



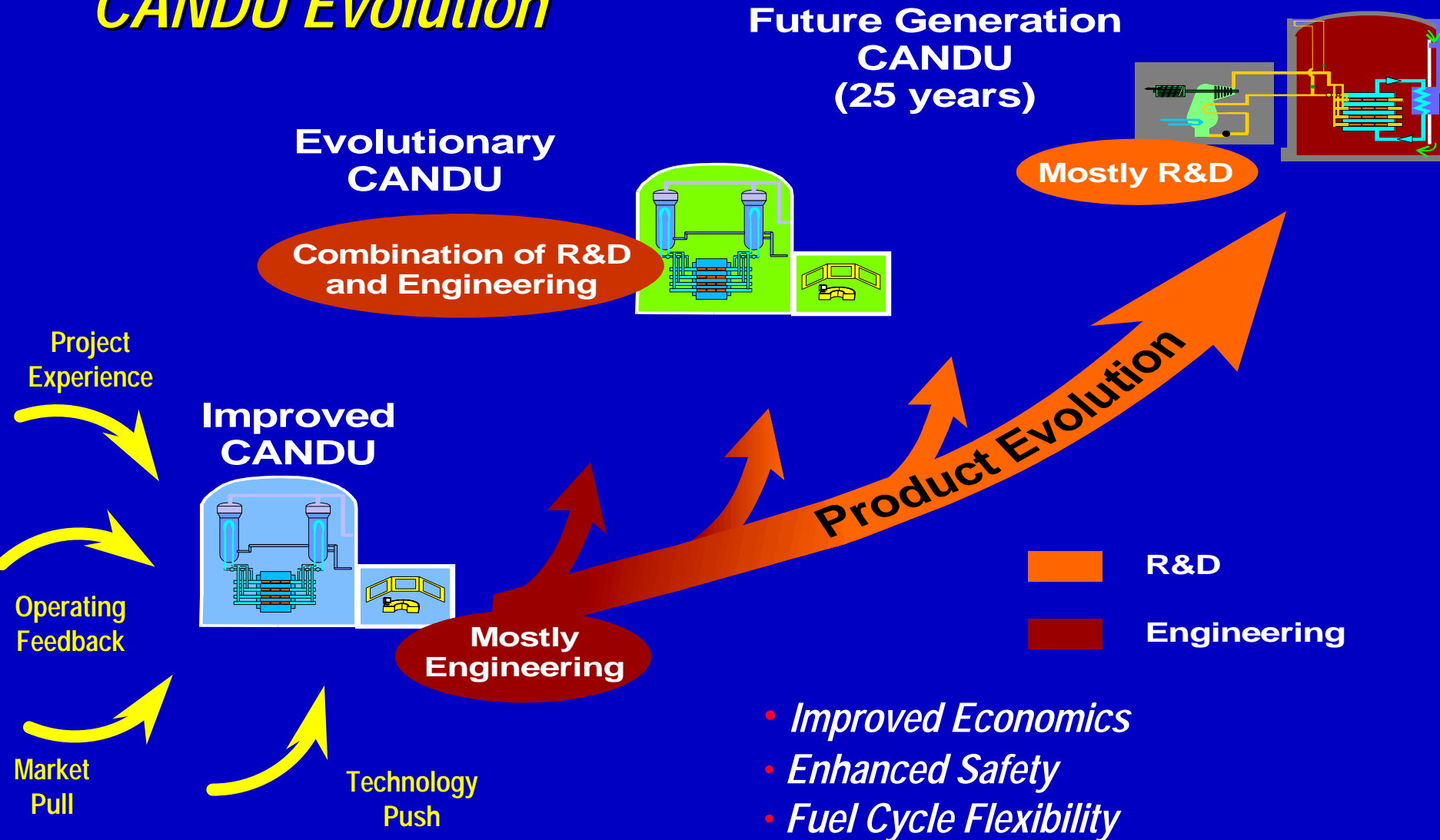
CANDU Safety

#18 - Safety Research and Development

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Director
Safety & Licensing

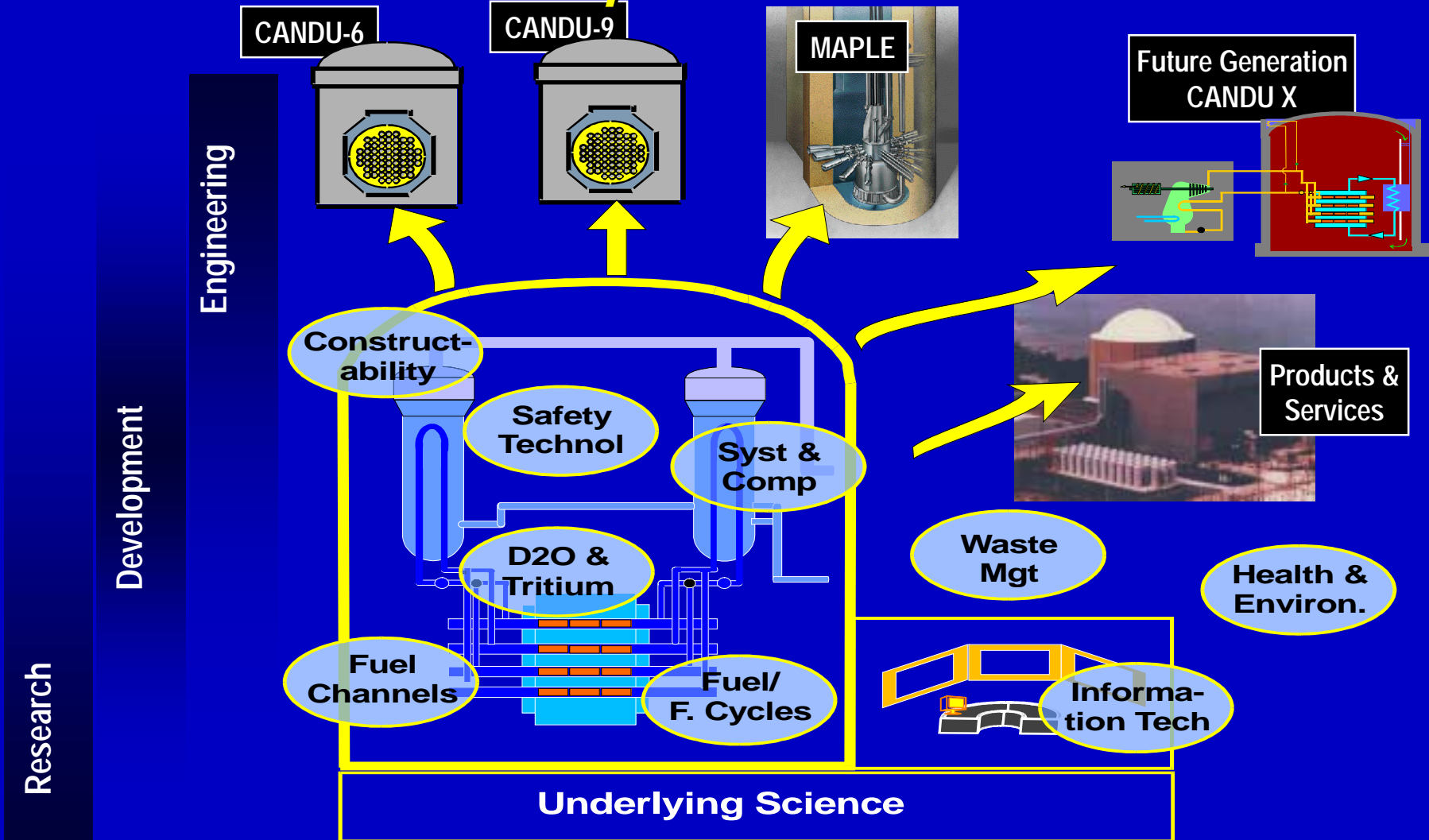


CANDU Evolution





Research & Development





Safety R&D Goals

- λ **Resolve AECB Generic Action Items**
- λ **Reduce releases during normal operation**
- λ **Improve protection against higher frequency events**
- λ **Improve system response to design basis events**
- λ **Contain severe core damage consequences**
- λ **Validate and improve safety analysis codes**
- λ **Develop passive and advanced safety concepts**



Focus

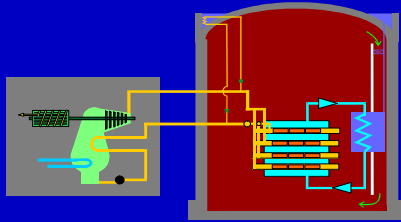
- λ safety R&D in Canada is done by the industry (AECL and the 3 domestic nuclear utilities)
- λ AECB does a small amount of confirmatory R&D and reviews & critiques the industry programme
- λ R&D split into 2 main areas:
 - unique aspects of CANDU
 - λ physics, fuel, fuel channels, heavy water, moderator
 - λ emphasis on realistic models
 - generic nuclear world-class R&D in areas of strength
 - λ hydrogen ignition and detonation, iodine behaviour



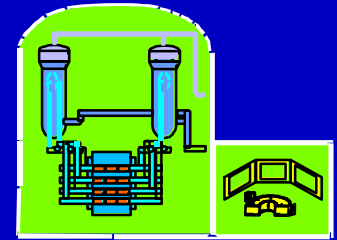
Linkage of Safety Research to Plant Licensing



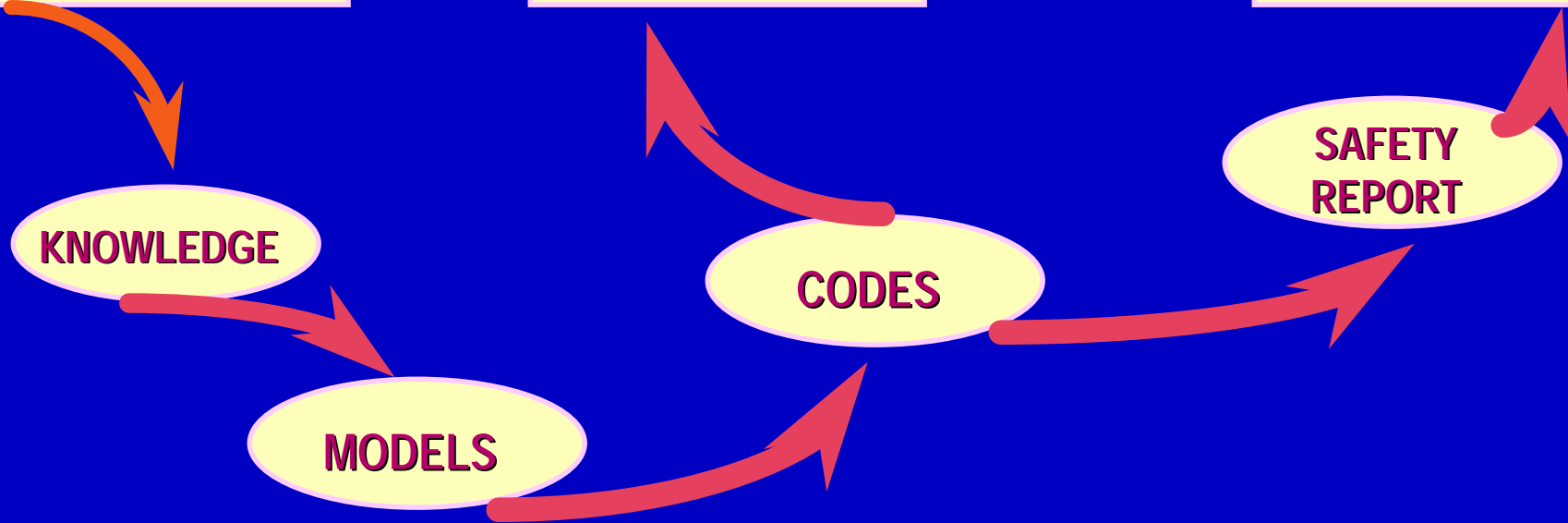
SAFETY R&D



ADVANCED DESIGNS



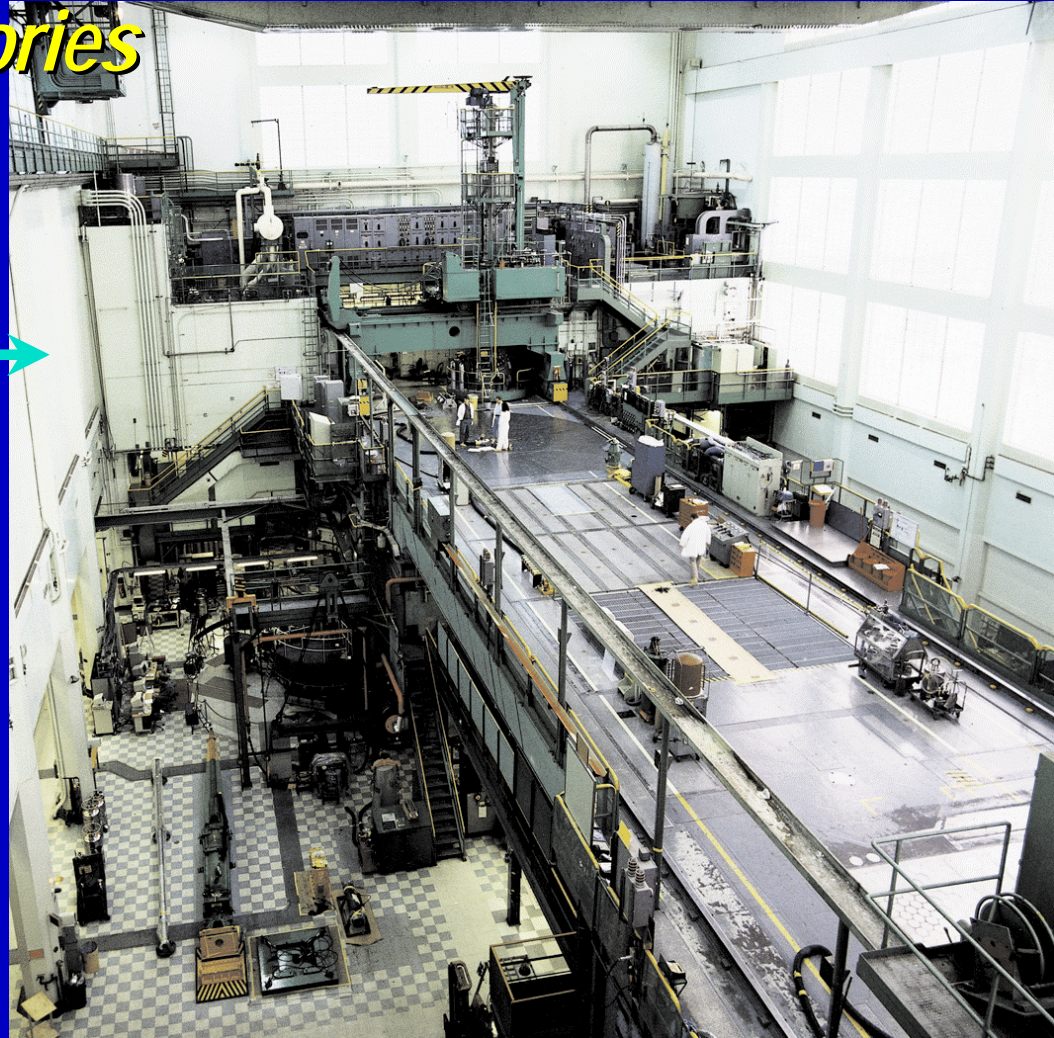
CURRENT PROJECTS





Chalk River Laboratories

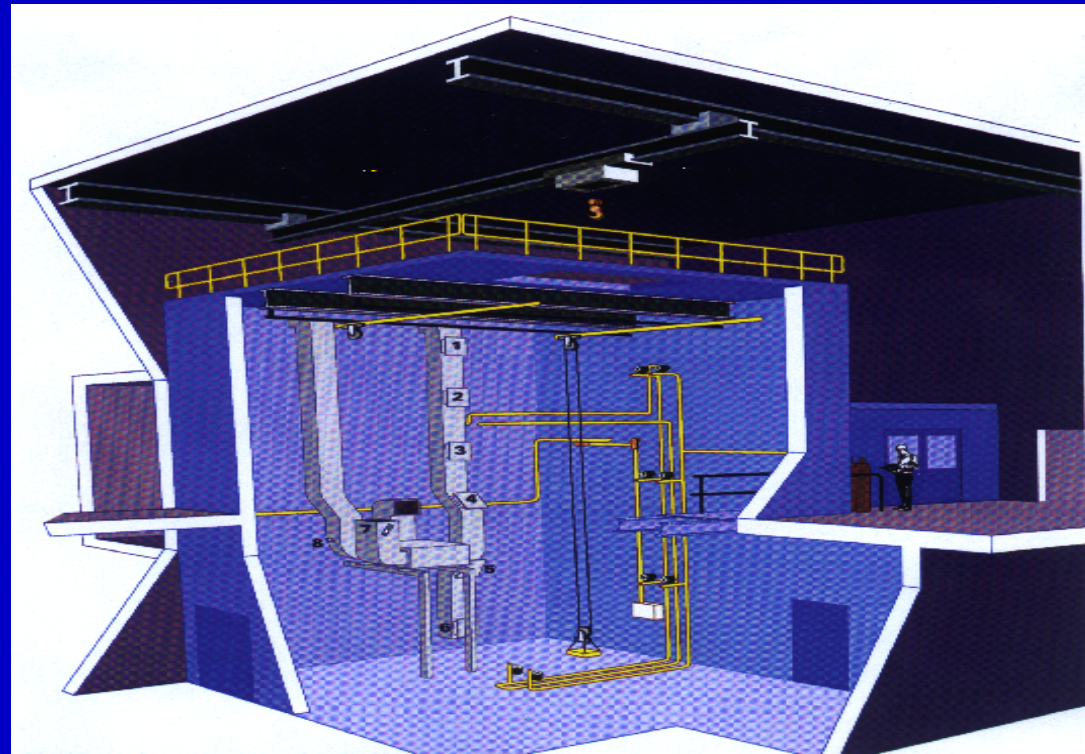
- λ 2000 people
- λ large (orig. 200 MW(th)) heavy-water moderated research reactor (NRU)
- λ severe accident in-reactor loop (Blowdown Test Facility) in NRU
- λ zero-energy reactor (ZED-2)
- λ hot cells
- λ fuel fabrication and test
- λ detritiation
- λ critical heat flux
- λ moderator circulation





Whiteshell Laboratories

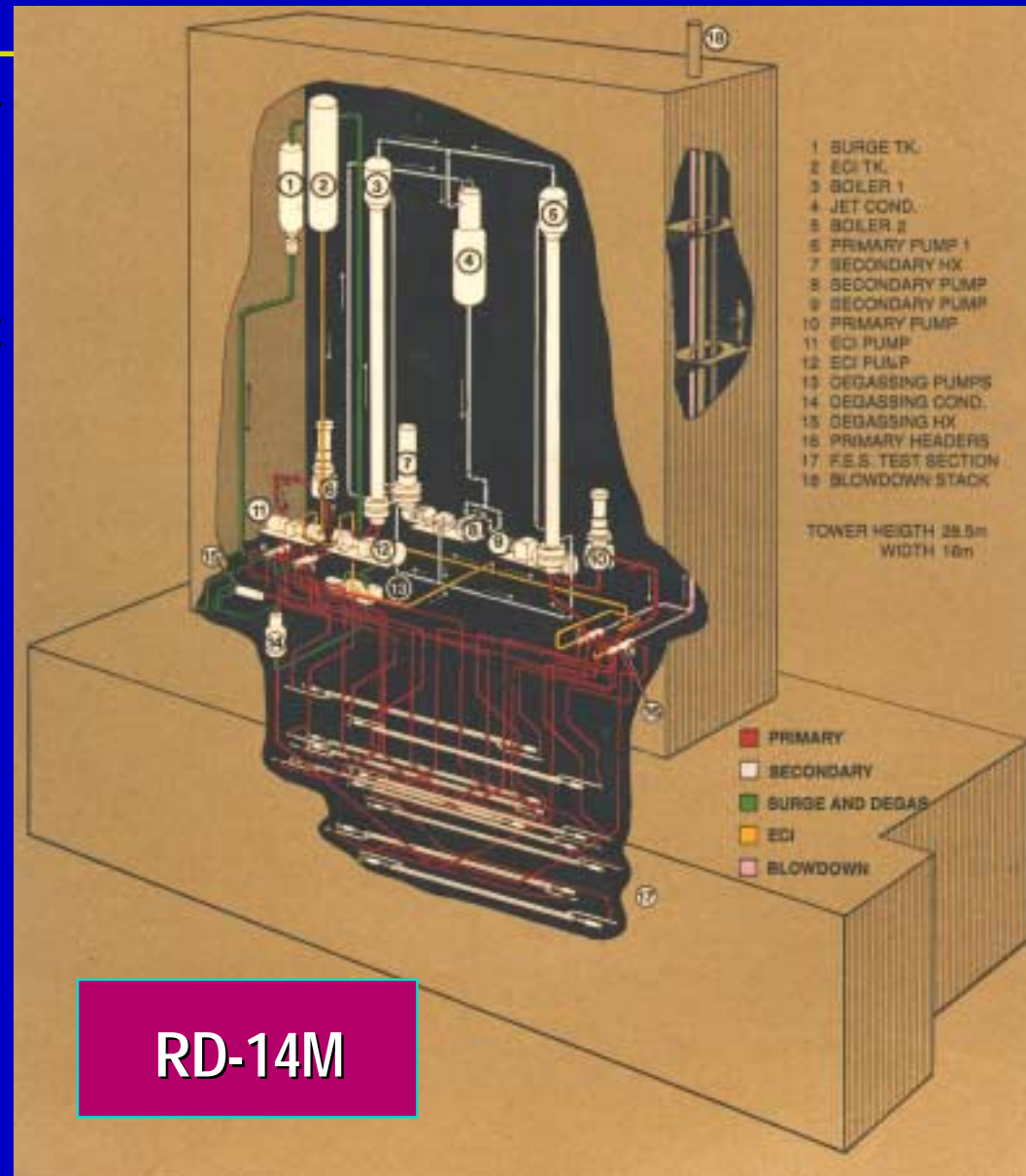
- λ organic-cooled reactor (now decommissioned)
- λ large scale vented combustion facility
- λ radio-iodine test facility
- λ RD-14M figure-of-eight thermohydraulics test loop
- λ large-scale gas mixing facility →
- λ pressure-tube ballooning and moderator subcooling





Thermohydraulics of Figure-of-Eight Loop

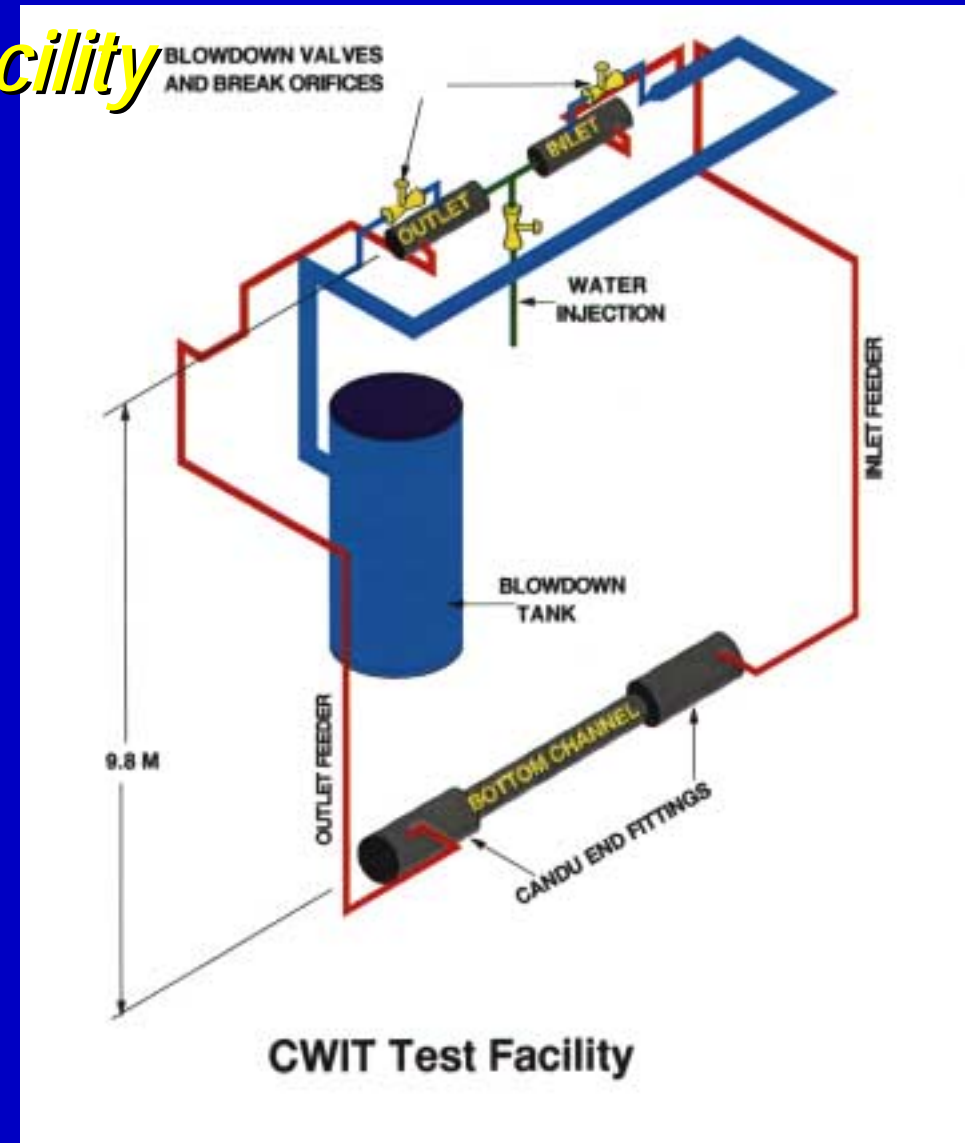
- λ full elevation simulation of heat transport system
- λ 10 full-length channels
- λ mass flux, transit times, pressure & enthalpy distribution similar to CANDU
- λ large and small LOCA
- λ ECC injection & refill
- λ natural circulation at full and partial inventory
- λ loss of shutdown cooling
- λ primary purpose: code validation





Cold Water Injection Facility

- λ full-scale, full length heated fuel channel
- λ representative feeders and end-fittings
- λ 37-element fuel
- λ blowdown and refill performance
- λ LOCA in CANDU channel can be tested in full scale
- λ primary purpose: code validation





Critical Heat Flux

- λ purpose: to determine with high accuracy the onset of critical heat flux under high-power conditions**
- λ used to determine overpower trip setpoints**
- λ fundamental & parametric studies in freon**
- λ final tests in full-scale, full-length heated 37-element channels with realistic bundle end-plates, appendages, etc.**
- λ onset of dry-patch, dry-patch spread, and post-dryout temperatures**
- λ now testing CANFLEX fuel (43-element)**
 - carrier for advanced high-burnup fuel**
 - increase margins for natural uranium fuel**



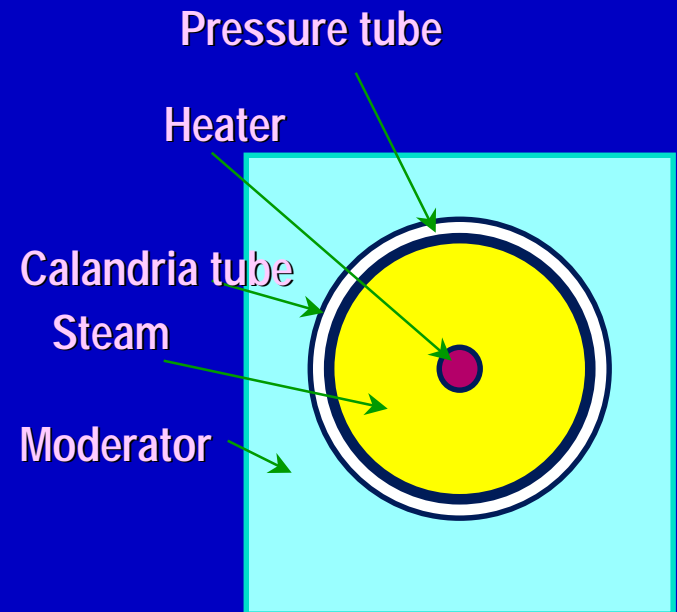
Pressure Tube Integrity

- λ fracture properties of pressure tube (Zr-2.5%Nb alloy) under normal operating conditions
- λ effects of irradiation and ageing (creep & growth)
- λ set fitness-for-service conditions
- λ support leak-before-break
- λ properties monitored by samples removed from operating reactors



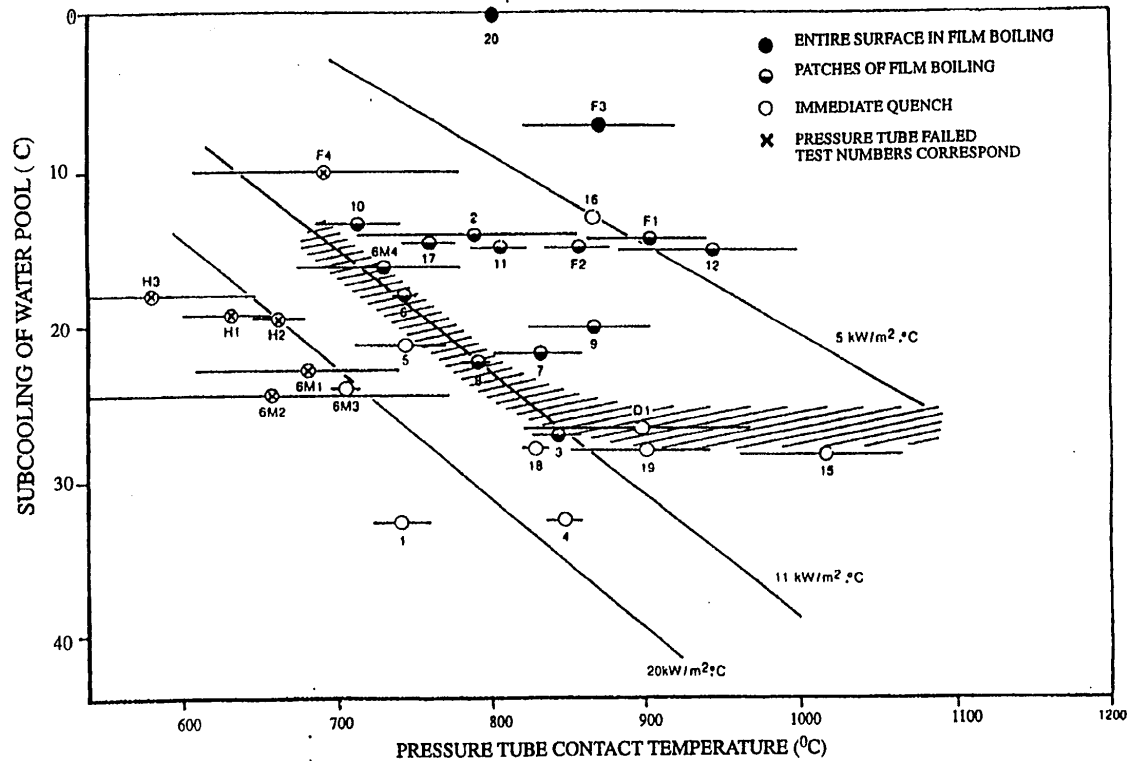
High Temperature Fuel Channel Integrity

- λ internally-heated and pressurized pressure-tube inside calandria tube inside water tank
- λ strains or sags to contact calandria tube
- λ integrity of pressure tube before contact
- λ integrity of channel after contact
- λ defines required moderator subcooling to prevent calandria tube dryout after contact





Moderator Subcooling Requirements

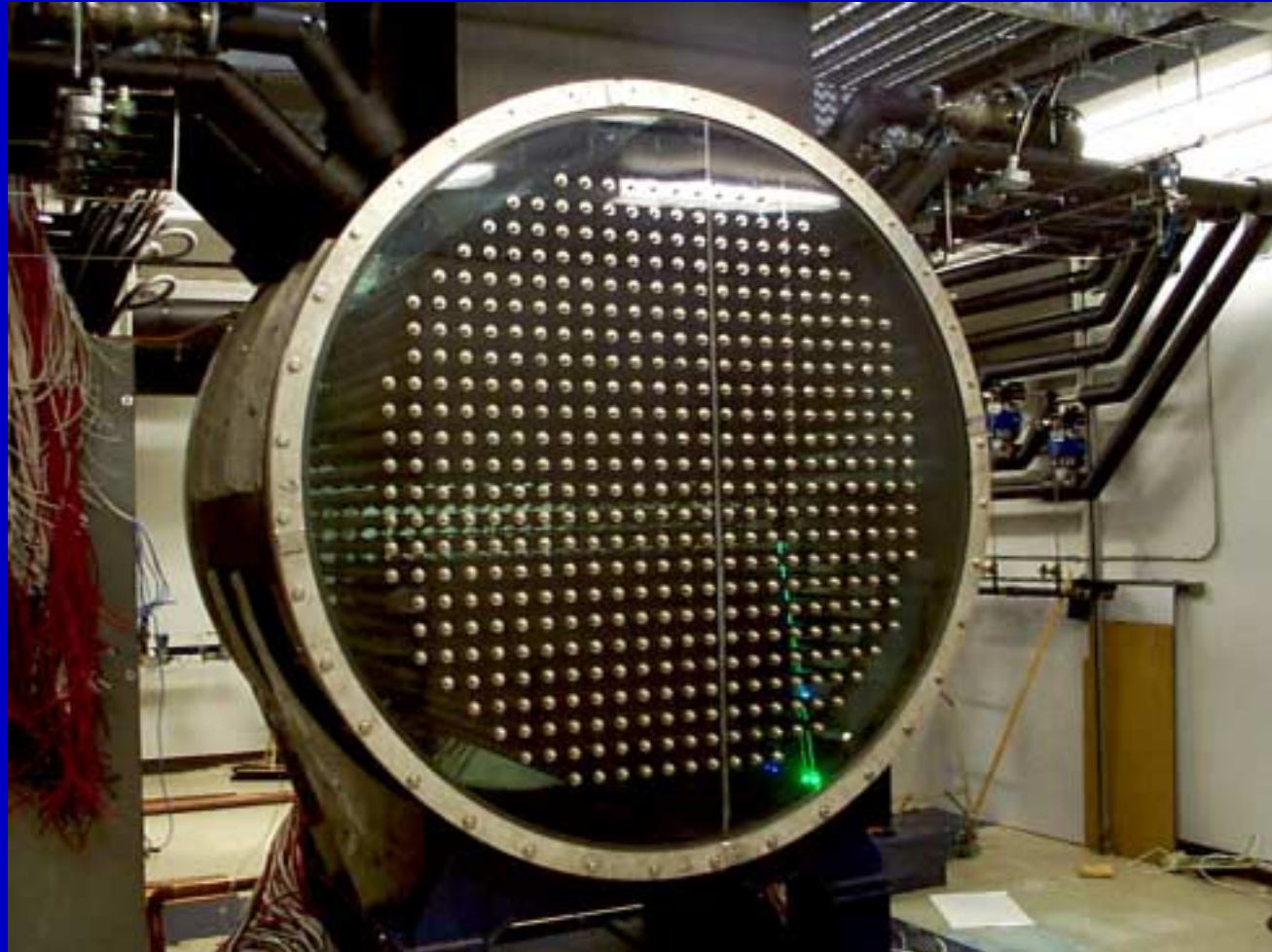


Results of Contact Boiling Experiments



Moderator Circulation

- λ measure three-dimensional velocity and temperature distributions in CANDU moderator geometry
- λ used for code validation
- λ inlet & outlet pipes can be configured for CANDU 6, 9 etc.





Hydrogen Mixing and Combustion

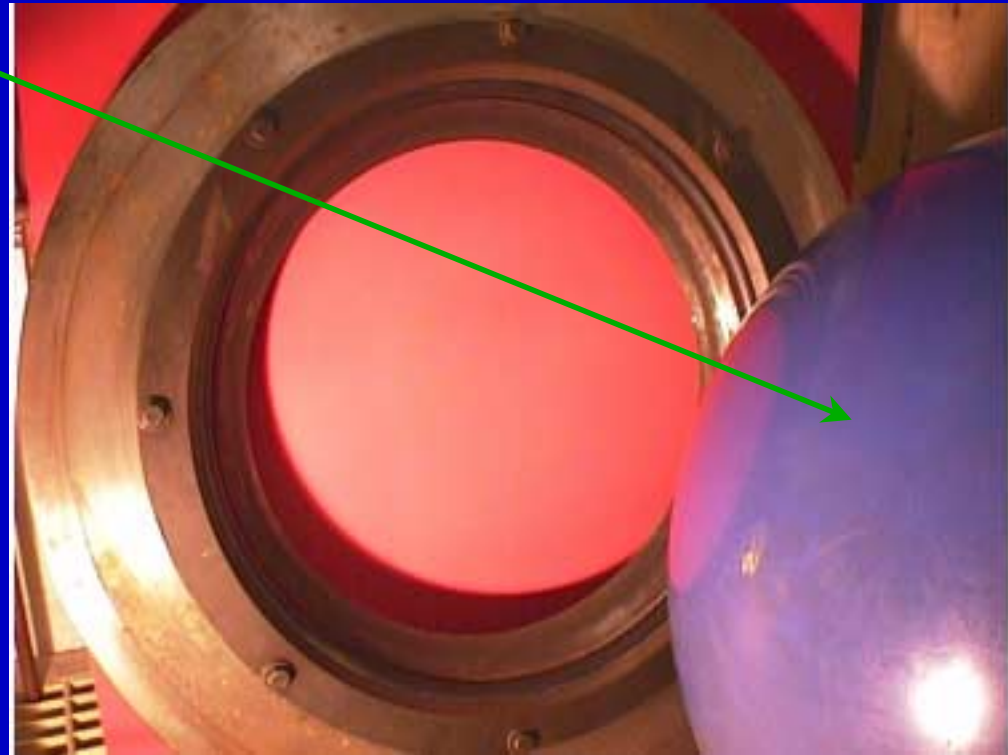
- λ Large Scale Vented Combustion Facility
- λ hydrogen combustion and detonation boundaries in various steam / air/ hydrogen mixtures
- λ interior geometry can be configured





CANDU 9 Simplification

- λ ECC water tank ball seal
 - leaktightness
 - surface flaws
 - vortexes
 - ageing
 - deformation
- λ ECC one-way rupture disk
 - large sustained flows from NRU high head tank
 - absence of fragments
 - flow area
 - reverse pressure



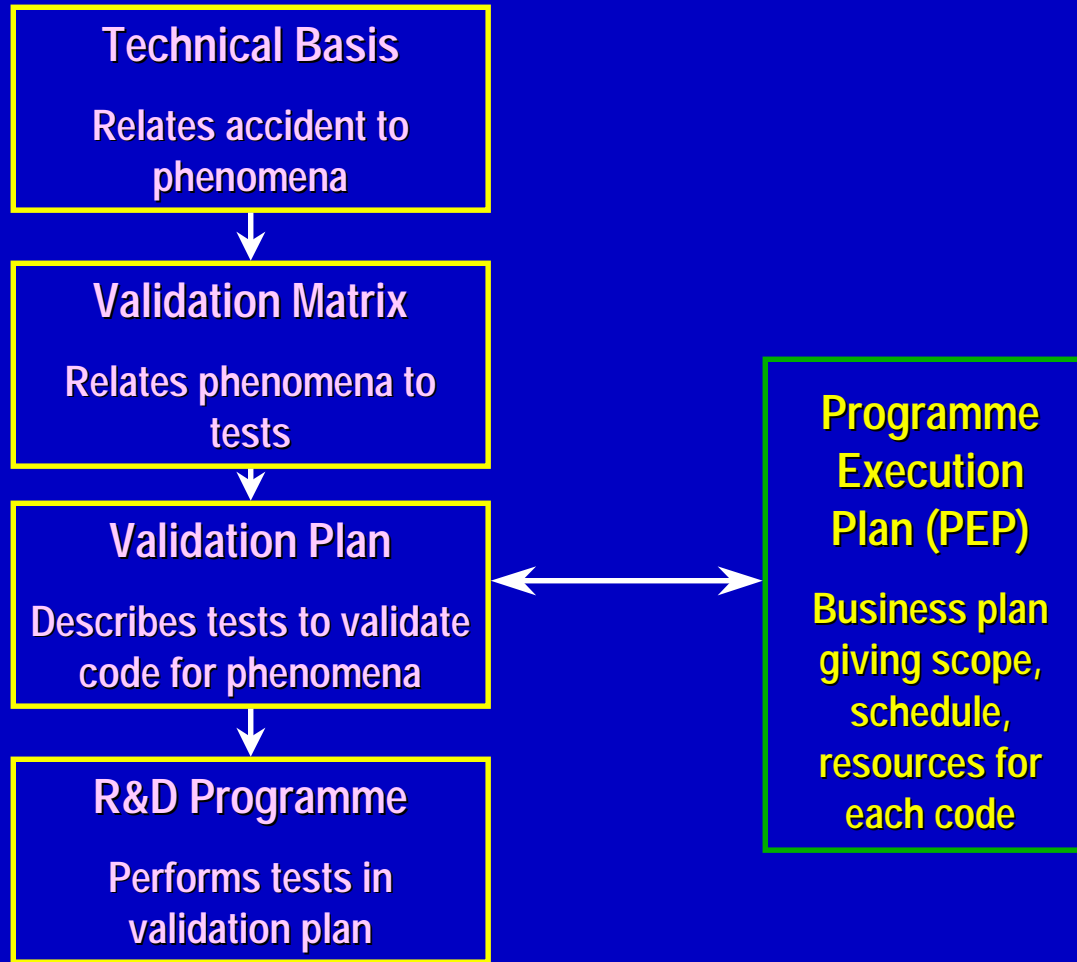


Other Areas

- λ fission product release and transport
 - goal is to develop physically realistic models
 - large feeder & end fitting surface area provides natural trap
 - hot-cell & in-reactor tests in NRU (Blowdown Test Facility)
- λ severe core damage
 - demonstrate basic phenomena of core collapse for CANDU in scaled facility
- λ containment thermohydraulics
 - not unique, use world data for code validation
- λ passive safety designs



Code Validation and R&D





Summary

- λ CANDU safety R&D focussed on aspects unique to CANDU
- λ some world-class generic R&D also performed
- λ industry carries special responsibility for safety R&D
- λ object is to develop physically realistic models based on experiments, to get an accurate picture of safety margins
- λ formal code validation process underway, which will require quantification of uncertainties