James Martin Center for Nonproliferation Studies, Monterey Institute

- Graduate program
- Professional certificate

- Fellows program
- Research
- Policy advice

How Can the Availability of Safe and Secure Research Reactors Be Assured in Future?

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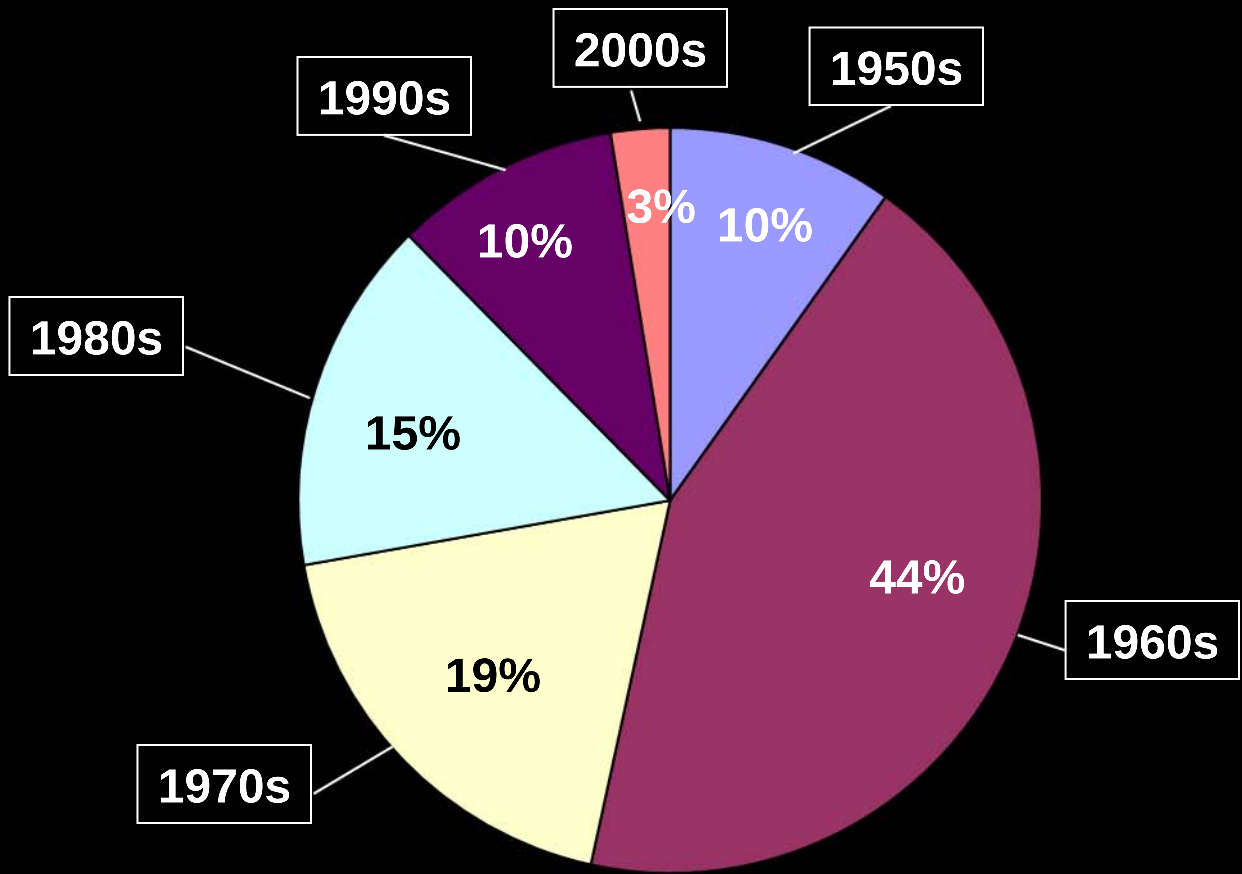
Photo source: Idaho national lab

Research Reactors Today

- 245 listed in IAEA research reactor database (RRDB) as operational
- Variety of reactor types, levels of neutron flux, and core size
- Are these reactors being effectively utilized? Will they meet future user needs?
- If not, how can these needs be met while minimizing proliferation risks? Meet Nuclear Nonproliferation Treaty Article IV commitment?

Age of Operational Research Reactors, by Criticality Date*



*IAEA RRDB, as of September 2009

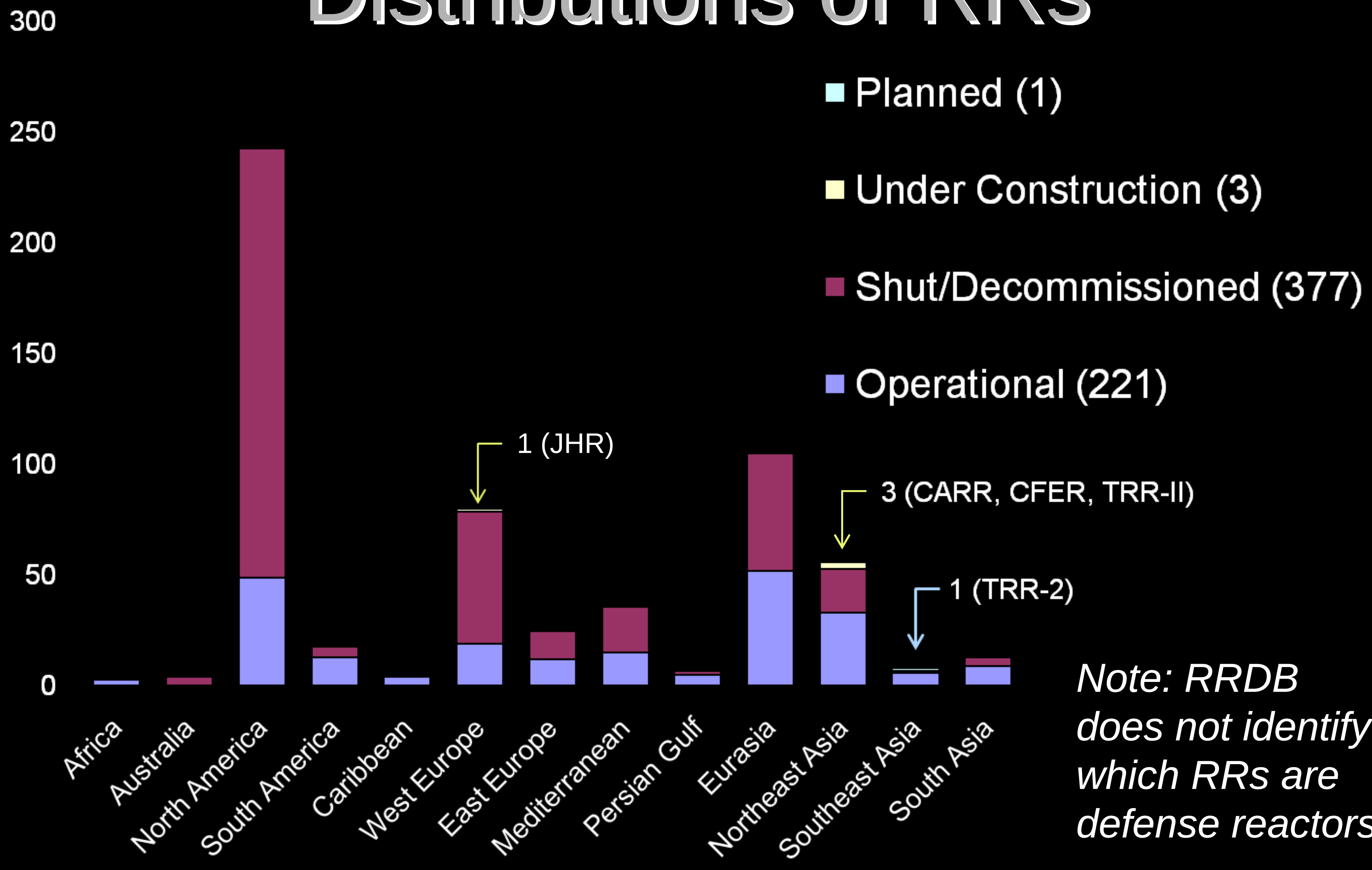
Note: about 63% of the reactors constructed to date have already been shut down

Increasing RR Construction Costs

- Brazil's IPR-RI (TRIGA Mark I): $250,000 in1960 ($1.8 million today)
- Morocco's MA-R1 (TRIGA Mark II): $4.2 million in 2007.
- High-end research reactors:
  - MURR: $3.5 million in 1966 ($23.3 million)
  - HFIR: $14.6 million ($100 million today)
  - FRMII: $435 million
  - OPAL: estimated $400 million for OPAL (cost not listed in IAEA RRDB).

Note: not clear what costs the IAEA RRDB captures

Uneven Geographic Distributions of RRs



Note: RRDB does not identify which RRs are defense reactors

Developing a RR park for the Future

- Research:

  "Materials irradiation studies utilizing fission reactors are becoming more and more expensive and time consuming. Collaboration among organizations participating fission-reactor materials irradiation will be inevitable." —Tatsuo Shikama, Tohoku University (IAEA, Nov. 2008)

- Medical isotope production: problem relying on national reactors and market mechanisms
- Training reactors: not available in many states considering NPP construction

Major Mo-99 Production Reactors

Reactor	NRU	BR-2	HFR	SAFARI	OSIRIS
Criticality	1957/11/03	1961/06/29	1961/11/09	1965/03/18	1966/09/08
Ave. Power	135 MWt	100 MWt	45 MWt	20 MWt	70 MWt
Max Thermal Flux (n/cm2-s)	4.0E14	1.0E15	2.7E14	2.4E14	2.7E14
Utilization	Hrs/Day **24** Days/Wk **7** Wks/Yr **39** MW Days/ Yr **32300**	Hrs/Day **24** Days/Wk **7** Wks/Yr **15** MW Days/ Yr **6500**	Hrs/Day **24** Days/Wk **7** Wks/Yr **44** MW Days/ Yr **12640**	Hrs/Day **24** Days/Wk **7** Wks/Yr **44** MW Days/ Yr **6060**	Hrs/Day **24** Days/Wk **7** Wks/Yr **36** MW Days/ Yr **15000**
Recent developments	Shut down Nov-Dec 2007; May 2009-present	Aug-Nov 2008, Mo99 production facilities shut after I131 release	Shut down Aug. 2008-Feb. 2009; extensive renovations begin March 2010	Max’ing Mo-99, shortened maintenance Aug. 30-Sept 4, 2009	Increased production. Got regulatory permission to employ Petten targets.

Potential major Mo-99 producers include…

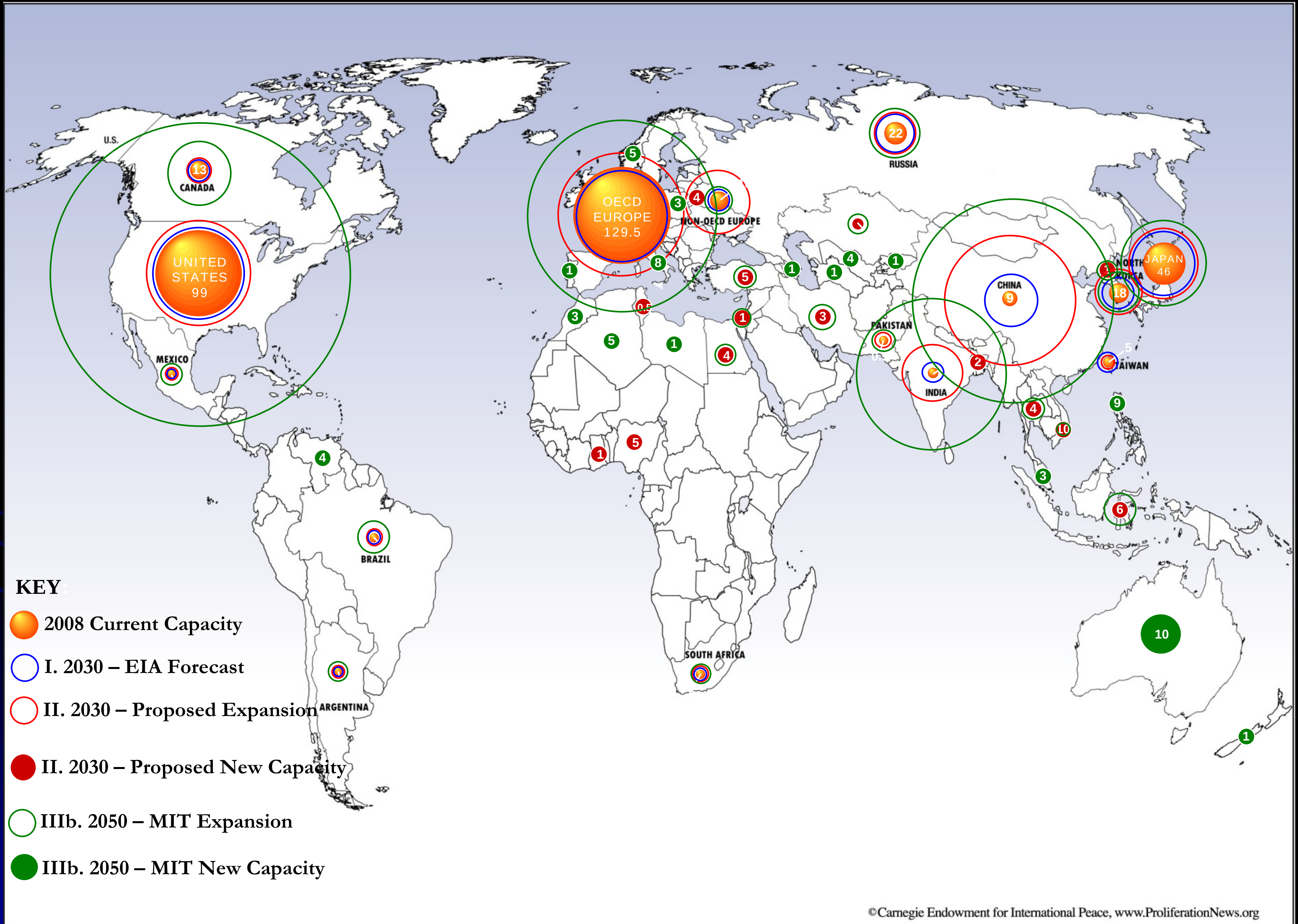
Reactor	Steady Power, Therm.	Max Thermal Flux (n/cm2-s)	Utilization: Hours/ Day	Days/ Week	Weeks/ Year	MW Days/ Year
MURR	10 MW	**6.0E14** BR2 FRM2	24	6	52	3285
HANARO	30 MW	**4.5E14**	24	3		3248
JMTR	50 MW	**4.0E14** NRU	24	7	26	9000
MARIA	30 MW	**3.5E14**	24	5	40	3000
TRIGA II Pitesti	14 MW	**3.3E14**	24	7	40	
OPAL	20 MW	**3.0E14**				
ETRR-2	22 MW	**2.8E14** HFR,	24	1	48	920
Siwabessy MPR	30 MW	**2.52E14** OSIRIS	24	7	21	2160
IRT-T	6 MW	**2.5E14** SAFARI	24	5	30	900
IRT-1, Tajoura	10 MW	2.0E14	20	1	14	55
VVR-Ts	15 MW	1.8E14	24	5	42	1900
PARR-1	10 MW	1.7E14	12	1	23	150
RP-10	10 MW	1.21E14	6	3	52	156
RECH-1	5 MW	7.0E13	24	1	50	250

Mo-99: a reactor problem?

- Generator producers want more reactors but…
- Price paid for irradiation services low (though doctors willing to pay more for assured supply)
- Pharmaceutical companies waiting for state action and worry about overcapacity (profit margins slim)
- Oligopolistic market structure

NPP Growth – Various Scenarios

(Gigawatts electric, GWe)



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New Nuclear States

RRs in Potential

Country	# RRs
Albania	None
Algeria	2
Azerbaijan	None, planned
Bangladesh	1
Belarus	None operational
Bosnia	None
Chile	1 operational, 1 shut
Croatia	None
Egypt	2
Estonia	None (dismantled)
Ghana	1 MNSR
Indonesia	3
Israel	2
Italy	4 (10 shut)
Jordan	Planned
Kuwait	None
Latvia	None (2 shut)
Libya	1
Malaysia	1
Mongolia	None
Morocco	1
Namibia	None
Nigeria	1 MNSR
Norway	2
Philippines	None (1 shut)
Poland	1 (4 shut)
Portugal	1
Thailand	1+1 in construction
Tunisia	None (feas. study ‘01)
Turkey	1 (2 shut)
Uganda	None
U.A.E.	None
Venezuela	None (1 shut)
Vietnam	1 (may construct)

Planning: RRDB wish list

- Better reporting on duty cycles (MW/yr, vs. hours, days, etc.)
  - don't always match up; hard to determine if underutilized
- Aging
  - criticality dates reported, but not planned shutdown date, whether RR modernized
- Uses reported in very general terms
  - Would be useful to know what instruments RR has (sometimes reported), flux at instruments & other key points, etc.

RRDB wish list, continued

- Plans for future reactors (only rarely reported)
- Defense reactors vs. civilian
- International cooperation/opportunities for cooperation
- Website links?

Planning to have the right capacities, minimum risks

- RRs vary in terms of security and proliferation risks
  - Type of fuel/enrichment
  - Size of stockpiles (esp. at CAs)
  - Level of burnup/age of spent fuel or target waste
  - Ease of safeguarding (an increasing problem if numbers of reactors increase in NNWS)
- “Proliferation resistance” planning should include RRs, not just NPPs
- A failure anywhere would harm the global nuclear community


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