Flexblue®: a Subsea Reactor Project
Considerations for its licensing

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Flexblue® : a Subsea Reactor
Differences for an innovative solution

- Competitive
  - Reasonable cost of energy

- Intrinsically Safe
  - Using the sea as a permanently available, infinite heat sink

- Environmentally Friendly
  - Reduced Site and Civil Works
  - Limited land print
  - Easy decommissioning and dismantling

- Reliable
  - Proven technologies
  - Simplified design, modular construction
    - 11 skids, 80 sub-skids
  - Standardized, Series production
  - Fully workshops/shipyard constructed

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2 July 2013 6th INPRO Dialogue Forum - Flexblue
Flexblue® : based on a Subsea Module

Power Output (per module) = 160 MWe
moored up to 100 meters depth
Length ≅ 146 m, Φ 14 m
Displacement ≅ 20 000 tons
Remote Operation, permanent accessibility
Flexblue® life cycle

To be adapted according to the refueling mode

First Flexblue® units: use of existing ship ➔ proven solution
Next Flexblue® units: dedicated solution, w/wo on-board refueling
**Flexblue® Safety Concept**
*Full use of passive systems capabilities*

- **Extended** and **passive** safety
- 1st line of defense ensured by active systems
  - Normal conditions, incidents: active systems
  - Accidents: passive systems with extended grace period

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**NORMAL ACTIVE SYSTEMS**

**PASSIVE SAFETY SYSTEMS**

- Passive core cooling
- Depressurization + flooding

**Infinite heat sink**

Residual heat removal needed

Injection needed
## Inherent Nuclear Safety

### Flexblue® Specific Advantages

#### IAEA « INSAG 10 » levels

1. **Prevent abnormal operation and failures**
   - Fully manufactured in factory and Shipyard
   - Immersion
   - High Quality, Standardization, Proven Technologies
   - Elimination of main External Hazards

2. **Control abnormal operation and detect failures**
   - Fully automated

3. **Control accidents within design basis**
   - Passive safety systems, Infinite heat sink
   - External vessel core cooling
   - No need for operator action
   - Improved prevention of core melt

4. **Control severe conditions, prevent accident progression**
   - Hull flooding capability
   - No radiological releases

5. **Mitigate radiological consequences of significant releases**
   - Reduced source term, Significant releases precluded; in case, retention on board, no neighboring population
   - No atmospheric releases, no sheltering, no evacuation required
   - Easier recovery of site
   - Transportable plant

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Concept Flexblue®
Siting considerations

- Large number of potential sites
  - Bathymetry, distance from the shore
  - Industrial, economical, environmental aspects easily taken into account
- Environmentally friendly concept
- Immersion provides natural protection against most external events
  - Exclusion of snow, wind, ...
  - Significant attenuation:
    - Waves, tsunami
    - Earthquake: design margins, robustness of passive systems
- Malevolent acts:
  - Limited accessibility
  - Monitoring devices
  - Intervention, according to specific country requirements

Immersion provides efficient tsunami attenuation

Monitoring and protection system
Inherent Nuclear Safety
A very narrowed time-limited EPZ

Flexblue as compared to large and medium NPPs

- Normal operation: no \(^3\)H releases (Boron Free Operation)
- The small power of the reactor, combined with passive systems and immersion, provides:
  - large, permanently available, heat sink: very low CDF
  - very long grace period
  - no direct atmospheric releases and a very narrowed, time-limited, EPZ

In highly hypothetical case:
- Radioactive inventory reduced
  >10 times vs a large NPP
- Robust containment function
- Retention on board
- No population in the immediate vicinity

Typical 10 miles radius EPZ for large land-based reactor

Flexblue: Narrowed and time-limited EPZ
Concept Flexblue®
Licensing considerations

- SMR Issues
  - Passive systems with infinite heat sink
  - Multi-module control room
  - Source term / EPZ : SMR specificities to be taken into account
    - Reduced ST – delay before consequences – low CDF/LRF

- TNPP Issues and Subsea Aspects
  - Various regulations :
    - Transportation of dangerous goods and nuclear materials (INF)
    - Nuclear ships (OMI)
  - No existing regulatory framework fully relevant for transportation of fuelled TNPPs
    - Necessity to adapt existing rules and guidance documents
    - Need for an international consensus
  - Transport related specifications for safety systems
  - Reliable, redundant, diversified communication means
International aspects

- **Need for international design certification**
  - Maintain sustainable standardization
  - Allow experience feedback and assistance to new comers

- **International life cycle**
  - Potential for multiple operators and regulators

- **Cooperation between states (governments, industry, regulators, …)**
  - E.g. information exchange, repartition of responsibilities, … in order to comply with national and international laws and conventions
The Flexblue® Concept …
Imagine…