TWG-4, Non-Classical

A Summary of Generation IV Non-Classical Nuclear Systems

Generation IV Roadmap TW-4, Non-Classical Concepts

Generation IV Roadmap Session II
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People Involved in this Work

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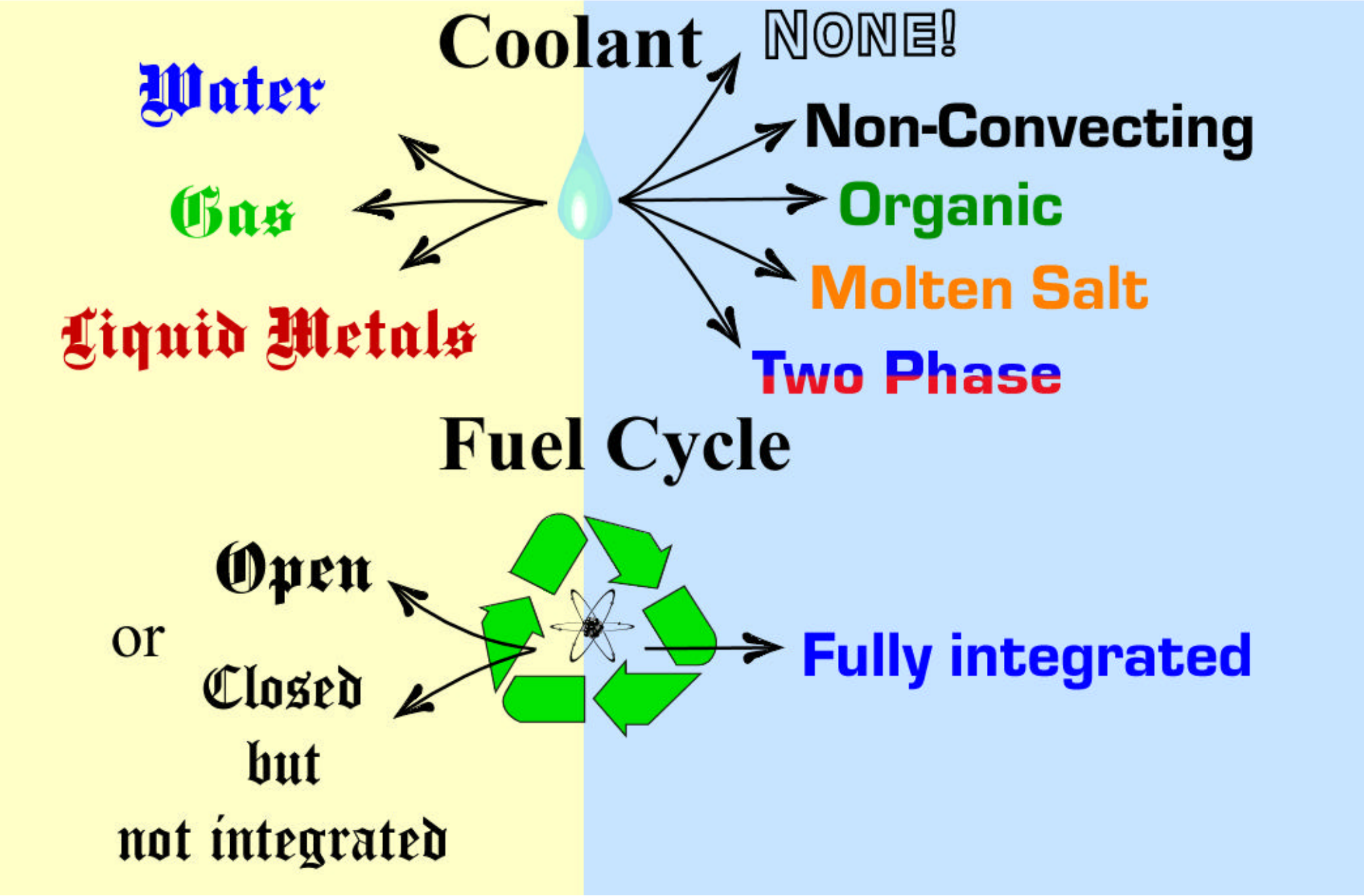
Classical vs Non-Classical – Coolant & Fuel

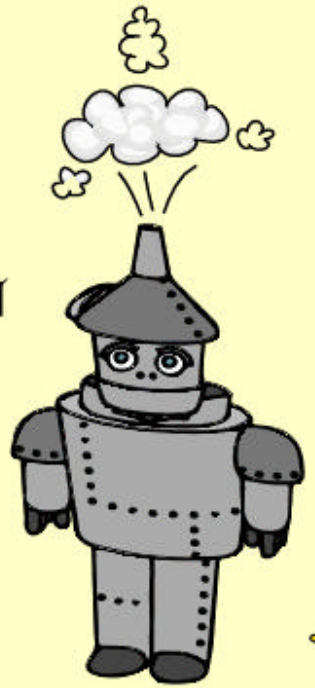


Classical vs Non-Classical – Fuel Design

Classical vs Non-Classical

Fuel Design

Solid Clad



No Clad

Liquid

Gas or Vapor

Thin Film

Classical vs Non-Classical – Power

Carnot ΔT

300-1000 K

300-3000 K

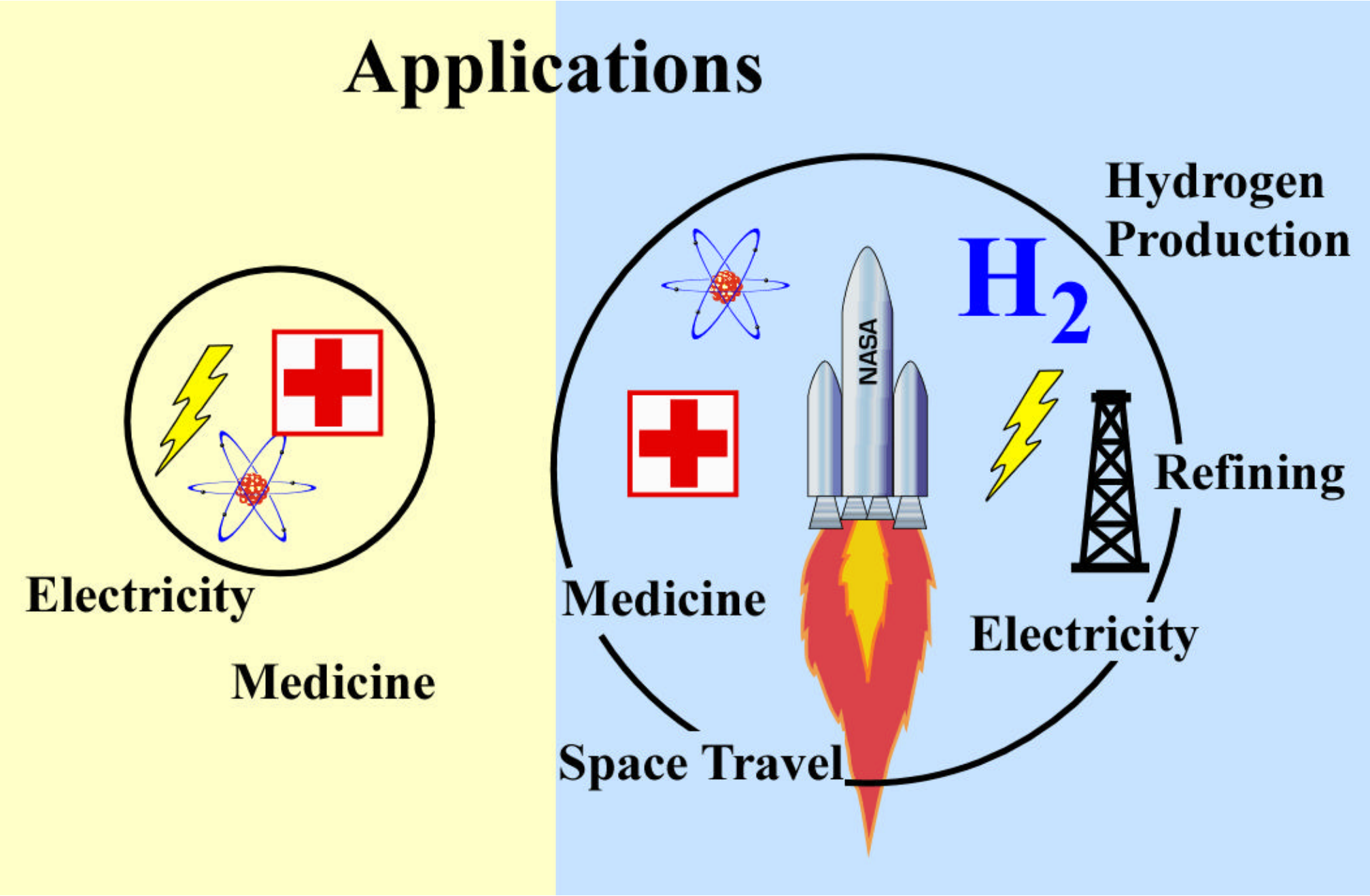
Power Cycle

Steam
Rankine
or
Brayton

Direct
MHD

Thermionic
AMTEC
Combined

Classical vs Non-Classical – Applications



Non-Classical* Reactor *Concepts

- **A total of 32 concepts gathered, among them 28 meet the Generation IV requirement of fission based self sustained criticality.**
- **Based on the primary design features , six "Concept Sets" are defined as:**
  - ***1. Liquid Core Reactors***
  - ***2. Gas Core Reactors***
  - ***3. Non-Conventional Coolant Reactors***
  - ***4. Non-Convection Cooled Reactors***
  - ***5. Direct Energy Conversion Reactors***
  - ***6. Modular Deployable Reactors***
- **Non-Classical reactor concepts feature higher potential to meet or exceed Gen IV performance goals at somewhat lower technology readiness level.**

A Summary of Liquid Core Reactor Concepts

Innovative Approaches

Examples

1. Molten Salt Core

HERACLITUS - Circulating fuel, natural thorium molten salt.

MSBR - Molten Salt Breeder, liquid uranium and thorium fluorides.

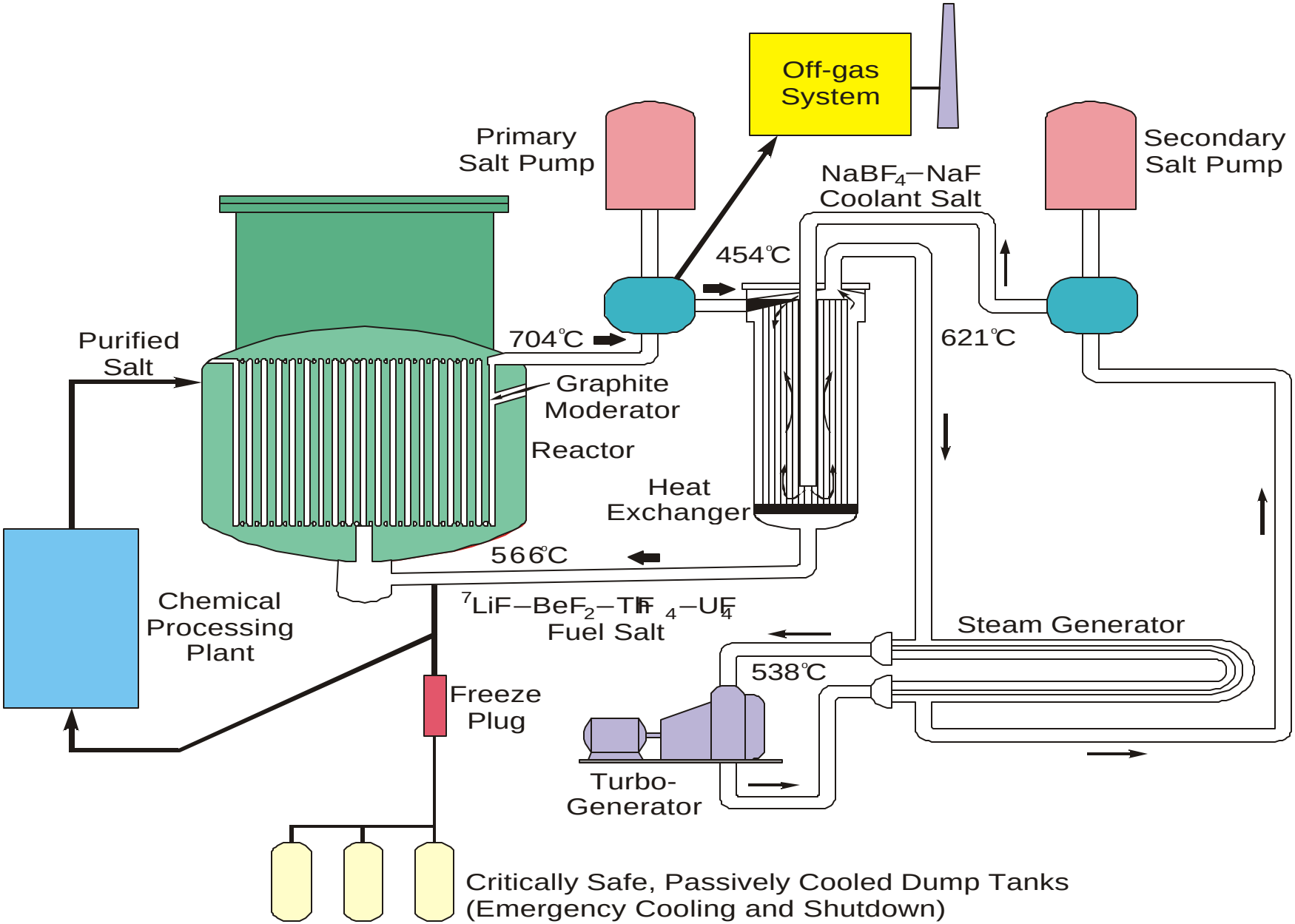
AMSTER - Actinides Molten Salt Transmuter

2. Liquid Metal Core

LM-FR - Liquid Metal Equilibrium Fast Reactor, Mg-Pu Eutectic.

MSBR - Molten Salt Breeder, liquid uranium and thorium fluorides.

Molten Salt Reactor



A Summary of Gas Core Nuclear Systems

Innovative Approaches

Examples

1. GCR/VCR-MHD

UF_4 with either KF vapor Rankine cycle or He Brayton cycle.

Efficient MHD energy conversion with fission enhanced ionization.

2. GCR-Graphite Wall

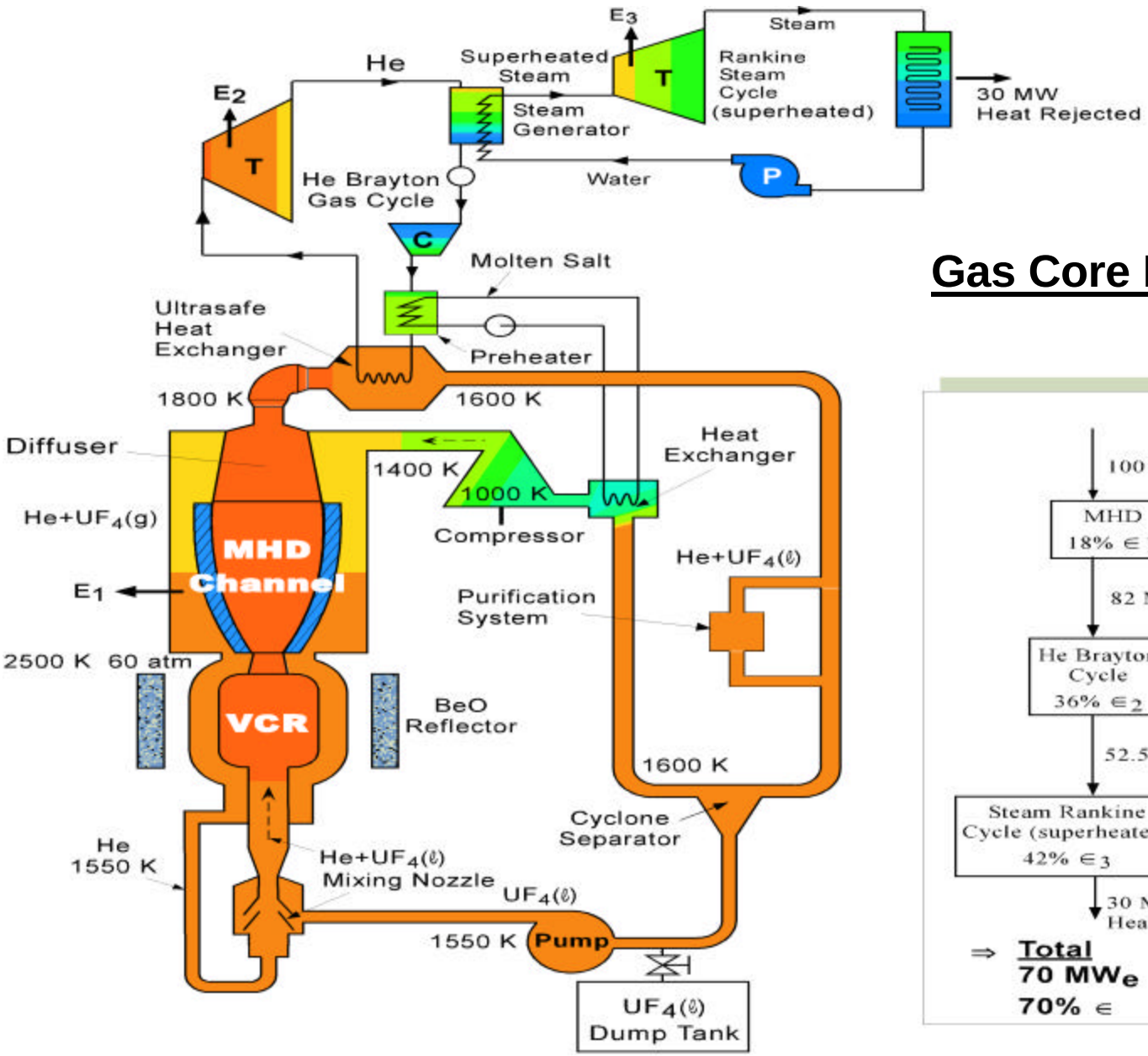
Neutralizes high temperature wall corrosion.

3. Plasma/Vortex Flow

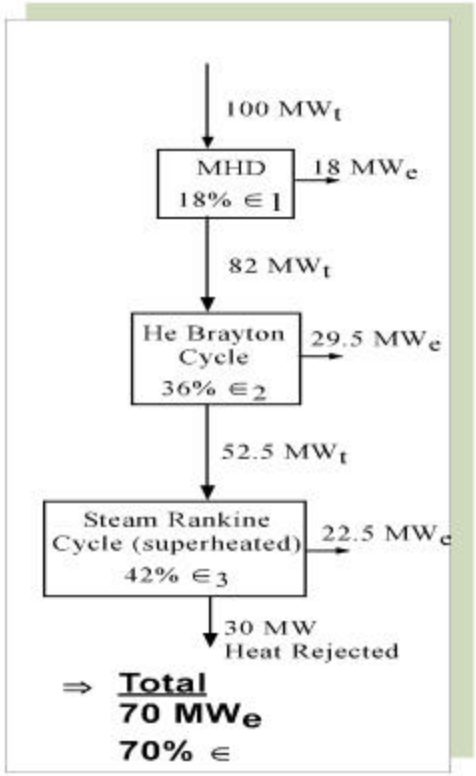
Varieties of vortex flow GCR's, high T, diverse uses.

UF_6 or U vapor with He or Argon.

Gas Core Reactor Power System



Vapor Core Reactor with Combined Direct/Indirect Energy Conversion (VCR-DEC)



Thermodynamic Efficiencies and Power Ouputs

Liquid and Gas/Vapor Core Reactor Properties

1. Significant advances can be made in conversion efficiency, diversificatio of energy products, resource utilization and waste minimization.

1. Excellent non-proliferation characteristics due to one to two orders of magnitude lower fuel inventory and plutonium buildup.

3. Minimized source term due to online separation and removal of fission products and ultralow equilibrium concentration of minor actinides.

4. Gas/vapor core reactors could potentially eliminate the need for Offsite Emergency Planning, which is a key safety goal for the Gen IV reactors.

5. Many technology challenges; high temperature materials, energy conversion, dynamics and control, remote operation, fuel chemistry and fuel handling, fission product separation, and safety.

A Summary of Non-Conventional Cooled Reactor Concepts

Innovative Approaches

Examples

1. AHTR - Advanced High T Reactor

Graphite Matrix - Molten Salt Cooled.

High temperature diverse uses.

2. OCR - Organic Coolant Reactors

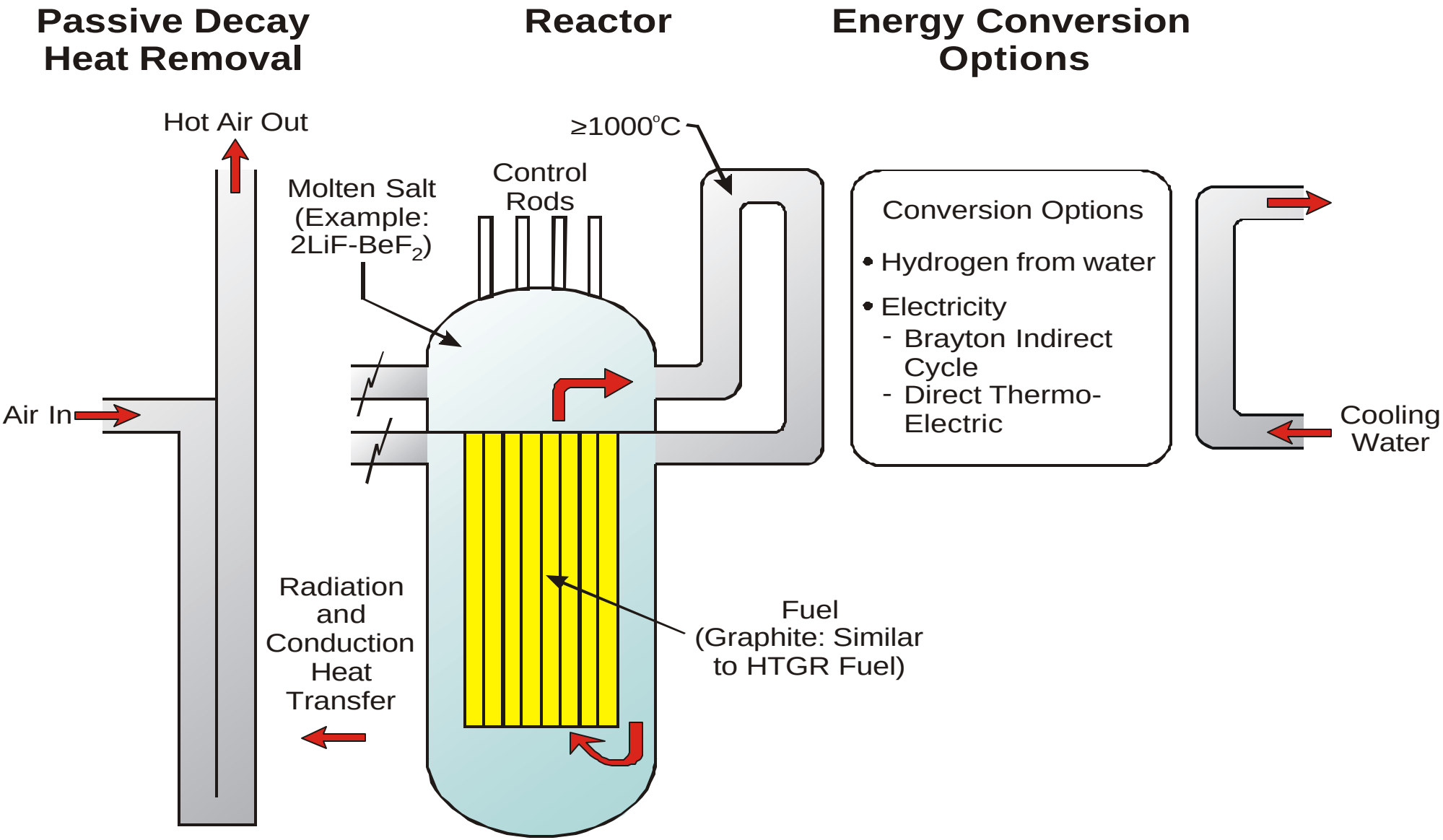
Cheaper efficient cooling, reduced costs.

3. FSEGT - Sodium Evaporation

Fast reactors, sodium evaporation cooling.

Unique sodium vapor gas turbines.

AHTR, Molten Salt Cooled Reactor



Non-Conventional Cooled Reactor Properties

1. Molten Salt Cooled Reactors

Significant advances can be made in conversion efficiency, and diversification of energy products.

High temperature operation at low pressure, low power density, high heat capacity.

High temperature materials, fuel design, molten salt to water heat exchanger, mixed nuclear/hydrogen safety issues.

2. Organic Cooled Reactors

High conversion ratio, superior coolant properties, low pressure operation, lower cost coolant (compared to CANDU).

Fuel (UC) reaction with water and air, coolant flammability, coolant fouling, coolant radiolysis, reactivity coefficients.

A Summary of Non-Convection Cooled Concepts

Innovative Approaches

Examples

1. ***Solid State-Heat Pipe Cooled***

Non-Convection Cooled Reactor Properties

Low fuel inventory, static energy conversion, small scale power applications, remote site applications.

High temperature fuels and materials, lifetime of energy conversion unit, dynamics and control, fuel cycle.

A Summary of Direct Energy Conversion Reactor Concepts

Innovative Approaches

Examples

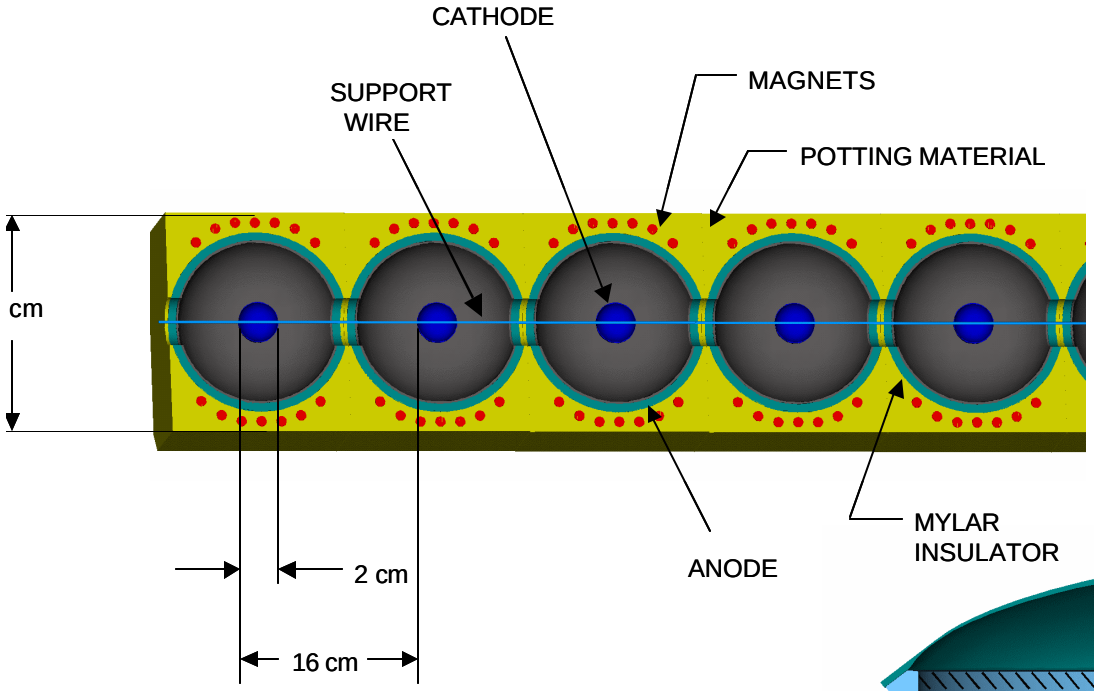
1. QSMC - Quasi-Spherical Fission Magnetic Cell

Direct conversion of fission fragment energy.
Cells coated with thin film of fissionable fuel.
Radiation cooling.

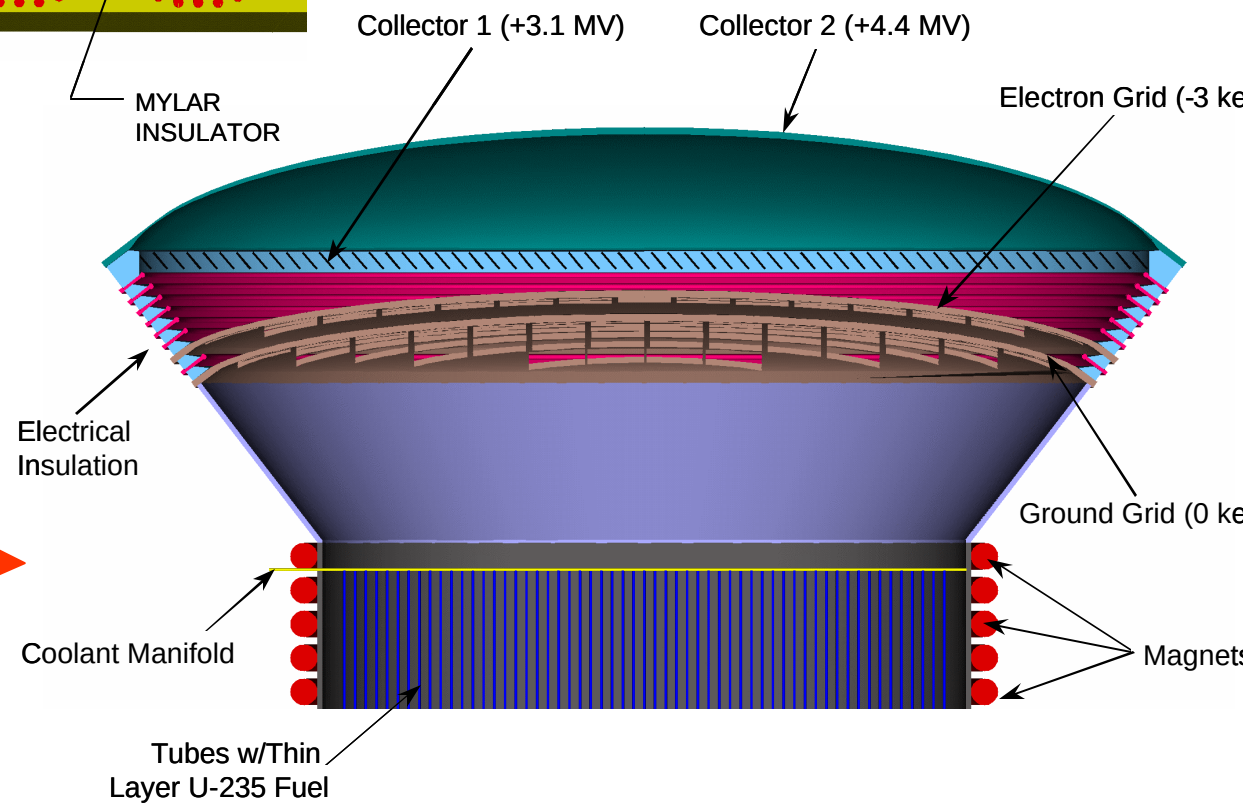
2. FFMC - Fission Fragment Magnetic Collimator

Magnetically guided fission fragment trajectories.
Thin films of UO_2.
Heavy water coolant.

Direct Energy Conversion Schematics



Array of fission cells



Venetian blind collector

Direct Energy Conversion Reactor Properties

1. Low fissile inventory, proliferation resistant, no moving parts, no coolant, no flow, barely critical.

2. Hard to make critical, large systems, very low burnup, magnet design, direct energy conversion.

A Summary of Modular Deployable Reactor Concepts

Innovative Approaches

Examples

1. MMDR - Multi-Modular Deployable Reactor

Modular construction, factory built.
Transportable, easily assembled

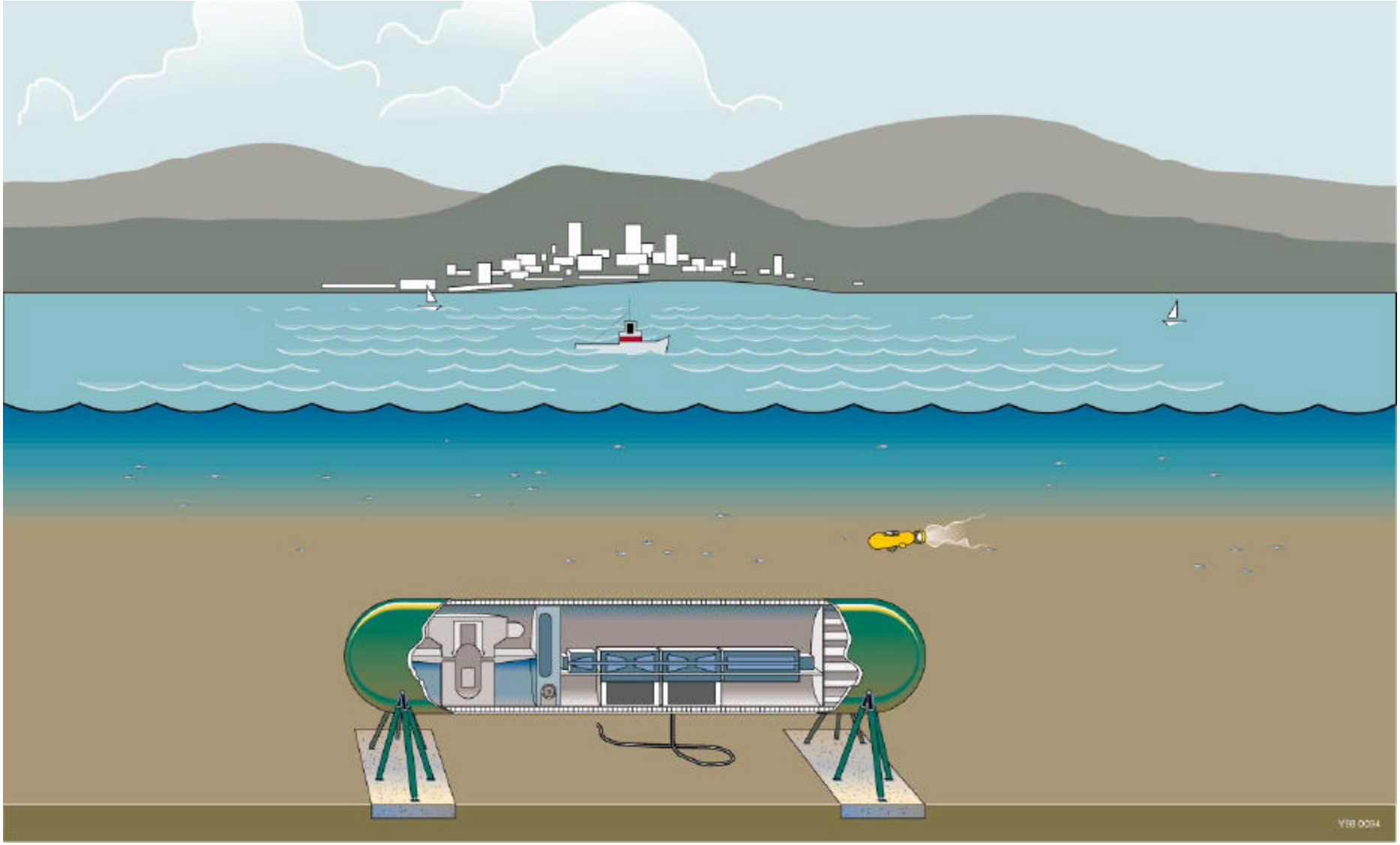
2. SPS - Submersible Power Station

Transportable, modular undersea siting.
Coastal siting niche.

2. DORC - Distantly Operated Reactor Complex

Remotely operated.
Liquid metal cooled.

Modular Deployable Nuclear Systems



Summary

1. **Despite many technology gaps and data uncertainties, there is no lack of innovation and revolutionary ideas in Non-Classical reactor concepts.**
2. **Several concepts such as gas/vapor core reactors offer promising advances toward the Gen IV goals for sustainability, safety, and economy, and have potential for making significant inroads toward achieving the optimum utilization of nuclear energy.**
3. **Gas/vapor core reactors set the upper performance potential in sustainability and safety with no insurmountable technology challenge.**
4. **Evaluations of modular deployable concepts are underway.**
5. **Direct energy conversion and non-convective cooled nuclear reactor systems are eliminated from further evaluation process.**