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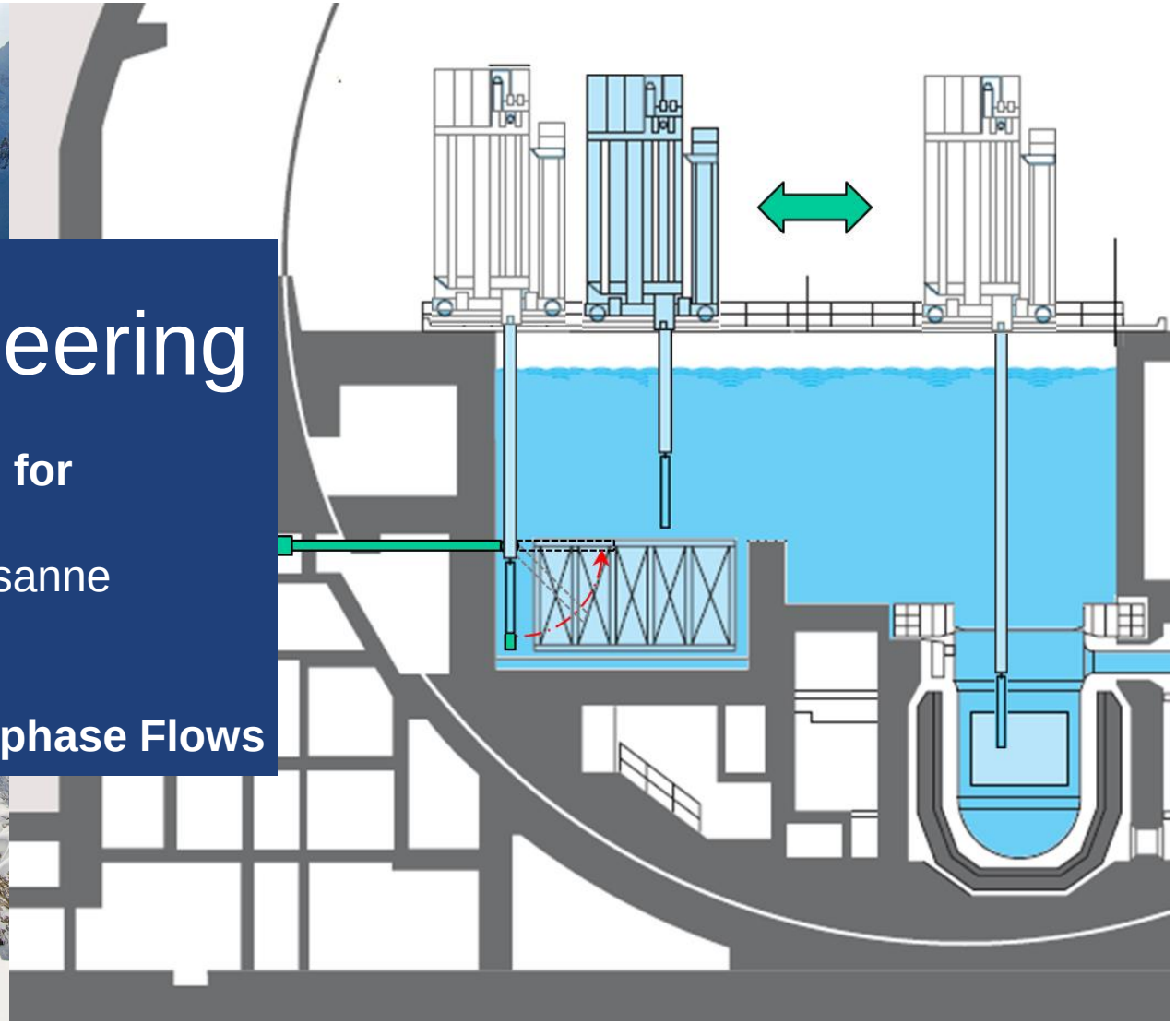
McS in Nuclear Engineering

Unleash benefits of nuclear technologies for humanity
A joint program of ETH Zurich and EFP Lausanne

Prof. Annalisa Manera
Laboratory of Nuclear Systems and Multiphase Flows



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Why nuclear engineering?
FISSION REACTORS / NUCLEAR POWER

- 445 nuclear power plants in operation world-wide (180 in Europe)
- 55 under construction (USA, UK, Korea, Finland, France, Slovakia, Turkey, China, Russia, India, Argentina, etc.) => Finland EPR Olkiluoto started operation, 1600 MWe
- 26 new nuclear power plants planned in Europe

  The Netherlands (2), France (14), Poland (6), Czech Republic (1), Finland (1), Bulgaria (1), Turkey (1)
- Nuclear included in EU taxonomy to support decarbonization efforts
- Japan plans to build new reactors (government announcement expected by Dec 2022)

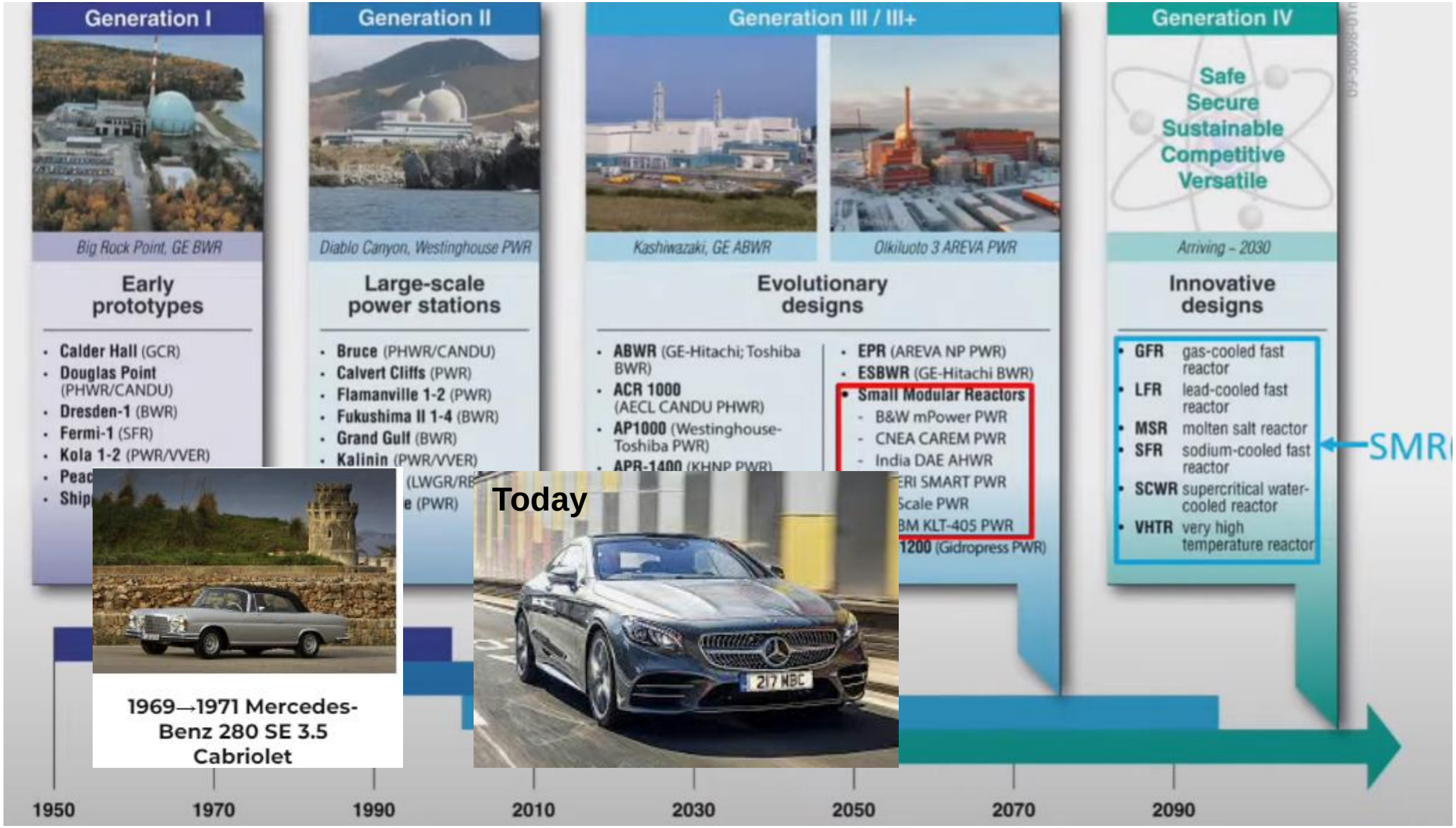
Klimaneutrale Stromversorgung ohne AKW – Selbst die Grünen liebäugeln jetzt mit Gaskraftwerken

Drone footage of snow across a San Antonio neighborhood. (Photo by Jesus Soliz)

WEATHER

Death toll from February Texas storm surpasses 150

Why nuclear engineering?
FISSION REACTORS / NUCLEAR POWER



Fukushima Daichi (1971)

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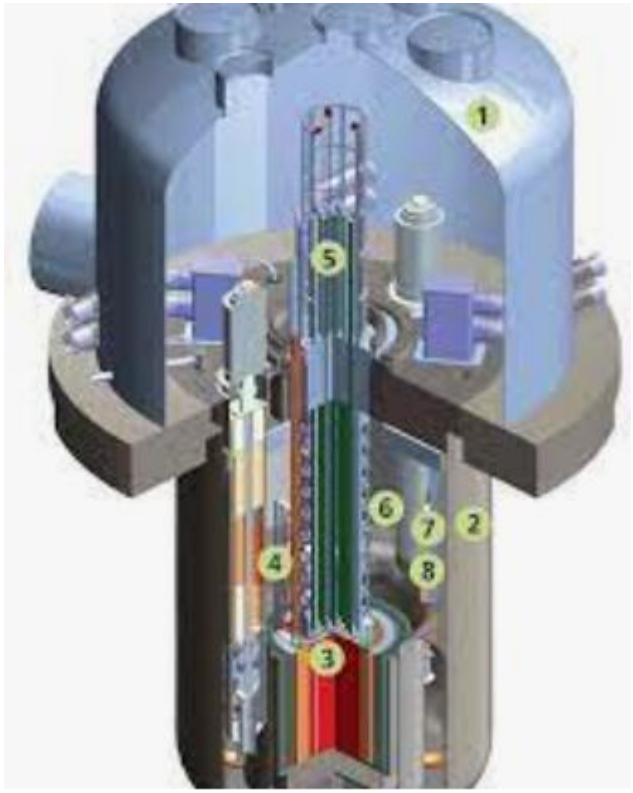
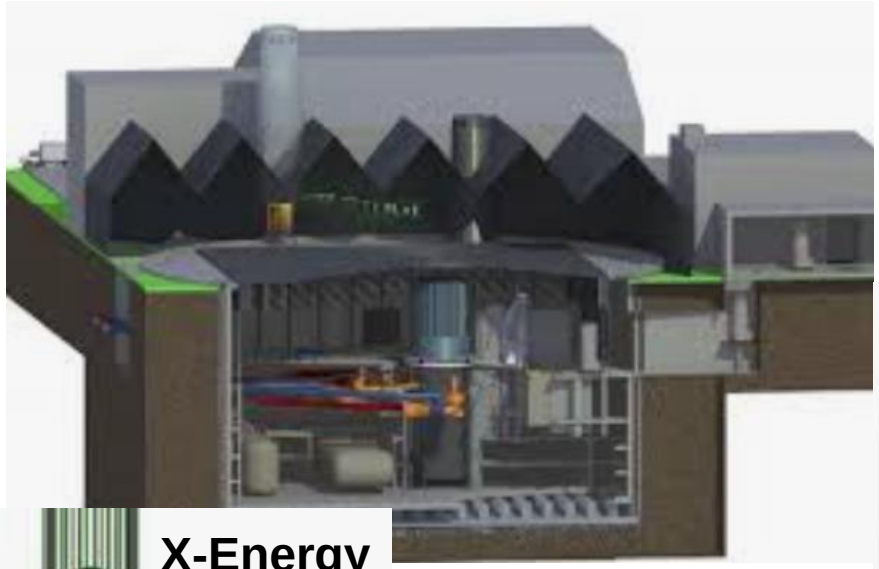
Why nuclear engineering?
FISSION REACTORS / NUCLEAR POWER

Terrapower



Nuscale SMR

Kairos FHR



X-Energy

Westinghouse

They are all hiring at all levels (BSc, MSc, PhD)
Strong shortage of nuclear engineers!!!!!
Also in Switzerland…

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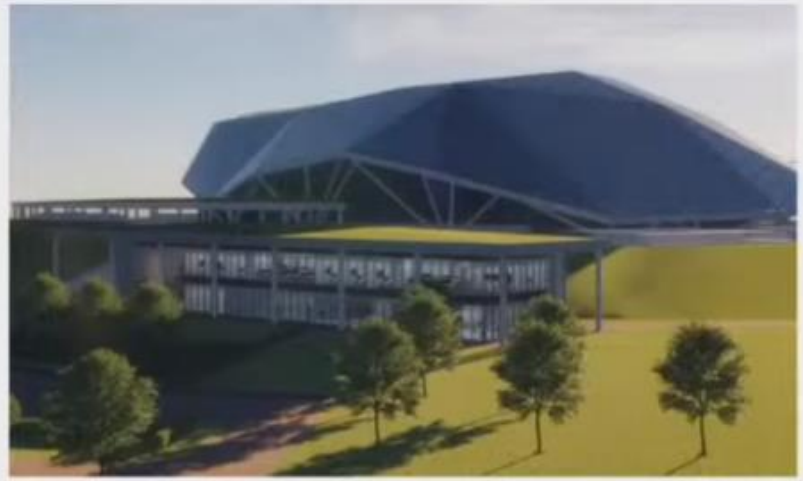
Why nuclear engineering?
FISSION REACTORS / NUCLEAR POWER

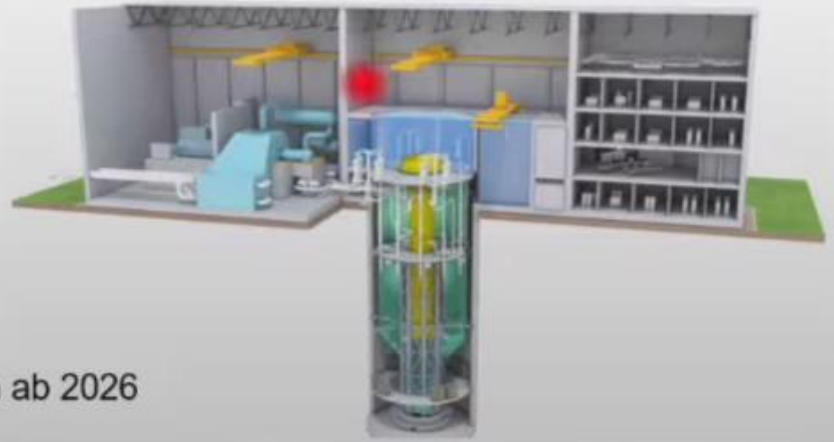
NuSCALE (6x77 MW), für Utah, ab 2027
LCOE: 65$/MWh, 3'600 $/kW installiert

NUWARD (EdF/Technicatome), 170 MW, ab 2030



UK SMR (Rolls Royce), 443 MW, ab 2030

SMART (Korea), 100 MW, Betrieb in Saudi-Arabien ab 2026

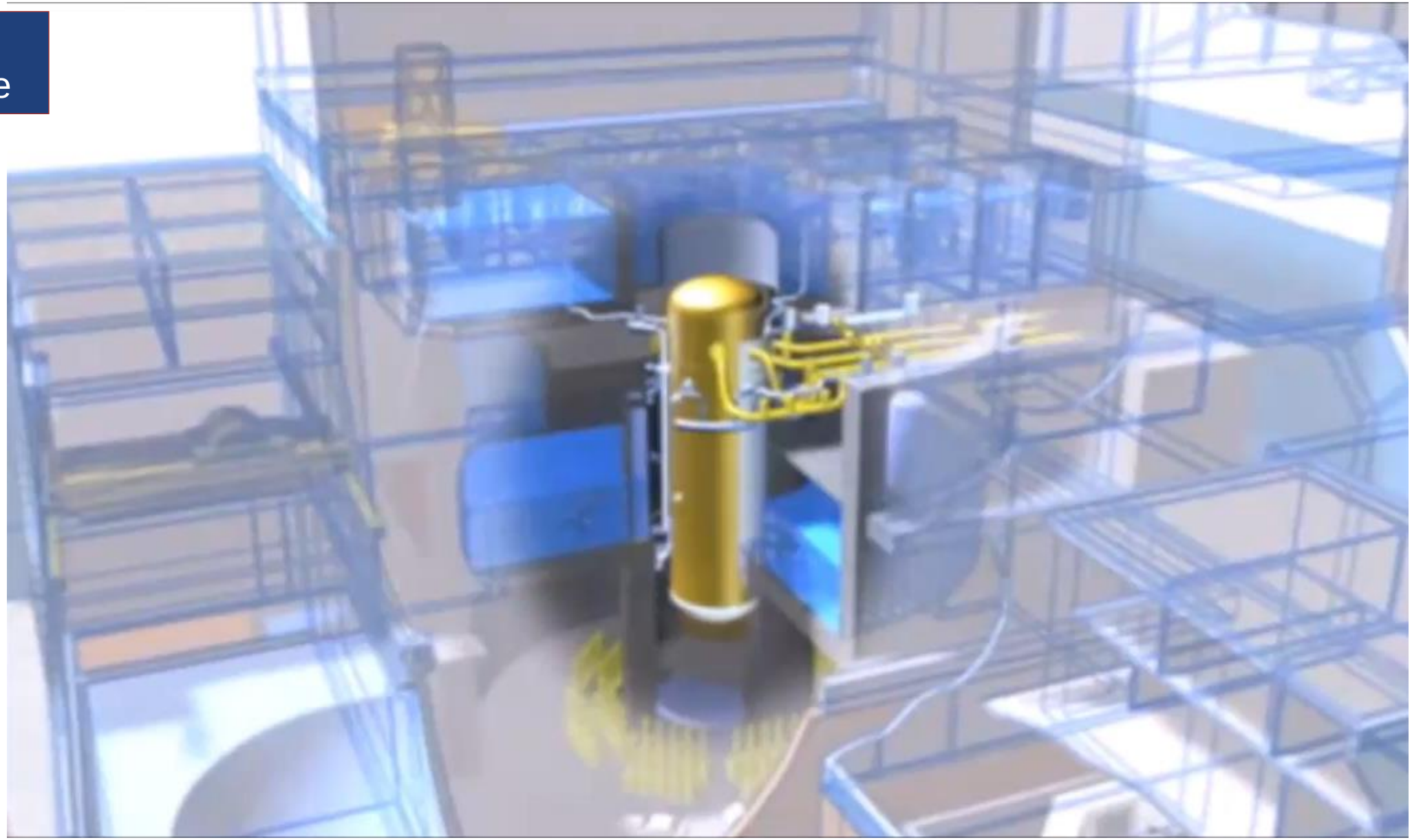


RITM-200 (Russia), Betrieb in Kirgistan ab 2028

BWRX-300 (GE/Hitachi) für Ontario Power, Betrieb ab 2028, mittelfristiges Preistarget: **2'250 $/kW**

Passive Sicherheitssysteme

General Electric ESBWR



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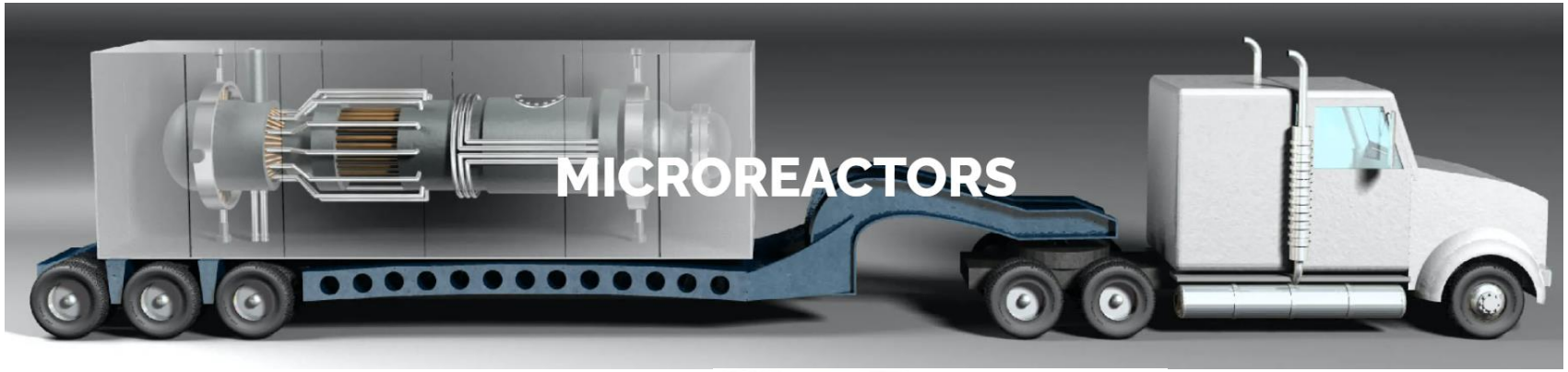
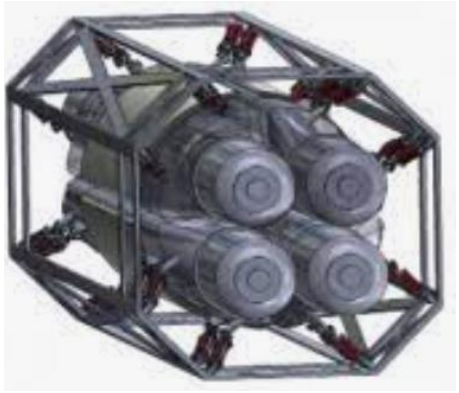
Why nuclear engineering?
MICROREACTORS FOR REMOTE AREAS



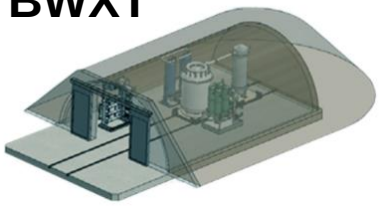
OKLO

Westinghouse

HOLOSGEN



BWXT



- Can operate as part of the electric grid, independently from the electric grid, or as part of a microgrid
- Fully factory built, designed to be portable
- Up to 20 MWth to generate electricity and provide heat for industrial applications
- Powering remote, rural communities relying on diesel generators; sources of zero-carbon energy for desalination, hydrogen production and other industries

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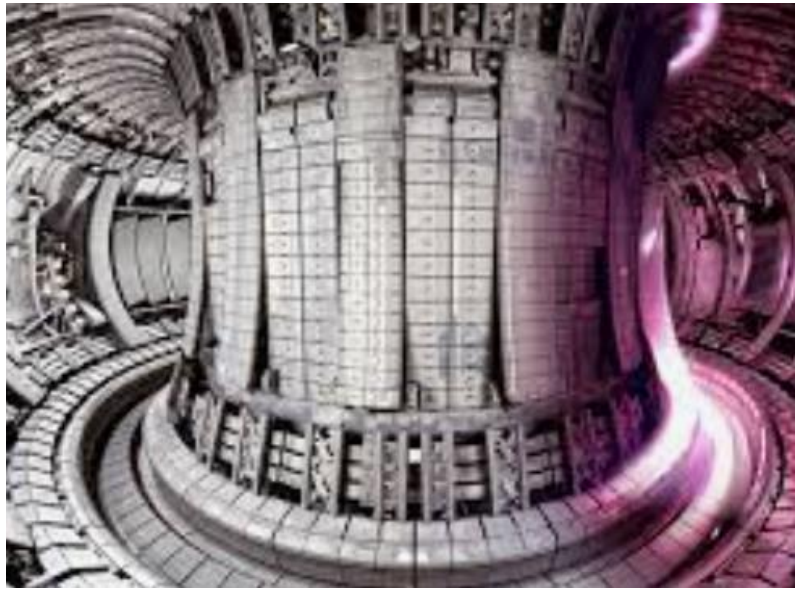
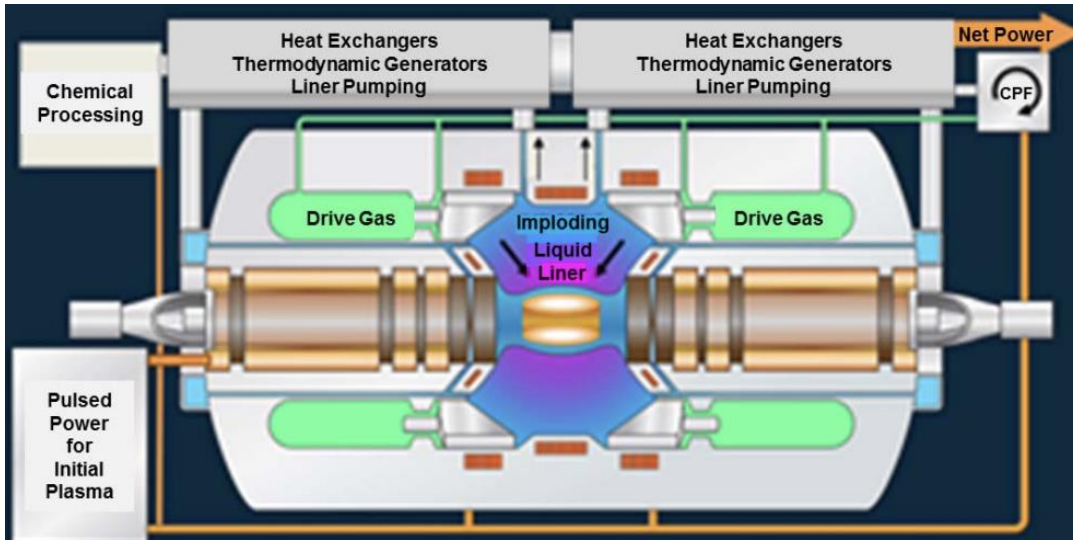
Why nuclear engineering?
FUSION POWER

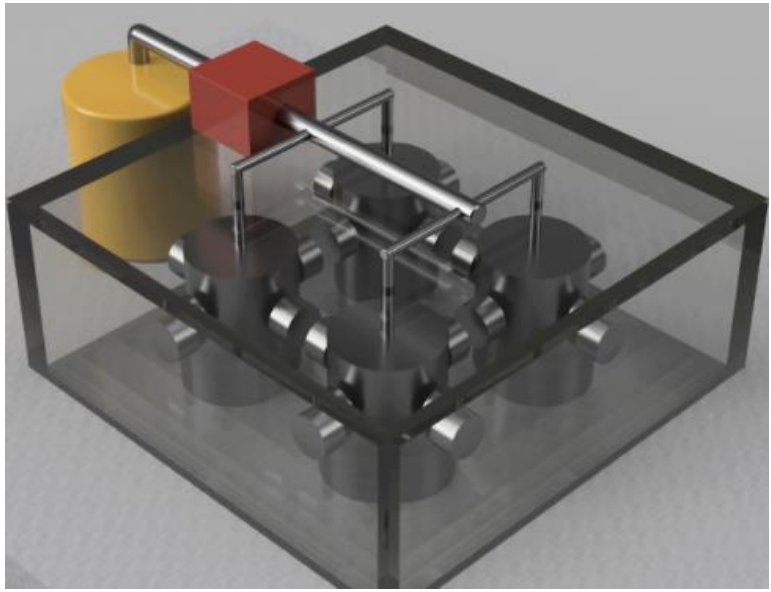
ITER / International effort



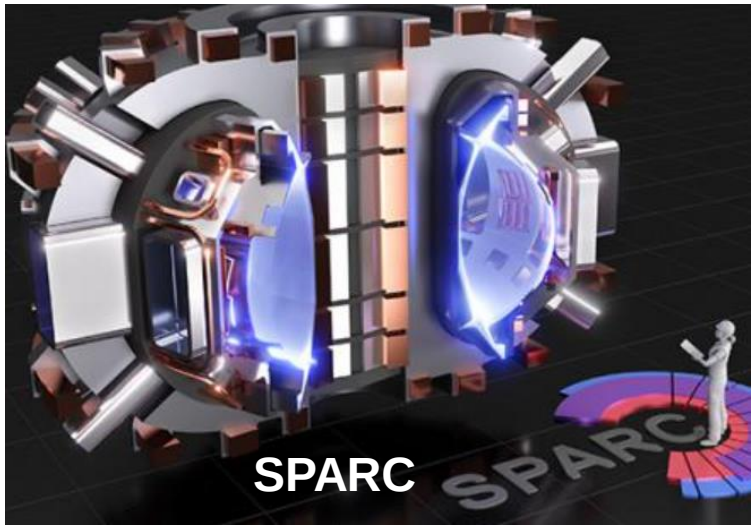
GENERAL FUSION



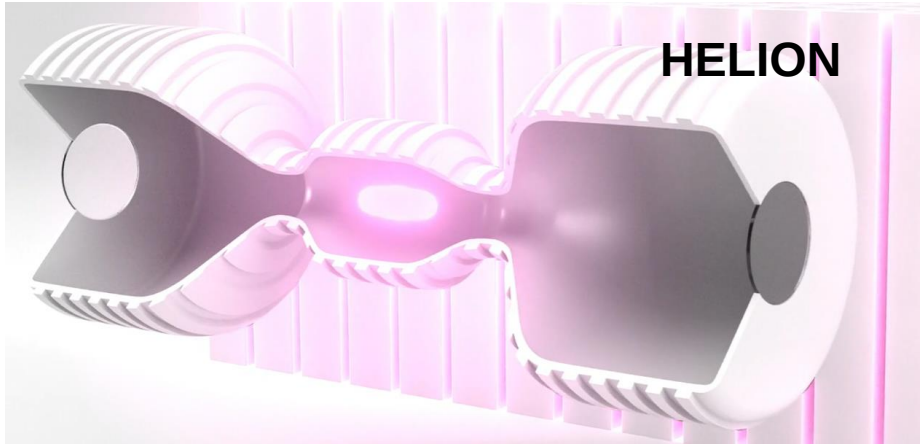
MIFGEN



SPARC



HELION



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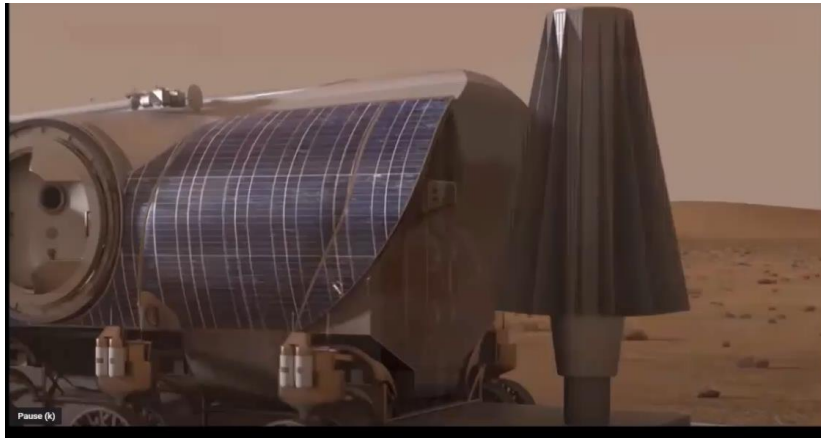
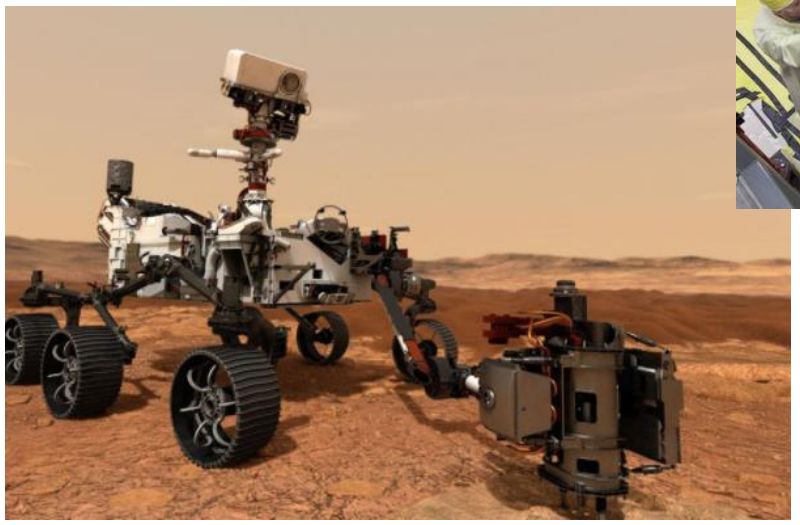
Why nuclear engineering?
SPACE EXPLORATION

spacepolicyonline.com

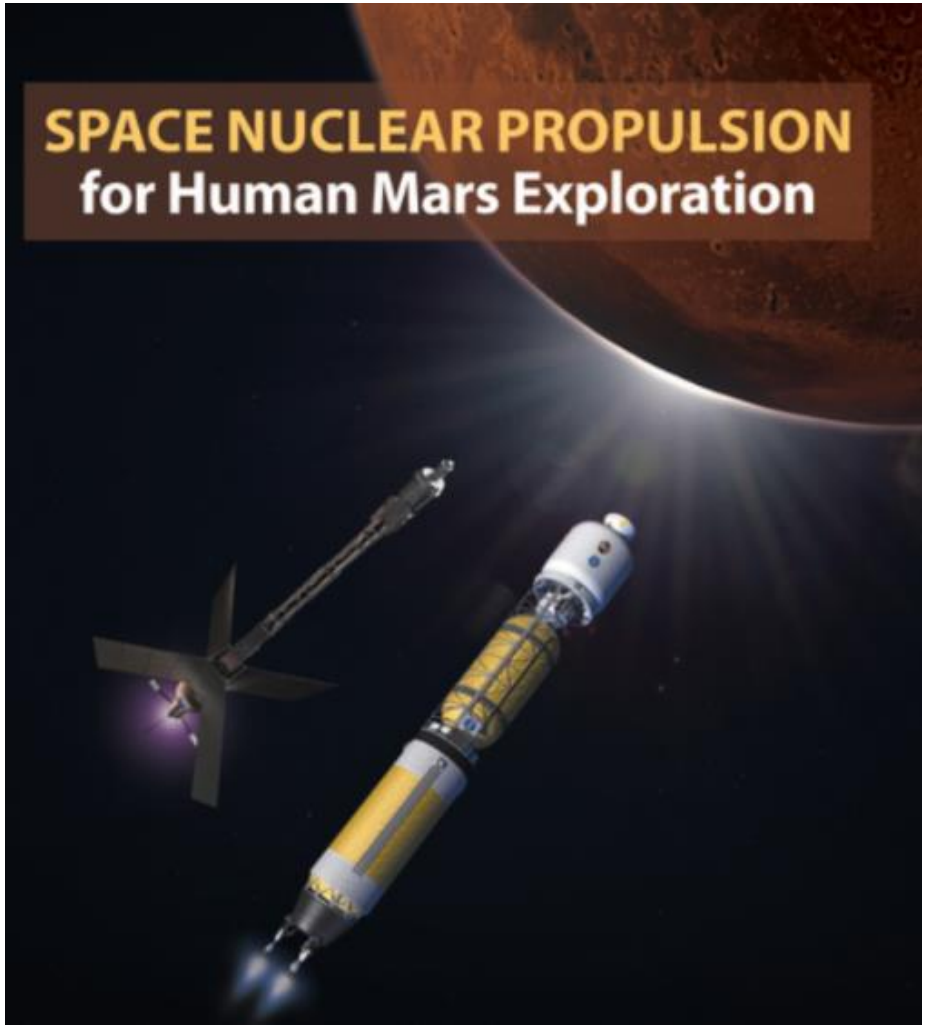
AGGRESSIVE NUCLEAR PROPULSION R&D EFFORT NEEDED TO SEND HUMANS TO MARS IN 2039





www.nasa.com

Nuclear Propulsion Could Help Get Humans to Mars Faster



Perseverance rover will run on nuclear power
RTG (**Radioisotope thermoelectric generator**)
will provide power for the rover for about 14 years

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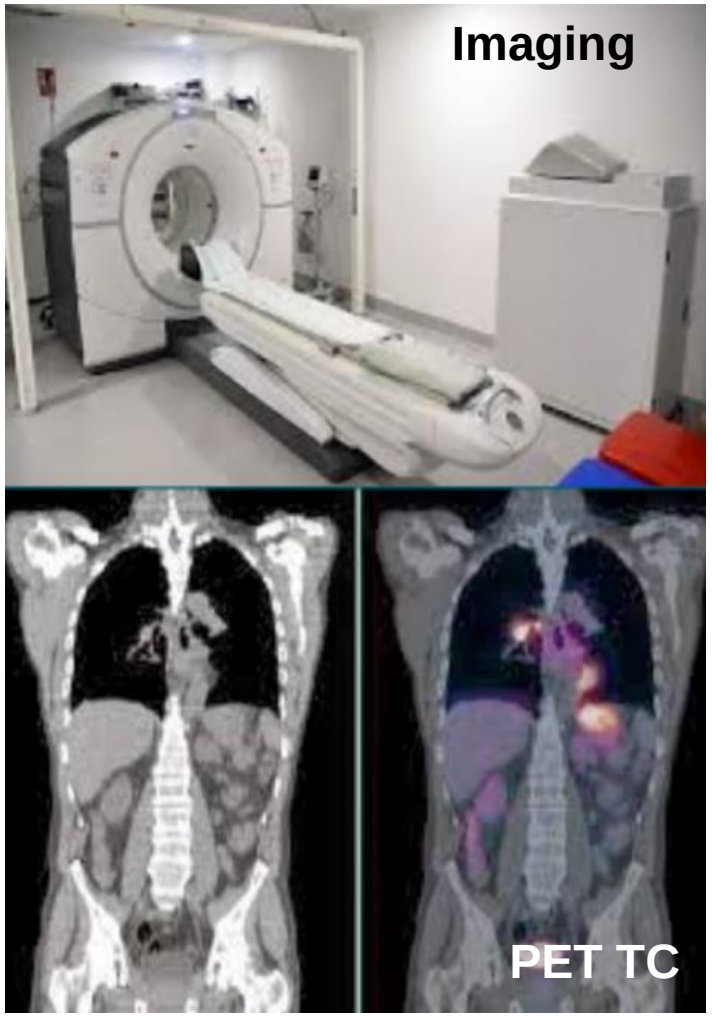
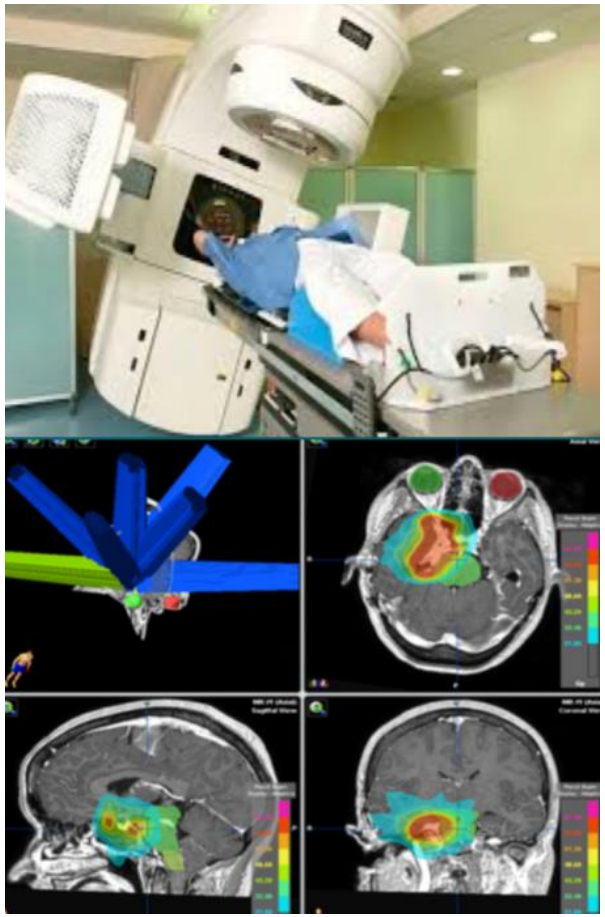
Why nuclear engineering?
NUCLEAR MEDICINE

Imaging



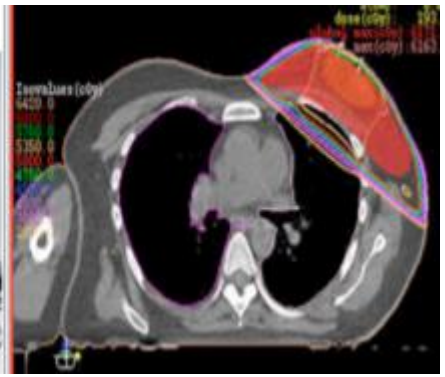
Radiotherapy



Nuclear engineers are experts in the interactions between **ionizing radiation** and matter, **nuclear imaging** instrumentation and **radiation dosimetry**.

- ❑ Therapeutic and diagnostic applications of radionuclides (except those used in sealed sources for therapeutic purposes)
- ❑ Equipment associated with their production, use, measurement and evaluation
- ❑ Quality of images resulting form their production and use
- ❑ Medical health physics associated with this subfield

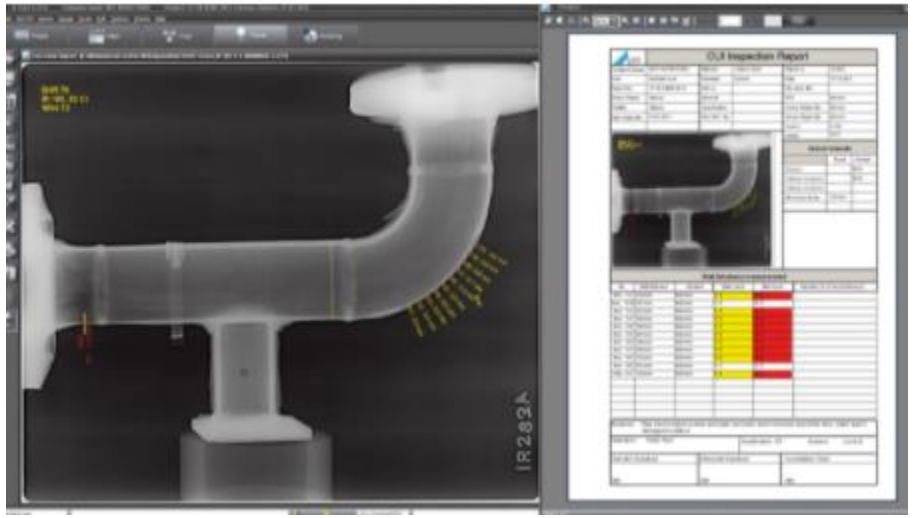
Irradiation plan design

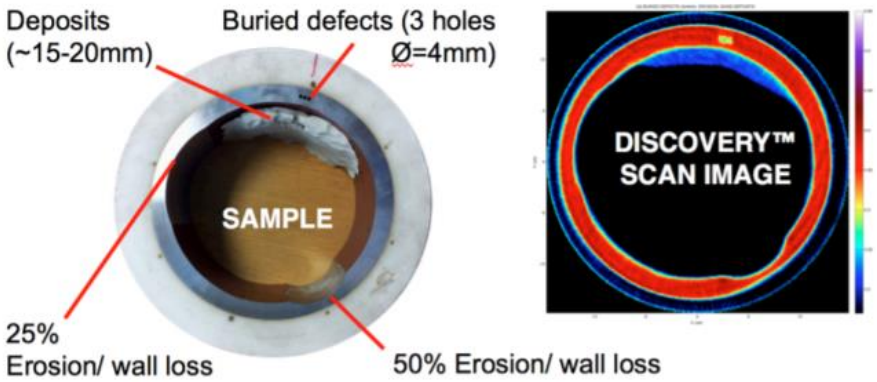


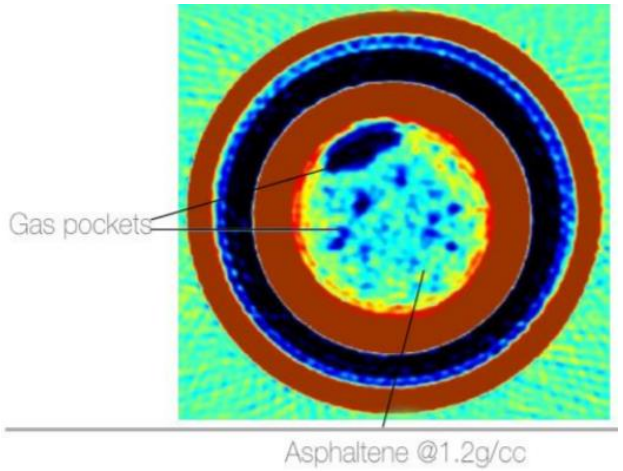
Why nuclear engineering?
INDUSTRIAL IMAGING

TOMOGRAPHIC IMAGING FOR UNDERWATER OIL/GAS PIPELINES

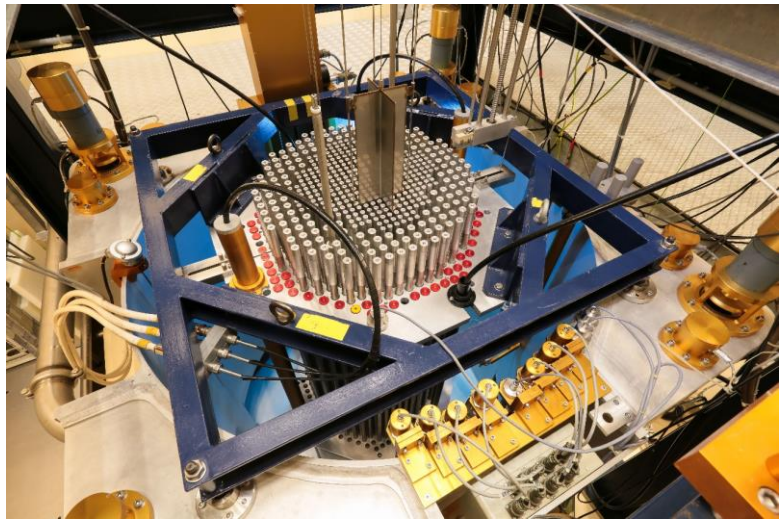
INDUSTRIAL RADIOGRAPHY



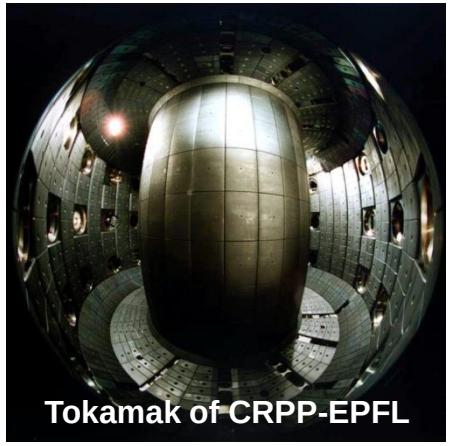




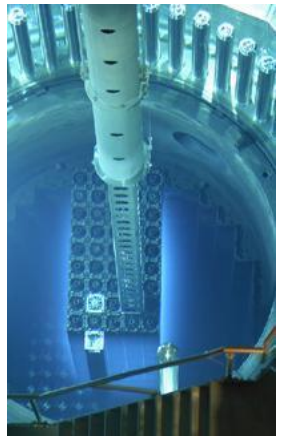
4 Semesters (120 credits)



- Fission technology as energy source (nuclear power plants)
- Neutronics
- Thermo-hydraulics and fluid-dynamics
- Nuclear safety, efficiency, environmental aspects
- Fusion reactors and plasma physics
- Nuclear Medicine, Research and industry beyond nuclear power plants
- Fuel cycle from Uranium mines to disposal
- Integration of nuclear power plants in the energy system, synergy with other energy technologies



Tokamak of CRPP-EPFL



The Swiss Nuclear Engineering Master Program

How is the Nuclear Engr. Master organized?

ETH zürich

EPFL

EPFL

1st Semester

ster

Elect

ENSI
Eidgenössisches Nuklearsicherheitsinspektorat

PAUL SCHERRER INSTITUT
PSI

nagra. aus verantwortung

Kernkraftwerk Gösgen

ZWILAG

BKW

axpo

apollo+ nuclear

ALPIQ

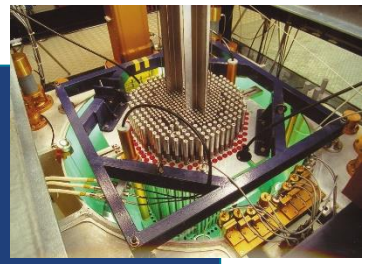
AFRY
ÅF PÖYRY

Kernkraftwerk Leibstadt

aktikumsplattform

The Swiss Nuclear Engineering Master Program

Organization



- **1st Semester, EPF Lausanne**

  Focus: Reactor physics, Neutron Transport, Radiation Biology and dosimetry, Plasma physics (fusion)

- **2nd Semester, ETH Zürich**

  Focus: Reactor technology, Nuclear fuel, Nuclear Safety, Thermo-hydraulics and fluid-dynamics, Material Science, Nuclear Medicine

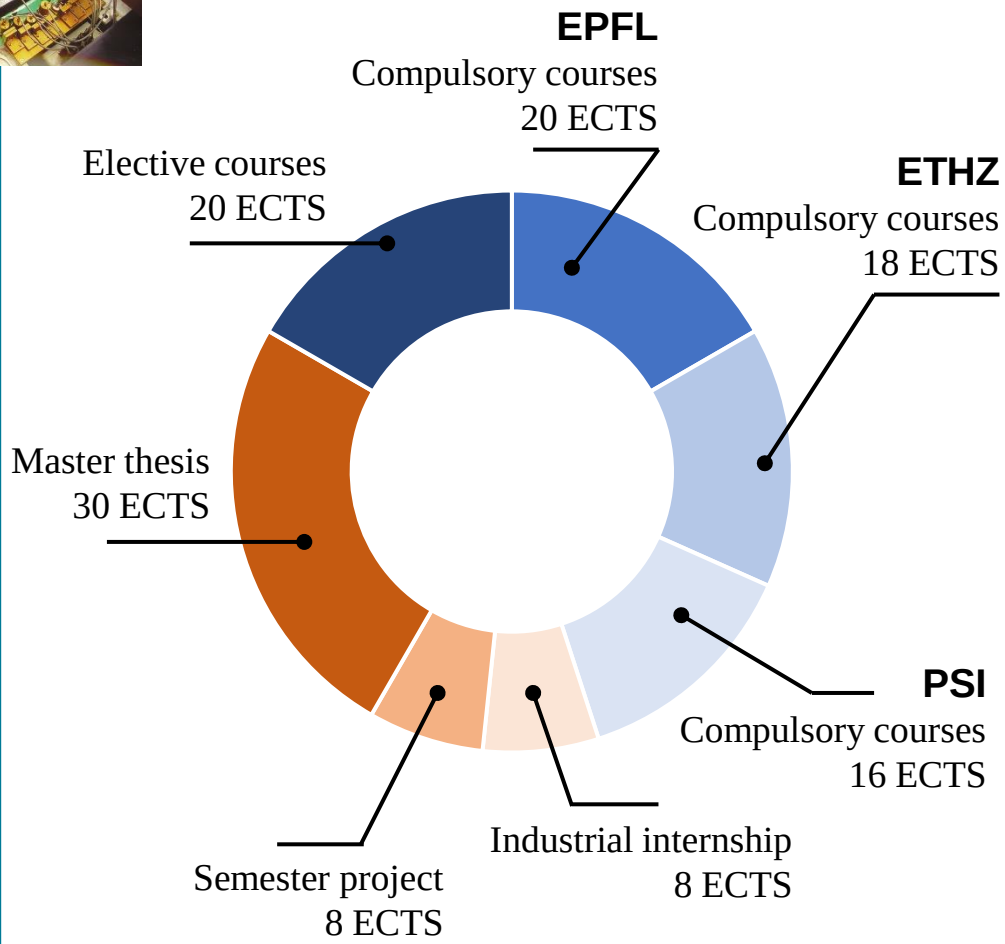
  Placeholder for 3 months industrial internship

- **3rd Semester, Paul Scherrer Institut / ETH Zürich**

  Focus: Research (Semester project), Deepening in Material science, Sever accidents, Decomissioning and waste disposal

- **4th Semester, PSI / ETH Zürich / EPF Lausanne / Extern**

  Focus: Research => Master thesis



The Swiss Nuclear Engineering Master Program

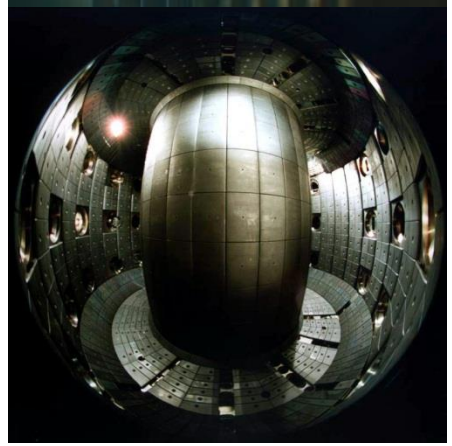
SPECIALIZATIONS

- Medical Physics
- Plasma physics and Fusion Reactors
- Fission reactors and NPPs
  - Thermal-hydraulics
  - Neutronics
- Energy Systems
- Materials
- Particle Physics and Detection
- Computational Methods

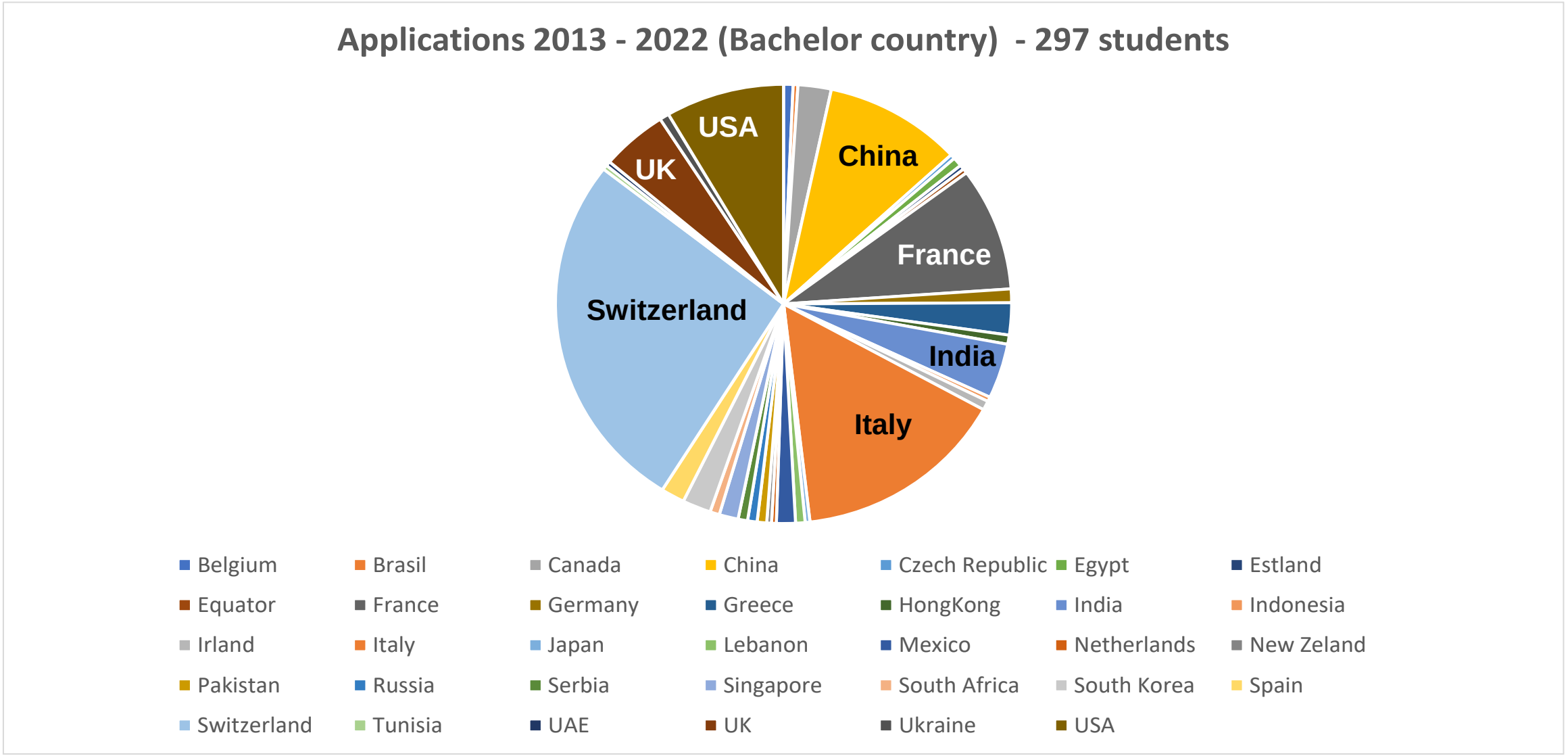
Why Nuclear Engineering?

Motivations

- ❑ More interesting, versatile and innovative than some people think!
- ❑ Very high energy density of nuclear fuel – Advantage (great effect from small amounts of substance)
- ❑ Nuclear energy supports the energy transition as a powerful, environmentally friendly competitor to coal, oil and gas
- ❑ Reduced storage requirements for renewables thanks to the ability to plan generation
- ❑ Nuclear methods open up a multitude of non-invasive measurement and diagnostic procedures in technology and medicine
- ❑ Strong therapy option for the most serious illnesses
- ❑ Enjoy internationality of the nuclear community and your study mates!
- ❑ High level of multidisciplinarity opens a broad range of carrier possibilities



Where are the students who apply come from (country of Bachelor degree)



International Collaborations

Massachusetts Institute of Technology

INIT

Universität Stuttgart

UNIVERSITY OF MICHIGAN

Texas A&M

PennState

TECHNISCHE UNIVERSITÄT DRESDEN

KTH VETENSKAP OCH KONST

TU Delft

SEOUL NATIONAL UNIVERSITY

uni.lu UNIVERSITÉ DU LUXEMBOURG

Budapesti Műszaki és Gazdaságtudományi Egyetem (BME)

LUT Lappeenranta University of Technology

KURRI Kyoto University Research Reactor Institute

TEL AVIV UNIVERSITY אוניברסיטת תל אביב

東京工業大学 Tokyo Institute of Technology

Rensselaer

KAERI Korea Atomic Energy Research Institute

HZDR

GRS Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH

Los Alamos NATIONAL LABORATORY

OAK RIDGE National Laboratory

Argonne NATIONAL LABORATORY

INL

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Director of Nuclear Engineering MSc Program
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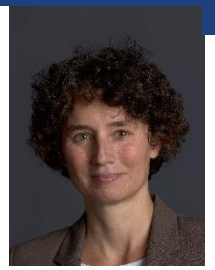
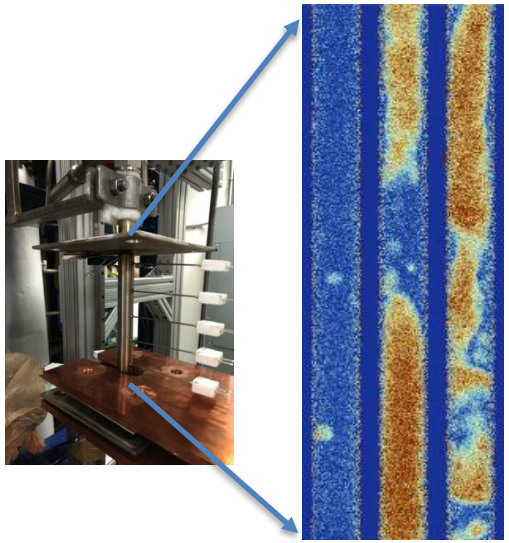
Laboratory of Nuclear Systems and Multiphase Flows
ETH-Zurich
ML K 13
Sonneggstrasse 3
8092 Zürich

Nucleary Systems and Multiphase Flows Lab

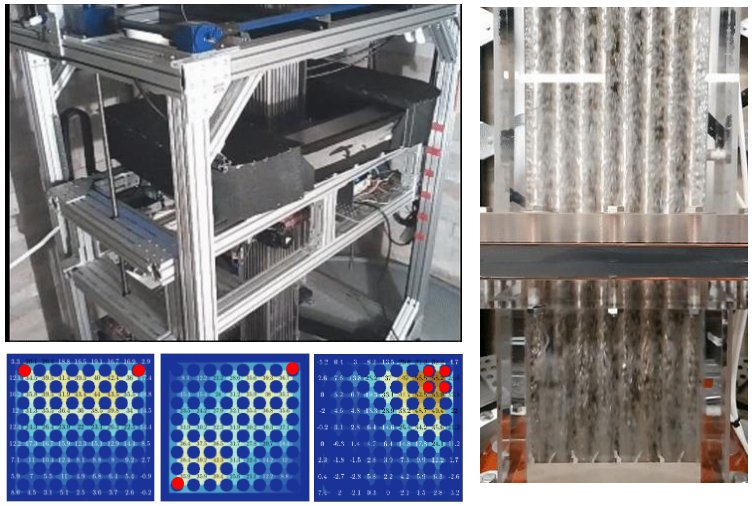
High-resolution experiments for single- and multiphase flows, advanced instrumentation, computational fluid-dynamics.



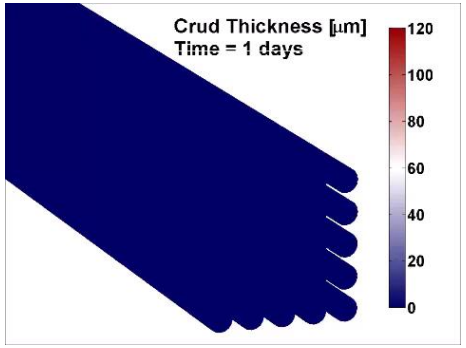
Prof. Annalisa Manera

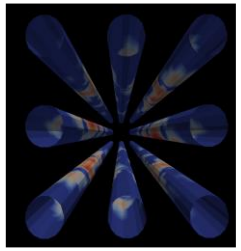


Xray radiography of Steam-water flow at 75 bar

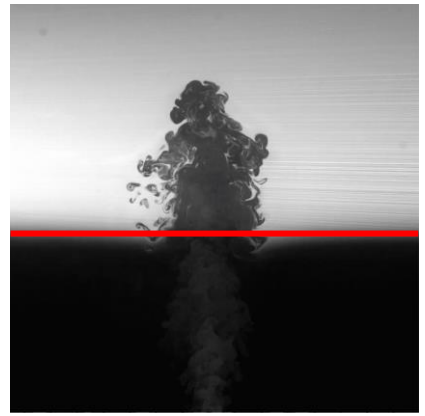


Void-fraction distribution in a fuel bundle using γ-tomography





CFD/chemistry multiphysics simulations of CRUD deposition on nuclear fuel



Buoyant jets in stratified environments using PIV + Refractive-index matching

Applications: nuclear power plants (LWRs, microreactors, advanced reactors) fluid-dynamics processes, imaging