International Atomic Energy Agency

INPRO

International Project on
Innovative Nuclear Reactors and Fuel Cycles

F. Depisch, ICTP, November 2005

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INPRO

(International Project on Innovative Nuclear Reactors and Fuel Cycles)

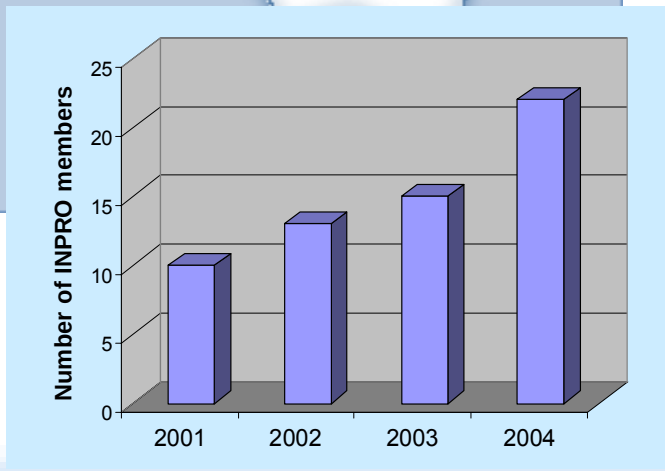
- **Basis of INPRO are the Resolutions**

  - ✓ **at the IAEA General Conference in 2000/2001/2002/2003/2004/2005**

    GC 2000 has invited "all interested Member States to combine their efforts under the aegis of the Agency"

  - ✓ **Also the UN took note of INPRO at General Assembly in 2001/2002/2003/2004**

INPRO members in the world



Argentina, Armenia, Brazil, Bulgaria, Canada, Chile, China, Czech Republic, France, Germany, India, Indonesia, Morocco, Netherlands, Republic of Korea, Pakistan, Russian Federation, South Africa, Spain, Switzerland, Turkey, Ukraine,USA and the European Commission

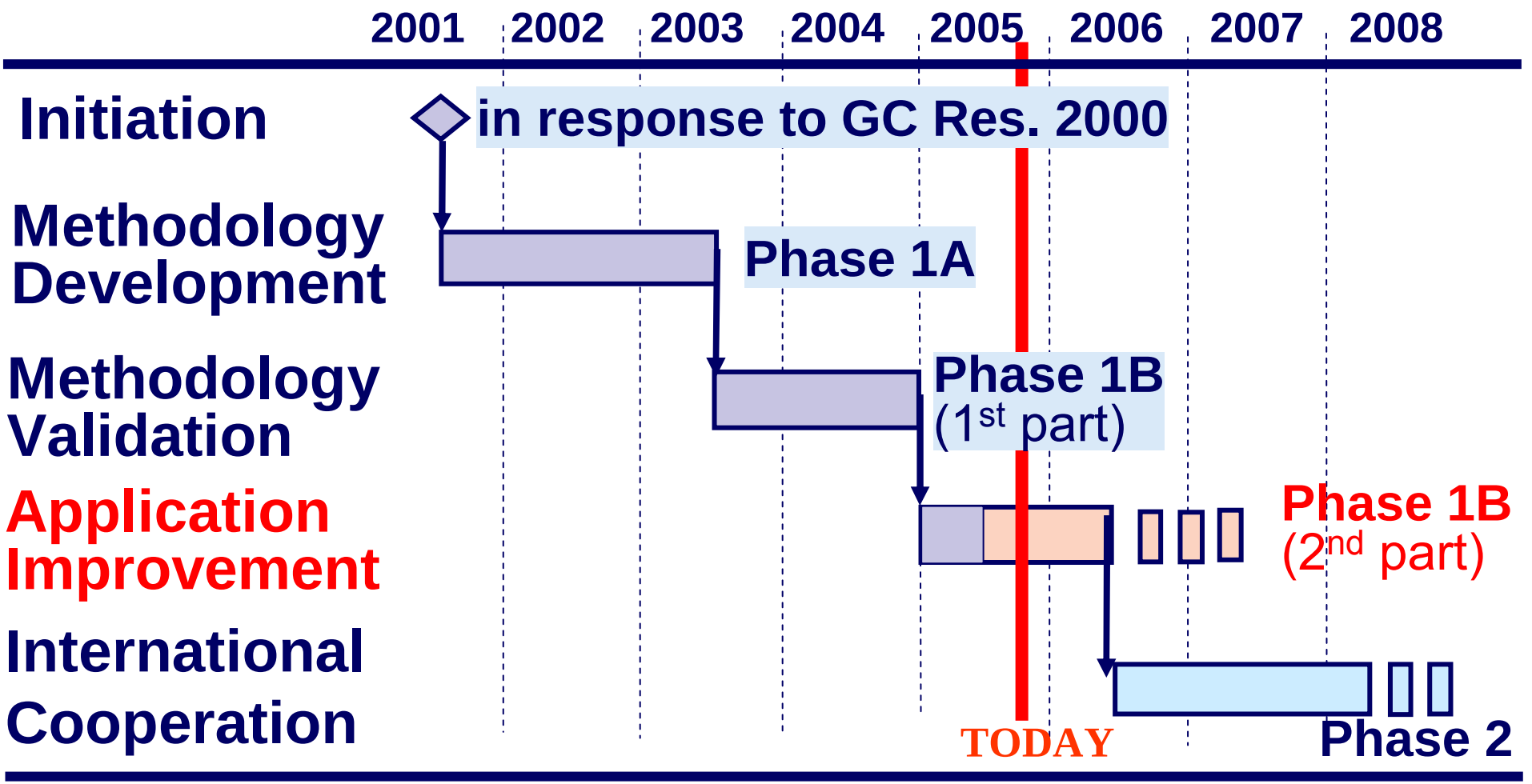
General Objectives of INPRO

- INPRO General Objectives:
  1. To help to ensure that nuclear energy is available to contribute in fulfilling energy needs in the 21st century in a sustainable manner.
  2. To bring together both technology holders and technology users to consider jointly the actions required to achieve desired innovations in nuclear reactors and fuel cycles.
- INPRO Time horizon is from today to 50 years into the future.

INPRO Mission

- To provide a forum for discussion of experts and policy makers from developed and developing countries on all aspects of nuclear energy planning as well as on the development and deployment of innovative nuclear energy systems (INS) in the 21st century.
- To develop the methodology to analyze INS on a global, regional and national basis and establish a set of recommendations for such assessments
- To facilitate coordinating and collaboration among member states for INS development and deployment
- To pay particular attention to the needs of developing countries interested in INS.

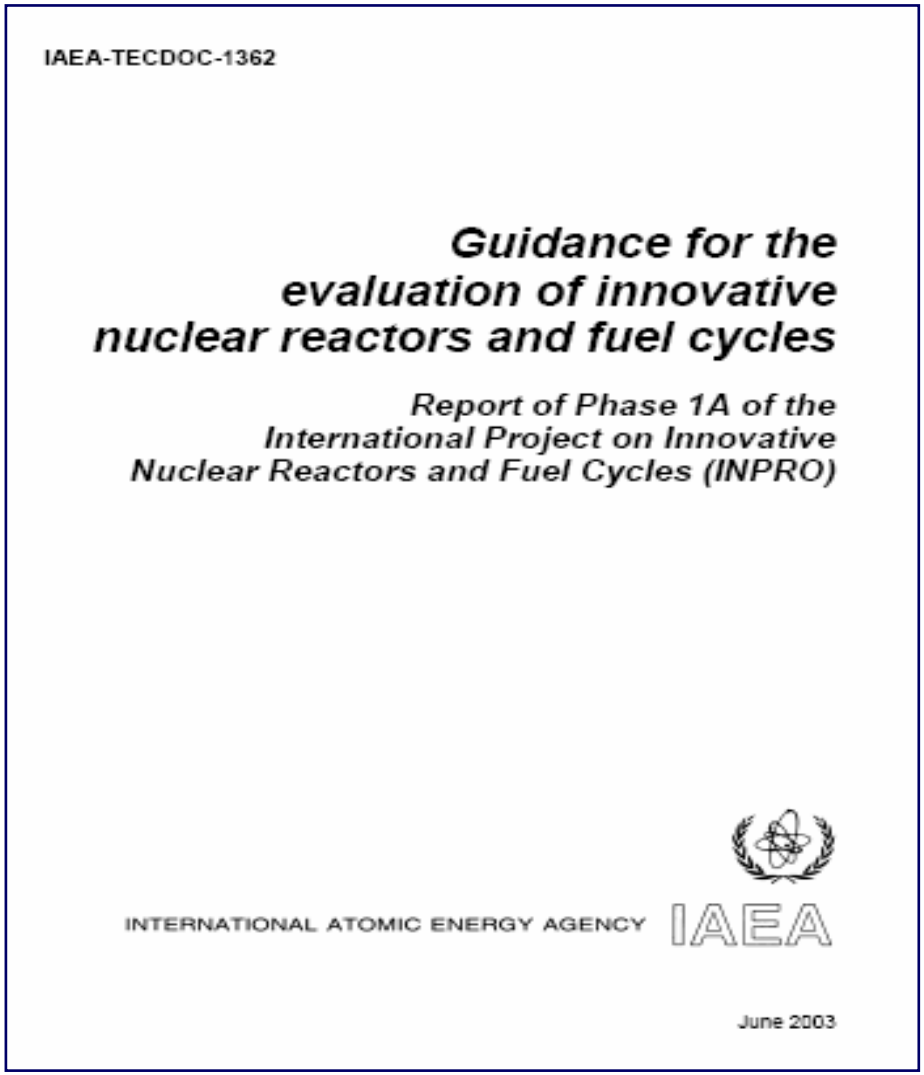
Overall INPRO Schedule



Conclusion of INPRO Phase 1A

- Formulation by INPRO in Phase 1A of Basic Principles, User Requirements and Criteria for Assessment of INS in all Areas (**Economics, Environment, Safety, Waste Management, Proliferation Resistance) and Recommendations in Cross Cutting Issues**.
- Documentation of Results of Phase 1A in an IAEA report (**TECDOC-1362**, Guidance for the evaluation of innovative nuclear reactors and fuel cycles) published in June 2003.

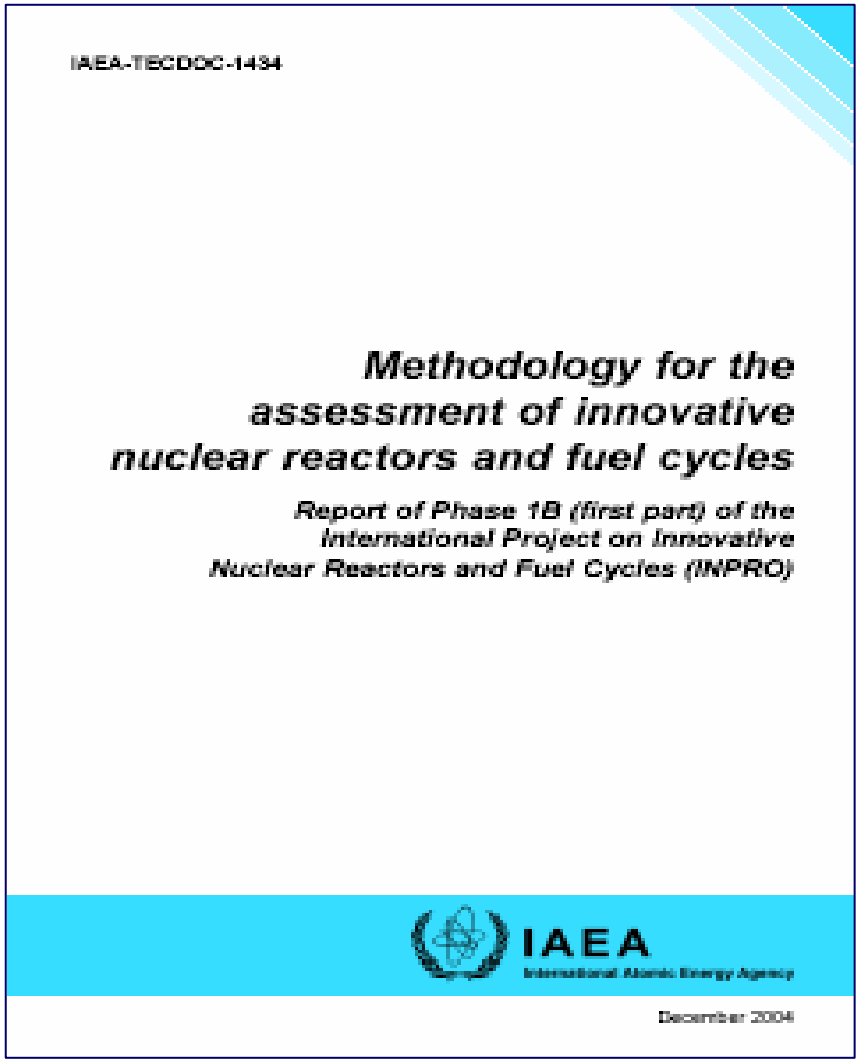
IAEA-TECDOC-1362



Conclusion of INPRO Phase 1B (1st part)

- INPRO Phase 1B (1st part) started in July 2003: **Testing/Validation** of INPRO Methodology via:
  - 6 National Case Studies performed by MS: Argentina, India, Republic of Korea, Russia, China, Czech Republic.
  - 8 Individual Case Studies performed by experts : Argentina, France, India, Russia.
- INPRO **Methodology updated** based on results of case studies and consultancies.
- **TECDOC-1434** (Methodology for the assessment of innovative nuclear reactors and fuel cycles) published in December 2004.

IAEA TECDOC 1434



INPRO Phase 1B (2nd part: 2005 - mid 2006)

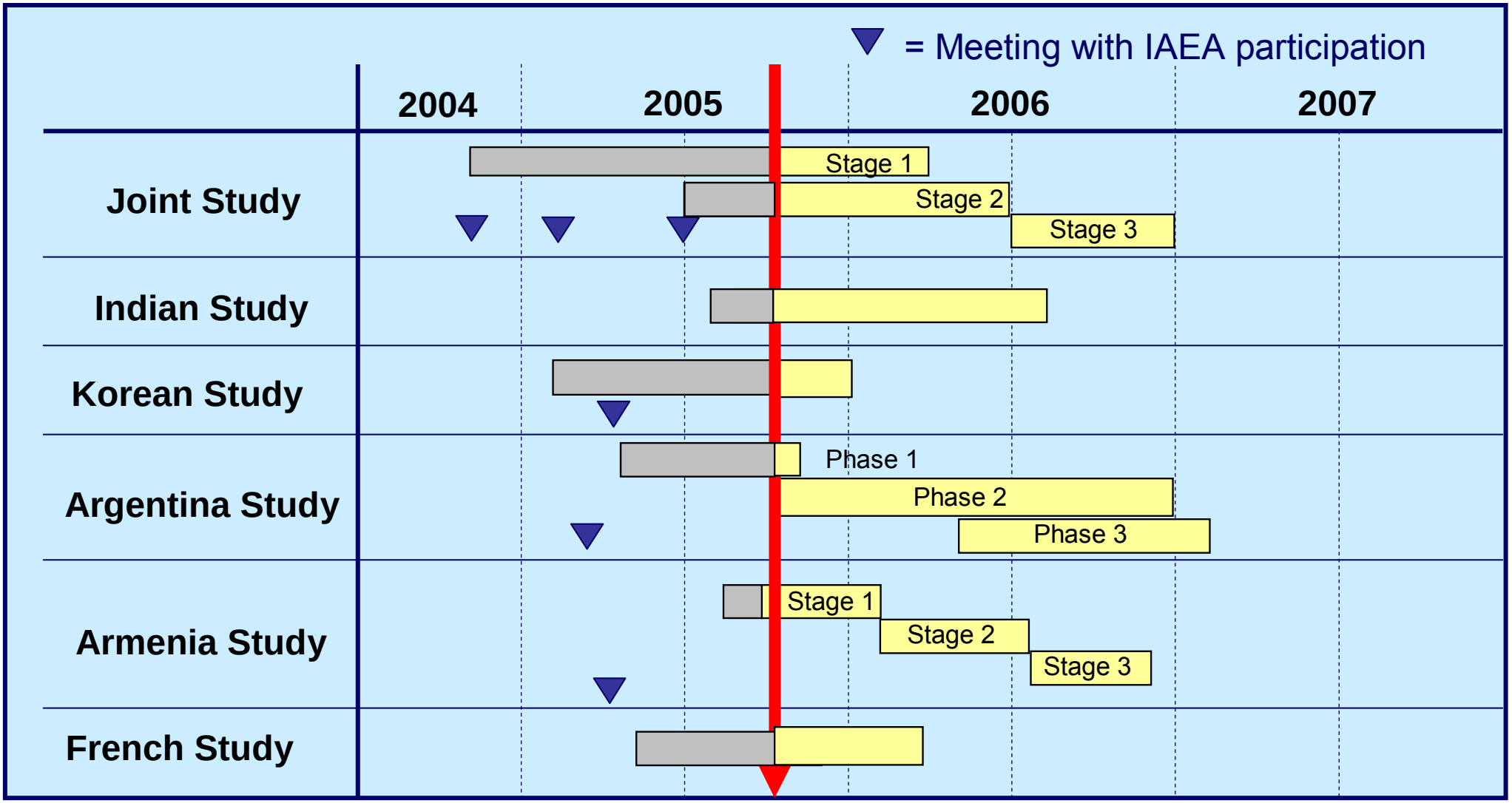
Major ongoing activities:

- Assessment of INS by MS using the validated methodology;
- Publication of a Users' Manual;
- Application and development of essential models, codes and techniques;
  Continuous improvement of methodology with a focus on a more quantitative approach;
- Determine national/regional/global balances of demands & resources by use of modelling tool
- Determine infrastructure needs for the introduction of INS
  - Including review of MNFC as components of MNFC
- Plan for facilitating coordination and collaboration among Member States for the development and deployment of INS (preparation for Phase 2)

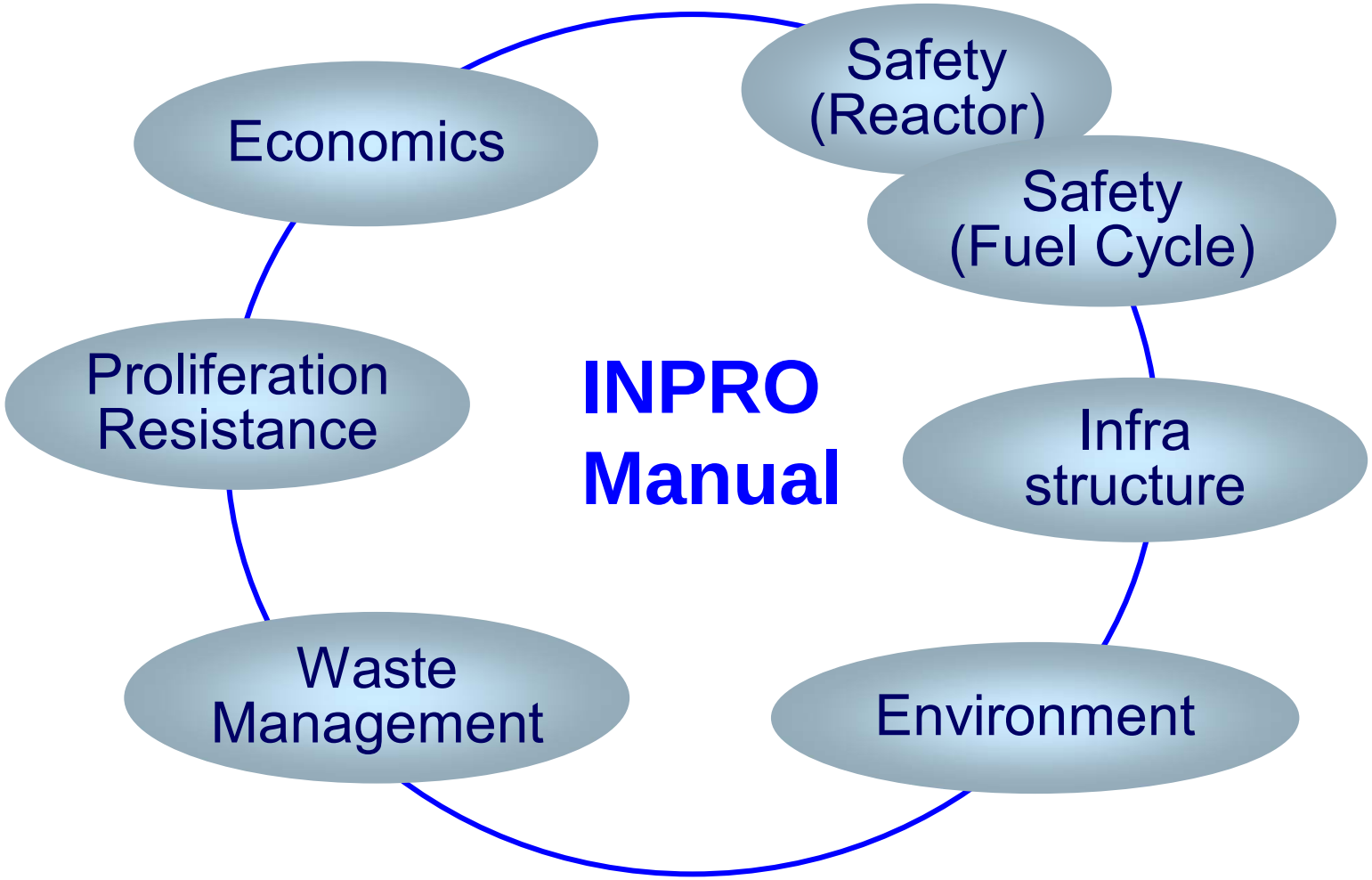
Ongoing INPRO assessments of INS by MS

- **Joint Study (Russian Federation, India, France, Rep. of Korea and China, and Japan as an observer) : Assessment of INS based on fast reactors w/closed fuel cycle.**
- **France: Transition phase between the current fleet towards the Gen IV fast neutrons systems.**
- **Armenia: INS for countries with small electricity grid.**
- **Argentina: Assessment of additional nuclear generation capacity in the country from 2010 to 2025.**
- **India: Assessment of INS based on high temperature reactors.**
- **Rep. of Korea: Assessment of complete DUPIC Fuel Cycle in the area of Proliferation Resistance.**

Schedule of INPRO Assessment Studies



Production of INPRO Manual



General Objectives of the INPRO Manual

- Enable **the applicant of the INPRO methodology,** the Assessor**, to** perform **a** quantitative assessment **of a given INS (or INSs).**

- Standardisation **of application of INPRO methodology.**

Plan for INPRO Phase 2

3 pillars envisioned;

- **Promotion of infrastructure development for development and deployment of INS**

  Consideration of options for regional development of INS (including Fuel Cycle Centers)

- **Further elaboration of INPRO methodology & Development of analytical tools**
  - ✓ **to enable assessment of the potential of INSs to meet national/regional/global energy demand/supply in a sustainable manner**
- Facilitating coordination and collaboration among Member States for the development and deployment

Cooperation with other international initiatives (GIF)

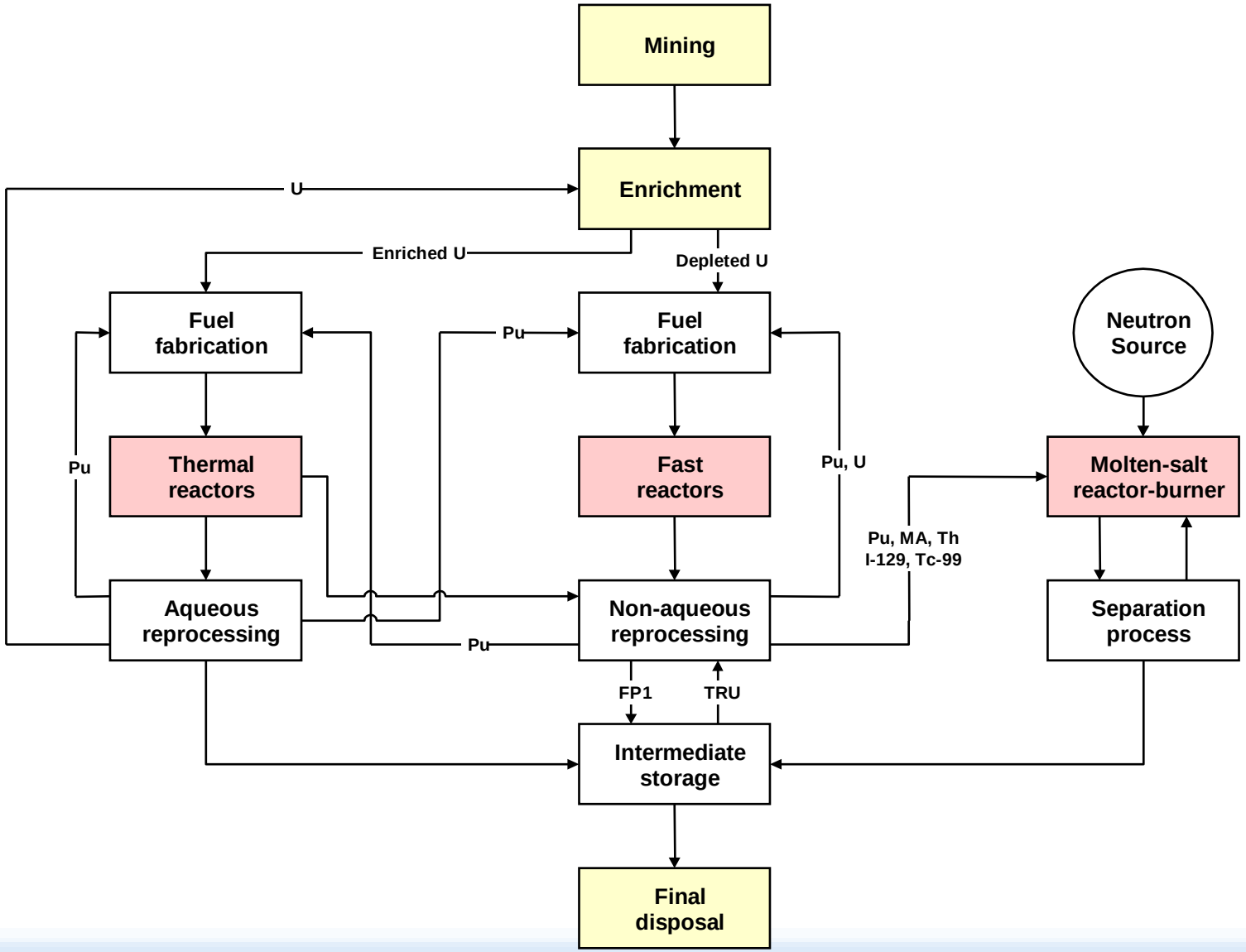
General features of the INPRO Methodology

- Holistic approach
- Hierarchy of demands on INS
- 3 Types of INPRO assessment
- 3 Steps of INPRO assessment

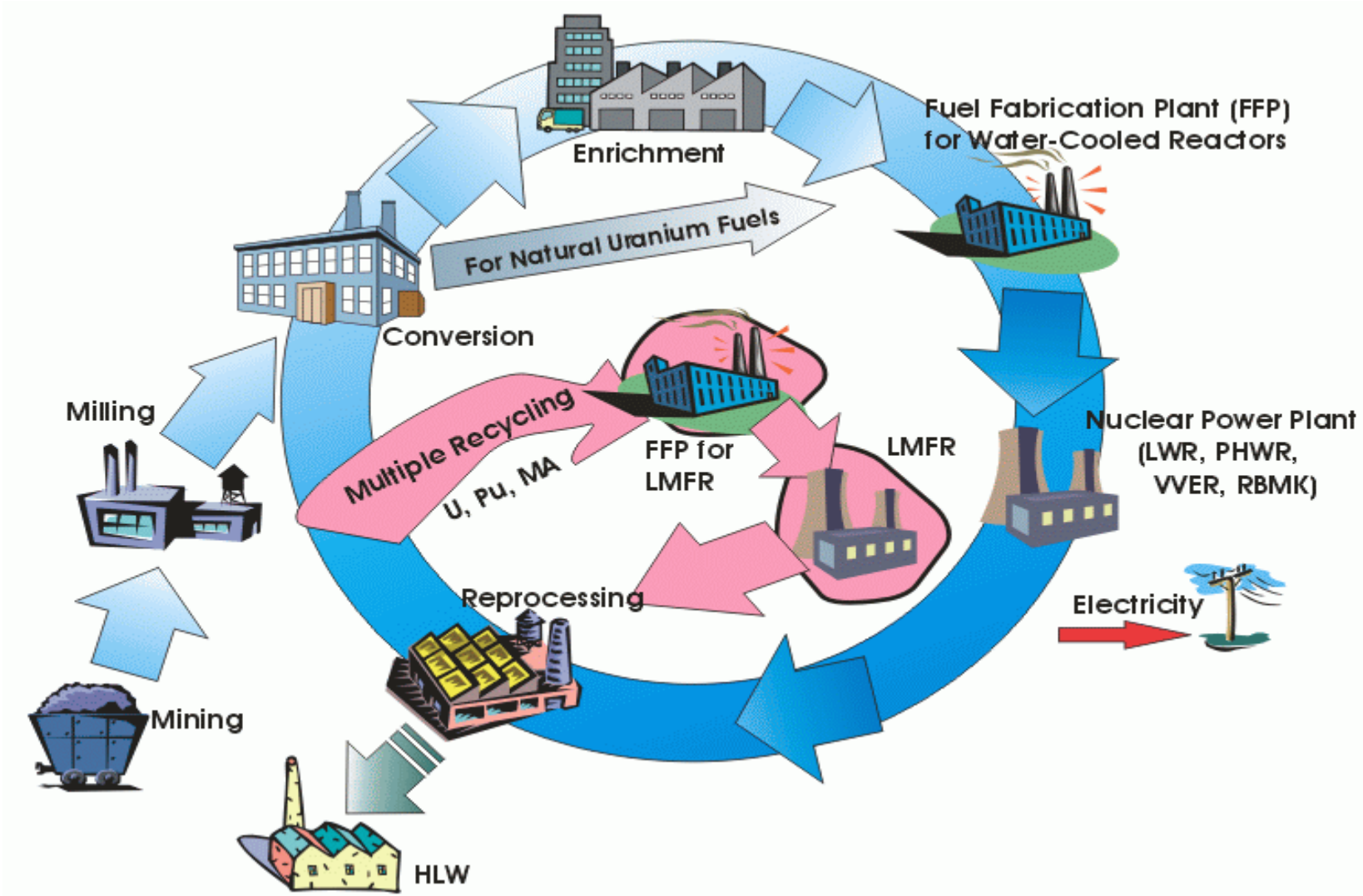
Holistic approach

- Definition of **I**nnovative **N**uclear Energy **S**ystem (INS):
  - **INS includes Innovative and Evolutionary Designs of all reactor types.**
  - **INS includes all Components:**
    - **Mining and Milling, Fuel Production, Enrichment, Fabrication, Production (incl. all types and sizes of reactors), Reprocessing, Materials Management (incl. Transportation and Waste Management);**
  - **INS includes Institutional Measures:**
    - **(e.g. agreements, safe guards,** infrastructure, **etc.);**
  - **INS includes all Phases:**
    - **cradle to grave**
- In INPRO all relevant areas covered; Economics, safety, environment, waste management, proliferation resistance, infrastructure

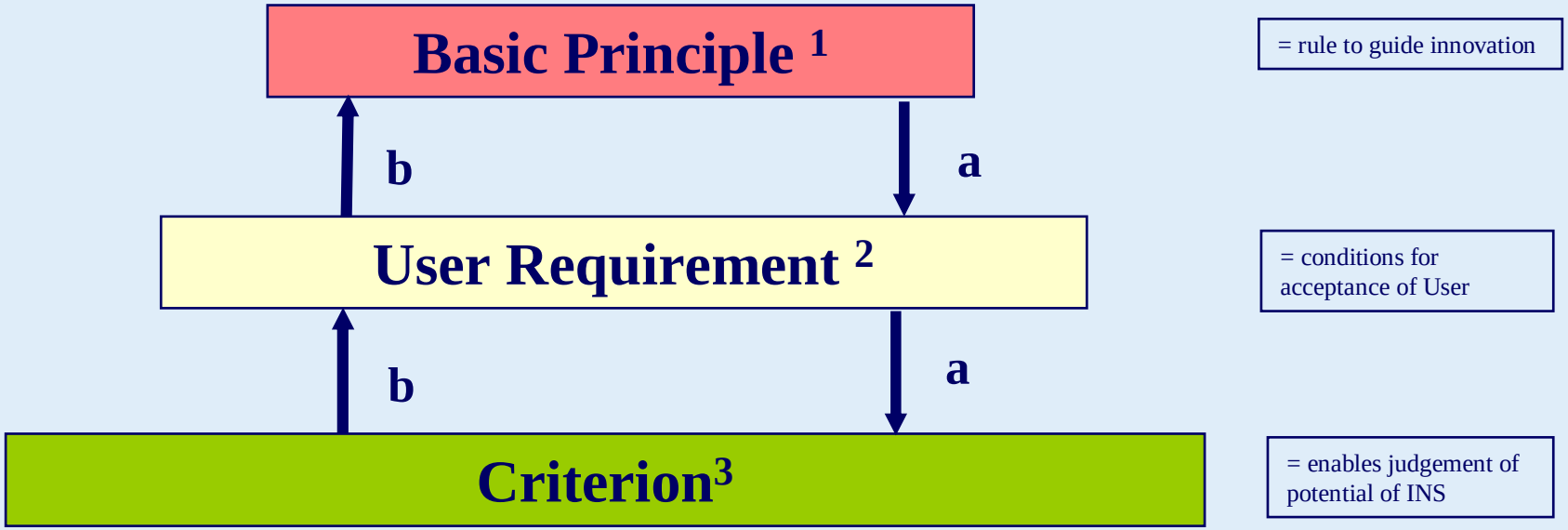
INPRO Example of INS



INPRO Methodology covers the entire NFC Process



Hierarchy of demands on INS



a = Derivation of hierarchy
b = Fulfilment of demands

1 ~ Goal in GIF
2 ~ Criteria in GIF
3 ~ Metrics in GIF

Hierarchy of demands on INS

- Basic Principle: **Statement of a general rule providing guidance for the development of sustainable INS.**
- User Requirement: **Conditions to be met to achieve acceptance of INS by User. Definition of measures to fulfill Basic Principle.**
- User: **Has a stake or interest in sectors where INS are applicable, e.g. designers, utilities (electricity, heating, desalination, etc.), regulators, national governments, NGO, press, international organizations and public. Includes countries in development and transition.**
- Criterion: **Consists of an Indicator and an Acceptance Limit. Used for Judgement of Potential of INS to fulfil the corresponding User Requirement.**

3 Steps of INPRO assessment

1. Modelling of scenario with INS.

2. Quantification of Criteria: Determination of value of Indicators and Acceptance Limits for an INS.

3. Judgement on potential/capability of INS.

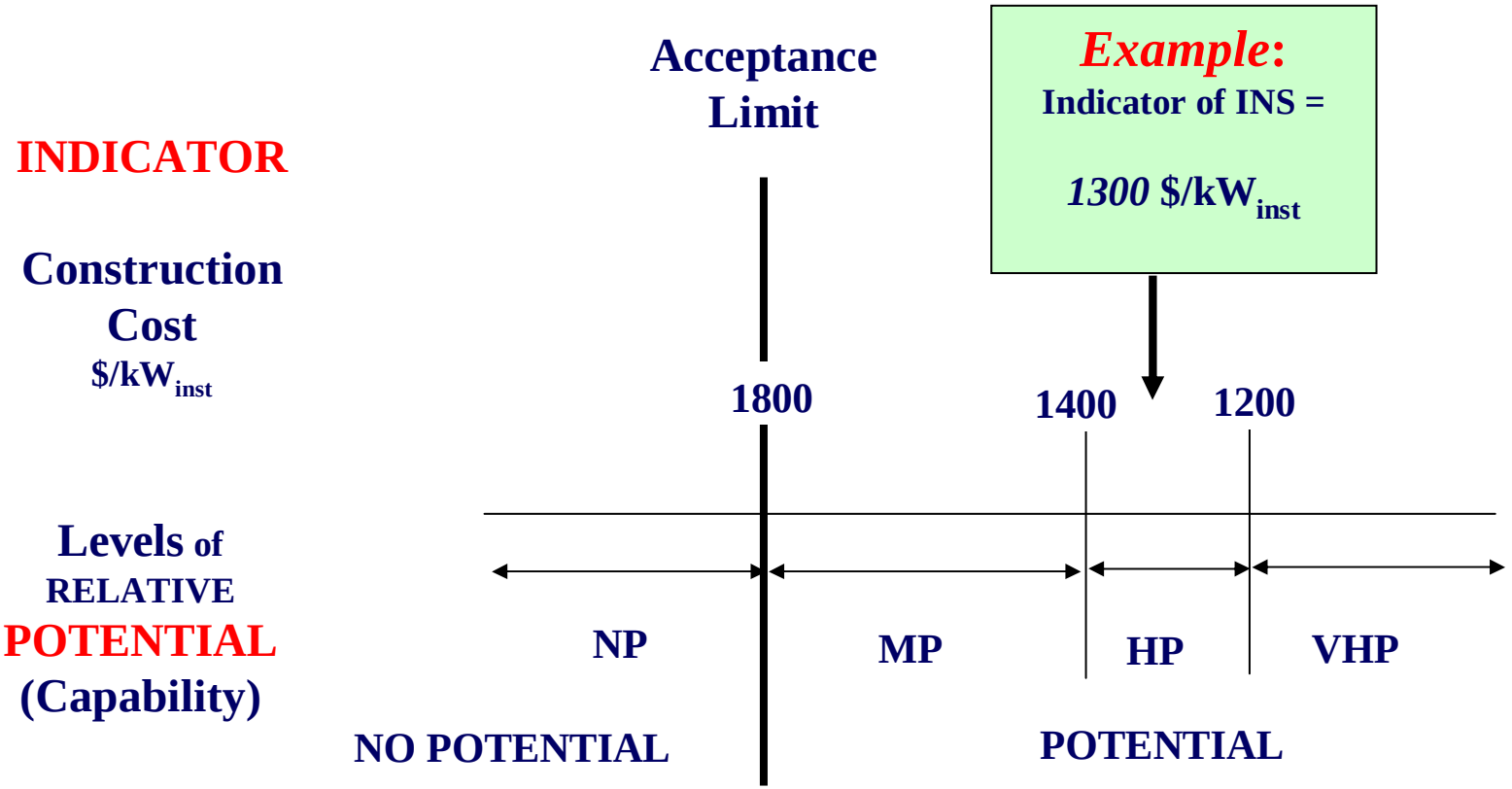
INPRO 3 types of assessment

- Screening of INS:
  check of compatibility with the INPRO set of Basic Principles and User Requirements;

- Comparison of different INS:
  determination of preferred or optimum INS;

- Identification of research and development: improve the performance of existing INS components and/or development of new components.

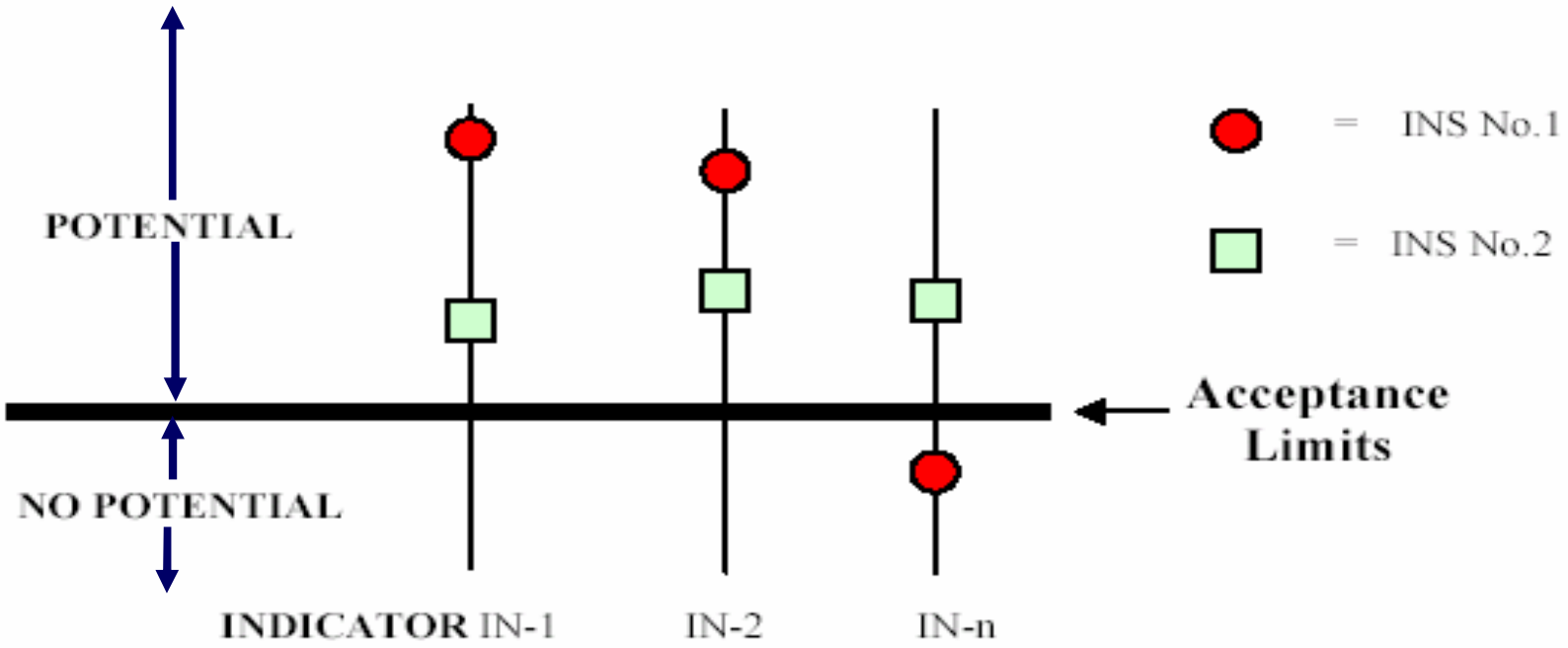
Example of Screening Assessment



Result of judgement (example) of INS against Indicator Construction Cost:

⇨ **INS has High Potential (HP) to fulfil this Criterion**

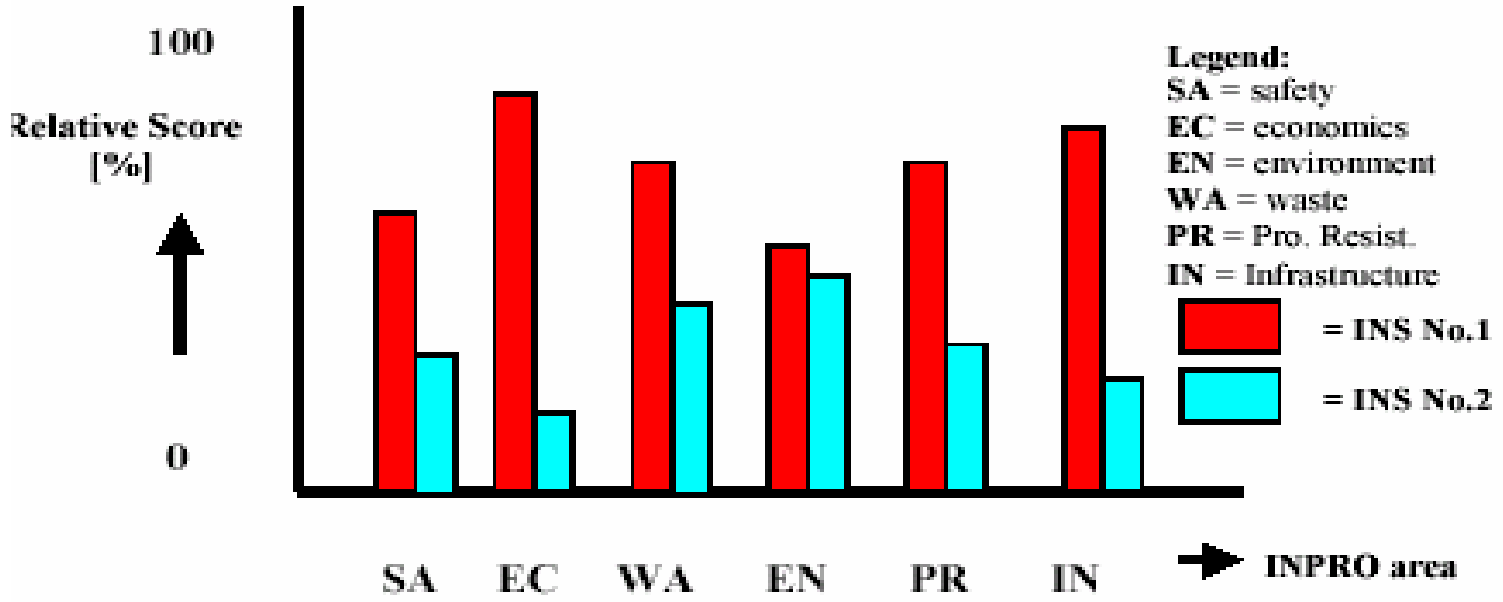
Result of INPRO Comparison of two INS



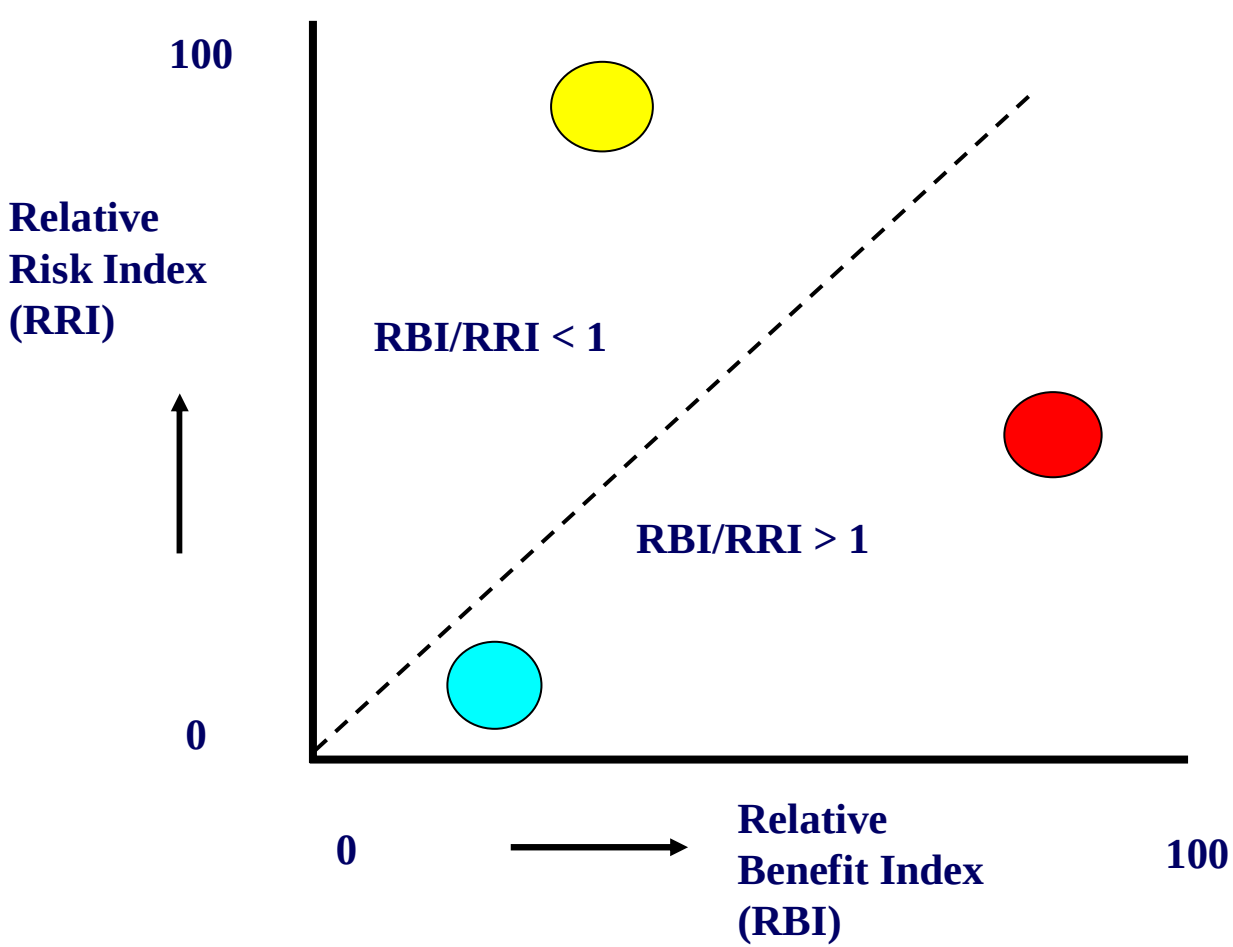
- **INS is superior for Indicator IN-1 and 2, however**
- **INS No1. is not acceptable (not sustainable) for Indicator IN-n , and needs either different component or RD&D**

Comparison of two INS regarding their capability/potential

INS No.1 has higher capabilities



Identification of RD&D



Legend

- = INS No.1: highly mature (low risk), low benefit to develop
- = INS No.2: high benefit to develop, medium risk
- = INS No.3: low benefit, too high risk

UN Concept of Sustainability and INPRO

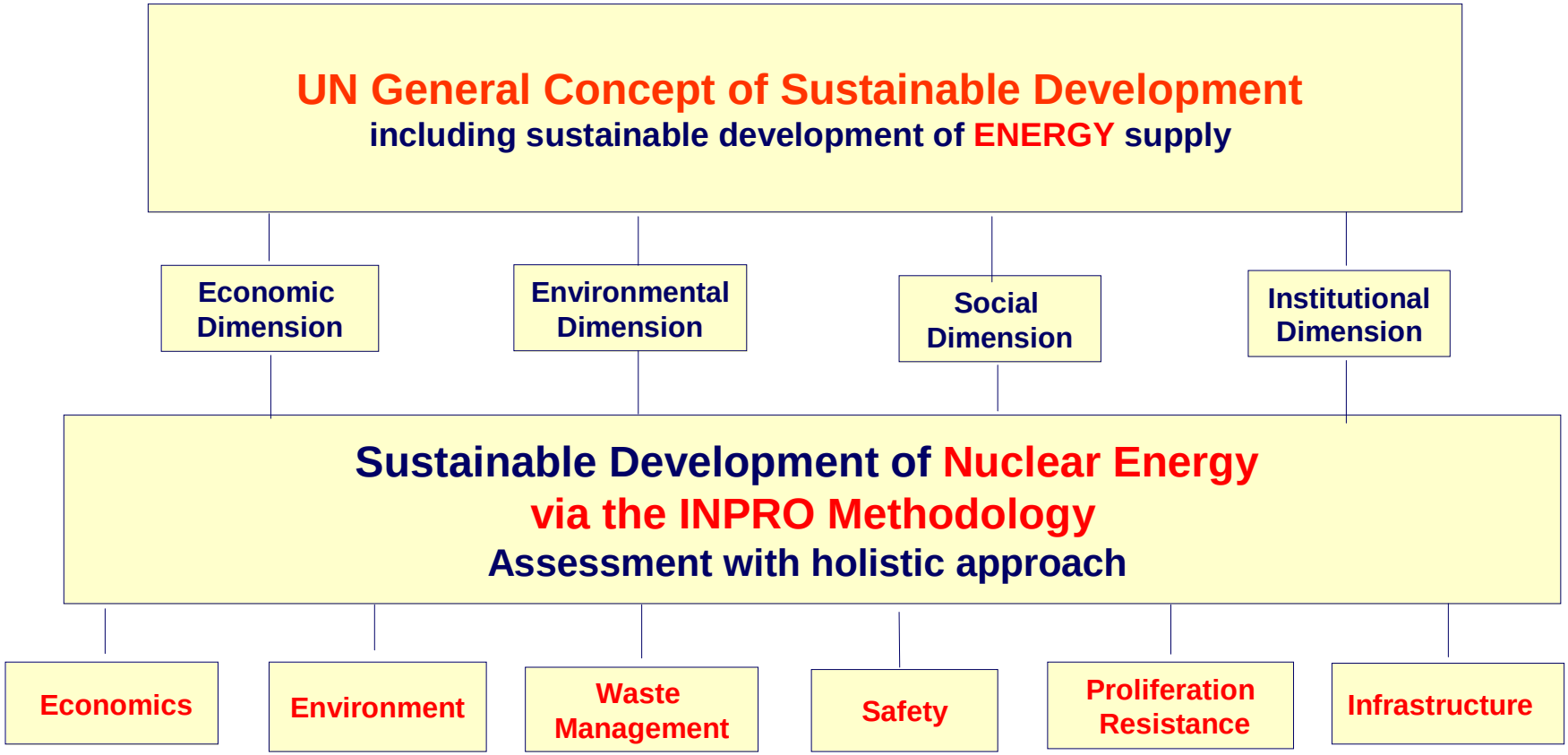
- History of concept of sustainability
  - Brundtland Report, Agenda 21, Commission on Sustainable Development, WEC, Kyoto Protocol, etc.
- UN concept of sustainability : 4 dimensions
  - Economic: durable growth, financial stability, etc.
  - Environmental: depletion of resources, degradation of environment.
  - Social: equity among groups, stability of cultural systems, safety, proliferation threat, etc.
  - Institutional: legal and policy instruments..

UN Concept of Sustainability and INPRO

- Energy supply important for all 4 dimensions of Sustainability
  - **Development of** energy supply **needed for sustainable development of world.**
  - **Development of** Nuclear Energy **needed for sustainable development of energy supply.**
  - **INPRO addresses all 4 dimensions of UN concept of sustainability**
  - **All INPRO requirements fulfilled by INS :**

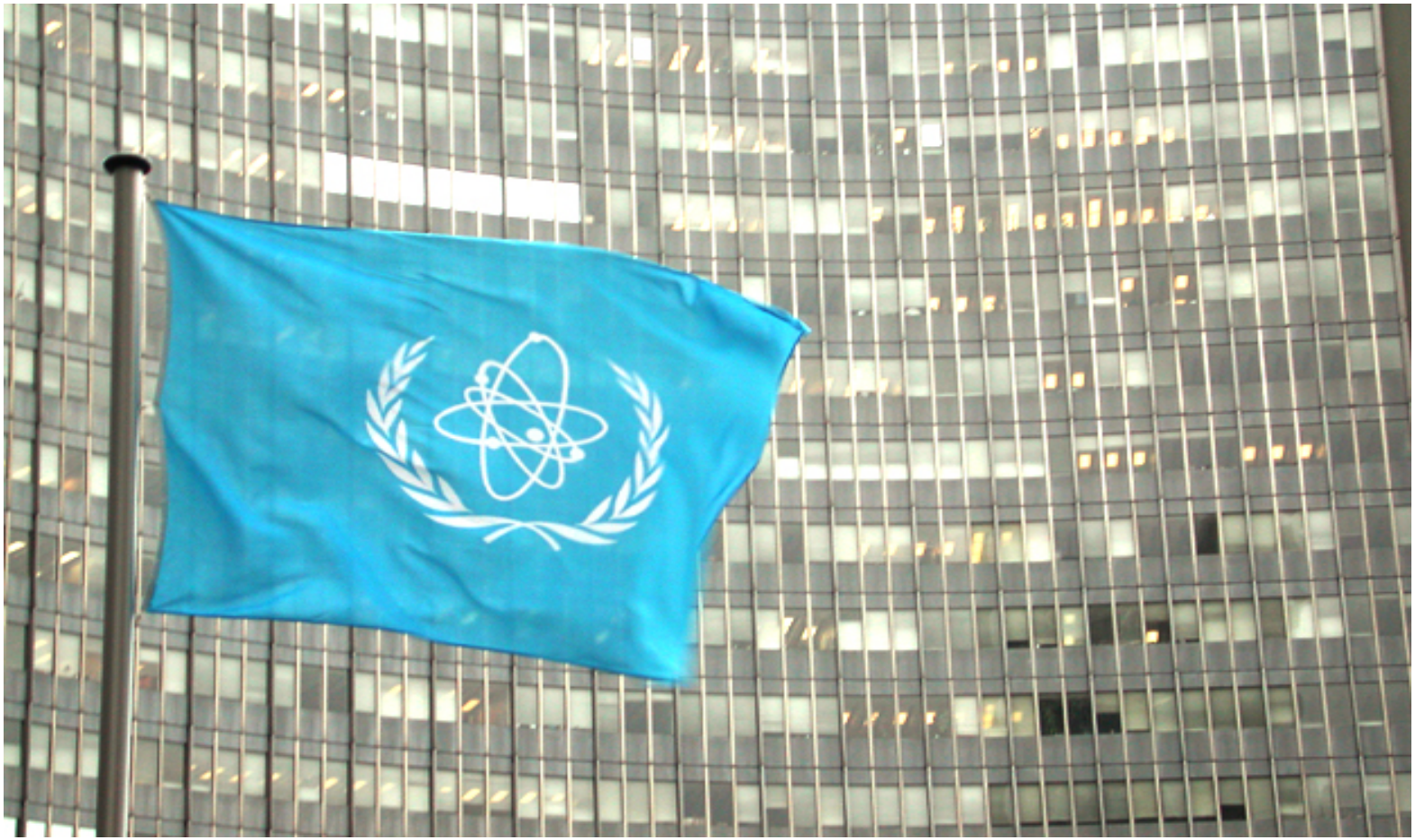
⇒ **sustainable NE systems, compatible with UN concept of sustainable development.**

UN Concept of Sustainability and INPRO



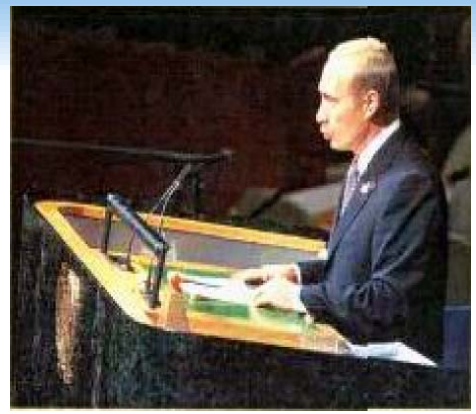
- Energy supply is fundamental to sustainable development of the world
- Sustainable energy supply needs significant contribution by NE
- INPRO assures that NE is available in a sustainable manner in the 21st century
- INPRO addresses all dimensions of the UN concept of Sustainability

Thank you



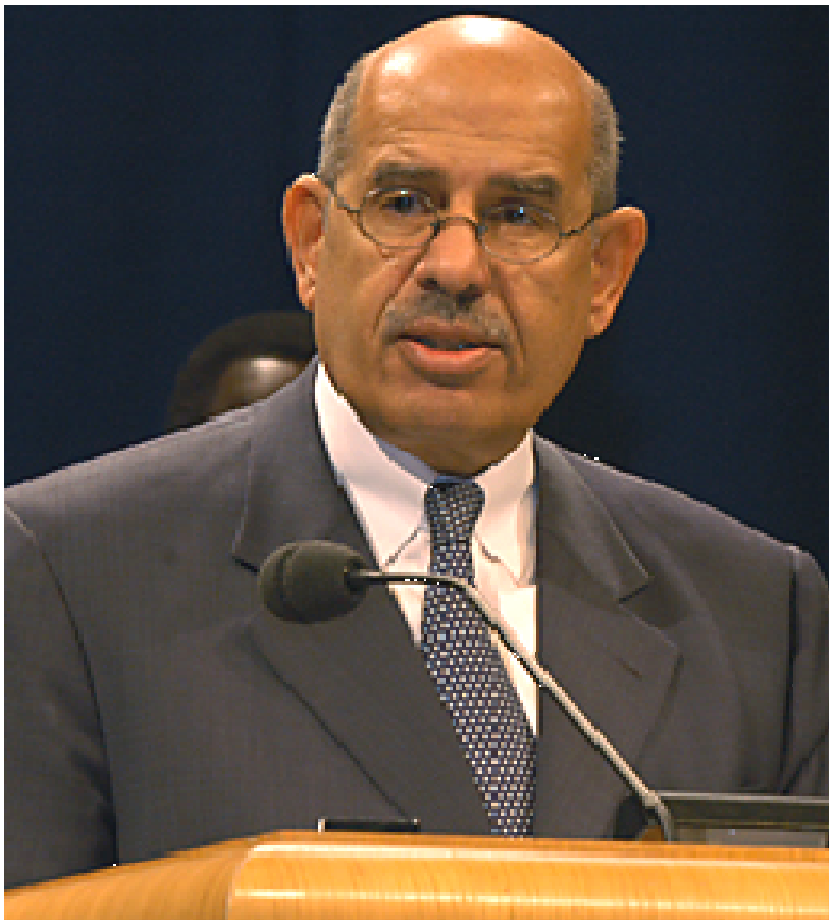
…Thank you for your attention

Speaking at the UN Millennium Summit on September 6, 2000, President of the Russian Federation V.V. Putin said in particular:



- “The ways for the sprawl of nuclear weapons should be securely blocked. This can be achieved, among other means, by phasing out enriched uranium and pure plutonium from use in peaceful nuclear energy production. Technically, this is quite feasible. But much more important is the fact that burning of plutonium and other radioactive elements paves the way for final resolution of the radioactive waste problem. It opens fundamentally new horizons for secure life on the planet. In this connection, Russia suggests preparing and implementing a relevant international project with participation of the IAEA.”

IAEA Director General Mohamed El Baradei delivers his statement to the 49 th General Conference. (Plenary, Austria Center, Vienna, Austria, 26 September 2004).



- ***INPRO´s primary contribution has been to ensure that the future needs of all countries (including developing countries) — related to reactor size, economics and infrastructure needs, as well as to safety, security, proliferation resistance and waste management — are considered when innovative nuclear systems are evaluated.***

IAEA GC(49)/RES/12-2005
Agency Activities in the Development of Innovative Nuclear Technology

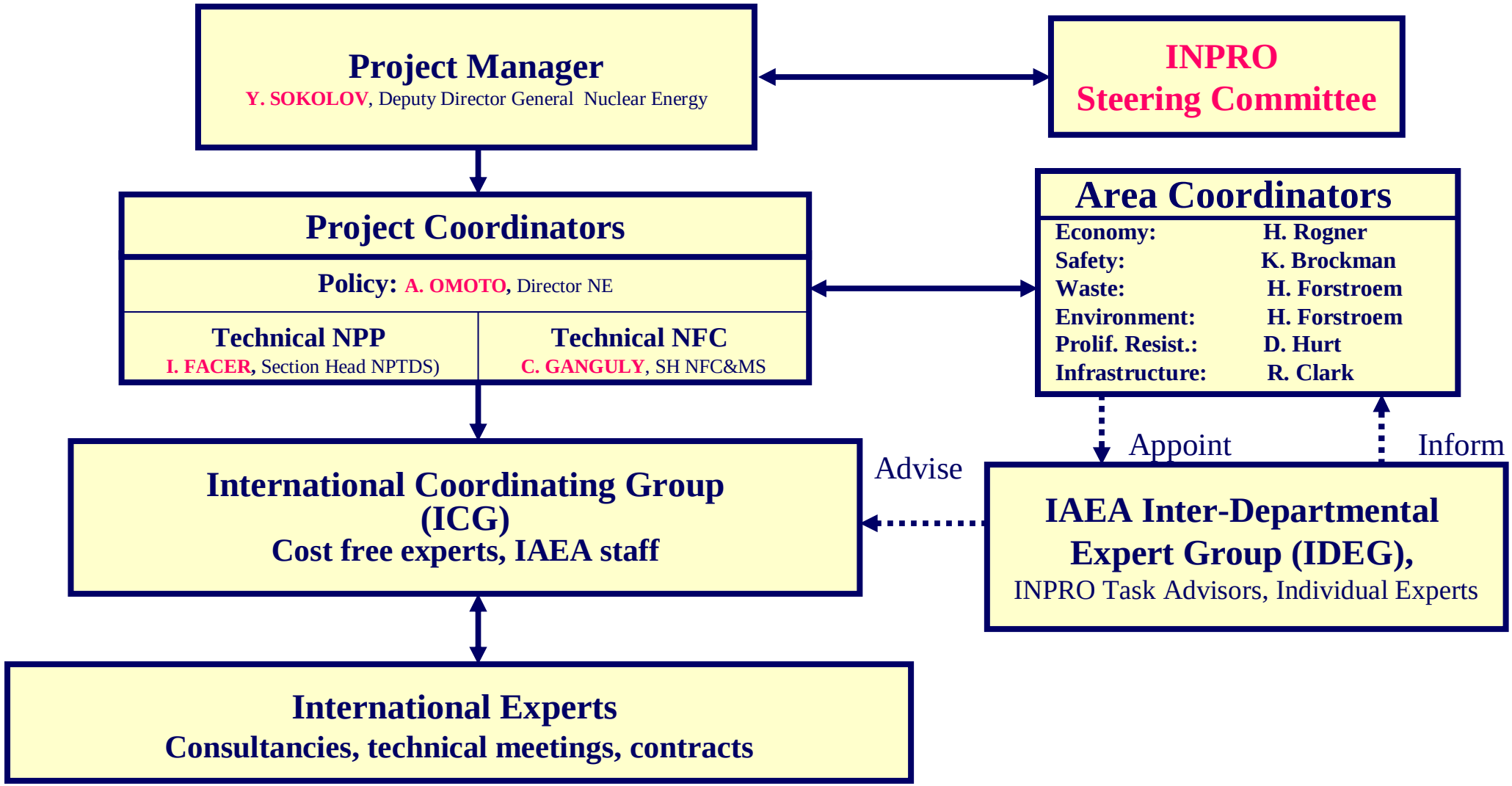
- Recognizing the unique role which the Agency plays, and in particular the current role it is playing through the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), by bringing together all interested Member States to consider jointly innovations in nuclear reactors and fuel cycle systems,
- Noting that 22 Member States and the European Union are now members of INPRO, with Armenia, Morocco and Ukraine having joined since the 2004 session of the General Conference, and that the **United States of America** has announced its intention to join INPRO at this session of the General Conference;
- Stresses the need for international collaboration for the development of innovative nuclear technology and the high potential and added value achieved through such collaborative efforts, as well as the importance of taking advantage of synergies between international activities on innovative nuclear technology development;
- Invites all interested Member States to contribute to innovative nuclear technology activities in terms of scientific and technical information, financial support or technical and other relevant experts and by performing joint innovative nuclear energy systems assessments;

Holistic Approach

In the framework of INPRO, an INS includes the following components:

- Uranium/ Thorium Mining and Milling
- Uranium Refining and Conversion
- Uranium Enrichment
- Fuel Fabrication
- Nuclear Reactor
- Spent Fuel Storage
- Spent Fuel Reprocessing including MA partitioning
- Re-fabrication including MA fuels and targets
- Radioactive Waste Management
- Waste disposal
- Decommissioning
- Transportation

INPRO Organizational Chart



INPRO and related IAEA activities

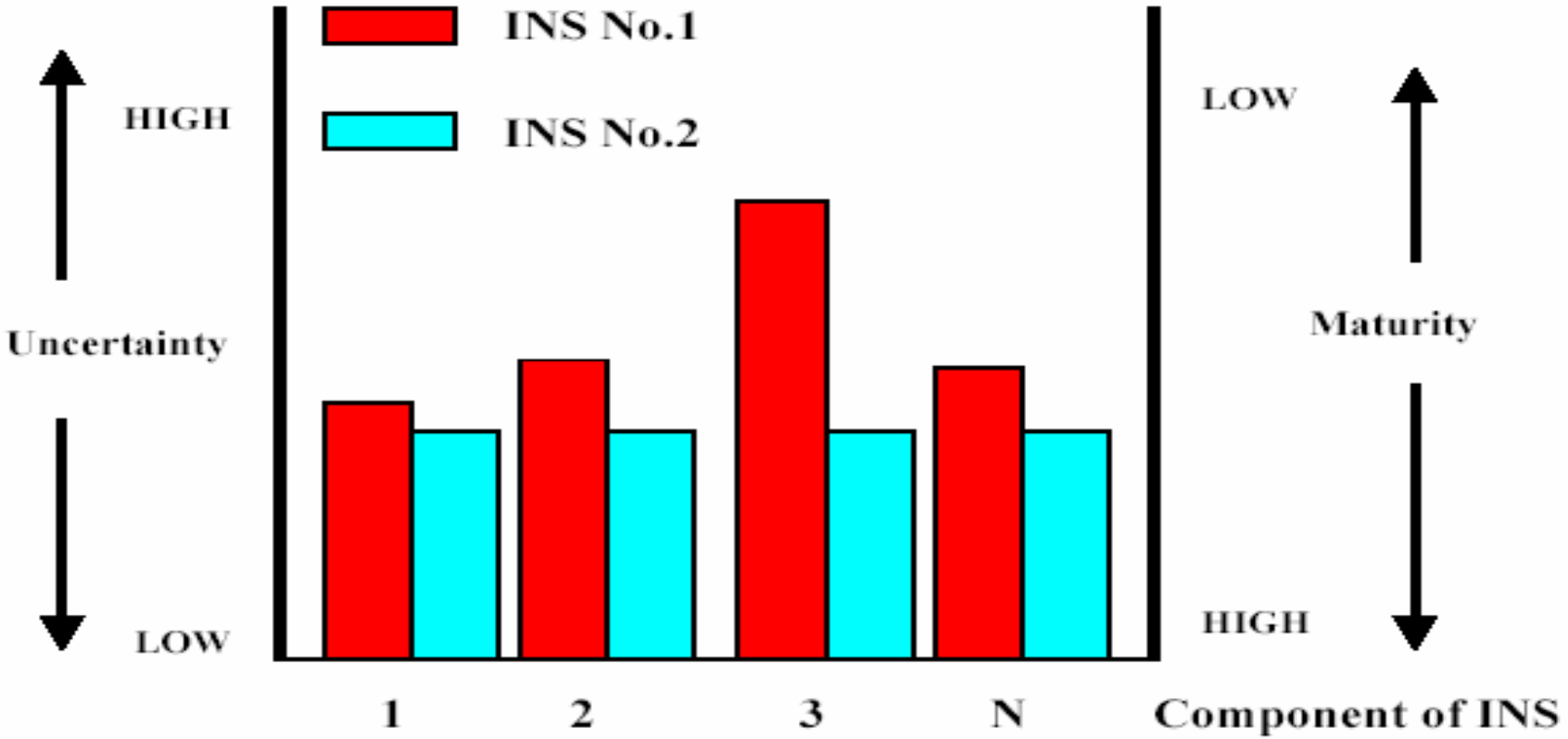
- INPRO compliments ongoing IAEA activities in areas, such as economics, safety, waste management, environment, PR, and infrastructure.
- A holistic INPRO assessment utilizes the output from IAEA activities.
- INPRO provides a gateway to the experience and resources of the IAEA, such as safety standards and guides, TRS and TECDOCs, TC, energy planning, safeguards.
- INPRO provides one way for the IAEA to identify the needs of their MSs.

Treatment of Uncertainties in INPRO

Stage of development of an INS (or a component thereof)	Level of Maturity of an INS	Level of Uncertainty of Judgement
No theoretical or experimental evidence exists that any of the Criteria cannot be met by the INS, due to some physical, technological or other limitation, which cannot be overcome by later technology developments.	Pre-Conceptual	Very High
Most important (Not all) components of the INS have been theoretically demonstrated or experimentally verified, and there is theoretical evidence that this INS could meet all the Criteria.	Conceptual Feasibility Established	High
All components of the INS have been theoretically demonstrated and, where necessary, experimentally verified and meet the Criteria.	Feasibility Demonstrated	Moderate
All components of the INS have been designed in enough detail to prepare a bid. If needed, a Pilot Plant (reduced size) was built and is operating successfully.	Developed and Demonstrated	Low
First of a kind plant (full size) built and operating.	Commercially Proven	Lower
Series of plants built and operated.	Full Commercial Exploitation	Lowest

Comparison of two INS regarding Uncertainty/Maturity

INS No.1 has higher Uncertainty because of lower Maturity



Types of INPRO Indicators

- Real Indicator: **experimentally verified or calculated value reflecting a property of INS,e.g. overnight construction cost.**
- Integer Indicator: **number in a list,e.g. number of barriers.**
- Logical Indicator: **Question, e.g. is level of knowledge adequate? Is nuclear law existing?**

Types of INPRO Acceptance Limits

- **Numerical Acceptance Limit :**
  - **Limiting value (real or integer) of an Indicator against which the INS value is to be compared enabling the judgement of potential/capability of INS.**
- **Logical Acceptance Limit:**
  - **"Yes" or "No" to question asked (e.g., Is nuclear law adequate?)**

Targets of GIF and INPRO

GIF

- **Selection of innovative reactor systems and fuel to be deployed after ~ 25 years (after 2025).**
- **Performance of R&D for (6) selected NE systems within next ~ 25 years, to be deployed primarily in developed countries**
- **Deployment of NE within next ~ 25 years of Generation III systems, to be done by industry + market.**

INPRO

- Development of methodology to define innovative nuclear energy systems (INS) to be deployed within next 50 years and beyond.
- Definition of necessary or desirable R&D for such INS suitable for all MS, especially for developing countries.
- Achievement of a sustainable development of nuclear energy in 21st century, national, regional and global.

Status 2005 of GIF and INPRO

GIF

- 6 concepts (reactor + fuel) selected.
- R&D programs started.
- Multinational cooperation programs for R&D established.

INPRO

- Methodology for assessment defined (Phase 1A).
- Methodology tested and validated (Phase 1B, 1st part).
- Methodology is applied to define suitable INS for MS and necessary R&D (Phase 1B, 2nd part).