: Delft, Politecnico di Milano, MIT, Stanford...
- See more information about CDIO at: [www.cdio.org](http://www.cdio.org)

## Other INGENIA projects at UPM (in total 14):



**PV facility**



**Videogame development**



**Design of Daily-life products**

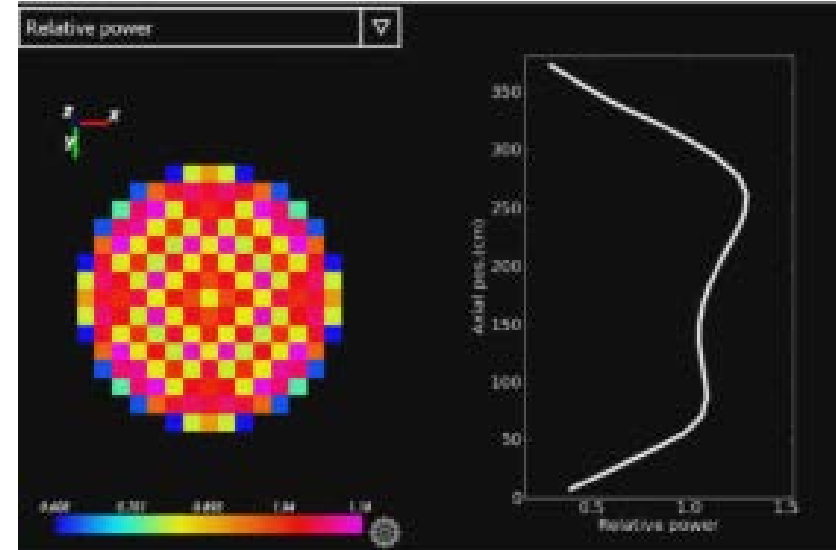
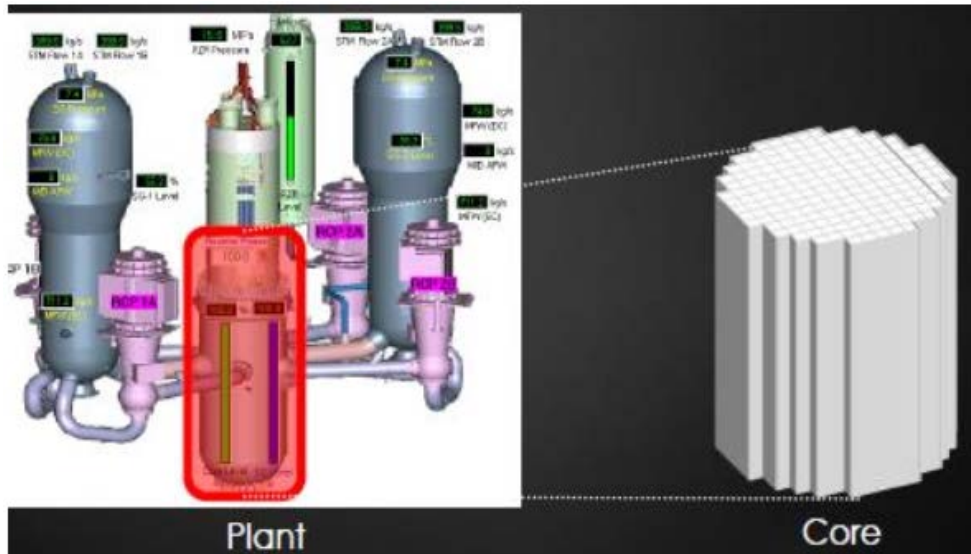


**Automotive Engineers**

Other INGENIA projects: Systems Engineering (to the construction of an intelligent technical system), Acoustic Engineering, Computer-aided Engineering (applied in material design), Thermal-Engine Design, Electric-System Design, Laser and Optics Design, .... Bioengineering,... , Beer Factory Project,...

## What we do ?

- INGENIA-NUCLEAR is focused “on design & simulation of a Pressurized Water Reactor
- **Flow of information from nuclear data productions to 3D/core simulators of PWRs**
- **Main objective: to work with 3D/core simulators + keeping special attention to safety**



*Pictures courtesy of NEL team, Japan & IAEA*

- ❑ Jose Cabrera – Zorita PWR - Interactive Graphic Simulator  
[David Piedra \(September 2019\)](#)
- ❑ Nuclear data for nuclear applications and the JEFF project  
[Arjan Plompen \(October 2019\)](#)
- ❑ BEACON Core Monitoring System (ENUSA)  
[Jose Herrero \(November 2019\)](#)
- ❑ Development of the SEANAP simulator (UPM)  
[Carolina Ahnert \(December 2019\)](#)
- ❑ Introduction to IAEA Nuclear Data Service and introduction to EXFOR Library-Mother of all libraries (IAEA)  
[Naohiko Otsuka \(February 2020\)](#)



*A. Plompen's conference, October 2019*



*N. Otsuka's Conference, February 2020*



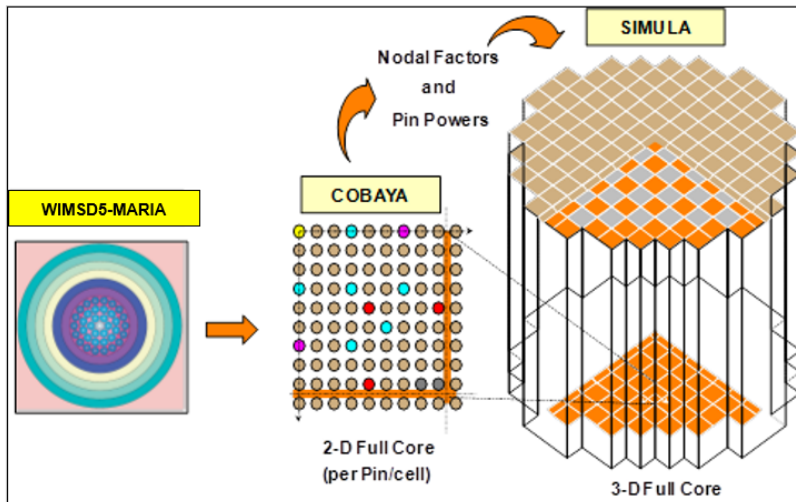
*C. Ahnert's Conference, December 2019*

Jose Cabrera - Zorita PWR - Interactive Graphic Simulator, September 2019

- ❑ This year INGENIA/NUCLEAR's edition is focused on **Accident Tolerant Fuels (ATFs)**
  - Cladding (Steel, coated and Csi)
  - Fuel technologies (TRISO, U3Si2 and Doped-BeO)
- ❑ ATFs have been compared with traditional UO2-Zircaloy to check: viability and performance
- ❑ PWR Core Analysis: System "SEANAP" ⇒ **"Updated is needed to simulate ATFs"**

## ❑ PWR Core Analysis System "SEANAP"

- **MARIA** system for lattice/assembly calculations (based on WIMSD5 code)
- **COBAYA** system for a detailed (pin-by-pin) core calculations
- **SIMULA** system for 3D/1-group corrected-nodal diffusion core simulation



**Figure.** SEANAP: WIMS-D5 + COBAYA + SIMULA

### References:

- ❑ "Validation of PWR Core Analysis system SEANAP-86 with measurements in test and operation", C. Ahnert et al., M&C87

See also, "upgraded SEANAP" with WIMSD5 + recent nuclear data evaluations

- ❑ **JEFDOC-1917, April 2018**
- ❑ **JEFDOC-1968, April 2019**

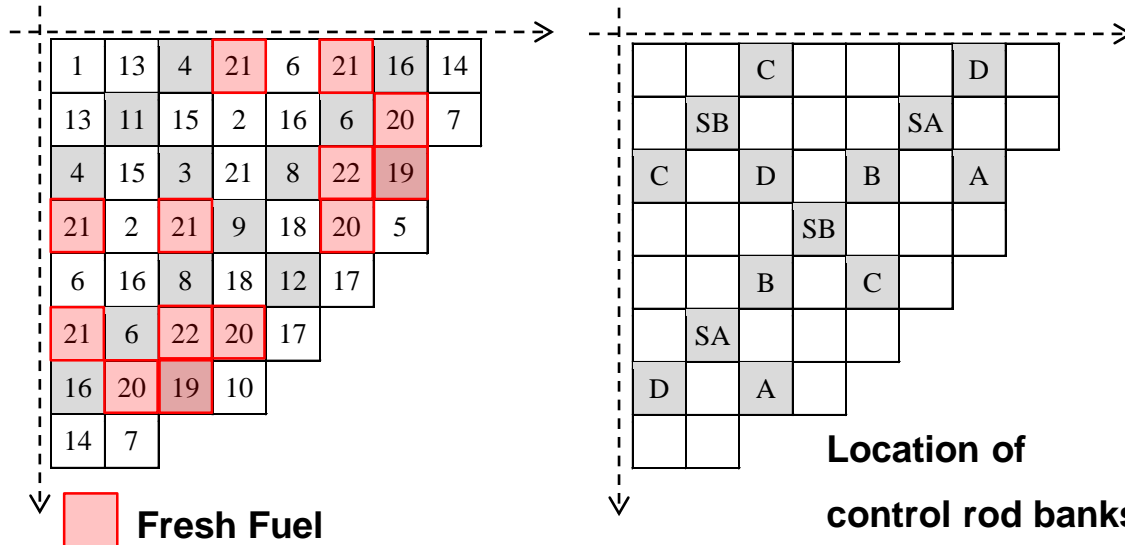
- ❑ A "Graphic Matlab-based Interface" has been developed for better visualization of 3D values

### ❑ PWR (Westinghouse-type), 3 loops.

- Power 2775 MWth
- 157 Fuel Assemblies (UO<sub>2</sub>): 17x17 – 264 fuel rods, active height: 365.76 cm
- Cycle-5: **48 Fresh fuel assemblies .... NEW ATFs!!!**
  - UO<sub>2</sub>/3.6wo – clad/Zircaloy thickness 0.5715 mm
  - Loading pattern: 8FA(0), 16FA(4), 16FA(8) and 8FA(12) : #FA (#wet annular burnable absorber)

¼ CORE

¼ CORE

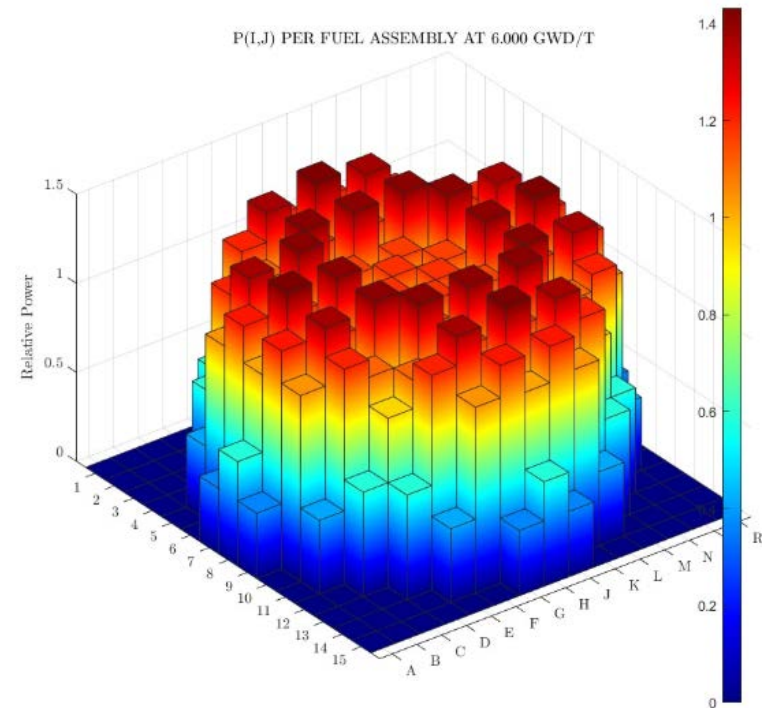


- Different Nuclear Data libraries (JEFF-3.3, 3.1 2.2 - ENDF/B-VII.1 and VIII.0) have been used for comparison

### ❑ Important!

- Fresh fuel loading of UO<sub>2</sub>/Zr-3.6%wo was optimized (loading pattern, WABAS position, etc ...)
- In this exercise, we assumed the same loading for the ATFs

- ❑ **INGENIA/NUCLEAR** course is a CDIO-Based subject which contributes to nuclear engineering education.
- ❑ This year's objective is **focused on ATFs** study and comparison with traditional UO<sub>2</sub>+Zircaloy fuel loads.
- ❑ The **SEANAP 3-D Core analysis** system has been used to carry out this work
- ❑ Different **ATFs technologies** have been tested
  - **Cladding:**
    - FeCrAl Steel
    - Coated-Cr, Coated-Ti<sub>2</sub>AlC
    - CSi
  - **Fuel:**
    - TRISO
    - U<sub>3</sub>Si<sub>2</sub>
    - Doped-BeO
- with different **nuclear data libraries:**
  - JEF-2.2, JEFF-3.1 and JEFF-3.3
  - ENDF/B-VII.1 and ENDF/B-VIII.0



**Figure.** Graphical MATLAB plot showing a 3D power assembly distribution