Applying systems thinking to safety assurance of Nuclear Power Plants

Francisco Luiz de Lemos
Instituto de Pesquisas Energeticas/ Comissao Nacional de Energia Nuclear
IPEN/CNEN _ Brazil

IMPRO Dialog Forum Workshop on Long Term Prospects for Nuclear Energy in the Post Fukushima Era – Seoul, Republic of Korea, 27-31 August 2012

Major projects

1- New fully digital Nuclear Power Plants / Renovation of old NPP`s

- Digital protection system

2- Multipurpose Research Reactor _ RMB

- Regulation aspects: licensing – commissioning – operation
- Complexity of interactions (radiopharmaceuticals – materials – basic research)

Motivation

- We are mostly concerned with the safety aspect of the complex sociotechnical systems as a basic pillar for a sustainable development in the context of a rapid changing in the technology.
- The increasing complexity in industrial systems created by the latest developments in computation technologies
  - New challenges, to designers and regulators, as for the safety assurance requirements for these systems, and in special for the nuclear industry.
  - With the advent of the fully digital nuclear power plants new, and unknown, hazards may have been created.

Brazilian Multipurpose Research Reactor, RMB.

The RMB is being designed to perform four main functions:

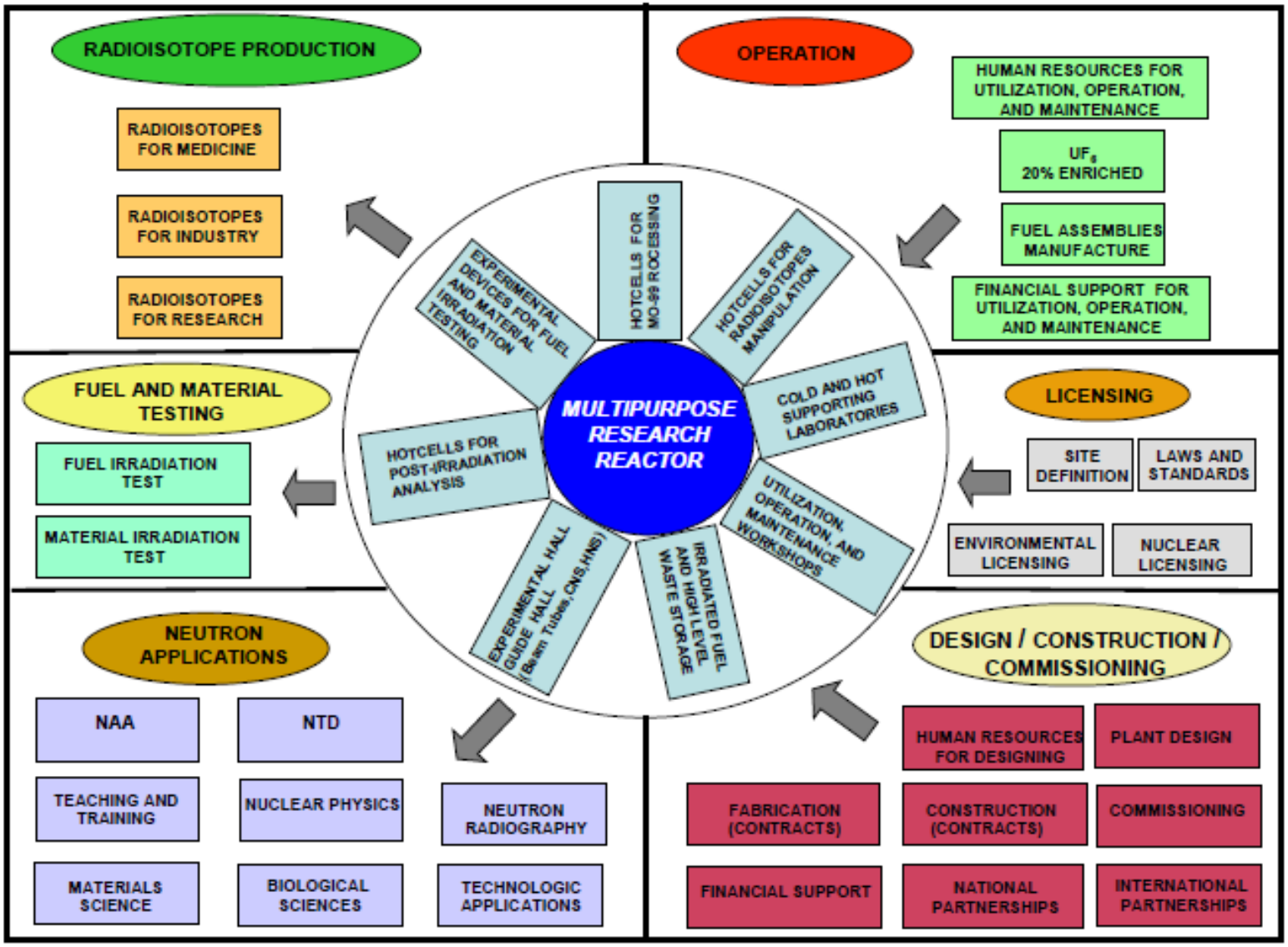
To support the Brazilian nuclear program proposal of increasing activities in the nuclear industry for the next decade;

To support the nuclear medicine in Brazil through the radioisotope production which is nowadays strongly dependent on international suppliers;

To support the nuclear industry, power generation and fuel technology, through materials testing under irradiation for an autonomous development;

To improve fundamental and technological research through neutron beam utilization

Brazilian Multipurpose Research Reactor scope



Systems thinking

There is a need to explore new ways of thinking that supports the government decisions in face of those new challenges

Systems thinking as a complement to traditional safety analysis

Complex sociotechnical systems

Recognizing the problem

- Containing technology sub-systems and components central to its performance
- Having societal/political/economic relevance and impact
  - Exhibits nested complexity- technical complexity within institutional complexity

Multidimensional decision making process

- Uncertainties
  - Quantitative and qualitative approaches
- Safety
  - Behavior difficult to predict (emergent property)
- Sustainability
  - Social and economic impacts
  - Stakeholders competing interests
  - Environmental protection
  - Security

Application: Reactor Digital Protection System

IPEN in cooperation with MIT: Application of STPA to a fully digital nuclear power plant

To investigate new forms, and modes, of accidents

To demonstrate the applicability, feasibility, and relative efficacy of using the new systems approach and hazard analysis technique (STPA) to help meet the challenges of assurance and licensing of the New Fully Digital Nuclear Power Plants.

http://psas.scripts.mit.edu/home/research/

Application: Brazilian Multipurpose Research Reactor

- A broader scope: will be a continuous process
- Search for gaps in the whole system structure, from government legislation to operation
- Propose changes in procedures; design; legislation
- Role of stakeholders in the formulation of rules and standards for “harmonization”

Systems theoretic Process Analysis - STPA

Based on systems thinking

The types of “accidents” grasped by STPA are not captured by traditional methods. For example, gaps in communication of control command, confusions, etc.

Not necessarily due to failures in equipment or software

Safety is a property that emerges from the interactions between components and subsystems

It is a control problem rather than a failure problem

Systems theoretic Process Analysis - STPA

Some assumptions that lead to the development of the STAMP method are:

Safety is an emergent system property

Accidents arise from interactions among system components (human, physical, social) that violate the constraints on safe component behavior and interactions

Losses are the result of complex processes, not simply chains of failure events

Most major accidents arise from a slow migration of the entire system toward a state of high-risk

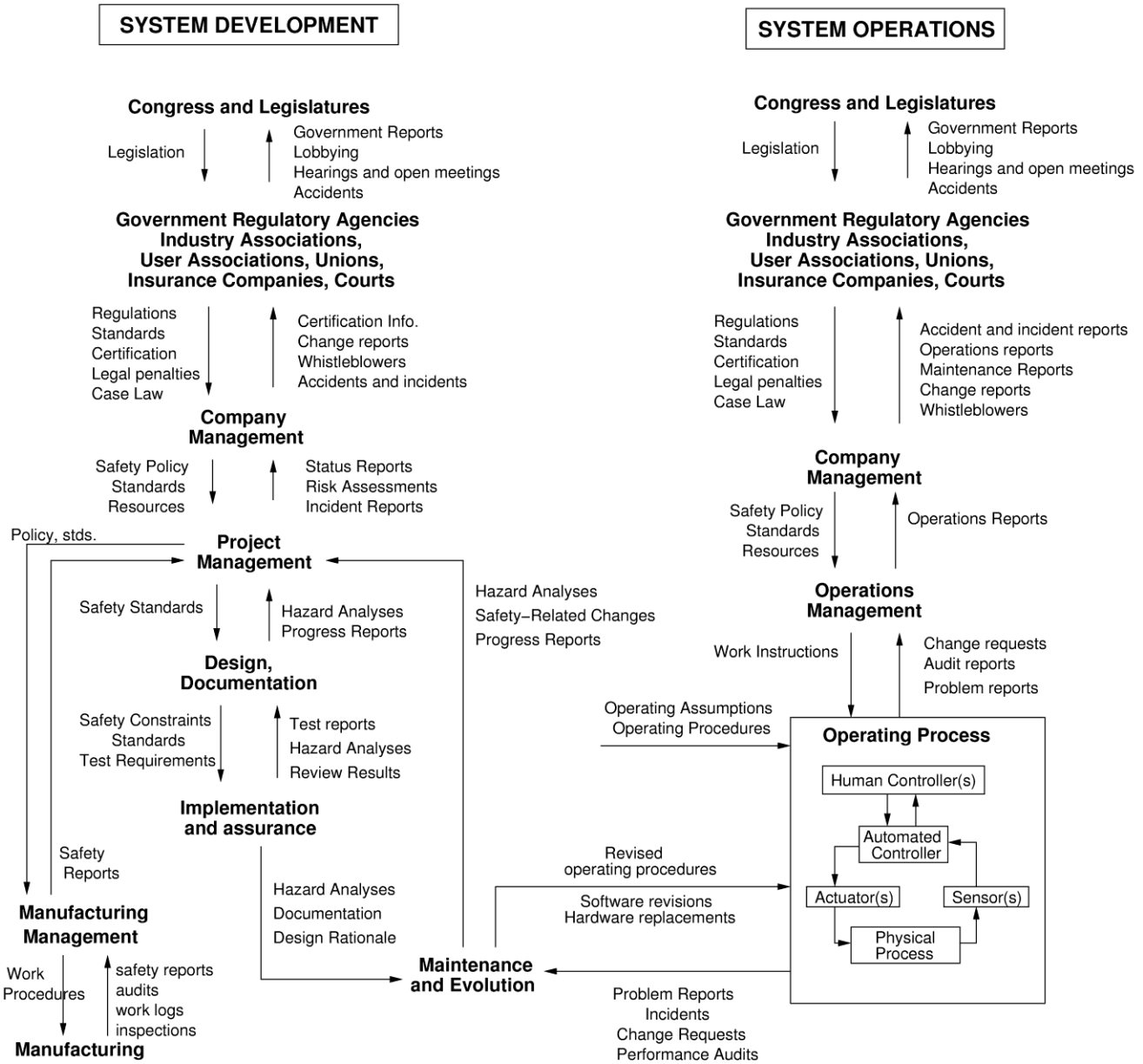


Figure 1. Generalized control structure diagram [from Safer World, Nancy Leveson].

Conclusions

Rapid technological change and globalization - two important factors that shape the decision-making environment for sustainable development

Based on safety – public acceptance / stakeholders participation – public / environmental protection – social / economic development

Systems thinking accounts for multiple stakeholder perspectives, by exploring flexibility, robustness, scalability, safety, security, durability, sustainability, reliability, quality, recyclability, and maintainability – the "ilities" often left out of traditional analysis, but critical to developing lasting solutions.

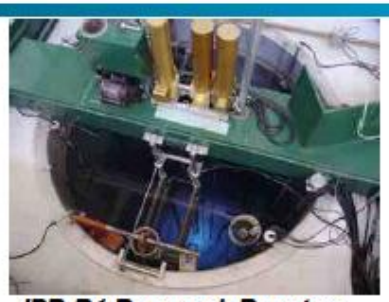
Conclusions

Research in this topic is focused on: 1) illuminating the complex relationship between designers, users, and technology to facilitate the design improvements and effective operation of complex systems; 2) recognizing that human interaction with complex technology has both individual and group elements; 3) developing methodologies and investigating key questions ranging from system design, to human-in-the-loop modeling, to process interventions, and to organizational structures.

Propose changes in project; requirements for licensing; public involvement; find gaps in the control structure; changes in the design

Thank you!

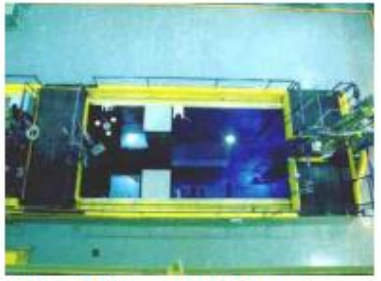
Research Reactors in Brazil



IPR-R1 Research Reactor

ARGONAUTA Research Reactor

IPEN/MB-01 Research Reactor



IEA-R1 Research Reactor

Future Perspectives for RR Utilization

Brazilian Nuclear Program Review

- Electricity produced by nuclear power plants
  - Brazil will continue to use nuclear energy in its electrical power matrix.
- Nuclear Fuel
  - Brazil has a significant uranium ore reserve and domains the fuel cycle technology, including U enrichment.
  - Increase of industrial activities for supplying the nuclear power plants needs.
- Naval Propulsion Development
- Nuclear Techniques Utilization
  - Increase of nuclear techniques applications and radioisotope utilization in the benefit of the society.
  - Increase of autonomous technology development