IRIS ADVANCED FEATURES AND STATUS

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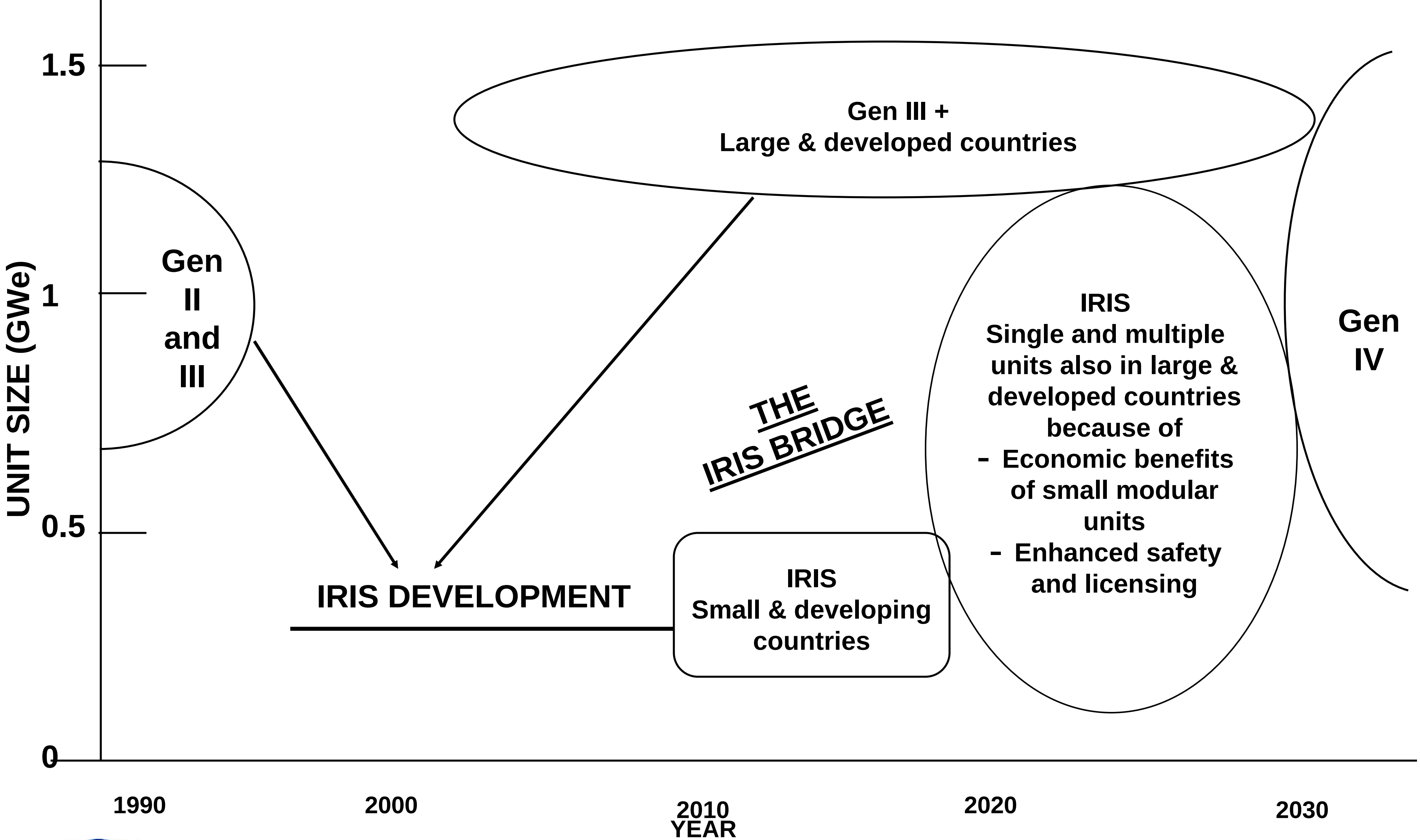
IRIS Schedular Objectives

• Program started	End 1999
• Assessed key technical & economic feasibility	End 2000
• Performed conceptual design, preliminary cost estimate	End 2001
• Initiated NRC pre-application licensing for Design Certification (DC)	Fall 2002
• Developed licensing plan	Fall 2002
• Outlined path to commercialization	Early 2003
• Completed NSSS preliminary design	Mid 2005
• On-going pre-application review with the US NRC	
• Initiate testing necessary for NRC Design Certification	Early 2006
• Complete above testing	Mid 2008
• Obtain Final Design Approval from NRC	End 2010
• First module deployment	about 2015

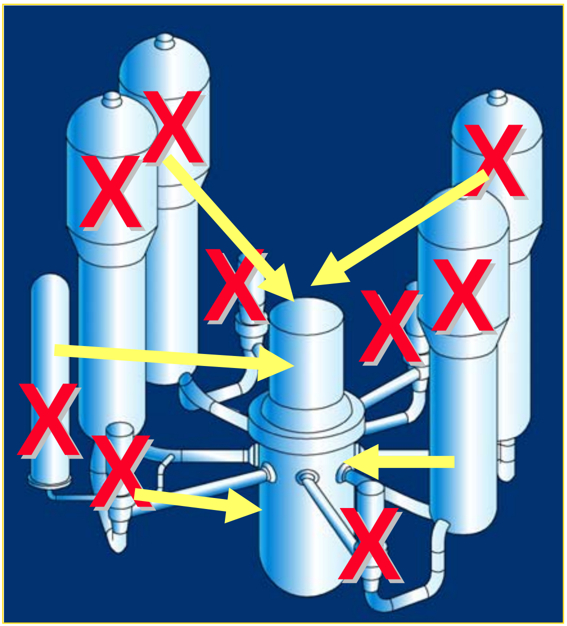
IRIS Provides the LWR Technology Bridge Between Nuclear Power 2010 and Generation IV

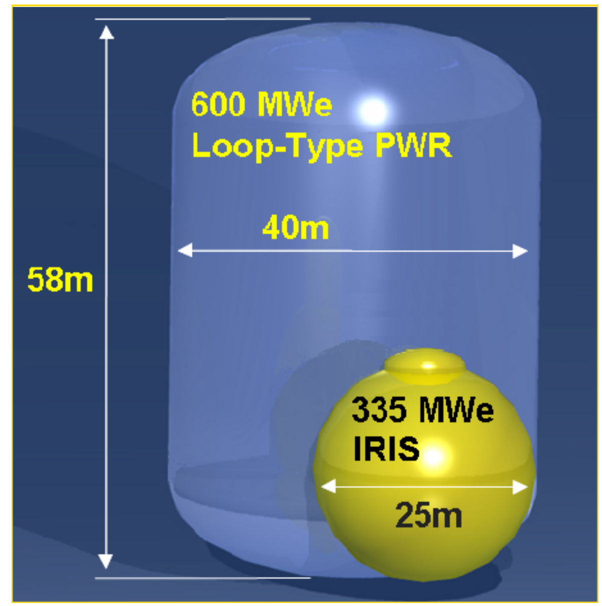


IRIS Most Significant Discriminators

- **Integral design configuration**
- **Simplicity**
- **Safety approach through safety-by-design™**
- **International team**

Integral Primary System Configuration

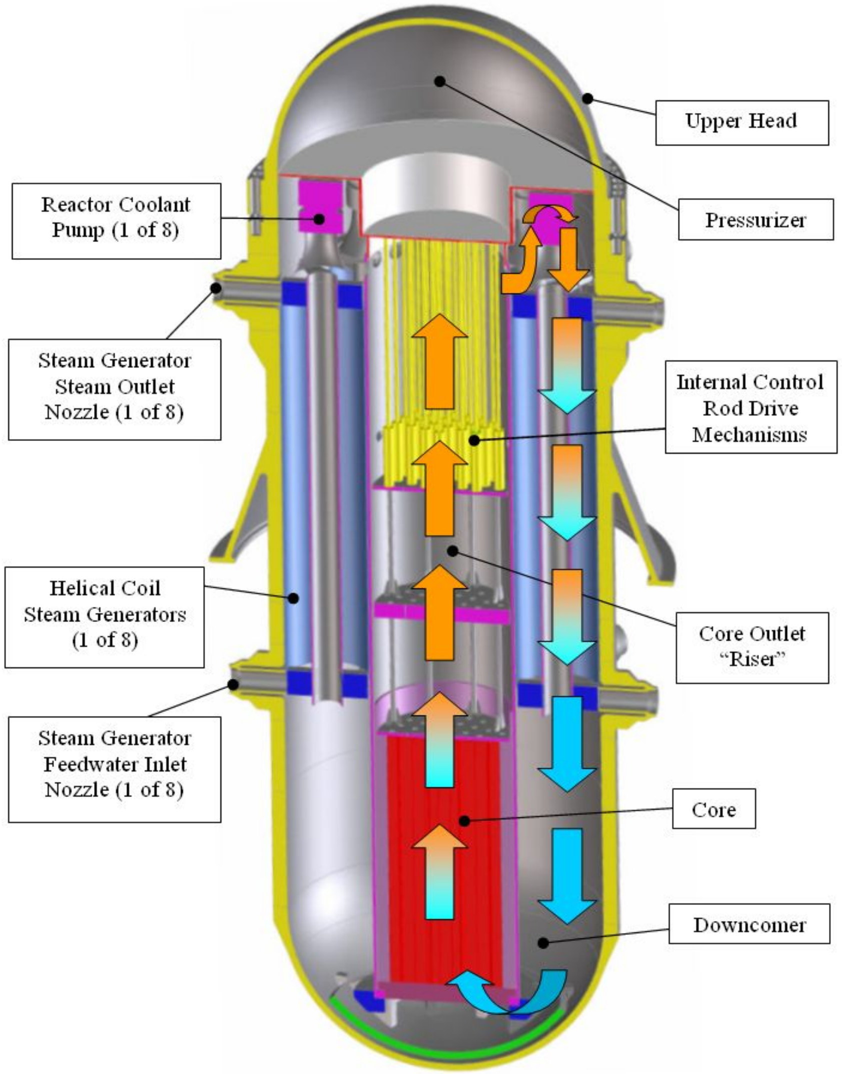




Integral vessel configuration eliminates loop piping and external components, thus enabling compact containment and plant size

- **Improves safety, reduces cost**

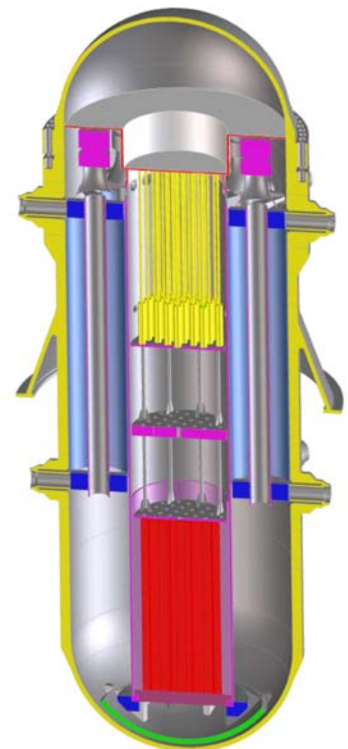
IRIS Integral System



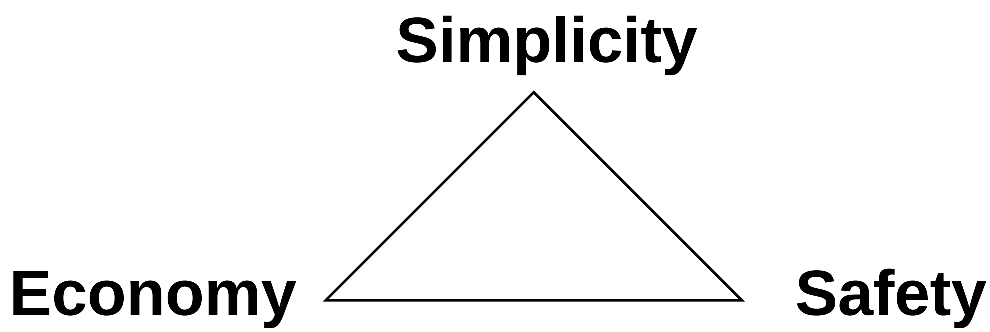
- **Integral configuration** (integral primary loop)
- **All major primary loop components are inside a single pressure vessel** (eliminates loop piping and external components)

Integral Components Offer Better Design and Performance

Steam generators	**Tubes in compression. Tensile stress corrosion cracking eliminated (responsible for over 70% reported failures)**
Primary coolant pumps	**No seal leaks. No shaft breaks. No maintenance.**
Internal CRDMs	**No head penetrations, no seal failures, no head replacements, no $800M cost a la Davis Besse**
Pressurizer	**Much larger volume/power ratio gives much better pressure transients control. No sprays.**
1.7m thick downcomer	**Vessel fast flux 10^5 times lower. Cold vessel. Almost no outside dose. No embrittlement, no surveillance. “Eternal” vessel. Simpler decommissioning.**
Fuel assembly	**Almost the same as standard W PWR, but can have extended cycle up to 48 months**
Maintenance	**Intervals can be extended to 48 months**



IRIS Approach



- **Driven by simplicity to ensure safety and economy**
- **Uses proven light water technology**
- **Implements engineering innovations, new solutions, but does not require new technology development**

IRIS "Safety-by-Design"™ Approach

Exploit to the fullest what is offered by IRIS design characteristics (chiefly integral configuration) to:

- **Physically eliminate possibility for some accidents to occur**
- **Decrease probability of occurrence of most remaining accident scenarios**
- **Lessen consequences if an accident occurs**

IRIS – Implementation of Safety-by-Design™

IRIS Design Characteristic	Safety Implication	Accidents Affected	Condition IV Design Basis Events	Effect on Condition IV Even by IRIS Safety-by-Design
Integral layout	No large primary piping	• Large break Loss of Coolant Accidents (LOCAs)	Large break LOCA	Eliminated
Large, tall vessel	Increased water inventory Increased natural circulation Accommodates internal Control Rod Drive Mechanisms (CRDMs)	• Other LOCAs • Decrease in heat removal various events • Control rod ejection, head penetrations failure	Spectrum of control rod ejection accidents	Eliminated
Heat removal from inside the vessel	Depressurizes primary system by condensation and not by loss of mass Effective heat removal by Steam Generators (SG)/Emergency High Removal System (EHRS)	• LOCAs • LOCAs • All events for which effective cooldown is required • Anticipated Transients Without Screen (ATWS)		
Reduced size, higher design pressure containment	Reduced driving force through primary opening	• LOCAs		
Multiple, integral, shaftless coolant pumps	Decreased importance of single pump failure No shaft	• Locked rotor, shaft seizure/ break • Loss of Flow Accidents (LOFAs)	Reactor coolant pump shaft break Reactor coolant pump seizure	Eliminated Downgraded
High design pressure steam generator system	No SG safety valves Primary system cannot over-pressure secondary system Feed/Steam System Piping designed for full Reactor Coolant System (RCS) pressure reduces piping failure probability	• Steam generator tube rupture • Steam line break • Feed line break	Steam generator tube rupture Steam system piping failure	Downgraded Downgraded
Once through steam generators	Limited water inventory	• Feed line break • Steam line break	Feedwater system pipe break	Downgraded
Integral pressurizer	Large pressurizer volume/reactor power	• Overheating events, including feed line break • ATWS		
			Fuel handling accidents	Unaffected

Preliminary PRA Level 1

Event	IEF	Result	%
Reactor Vessel Rupture	1.00 E-08	1.00 E-08	51.03
Loss of Offsite Power	1.18 E-01	3.48 E-09	17.78
Loss of Support Systems	1.95 E-02	2.43 E-09	12.42
Anticipated Transients Without SCRAM (ATWS)	-	1.83 E-09	9.34
Transients with main feed water	8.54 E-01	8.37 E-10	4.27
Loss of Condenser	8.50 E-02	4.78 E-10	2.44
Isolable Secondary Line Break	5.96 E-04	1.80 E-10	0.92
Unisolable Secondary Line Break	3.72 E-04	1.10 E-10	0.56
Steam Generator Tube Rupture	1.88 E-04	5.48 E-11	0.28
Interfacing System LOCA	5.00 E-11	5.00 E-11	0.26
DVI Line Break	1.32 E-04	4.78 E-11	0.24
Loss of Main Feedwater	6.05 E-02	4.76 E-11	0.24
Upper LOCA	8.85 E-04	4.12 E-11	0.21
Power Excursion	4.50 E-03	2.10 E-12	0.01
RCS leakage	4.65 E-03	3.99 E-13	<0.01
ADS Related LOCA	6.49 E-06	2.55 E-14	<0.01
Total for internal events		1.96 E-08	78.7
Tornadoes (F0-F1)	8.77 E-04	2.02 E-11	0.04
Tornadoes (F2-F6)	9.45 E-05	4.31 E-09	81.1
Tornadoes (>F6)	1.00 E-10	1.00 E-10	0.4
Floods (Conservative estimate)		8.82 E-10	16.6
Total for analyzed external events		5.31 E-09	21.3
Total		2.49 E-08	

IRIS Safety-by-Design™: the Bottom Line

Criterion	Proposed Advanced LWRs	IRIS
Defense-in-Depth (DID)	Passive systems; active systems	Safety-by-Design™ Fewer passive safety systems, no active safety-grade systems
Class IV Design Basis Events	8 typically considered	Only 1 remains Class IV (fuel handling accident)
Core Damage Frequency (CDF)	$\sim 10^{-6}$—10^{-7}	$\sim 10^{-8}$
Large Early Release Frequency (LERF)	$\sim 10^{-6}$—10^{-8}	$\sim 10^{-9}$

NOTE:

Both advanced LWRs and IRIS are extremely safe plants

Extremely low internal events CDF is a direct consequence of IRIS Safety-by-Design™ Philosophy

- **IRIS eliminates most of the accidents which are very improbable**
- **There is no need for corrective systems**
- **There are fewer things which can go wrong**
- **Reliability increases**
- **Improved response to those accidents which are less improbable**

IRIS Safety-by-Design™: The 5 most severe accident precursors since 1979 as ranked by NRC (NN, Oct. 2004) cannot occur or are intrinsically mitigated in IRIS

Rank	Year	Plant	Accident Precursor	IRIS
1	1979	Three Mile Island	Pressurizer Power Operated Relief Valve stuck open **Partial Core Meltdown occurred**	Same accident cannot occur: IRIS has integral pressurizer and no power operated relief valve. Similar accidents (any small break LOCA) have intrinsic mitigation (core always covered)
2	1985	Davis Besse	Total Loss of Feedwater (main and auxiliary) **Core Damage Probability = $7*10^{-2}$**	Cannot occur: IRIS safety grade decay heat removal system (EHRS) does not require any source of water injection to the steam generators; also, increased primary side thermal inertia inherently mitigate loss of main feedwater events
3	1981	Brunswick	Residual Heat Removal (RHR) U-tubes Heat Exchanger Failure due to blockage (oyster shells) **Core Damage Probability = $9*10^{-3}$**	BWR Event; eliminated by design and operational procedures for RHR, inherent mitigating features
4	1991	Shearon Harris	Unavailability of high pressure safety injection (HPSI) pump **Core Damage Probability = $6*10^{-3}$**	Cannot occur: IRIS does not need, thus does not have safety related HPSI pumps
5	2002	Davis Besse	Degraded vessel head; unqualified coatings and debris in containment; potential HPSI pump failure during recirculation **Core Damage Probability = $6*10^{-3}$**	Cannot occur: IRIS has no vessel head penetrations by adoption of internal CRDMs and has no HPSI pumps

Safety Impact on Economics

- **What does it really mean 10^{-6} versus 10^{-8} CDF and "improved safety"?**

- **Improved safety is not achieved by adding more and/or better safety systems; it is achieved through safety-by-design™ by eliminating safety systems and/or simplifying remaining ones**
  - **Result: enhanced safety <u>and</u> reduced cost**

- **Potential for enhanced licensing, i.e., with reduced or eliminated off-site emergency planning requirements, and reduced/eliminated needs for new infrastructure**
  - **Result: enhanced public acceptance <u>and</u> reduced cost**

- **IRIS capitalizes on its safety advantage with <u>probability=1</u>**

Licensing Regulations

- **The combined effect of safety-by-design™ and PRA-guided design has resulted in far lower probability for core damage and radiation release than those considered acceptable when current licensing regulations were promulgated**

- **Possibility to license IRIS with revised emergency planning such to significantly reduce emergency planning zone and possibly collapse it into the site boundary**

Some Advantages of No Emergency Response

Economic

- **No need of special measures and infrastructure (e.g., new roads) for rapid evacuation**
- **Can locate plant near user (reduced transmission lines, and allowance of co-generation, e.g., desalination and district heating)**
- **No impediment to further development and settlement in area around the plant**
- **No need for special training of personnel and for periodic drills**
- **Reduces licensing uncertainties**

Social

- **IRIS will be treated no differently than any other power producing industrial facility**
- **Removes stigma from nuclear power**
- **No more "NIMBY" (not in my back yard)**
- **Public acceptance increased**

IRIS Emergency Planning Status

- **IRIS is in forefront of effort to revise emergency licensing regulations**
- **Position and proposed procedure presented to NRC at Workshop on March 14-16, 2005, and well received by NRC. Also presented at OECD Workshop on April 26, 2005.**
- **Position and proposed procedures presented to IAEA at technical meeting on November 15-19, 2004. IAEA established within a 3-year CRP on "small and medium reactor with infrequent on site refueling" five studies on reducing/eliminating off-site emergency response planning by the following IRIS organizations:**
  - **Westinghouse: Regulatory procedures**
  - **Polytechnic of Milan, Italy: Methodology**
  - **University of Zagreb, Croatia: Transient analyses**
  - **Lithuanian Energy Institute: Impact of external events and economics aspects especially with respect to district heating**
  - **Eletronuclear, Brazil: Economics and utility perspective**

  First year accomplishments reviewed at IAEA on Nov. 21, 2005.
- **Will be officially taken up with NRC in 2006 as part of IRIS pre-application licensing.**

Pre-application Licensing

THREE AREAS

- **IRIS unique safety features, safety-by-design™**
  - **Documentation provided to NRC for review**
    No negatives
- **Testing for Design Certification**
  - **Prepared PIRTs, Scaling Approach, Testing Plan**
  - **Received and resolved comments**
  - **Testing to start early 2006**
- **Revised emergency response requirements**
  - **To be addressed in 2006**

DESIGN CERTIFICATION SUBMITTAL PLANNED LATE 2008

International Reactor Innovative and Secure

19 organizations
10 countries

Industry
Laboratories
Universities

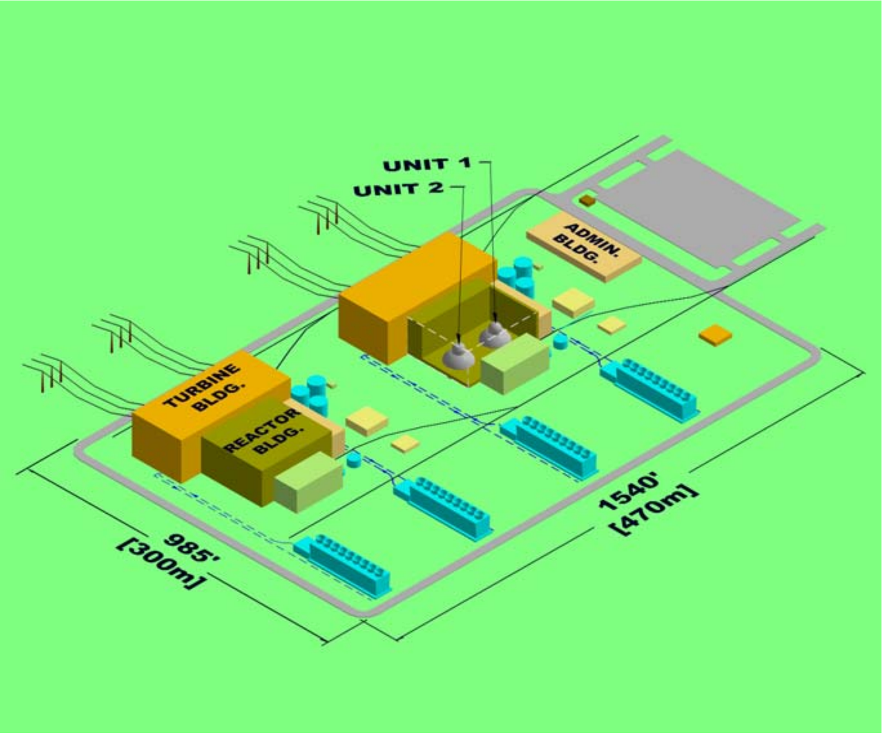
IRIS Team

INDUSTRY		
Westinghouse	USA	Overall coordination; leading core design, safety analyses and licensing
BNFL	UK	Commercialization and fuel cycle
Ansaldo Energia	Italy	Steam generators design
Ansaldo Camozzi	Italy	Steam generators fabrication
ENSA	Spain	Pressure vessel and internals
NUCLEP	Brazil	Containment
OKBM	Russia	Testing, desalination and district heating co-gen
LABORATORIES		
ORNL	USA	I&C, PRA, desalination, shielding, pressurizer
CNEN	Brazil	Transient and safety analyses, pressurizer, desalination
ININ	Mexico	PRA, neutronics support
LEI	Lithuania	Safety analyses, PRA, district heating co-gen
UNIVERSITIES		
Polytechnic of Milan	Italy	Safety analyses, shielding, thermal hydraulics, steam generators design, advanced control system
MIT	USA	Advanced cores, maintenance
Tokyo Institute of Technology	Japan	Advanced cores, PRA
University of Zagreb	Croatia	Neutronics, safety analyses
University of Pisa	Italy	Containment analyses, severe accident analyses, neutronics
Polytechnic of Turin	Italy	Source term
University of Rome	Italy	Radwaste system, occupational doses
POWER PRODUCERS		
Eletronuclear	Brazil	Developing country utility perspective

International Consortium

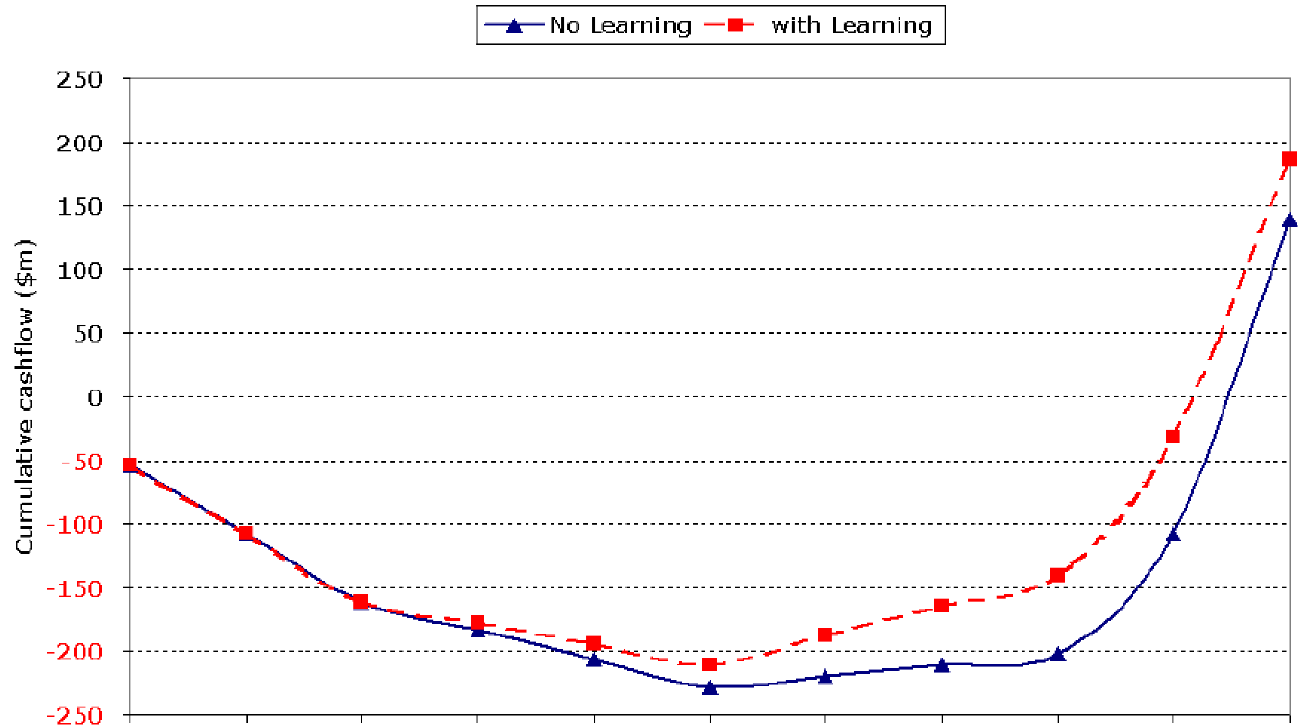
- **Westinghouse leads project, but is “primus inter pares” (first among equals). All members are stakeholders**
- **IRIS members contribute to project at their own risk and will share in rewards, commensurate to their contribution**
- **Regardless of size of contribution, all members have access to totality of information generated and participate to all deliberations**
- **Universities and laboratories are integral parts of design team**

IRIS -- Site Plot Arrangement



- ESP (Early Site Permit) process by three US utilities
- IRIS included in the design envelope
- Plot site arrangements developed:
  - Multiple single-units (e.g., 3 single units, 1005 MWe)
  - Multiple twin-units (e.g., 2 twin-units, 1340 MWe)

Attractive Financing –
Limited Cash Outflow Due to Incremental Build



YEAR FROM START	1	2	3	4	5	6	7	8	9	10	11	12
IRIS-1 335 Mwe	CONSTRUCTION			OPERATION -->								
IRIS-2 335 Mwe				CONSTRUCTION			OPERATION -->					
IRIS-3 335 Mwe							CONSTRUCTION			OPERATION -->		

- **Example – construction of 3 modules (1005 MWe) with 3 years in between**
- **Under the considered conditions, cumulative cash outflow for 3 modules remains below $300M.**

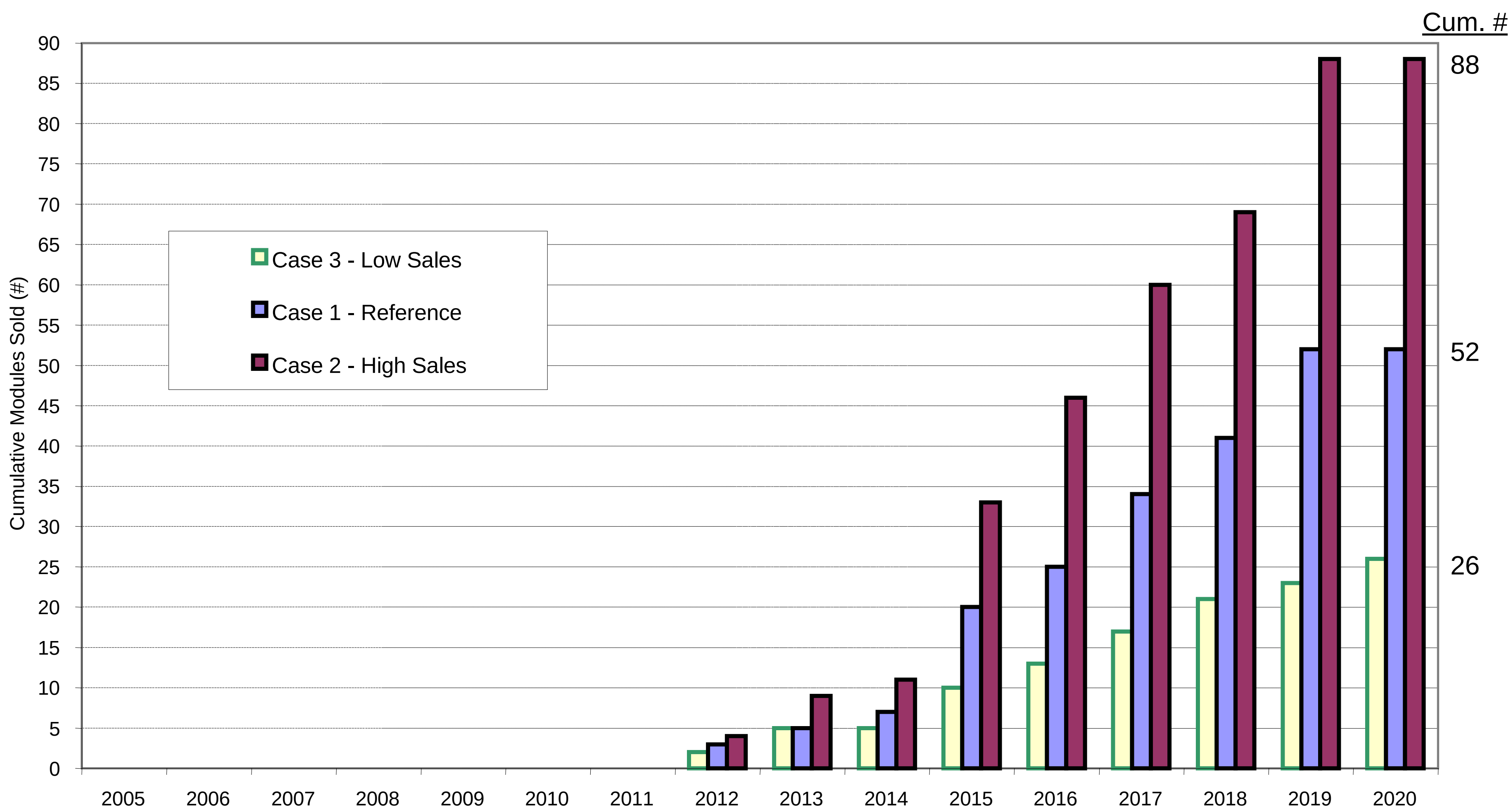
IRIS Economics: The Bottom Line

- **Competitive with other electricity generating options, nuclear and non-nuclear**
  - **Cost of electricity about 4¢/kWh**
  - **Cost estimated to be in the range $1300-1700/kWe (depending on the number of modules at site, financing option, etc.)**
- **Simplicity, multiple modules, learning**
- **Limited cost/module, flexibility in deployment, limited cash outflow**
- **Fits both developed and developing countries. Uniquely suited for smaller countries with limited electric grid.**

Markets

- **For large power requirements / developed countries**
  - **Multiple modules**
  - **Stepwise power hookup, limited financing**
- **For limited power requirements / developing countries / small countries**
  - **Niche market**
  - **Familiar, proven water technology**
  - **Limited grid addition**
  - **Limited financing**
- **Four IRIS consortium countries (Croatia, Lithuania, Mexico, Brazil) are investigating IRIS deployment by 2015**

Projected Modules Sales Through 2020



Education/Research Aspect of the IRIS Project – IRIS Students (as of March 2005)

University	Undergraduate	Graduate	Doctorate
Polytechnic of Milan	1	25	7
Massachusetts Institute of Technology	1	4	1
Tokyo Institute of Technology		6	6
University of Pisa	28	8	1
University of Zagreb	3	1	3
Polytechnic of Turin		1	
University of Rome		1	1
University of California at Berkeley		2	
University of Tennessee	1	4	
Ohio State University		4	1
University of Michigan	6	2	
Total (3/1/05)	40	58	20
		118	

- IRIS project – provided opportunity to over 100 students to work on a real-life, advanced, applied technology project, and make actual contributions

Financing

PAST

- **Started in 1999 with first NERI: ~$1.7M over 3 years**
- **Additional DOE funds through NERI 2000-2005: ~$5M**
- **In-kind (prior art, manpower) contributions by consortium 2000-2005: ~$40M**

CURRENT / FUTURE

- **DOE: 2 I-NERIs Brazil: ~$3M**
  Other?
- **Consortium: Increased manpower**
  Italy: ~50M Euros, responsible for testing

Conclusions

- **Next step in LWRs**
- **Flexibility in deployment**
- **Simplicity and safety**
- **Option of No EPZ could be dramatic breakthrough**
- **Outstanding team, tremendous progress on a shoestring**
- **Ready for big time**