THE HFR AND PALLAS ERA. DUTCH RESEARCH INFRASTRUCTURE

R.P.C. SCHRAM, S. KNOL, T.M.H.E. TIELENS, G. J. L.M. de HAAS
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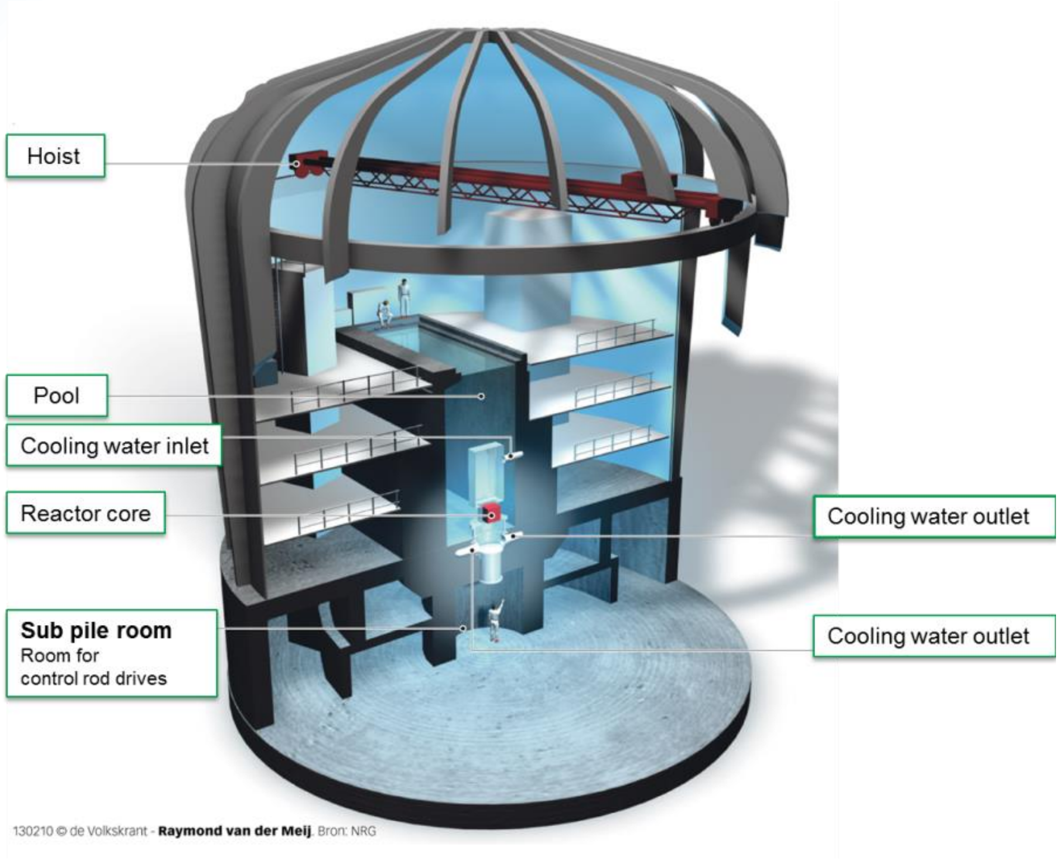
Sustainable Nuclear Energy Technology Platform

EU DuC = N

High Flux Reactor



- High flux
- 45 MW thermal power
- Stable and constant flux profile in each irradiation position
- Main applications
  - Isotope production
  - Nuclear energy irradiation services
  - R&D
- 31 operation days per irradiation cycle
- 260-265 full power days per year

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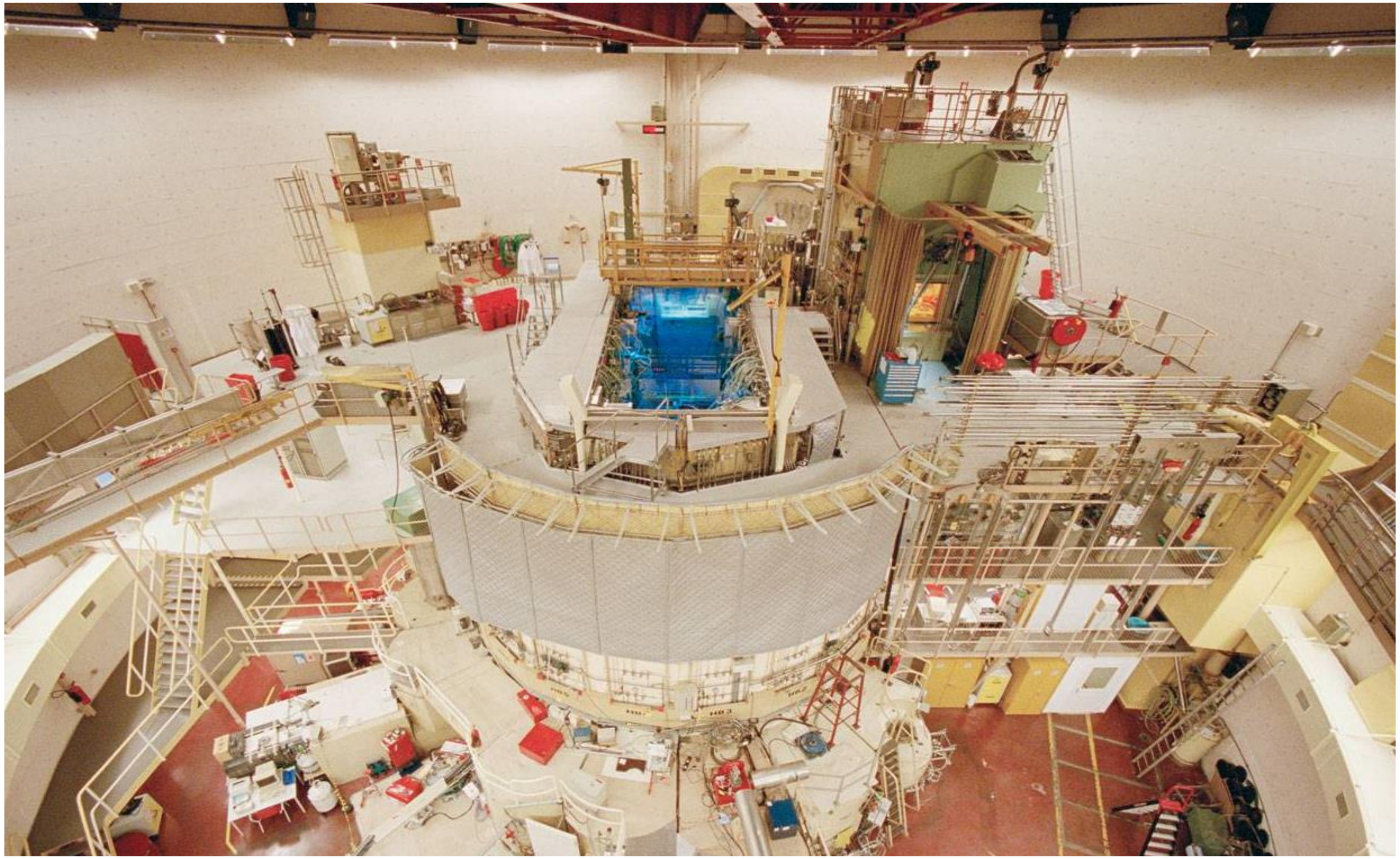
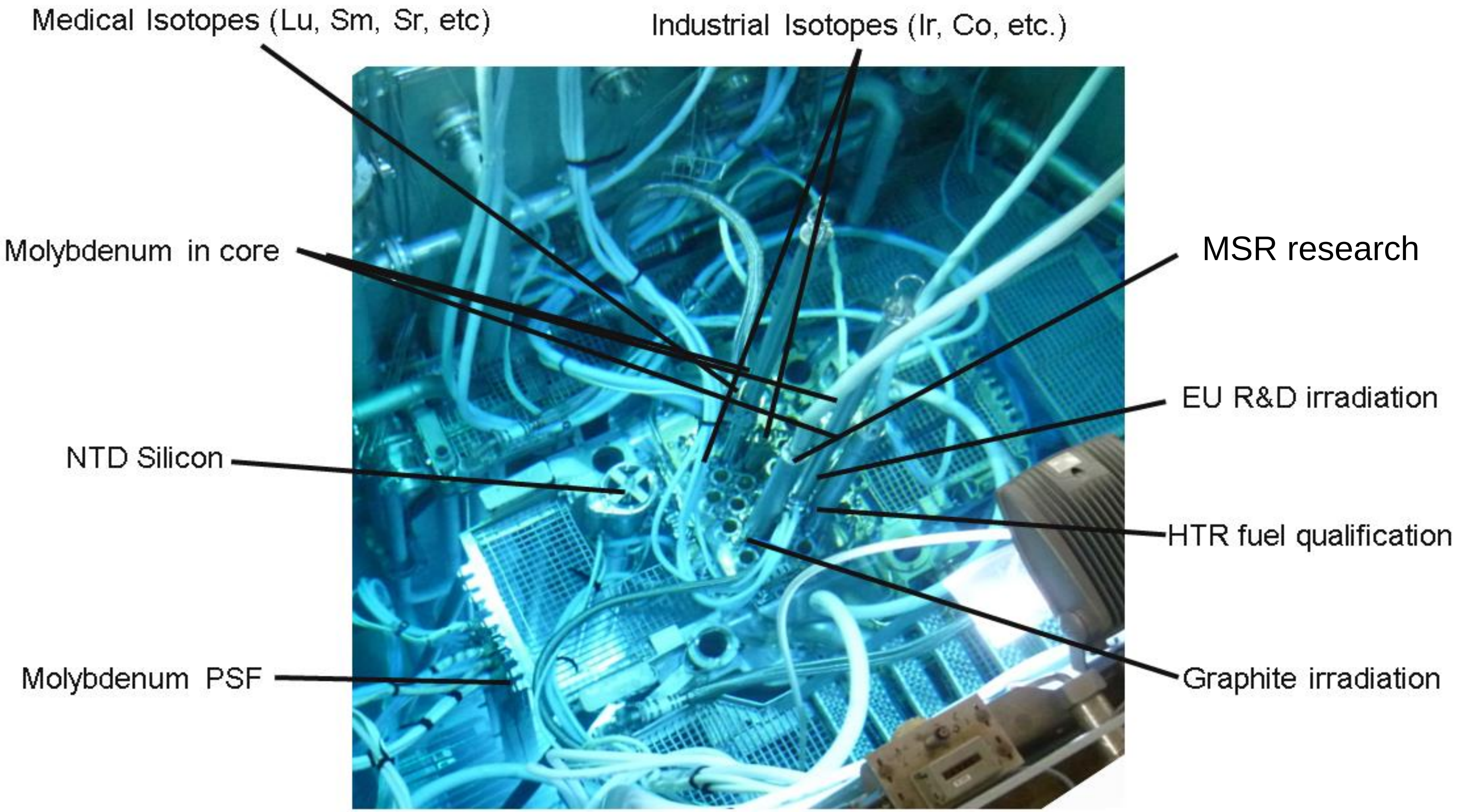
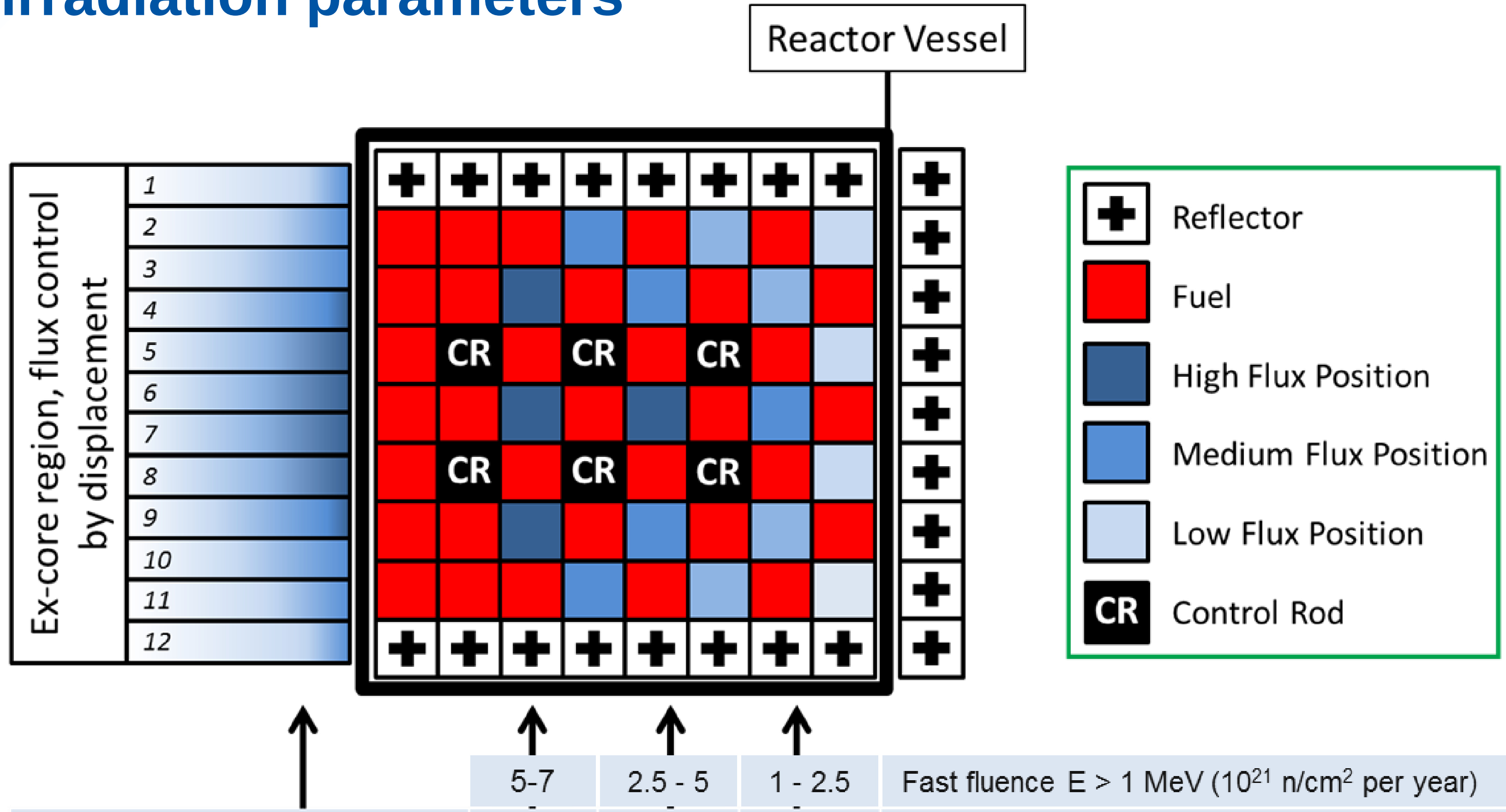
HFR – tank in pool type reactor



HFR – multipurpose reactor



HFR – irradiation parameters



	5-7	2.5 - 5	1 - 2.5	Fast fluence E > 1 MeV (10^{21} n/cm^2 per year)
0-3, location dependent	5-8	3-5	1-3	Material DPA rate (DPA/year)
0-700, displacement controlled	n/a	500-700	300-400	Linear heat rate (W/cm fresh LWR fuel)

The stable and constant flux profile in each irradiation position is a unique HFR feature

HFR – Large experience base: past 20 years material irradiations

Experiment Name	Application Area
• **SUMO-1 to -12:**	**9Cr steels & joints for fission/fusion**
• **STROBO-1 to -7:**	**Stress-relaxation of bolt materials**
• CIWI:	BWR core shroud welds
• **SOSIA-1 to -5:**	**Creep & creep fatigue of 9Cr steels**
• **PARIDE 1 and 2**	**ITER FW and divertor materials**
• **SPICE 1 and 2**	**Irradiation of RAFM steels**
• IBIS:	Structural material in lead-bismuth
• INNOGRAPH-1A, -1B, -2A, -2B:	HTR graphite irradiations
• EXTREMAT-1, -2:	High temperature advanced materials for Fusion and fission
• BODEX:	Transmutation targets
• **PRIMUS**	**ITER first wall components**
• LYRA-1 to -10:	RPV steel irradiations
• PYCASSO-I, -II:	HTR surrogate particles
• **HICU:**	**Breeder material for fusion**
• **EXOTIC 1 to 9:**	**Solid tritium breeder materials**
• **LIBRETTO 1 to 5:**	**Liquid tritium breeder materials**
• **HIDOBE-1, -2:**	**High dose beryllium irradiation**
• **PebbleBedAssembly:**	**Integrated fusion breeding blanket experiment**
• **CORONIS 1+2**	**Copper Chrome Zirconium mechanical properties after irradiation**
• ENICKMA	Molten salt reactor; embrittlement of Ni-based alloys

fusion
fission

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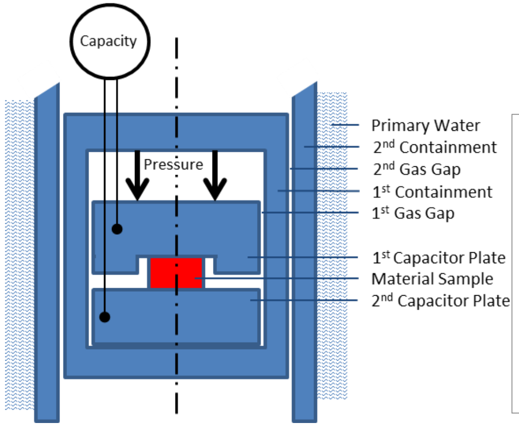
HFR – Large experience base: past 20 years material irradiations

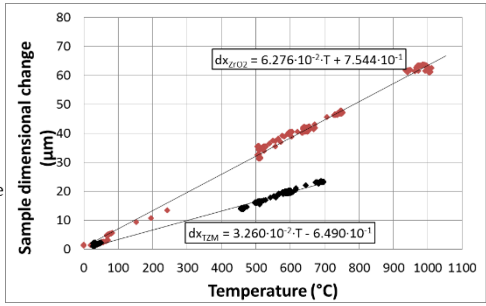
Experiment	Application Area
OTTO:	Once through then out Pu-transmutation
THORIUM CYCLE:	Thorium fuel experiment
EFFTRA-T4+T4bis+T4ter:	Transmutation experiments under EFFTRA
HELIOS:	Minor actinide fuels and targets
CONFIRM:	Nitride fuels for fast reactors
FUJI:	FBR innovative fuels, commercial
MARIOS:	SFR minor actinide fuel irradiation
INET:	HTR-PM fuel qualification, commercial
HFR-EU1+HFREU1bis:	HTR pebble irradiations
SMART:	Nitride for advanced fuels
TRABANT:	Fast reactor annular MOX fuel irradiation
SPHERE:	Minor actinide bearing sphere-pac fuel
MARINE:	Fast reactor minor actinide bearing fuel
SALIENT-01	Molten salt reactor (fuelled salt, Th)
Fuel Creep	On-line measuremt of fuel creep

HFR – example – fuel creep

Design goals

- Sample temperatures in the range of 400-1300°C
- Online control of sample stress in the range of 0-100 MPa
- Multiple samples to be individually measured simultaneously
- Online displacement measurement with an accuracy of <<1 µm





Selected method: capacity measurements with parallel plates:

$$C = k\,\varepsilon_o\,(A / d)$$

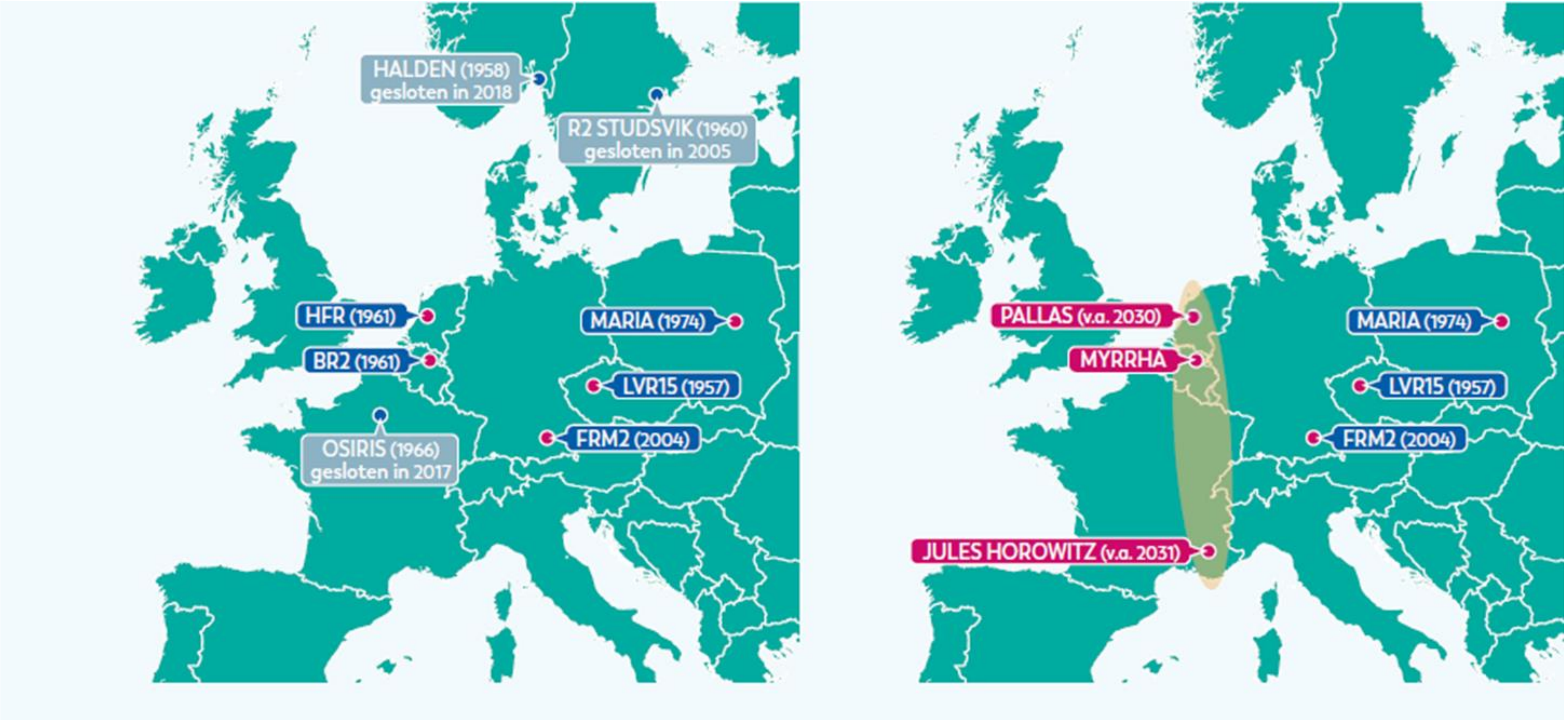
Proof of principle

- Test showed displacement accuracy <100 nm
- Dimensional measurement as a function of temperature, the CTE can be determined, showing excellent reproducibility

Irradiation parameters:

- Ready for fuel (UO2, MOX, ATF, etc.)
- Accommodates 6 samples

Irradiation infrastructure evolution in Europe



Strengthening of European Irradiation infrasructure is vital.

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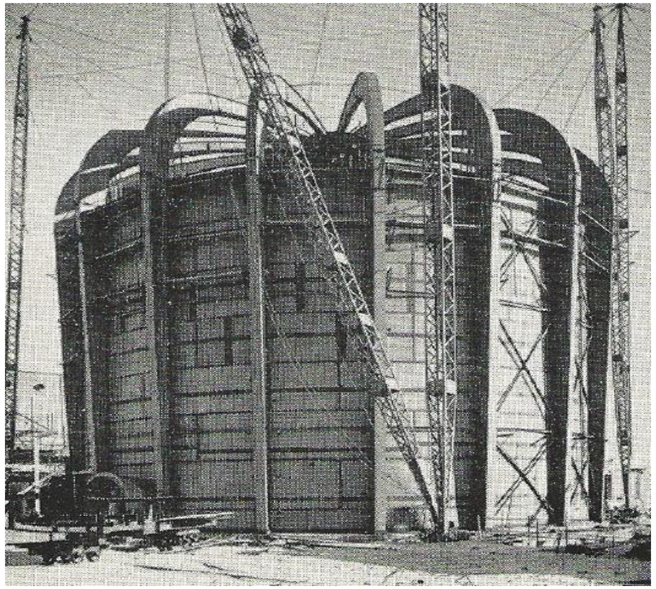
Irradiation infrastructure evolution in Petten, the Netherlands

60 Years High Flux Reactor



- Designed for research
- Construction 1957-1960
- Operational since 1961

PALLAS reactor

- Designed for medical isotopes and research
- Project started in 2013
- Start operation target 2030

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Research infrastructure in Petten - Existing

HIGH FLUX REACTOR

HOT CELL LABORATORIES

MOLYBDENUM PRODUCTION FACILITY

DECONTAMINATION & WASTE TREATMENT

ACTINIDE & RADIOLOGICAL LABORATORIES

WORLDWIDE LOGISTICS

Research infrastructure in Petten – New Build Programme

	Existing	New Build Programme
Irradiation	 High Flux Reactor	 PALLAS-reactor
Innovation	 Laboratoria	 FIELD-LAB
Processing	 Molybdenum Proces Faciliteit	 Nuclear Health Centre

1. Irradiation – research & medical isotopes

2. Hot Cell Laboratories/PIE, radiological labs, FIELD-LAB (medical research)

3. Processing facilities (medical only)

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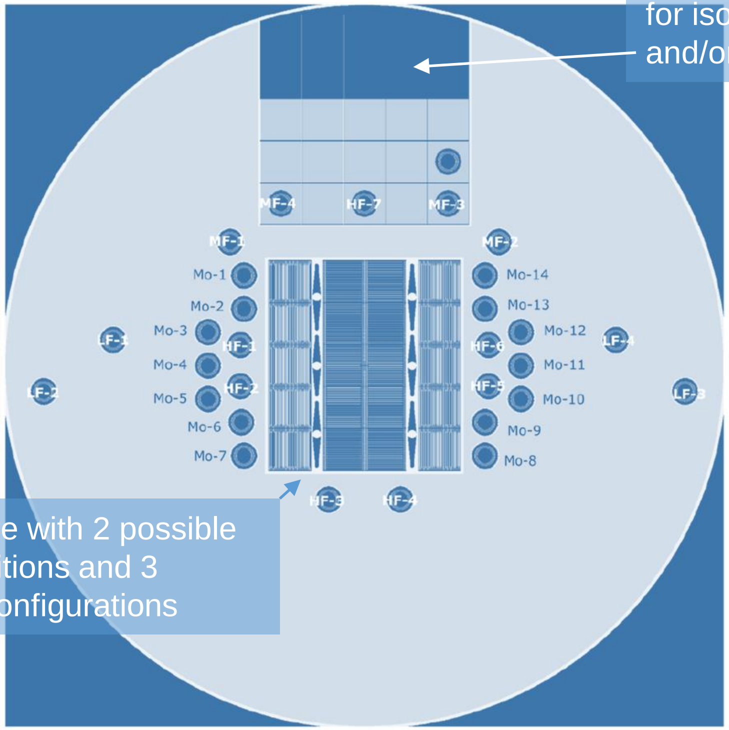
Research possibilities Petten

- **Capsule irradiations, inert gas or sodium filled**
  - Rodlets, fuel discs, cladding tubes, material samples
- **Extensive experience with instrumentation**
  - thermocouples, Halden LVDT-based, SPNDs, activation monitors, capacitive dimension change, off-gas monitoring, …
- **(Re)fabrication of rods in collaboration**
  - Refabrication of rods elsewhere, irradiation in HFR
- **Extensive on-site PIE**
  - Non-destructive examination (visual, profile, gamma, Eddy current)
  - Extensive mechanical testing equipment
  - Rod puncture + mass spectrometry for fission gas analysis
  - Light and electron microscopy in alpha-tight hot cell (SEM/EDS/WDS/EBSD)
- **Experience with international fuel transports**

PALLAS reactor

Core design (illustrative)

Beryllium grid adaptable for isotope production and/or experimental loop



Flexible core with 2 possible in-core positions and 3 operating configurations

- 25 MW power
- 300 Full Power Days per year
- Research facilities
  - Capsule-based experiments in regular positions
  - Two in-core positions for fast flux
  - Provisions for simple loop system
- Research profile
  - Fuel qualifications
  - Advanced SMR development

PALLAS – research capabilities

Pallas research
- Support to NPP
- Development of GenIV

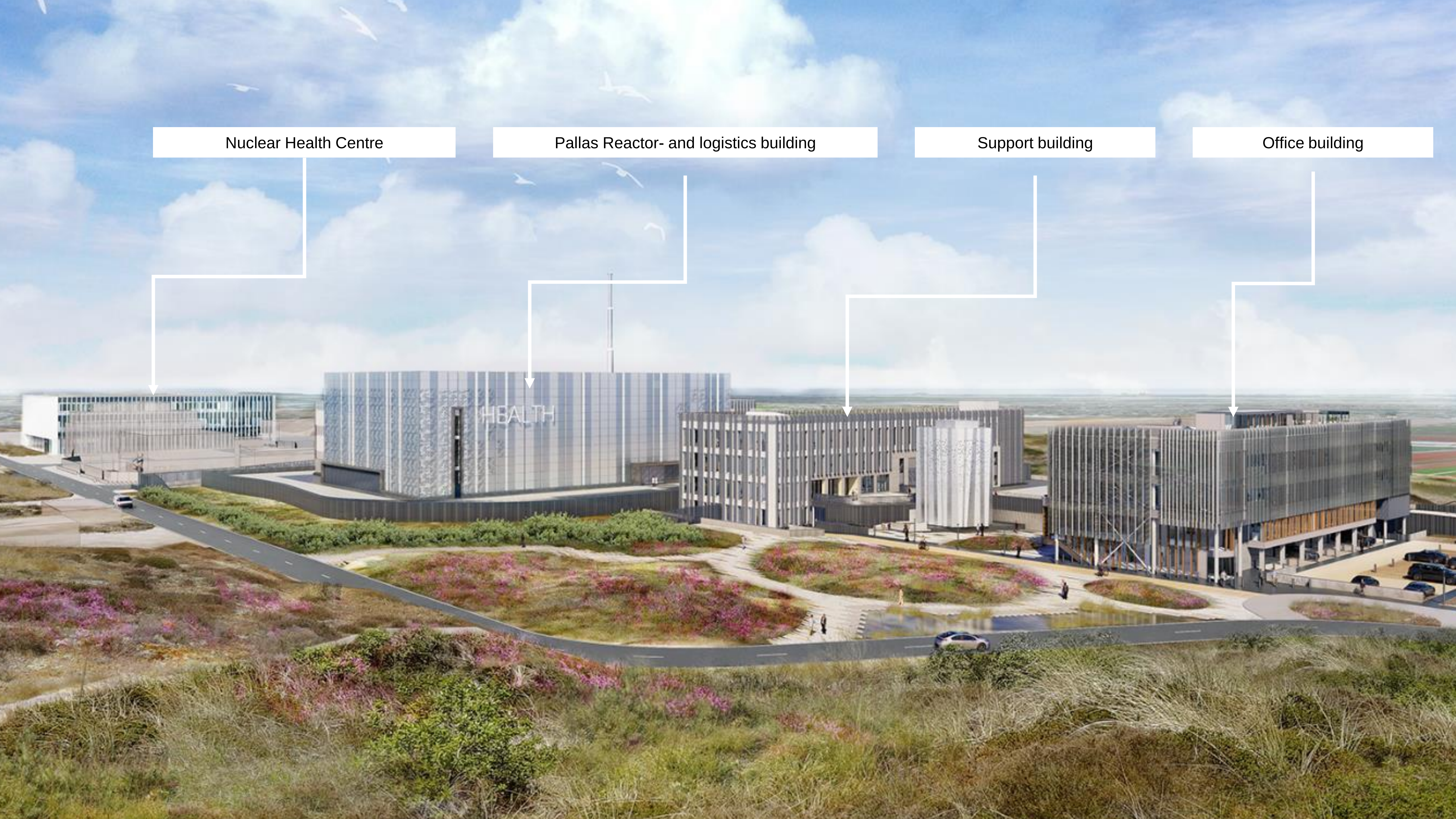
- Research for **Gen-IV reactor designs**: in particular for deployment as SMR
- **Basic testing** a of fundamental **fuels** and **materials** behaviour
- Testing prototypic conditions, **different coolant mediums** Gen-IV reactor concepts, not being high temperature and pressure water environment.
- **Low-pressure capsule-based tests** with e.g. high temperature gas or molten salt environment suitable for testing Gen-IV fuels, e.g., thorium molten salt fuels
- The potential introduction of replacement fuels for conventional Gen III/III+ reactors, i.e., **ATF**.

- **Gen-IV structural materials**, e.g., graphite, can also be tested in capsules, but would require some additional test condition upgrades to achieve higher fast flux.
- More sophisticated analytical experiments, fuel/mat creep, instrumented fuel stack (**test condition upgrades**)

PALLAS reactor now entering detailed design phase

Existing situation


New situation
Nuclear Health Centre
PALLAS-reactor & logistics
Support building
Offices


Nuclear Health Centre
Pallas Reactor- and logistics building
Support building
Office building
HEALTH

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