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ICTP 40th Anniversary

SMR.1555 - 33

Workshop on
Nuclear Reaction Data and Nuclear Reactors:
Physics, Design and Safety

16 February - 12 March 2004

Operational Performance of Nuclear Reactors: Nuclear Power Information System

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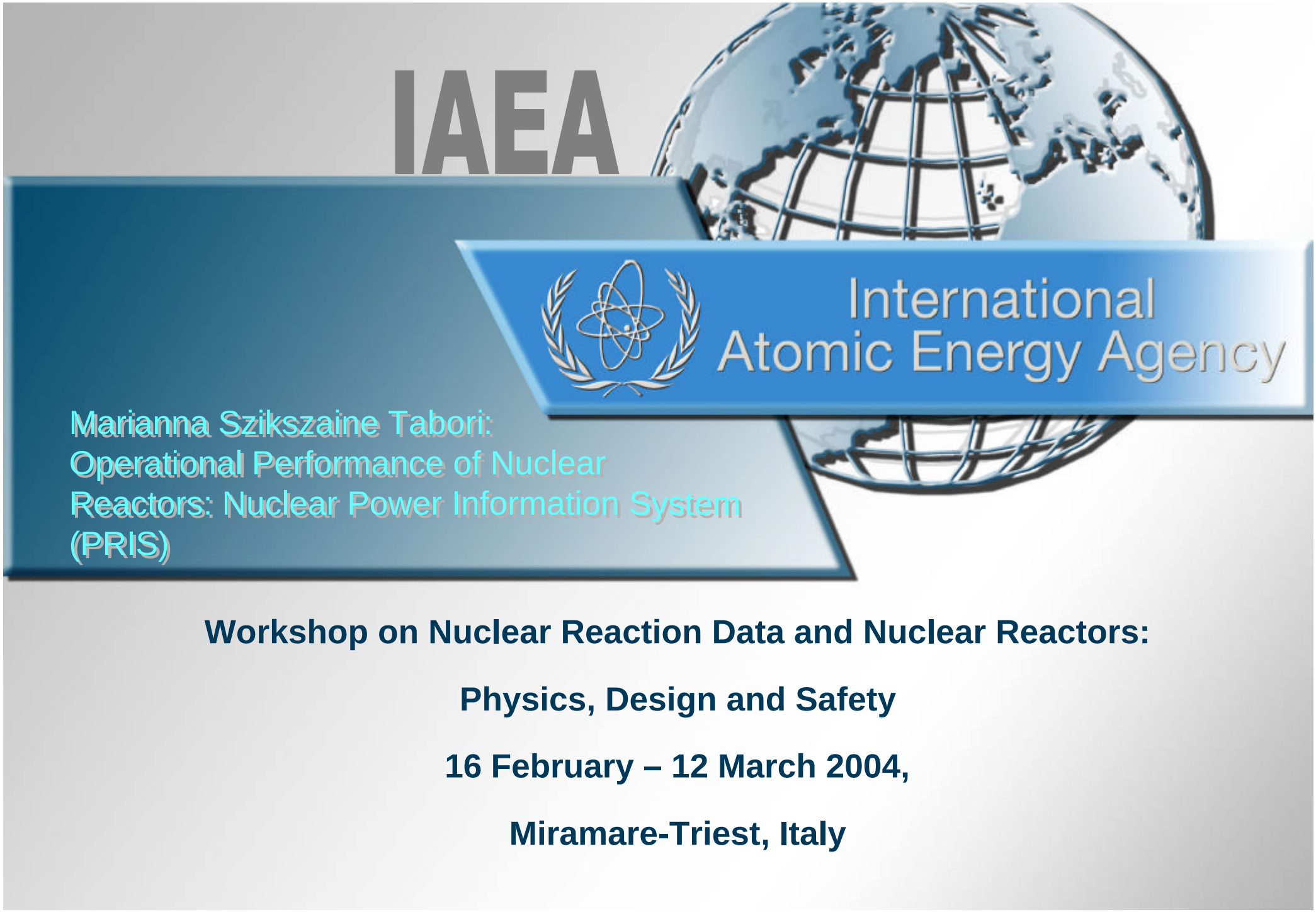


Marianna Szikszaine Tabori:
Operational Performance of Nuclear Reactors: Nuclear Power Information System (PRIS)

Workshop on Nuclear Reaction Data and Nuclear Reactors:

Physics, Design and Safety

16 February – 12 March 2004,

Miramare-Triest, Italy

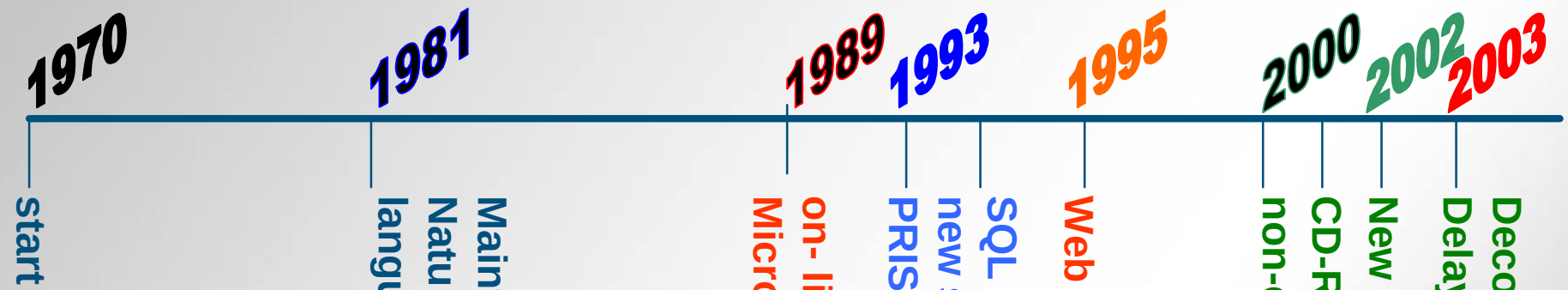
Content

- What is PRIS?
- PRIS Structure
- PRIS Data Gathering
- Performance Indicators and Statistics
- PRIS Outputs

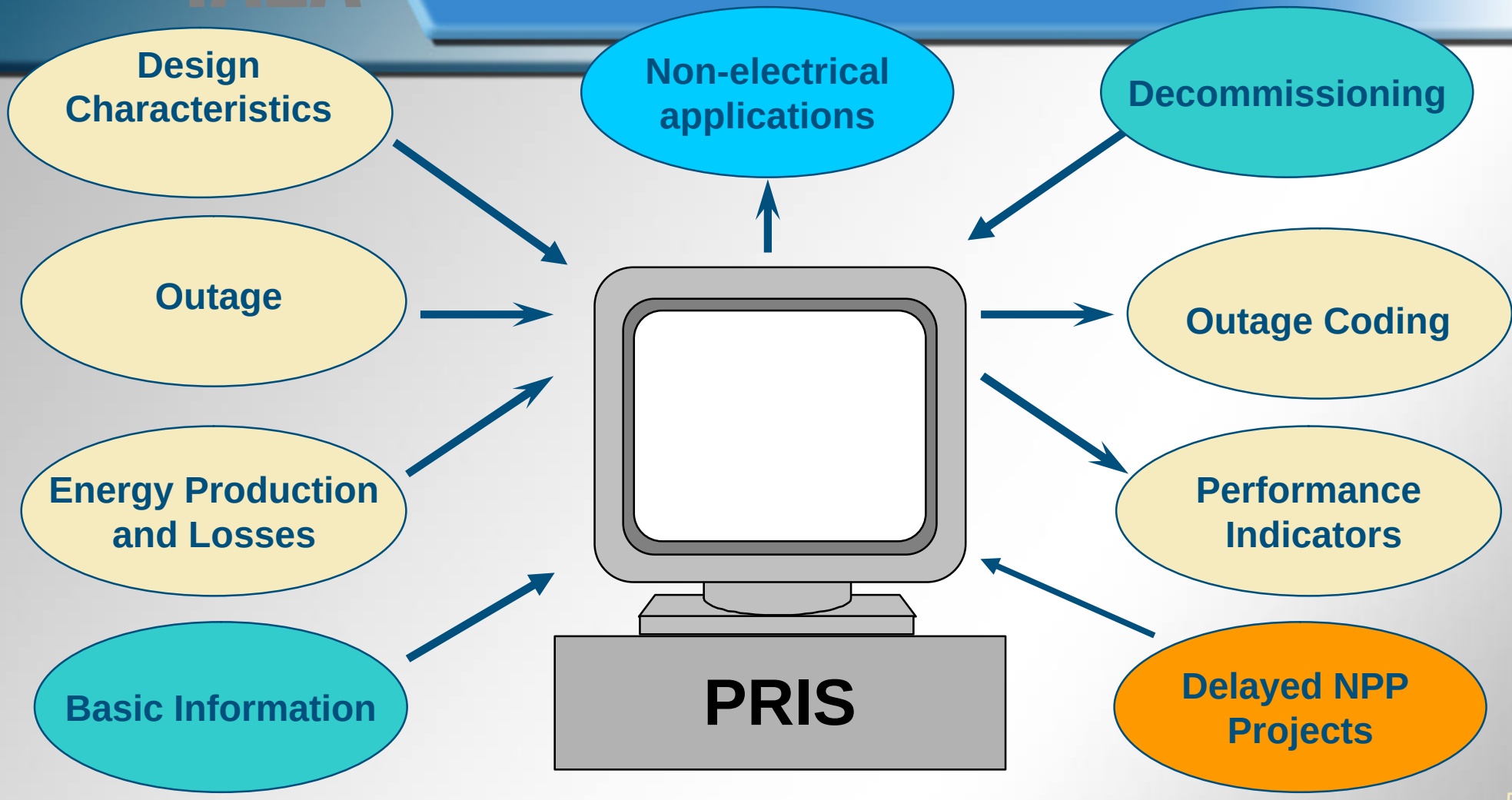
What is PRIS? Background

- New environment and challenges for the nuclear industry
- Necessity to analyse and monitor plant performance, availability and energy losses
- Historical data in PRIS
- Results of the IAEA CRP on International Outage Coding System (closed in 2001)

What is PRIS?
A bit of history



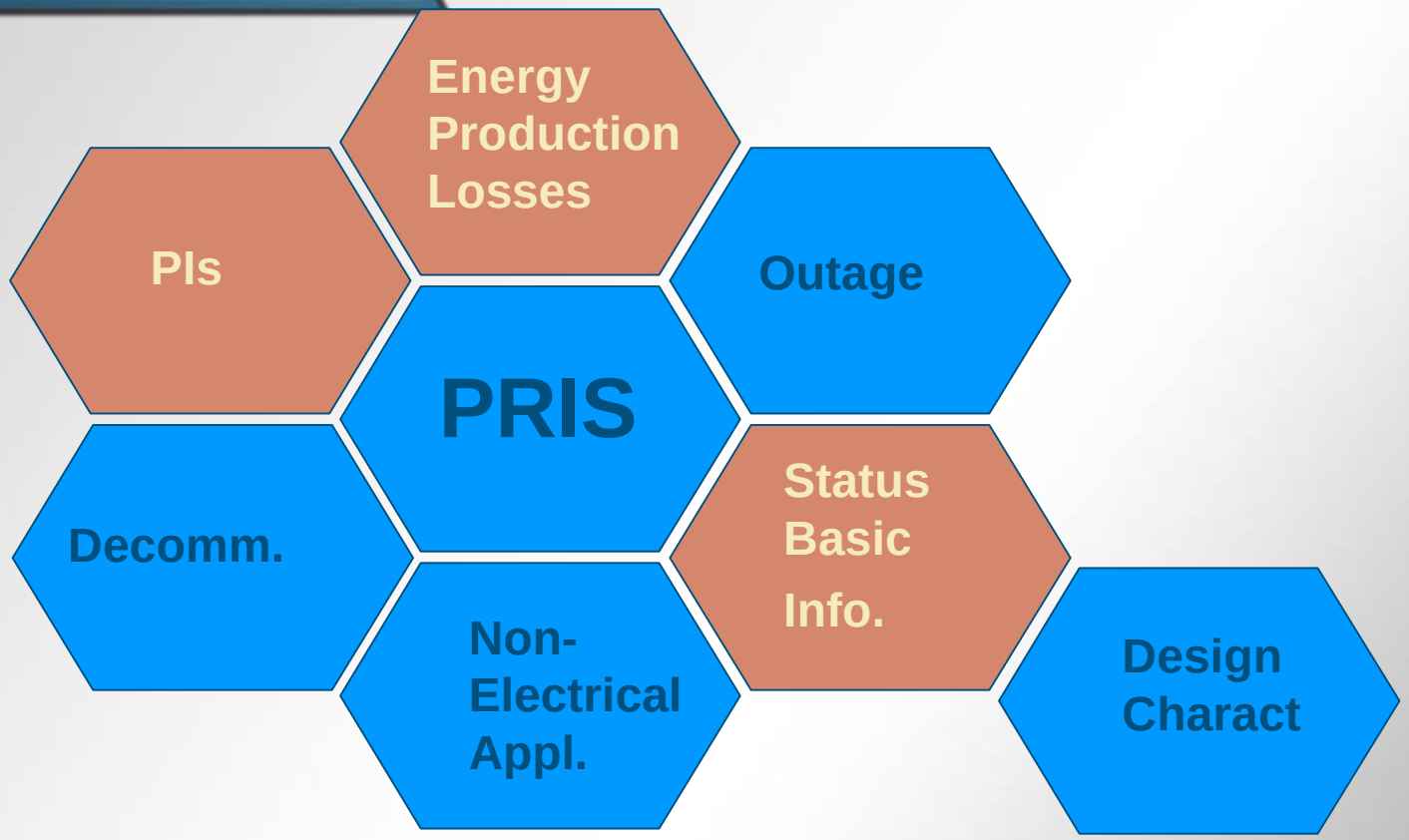
PRIS structure
Structure/development



PRIS structure cont.

Public Information

Non Public Information



PRIS structure
Contents

- All NPPs in operation, under construction and shutdown (delayed NPP)
- General information:
  - date of: construction start, grid connection,commercial operation, shutdown
  - net/gross electrical capacity
  - supplier, operator, etc

PRIS structure
Contents cont.

- **Design Characteristics**
  - core and reactivity control
  - reactor coolant system
  - safety and safety related system
  - conventional thermal cycle
  - spent fuel storage

PRIS structure
Contents cont.

- Operating experience:
  - energy production and losses
  - outages
- Perfomance Indicators
  - Production related
  - Unavailability related
  - Operating experience related
- Non-electrical applications

PRIS structure
Contents cont

- Decommissioning information
  - shutdown reason
  - decommissioning strategy
  - scheduled decommissioning phase
  - management of fuel removal

PRIS structure
Non-electrical application

- **Non-electric application**:"all nuclear energy used for non-electricity production, including on-site seawater desalination, but excluding heat used for nuclear plant internal services such as building heating, ventilation, turbine driven pumps."
- **district heating** --- providing heat to space heaters installed at houses, buildings and facilities outside the power plant. In some cases supply of hot water for living is combined with this system.
- **process heating** --- providing heat to chemical processes for producing commodities. Typical products are cardboards, concrete, heavy water and saltern. Utilization of waste heat in the form of warm water for fish industry or green houses can also be included but usually excluded.

PRIS - Data Gathering

- Designated national correspondents and Liaison Officers
  - all IAEA Nuclear Operating Member States
  - Wedas – web based data acquisition system

PRIS - Data Gathering

PRIS Questionnaire Form

- Well-arranged forms for data entry (include new data items):
  - I. Production data
  - II. Unavailability data
  - III. Operating experience data
  - IV. Outage data
  - V. Non-electrical application production data

PRIS - Data Gathering Cont.

Reporting Instructions:

- Close relation to the PRIS Questionnaire Form
- Clear definitions of terms to avoid misinterpretations or errors in data reporting

Year: |_|_|_|_|

IAEA plant unit code: |_|_| - |_|_|_|

Station name and unit number: _____

Reference unit power (net) at the beginning of the year *[MWe]*: |_|_|_|_|

Does your plant supply energy for non-electrical applications[1]? ☐

Monthly electricity generation (net) during the year:

	Electricity Generated (net) EG *[MWe·h]*	**On-line Hours t** *[hours]*	**Reference Period T** *[hours]*
January	|_|_|_|_|_|_|	|_|_|_|_|_|_|	|_|_|_|_|_|_|
February	|_|_|_|_|_|_|	|_|_|_|_|_|_|	|_|_|_|_|_|_|
March	|_|_|_|_|_|_|	|_|_|_|_|_|_|	|_|_|_|_|_|_|
April	|_|_|_|_|_|_|	|_|_|_|_|_|_|	|_|_|_|_|_|_|
May	|_|_|_|_|_|_|	|_|_|_|_|_|_|	|_|_|_|_|_|_|
June	|_|_|_|_|_|_|	|_|_|_|_|_|_|	|_|_|_|_|_|_|
July	|_|_|_|_|_|_|	|_|_|_|_|_|_|	|_|_|_|_|_|_|
August	|_|_|_|_|_|_|	|_|_|_|_|_|_|	|_|_|_|_|_|_|
September	|_|_|_|_|_|_|	|_|_|_|_|_|_|	|_|_|_|_|_|_|
October	|_|_|_|_|_|_|	|_|_|_|_|_|_|	|_|_|_|_|_|_|
November	|_|_|_|_|_|_|	|_|_|_|_|_|_|	|_|_|_|_|_|_|
December	|_|_|_|_|_|_|	|_|_|_|_|_|_|	|_|_|_|_|_|_|
TOTAL	|_|_|_|_|_|_|	|_|_|_|_|_|_|	|_|_|_|_|_|_|

Lifetime Cumulative Electricity Generation (net) *[GWe·h]:* |_|_|_|_|_|_|_|_|

INTERNATIONAL ATOMIC ENERGY AGENCY

POWER REACTOR INFORMATION SYSTEM
ANNUAL QUESTIONNAIRE

(II) UNAVAILABILITY DATA

Month	Planned Energy Losses (net)	Unplanned Energy Losses (net) (due to causes under the plant management control) UEL		Other Energy Losses (net) (due to causes beyond the plant management control)
	PEL *[MW(e)·h]*	**OFEL** **Unplanned shutdowns or load reductions** *[MW(e)·h]*	**UEPEL** **Unplanned outage extensions** *[MW(e)·h]*	**XEL** *[MW(e)·h]*
January	_____	_____	_____	_____
February	_____	_____	_____	_____
March	_____	_____	_____	_____
April	_____	_____	_____	_____
May	_____	_____	_____	_____
June	_____	_____	_____	_____
July	_____	_____	_____	_____
August	_____	_____	_____	_____
September	_____	_____	_____	_____
October	_____	_____	_____	_____
November	_____	_____	_____	_____
December	_____	_____	_____	_____
TOTAL	_____	_____	_____	_____

new

INTERNATIONAL ATOMIC ENERGY AGENCY

POWER REACTOR INFORMATION SYSTEM
ANNUAL QUESTIONNAIRE

(III) OPERATING EXPERIENCE DATA

Highlights of Operation:

Number of critical hours in the year [hrs]: |_|_|_|_|

Number of unplanned automatic scrams in the year: |_|_|

Number of unplanned manual scrams in the year: |_|_|

INTERNATIONAL ATOMIC ENERGY AGENCY

POWER REACTOR INFORMATION SYSTEM
ANNUAL QUESTIONNAIRE

PRIS

(IV) OUTAGE DATA

Start Date: *[yyyymmdd]*	Duration: *[hours]*	Energy Loss (net): *[MW(e)·h]*	Type Code:	Cause Code:
|_|_|_|_|_|_|_|_|	|_|_|_|_|	|_|_|_|_|_|_|	|_|_|/|_|	|_|/|_|_|.|_|_|

Description of the outage (cause and mode):

Start Date: *[yyyymmdd]*	Duration: *[hours]*	Energy Loss (net): *[MW(e)·h]*	Type Code:	Cause Code:
|_|_|_|_|_|_|_|_|	|_|_|_|_|	|_|_|_|_|_|_|	|_|_|/|_|	|_|/|_|_|.|_|_|

Description of the outage (cause and mode):

Start Date: *[yyyymmdd]*	Duration: *[hours]*	Energy Loss (net): *[MW(e)·h]*	Type Code:	Cause Code:
|_|_|_|_|_|_|_|_|	|_|_|_|_|	|_|_|_|_|_|_|	|_|_|/|_|	|_|/|_|_|.|_|_|

Description of the outage (cause and mode):

Performance Indicators and statistics
Production data

Related Performance Indicators:

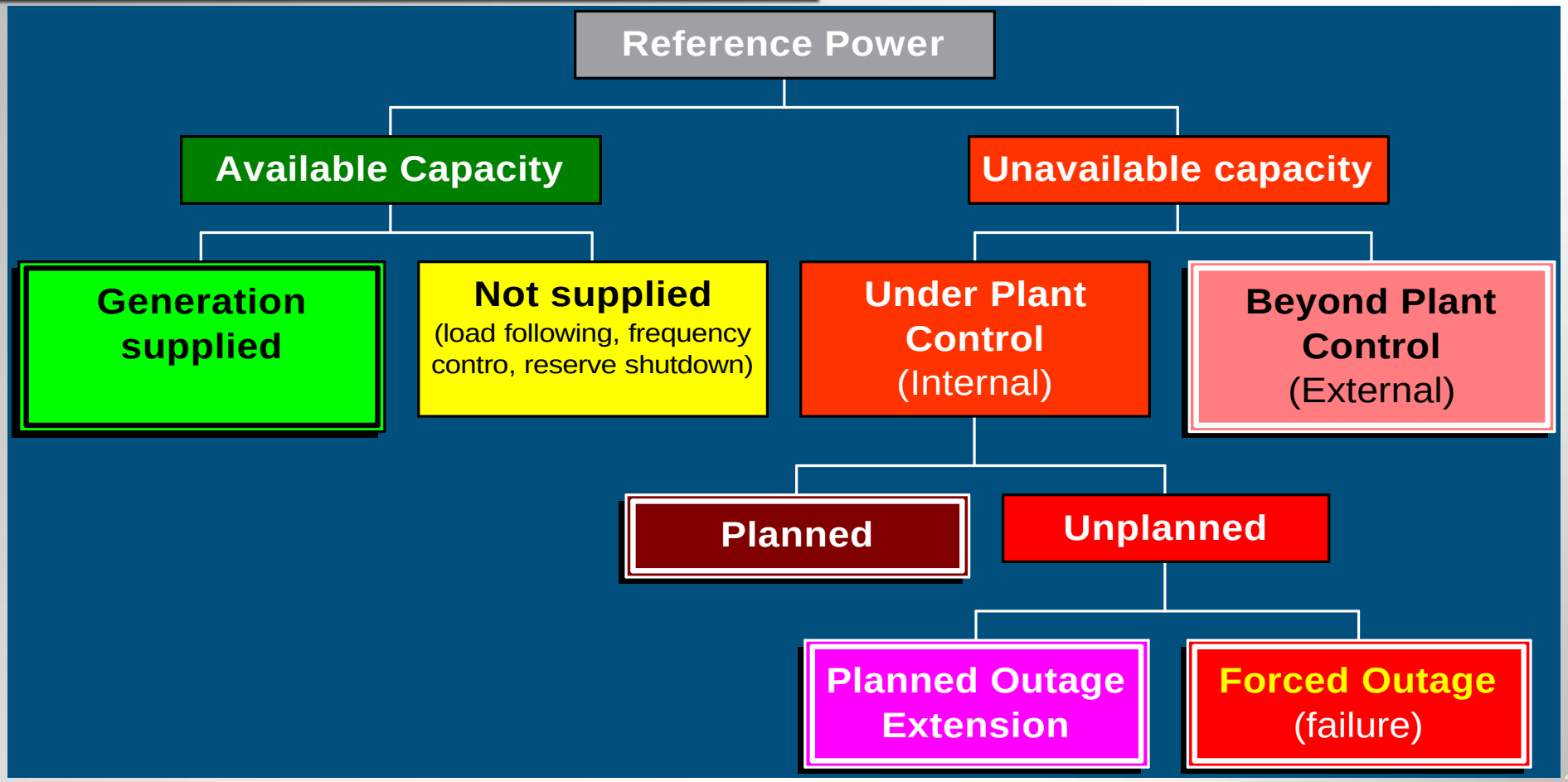
Load Factor (LF) [%]

$$LF = \frac{EG}{REG} * 100$$

Operation Factor (OF) [%]

$$OF = \frac{t}{T} * 100$$

Performance Indicators and statistics
Unavailability Concept



Performance Indicators and statistics
Unavailability Data

Related Performance Indicators:

Energy Availability Factor (EAF) [%]

$$EAF = \frac{REG - PEL - UEL - XEL}{REG} * 100$$

Energy Unavailability Factor (EUF) [%]

$$EUF = 100 - EAF$$

Unit Capability Factor (UCF) [%]

$$UCF = \frac{REG - PEL - UEL}{REG} * 100$$

Unplanned Capability Loss Factor (UCL) [%]

$$UCL = \frac{UEL}{REG} * 100$$

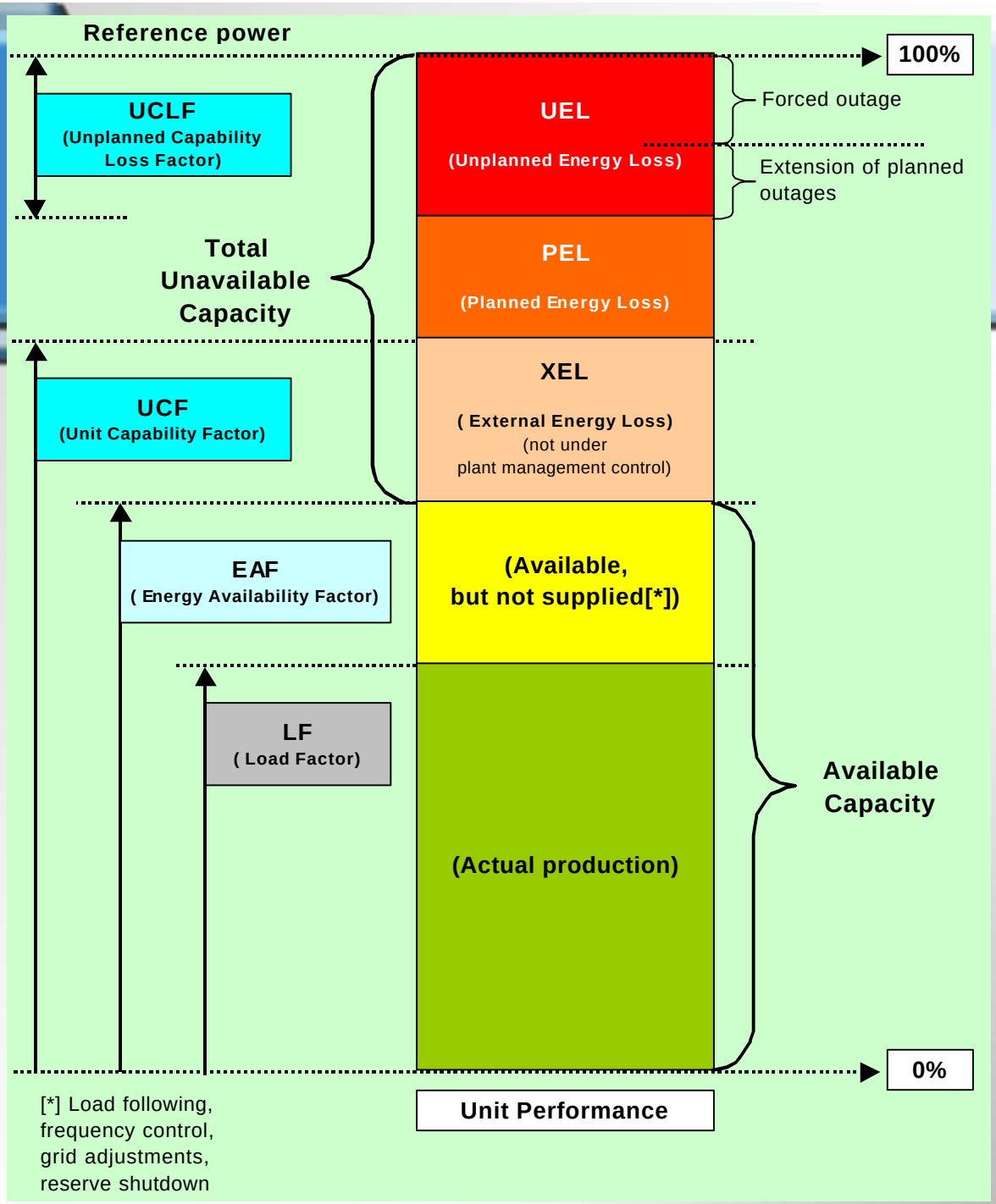
Planned Capability Loss Factor (PCL) [%]

$$PCL = 100 - UCF - UCL$$

Forced Loss Rate (FLR) [%]

$$FLR = \frac{OFEL}{REG - PEL - UEPEL} * 100$$

Indicators


Reference power
100%
UCLF
(Unplanned Capability Loss Factor)
UEL
(Unplanned Energy Loss)
Forced outage
Extension of planned outages
Total Unavailable Capacity
PEL
(Planned Energy Loss)
XEL
(External Energy Loss)
(not under plant management control)
UCF
(Unit Capability Factor)
EAF
(Energy Availability Factor)
(Available, but not supplied[*])
LF
(Load Factor)
(Actual production)
Available Capacity
0%
Unit Performance
[*] Load following, frequency control, grid adjustments, reserve shutdown

Performance Indicators and statistics
Operating Experience Data

Related Performance Indicators:

Unplanned Automatic Scrams per 7000 Hours Critical (UA7):

$$UA7 = \frac{UAS}{HC} * 7000$$

Unplanned Manual Scrams per 7000 Hours Critical (UM7):

$$UM7 = \frac{UMS}{HC} * 7000$$

UAS: Number of unplanned automatic scrams

UMS: Number of unplanned manual scram

HC: Hours with critical reactor in the reporting period

Performance Indicators and statistics
Outage Coding System

Concept:

- ❑Outage specification
- ❑Type code
- ❑Cause code
- ❑Code for system involved/affected
- ❑Brief description

Outage:

Any status of the unit, when the actual unit power is lower then the reference unit power for a period of time. It includes both power reduction and unit shutdown.

Performance Indicators and statistics

Outage Coding System - Type code

First character:

P - Planned outage due to causes under the plant management control

U - Unplanned outage due to causes under the plant management control

X - Outage due to causes beyond the plant management control (external)

Second character:

F - Full outage

P - Partial outage

Performance Indicators and statistics

Outage Coding System – Type code Cont.

Third character:

1 - Controlled shutdown or load reduction that could be deferred

2 - Controlled shutdown or load reduction that had to be performed in the next 24 hours

3 - Outage extension

4 - Reactor scram, automatic

5 - Reactor scram, manual

Performance Indicators and statistics

Outage Coding System – Cause code

A	Plant equipment failure
B	Refuelling without a maintenance
C	Inspection, maintenance or repair combined with refuelling
D	Inspection, maintenance or repair without refuelling
E	Testing of plant systems or components
F	Major back-fitting, refurbishment or upgrading activities with refuelling
G	Major back-fitting, refurbishment or upgrading activities without refuelling
H	Nuclear regulatory requirements
J	Grid failure or grid unavailability
K	Load-following (frequency control, reserve shutdown due to reduced energy demand)
L	Human factor related

X - planned

X - unplanned

X - external

X - ambiguous

Performance Indicators and statistics

Outage Coding System – Cause code

M Governmental requirements or court decisions

N Environmental conditions (flood, storm, lightning, lack of cooling water due to dry weather, cooling water temperature limits etc.)

P Fire

R External restrictions on supply and services (labour strike, spare part problems, lack of funds due to delayed payments from customers, etc.) *Outages caused by plant personnel strikes are coded "L"*

S Fuel management limitation (including high flux tilt, stretch out or coast-down operation)

T Off-site heat distribution system unavailability

U Security and access control

Z Others

X - planned

X - unplanned

X - external

X - ambiguous

Status of NPP as of 1 January 2004

- 440 NPP in operation, 360.94 GW(e)
- 31 NPP under construction, 25.487 GW(e)
- Two new NPPs connected to grid in 2003:

  China: QINSHAN 3 – 2, PHWR, 665 MWe

  Korea: Ulchin 5, PWR, 960 MWe
- Two re-commercial NPPs following lay-up in 2003:

  Canada: Pickering 4, PHWR, 515 Mwe

  Bruce 4, PHWR, 790 MWe

Status of NPP as of 1 January 2004

- **Construction started in one NPP:**

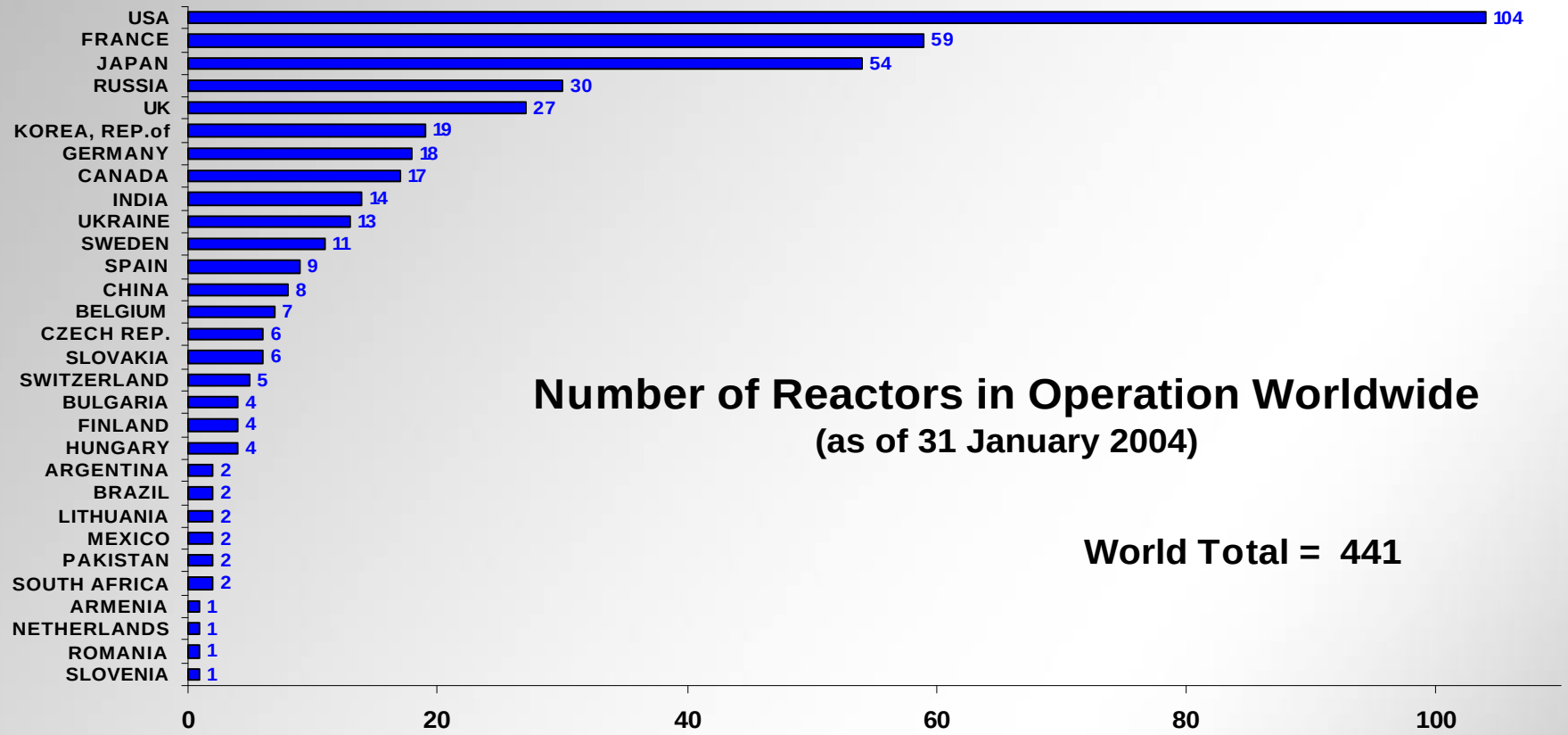
  India:

  - **Rajasthan 6, PHWR 202 MWe**

- **Permanently shutdown – 5 units:**

  - **Germany: STADE (KKS), PWR, 640 MWe**
  - **UK: CALDER HALL units 1, 2, 3 and 4, GCR, 50 MWe**

Performance Indicators and Statistics

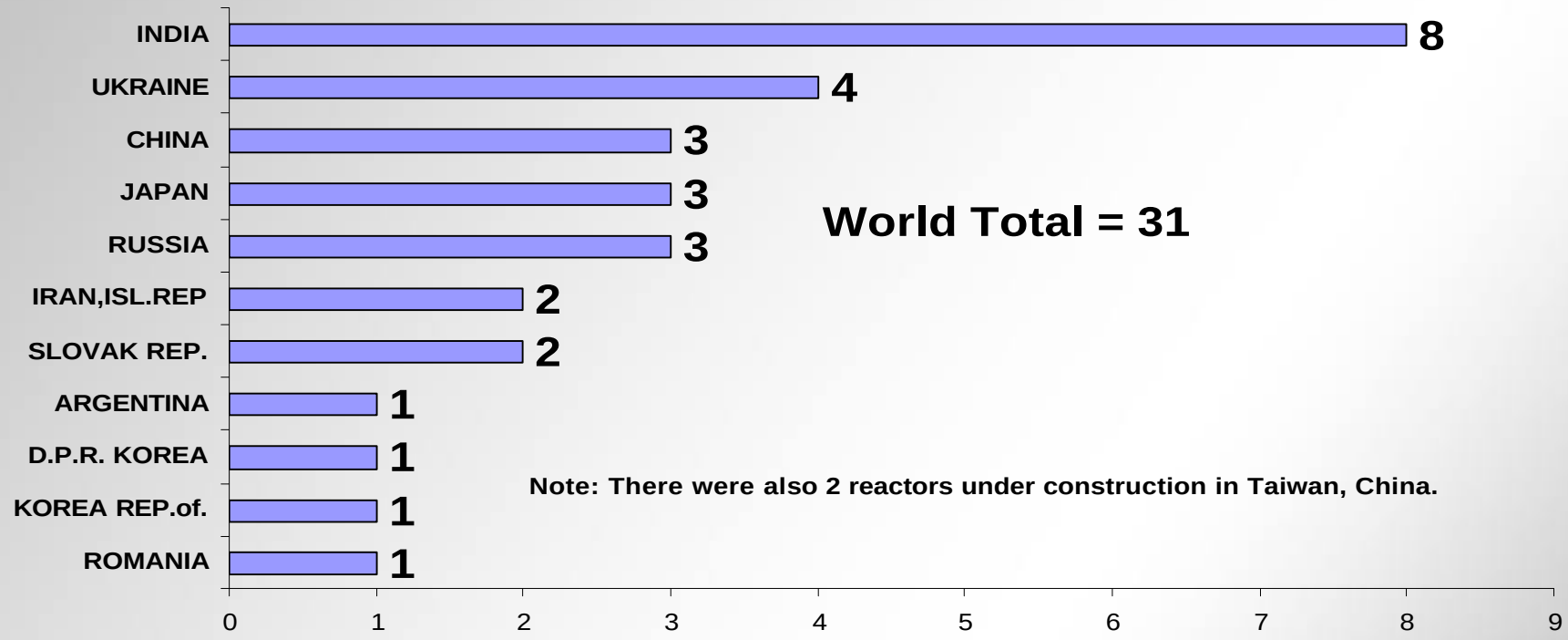


Number of Reactors in Operation Worldwide
(as of 31 January 2004)

World Total = 441

Performance Indicators and Statistics

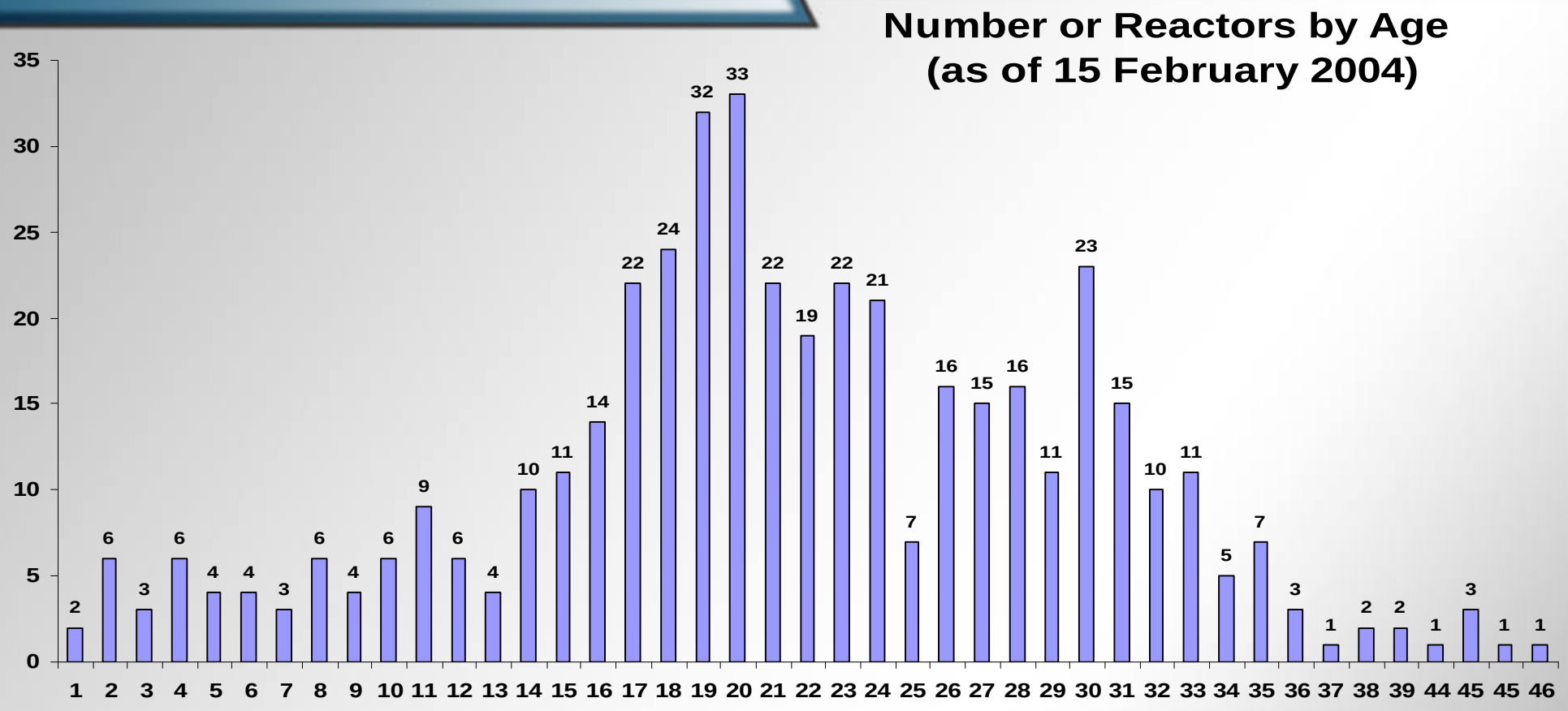
Number of Reactors under Construction Worldwide (as of 31 January 2004)



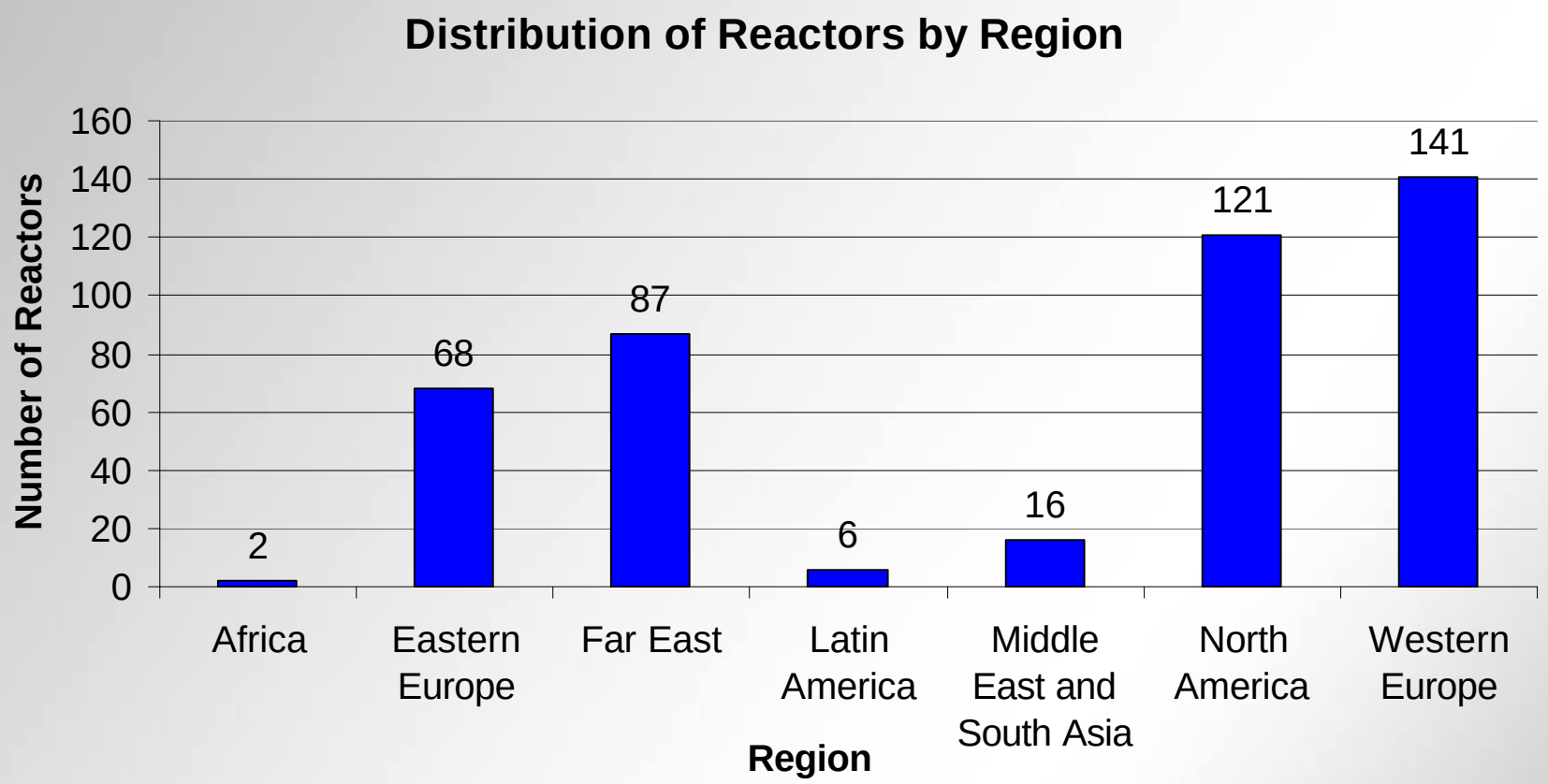
World Total = 31

Note: There were also 2 reactors under construction in Taiwan, China.

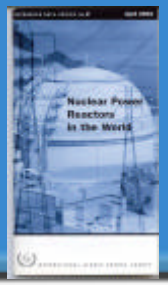
Performance Indicators and Statistics



Performance Indicators and Statistics



PRIS Outputs



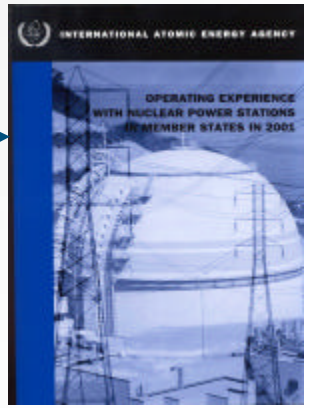
RDS-No.2

(> 2000 copies/year)

Free distribution

PRIS

Priced publications



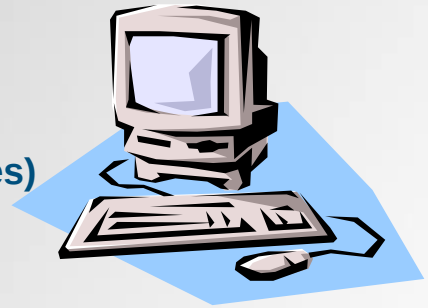
Operating Experience with NPP in MS (>500 copies)

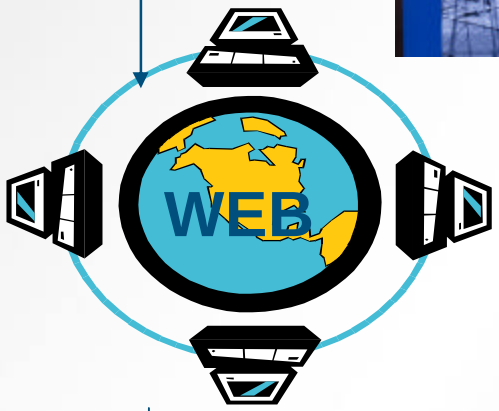
Free distribution

MicroPRIS

PRIS on CD

(more than 300 copies)





Homepage – one of the ten top IAEA gateways!

http://www.iaea.org/programmes/a2

PRIS-PC

(more than 750 users)

Results

- **Number of subscribers has grown in a rate of more than 25% per year**
- **This growth improved to about 40% with the release of PRIS-PC, the on-line access through the INTERNET in 1996 and has continuing increased in a rate of 30 to 35% since then**