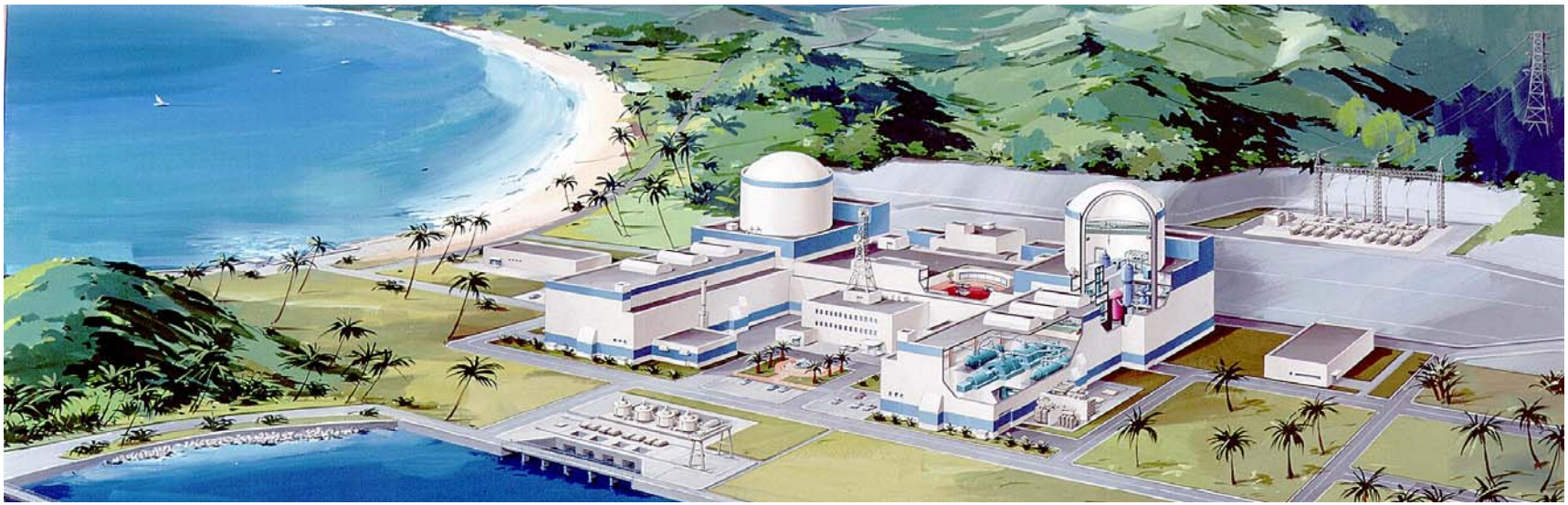
Advanced Design of Mitsubishi PWR Plant for Nuclear Renaissance



October 28, 2009

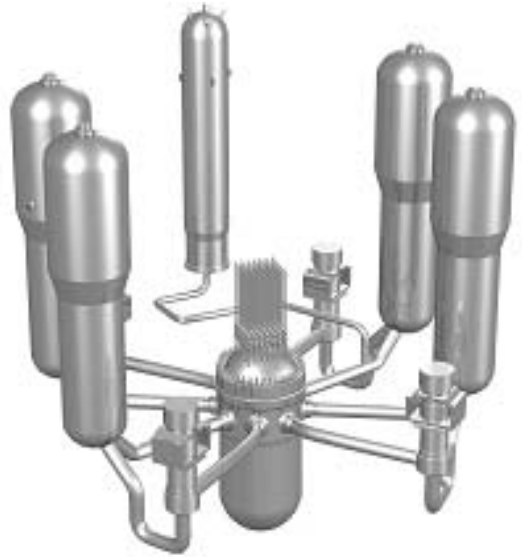
Etsuro SAJI

General Manager, Reactor Core Engineering Department

Mitsubishi Heavy Industries, Ltd.

Contents

1. Nuclear Renaissance
2. Mitsubishi PWR Nuclear Power Plant
3. Advanced design of APWR
4. Line-up of Mitsubishi PWR



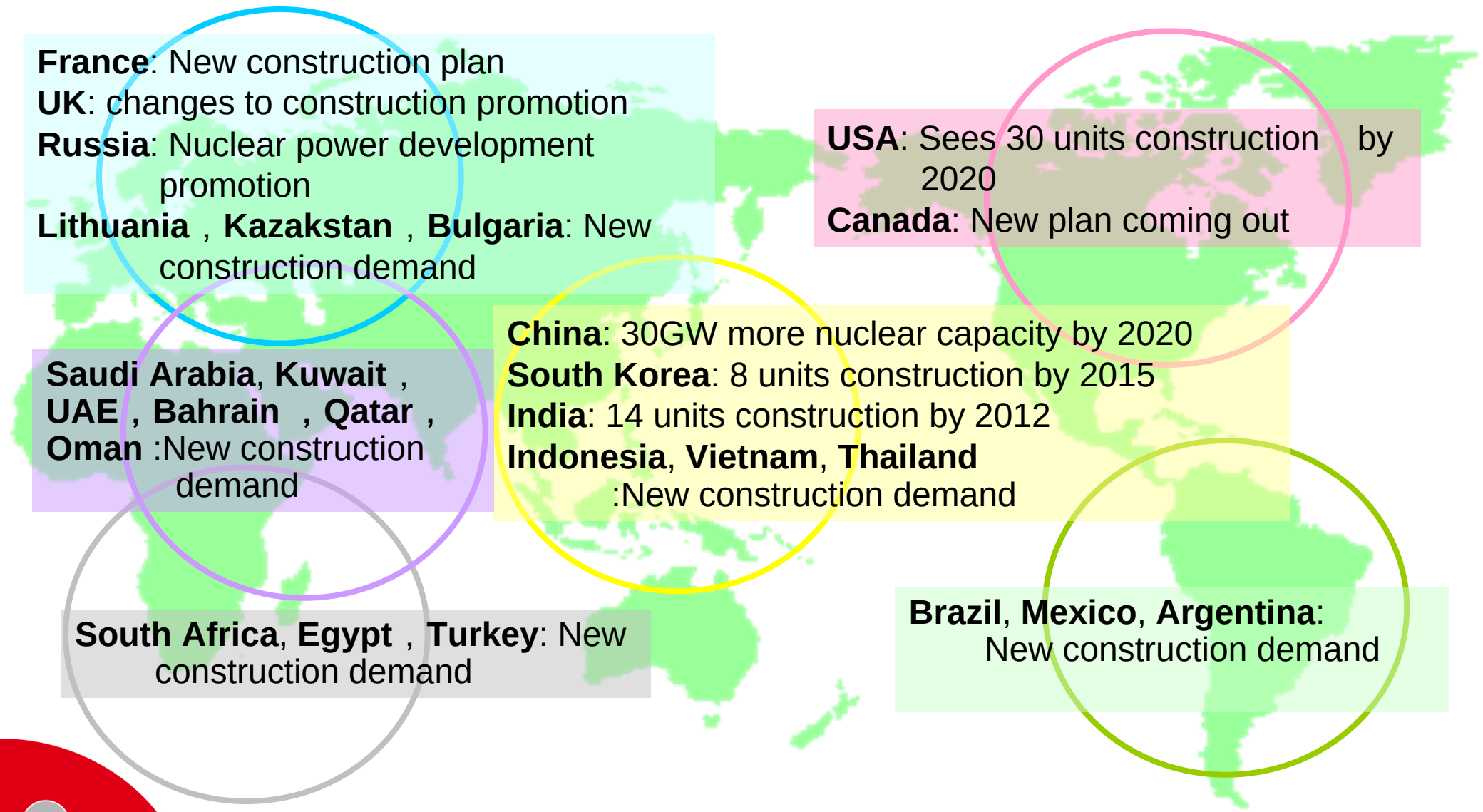
Contents

Nuclear Renaissance

- **The importance of nuclear power plant (NPP) has been understood with increasing attentions.**
  - ✓ ***Energy security***
  - ✓ ***Environmental issues***
- **And also the economical advantage of NPP has been widely recognized through their enhanced safe and reliable operation in recent years.**

Worldwide Nuclear Renaissance

New NPP Construction Plan in the World



France: New construction plan
UK: changes to construction promotion
Russia: Nuclear power development promotion
Lithuania , **Kazakstan** , **Bulgaria**: New construction demand

USA: Sees 30 units construction by 2020
Canada: New plan coming out

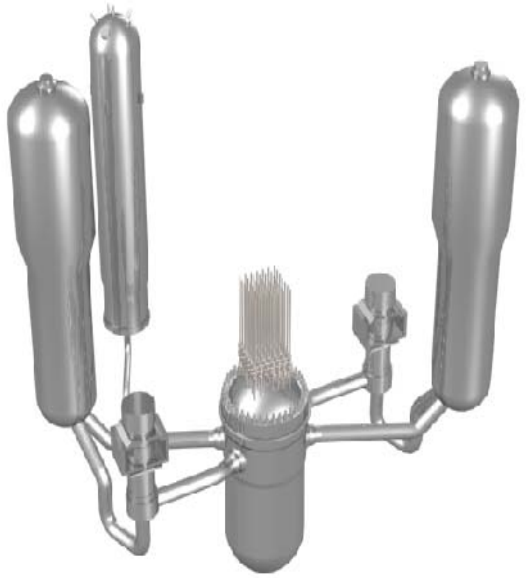
China: 30GW more nuclear capacity by 2020
South Korea: 8 units construction by 2015
India: 14 units construction by 2012
Indonesia, **Vietnam**, **Thailand** :New construction demand

Saudi Arabia, **Kuwait** , **UAE** , **Bahrain** , **Qatar** , **Oman** :New construction demand

South Africa, **Egypt** , **Turkey**: New construction demand

Brazil, **Mexico**, **Argentina**: New construction demand

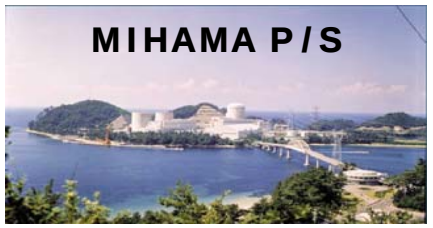
Contents

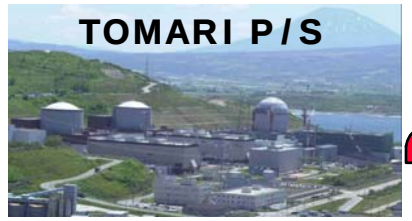


Mitsubishi Experiences of PWR in Japan

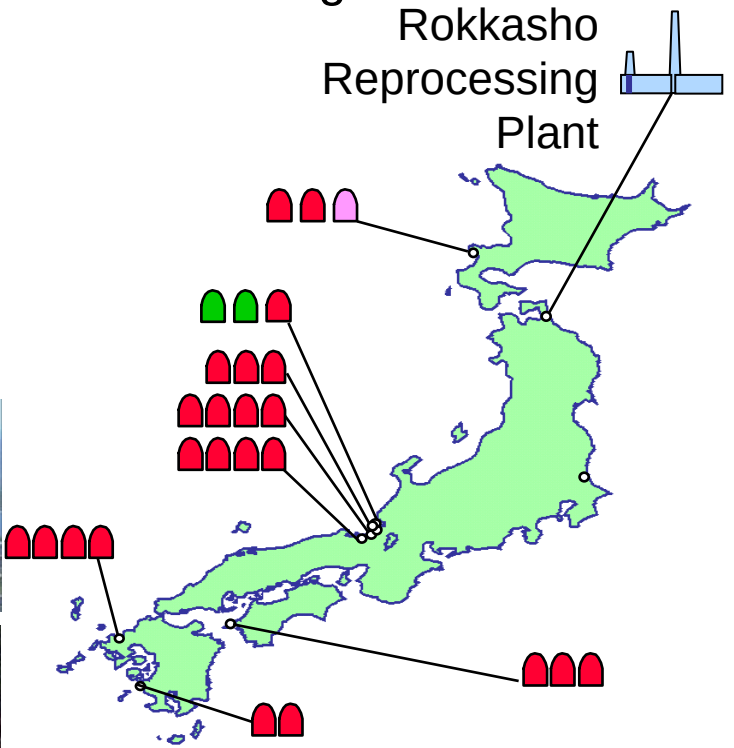
Contribution to All of the 26 Japanese PWR Plants

- ✓ ***From First PWR Power Plant Mihama 1u in 1970 to the 21st Century's Latest APWRs***
- ✓ ***New Build or Replacement Projects Continued Constantly even in the 80-90's "Nuclear Stagnation" in USA and Europe***
- ✓ ***Developed Our Own Technologies throughout Long History to Our Core Competence***



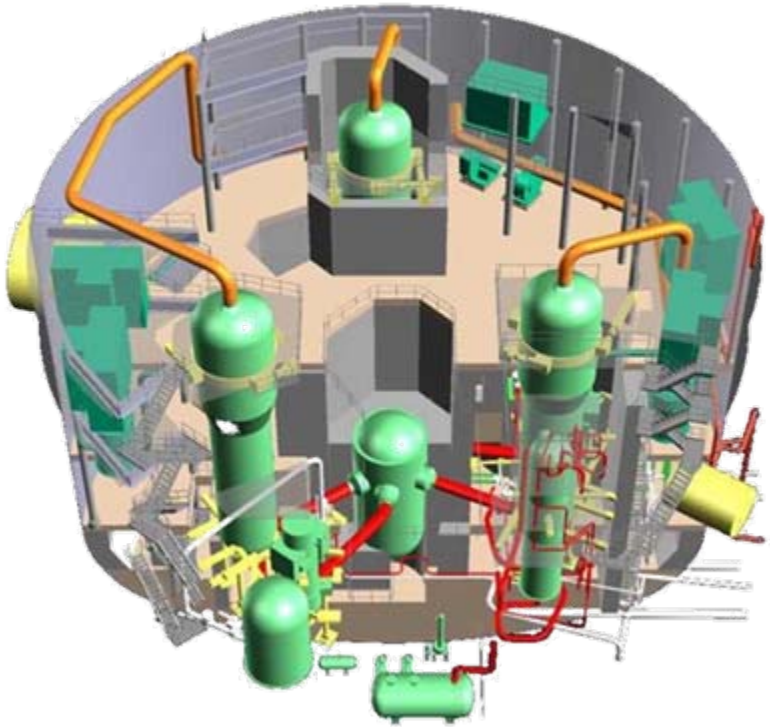


- 23 PWRs in operation
- Tomari-3 under Commissioning
- Tsuruga -3/4 APWRs under Licensing

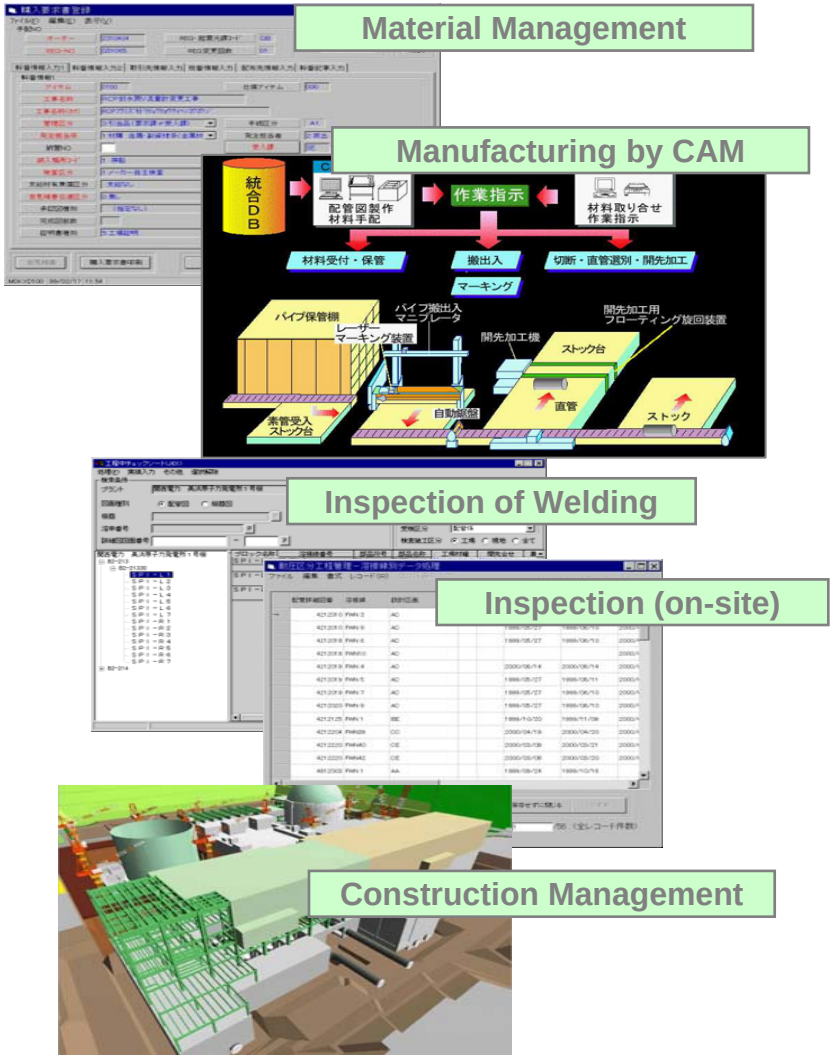


Manufacturing and Construction 3D CAD Systems

- **Integrated database is also used for manufacturing and construction.**

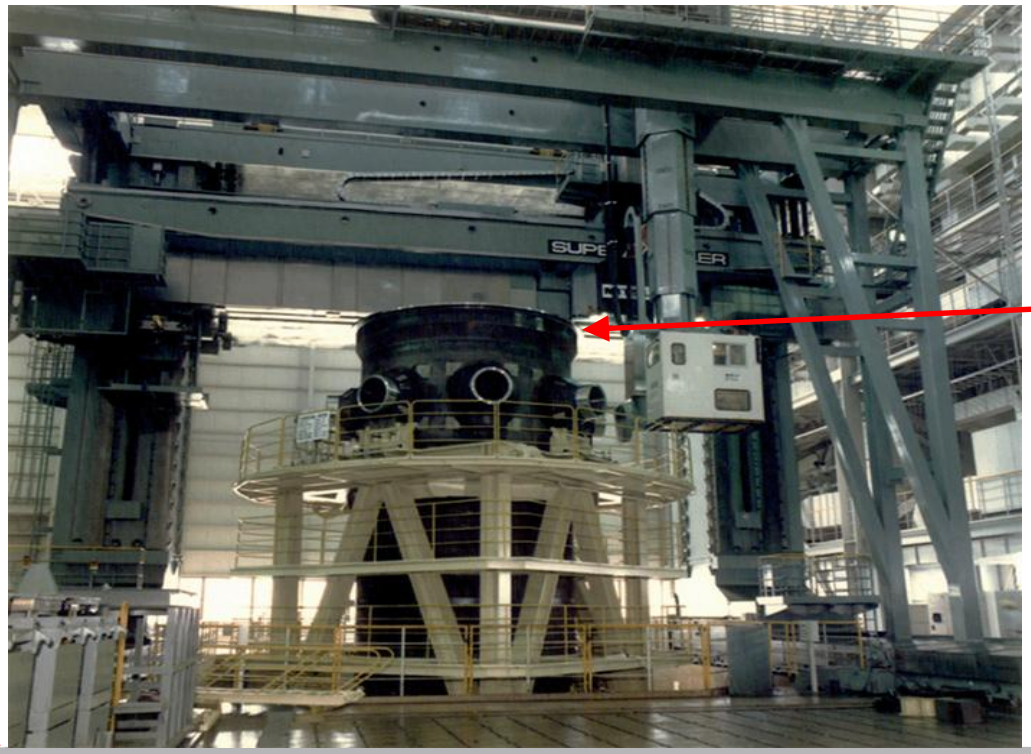


Integrated Database



Manufacturing

- **Major Components (RV, SG, RCP, Internal, CRDM, PZR,Turbine etc) are in our hands.**
- **Works and Machines have been updated/enlarged and are prepared for the global deployment.**



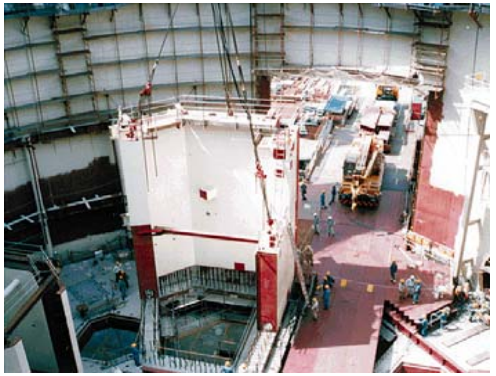
Super-large combined machine tool "Super Miller"

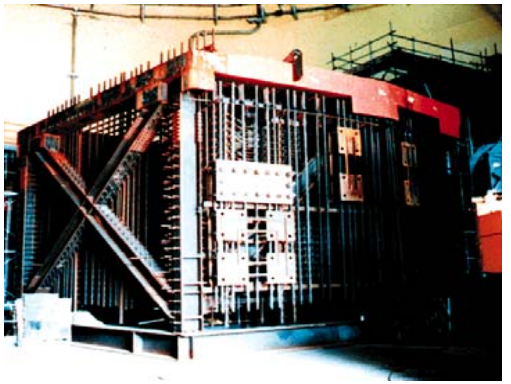
Reactor vessel

✓High-Accuracy, High-Quality Processing in Upright Installation Position

Construction

- **Reduction of on-site work volume and construction period**





✓*Rational designs like*
- *Internal Structures Using SC(-Left) (Steel Plate Reinforced Concrete)*
- *Large Prefabricated Blocks (-Right)*

✓*Tools for efficient construction like Super-large-capacity cranes*
(*On-site welding of Containment and Formation*)

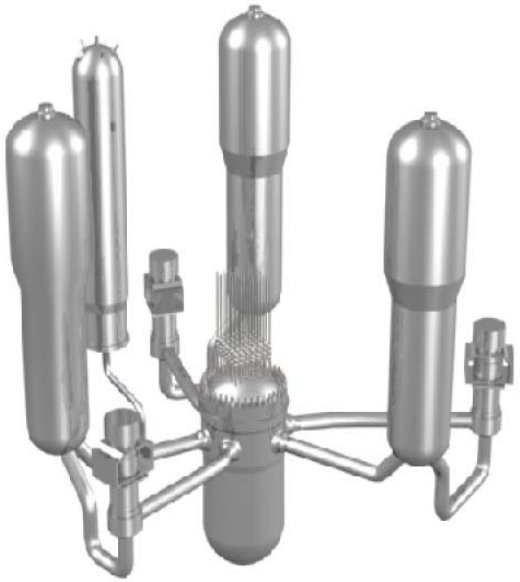
✓*Ability for comprehensive coordination of civil & installation work*

Brilliant Successes

(1st Concrete to Fuel Loading)

2 loop	: 34.5 months
3 loop	: 37.5 months
4 loop	: 40.0 months

Contents

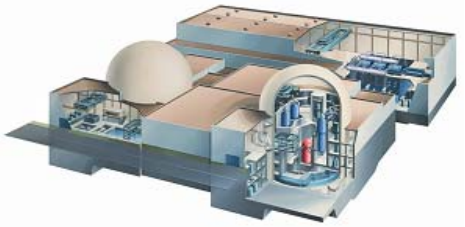


APWR : Tsuruga 3/4

- **Application for Reactor Establishment License: March, 2004**
- **Commercial Operation**

  Unit 3 : March, 2016

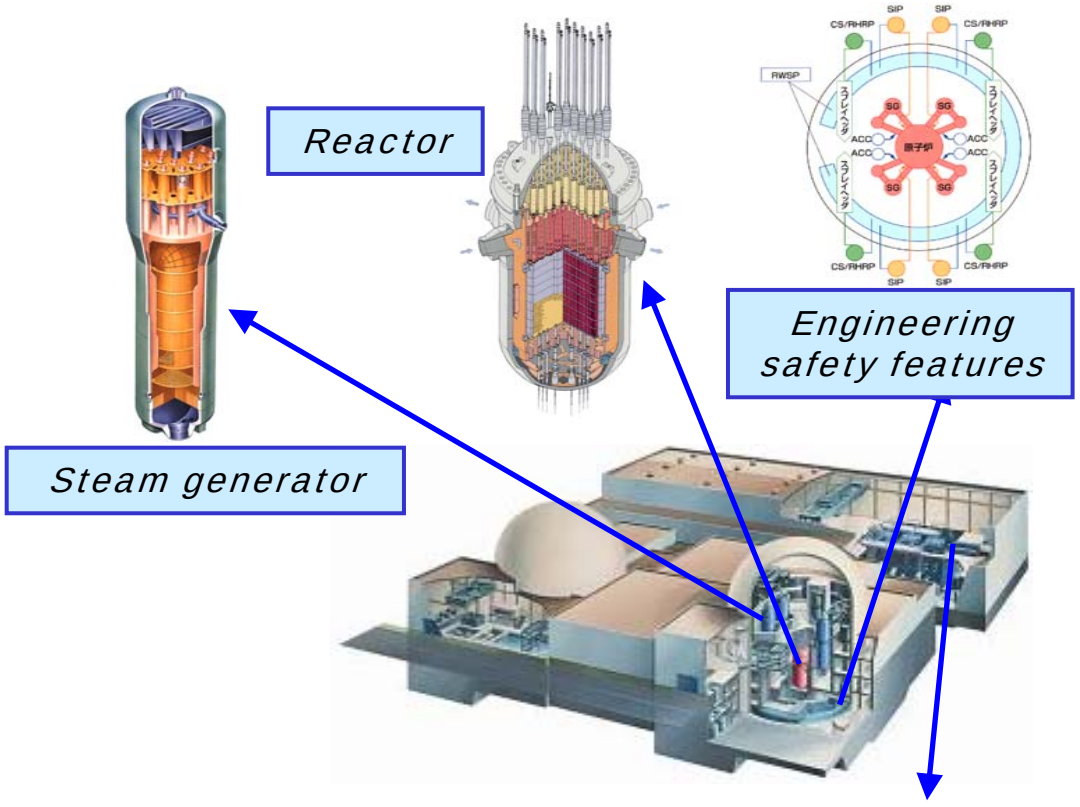
  Unit 4 : March, 2017

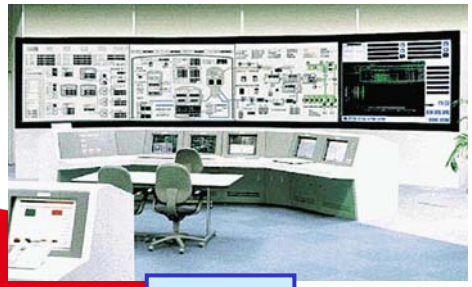


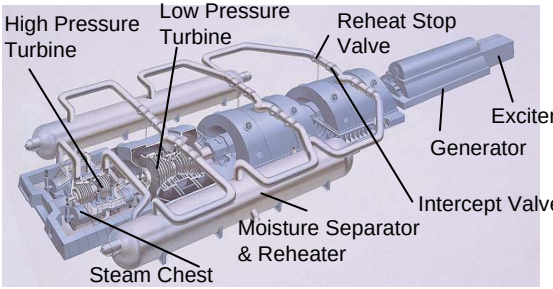
(From web-site of the Japan Atomic Power Company)

	Tsuruga Units 3 and 4
Utility	Japan Atomic Power Company
Output of Thermal Power	4,451 MWt
Output of Electric Power	1,538 MWe
Reactor	Mitsubishi 4 Loop PWR
Fuel	Low Enriched UO_2 17×17–12ft
Condenser Cooling	Sea Water
Layout	Twin Unit
Commercial Operation	Planned in 2016
Cycle	60 Hz

Features and Advanced Technologies of APWR




I & C



Turbine Generator

Attractive Economics

- Large capacity (RV,SG,TG)
- Construction cost reduction (compact layout, simplified systems and component)
- Improved neutron economy (radial reflector)
- Improved plant availability

Enhanced Safety

- 4 Mechanical systems of engineered safe t y features
- Advanced Accumulator
- Refueling water storage pit installed in containment vessel

Enhanced Reliability

- Improved core internals
- Improved steam generator

Operation & Maintenance

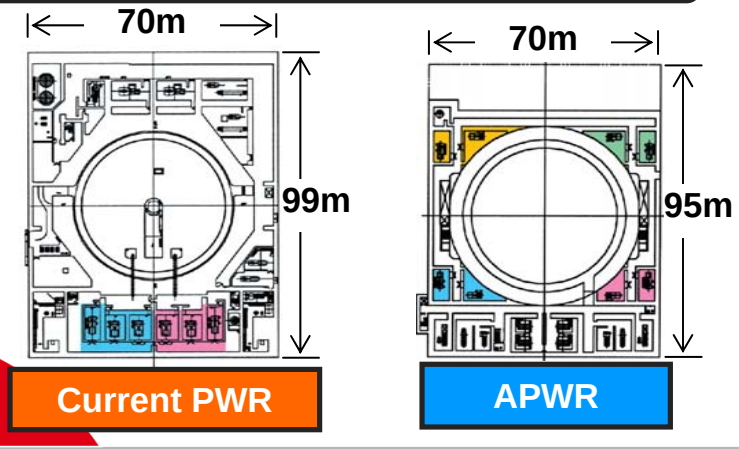
- Advanced control room
- All digital I&C

Attractive Economics of APWR

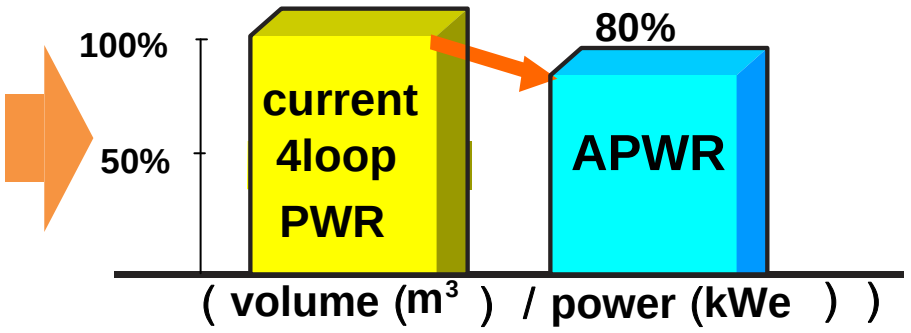
Simple & Efficient Design	Construction
■ **Safety Systems** reduction component number & capacity, efficient layout ■ **Digital I&C System** compact control board, reduction of cables ■ **Plate type heat exchangers** ■ **Utilization of Enriched ^{10}B**	■ **SC structure** employ SC widely for in-containment structure

→ ***Cost reduction***

Compact layout of R/B

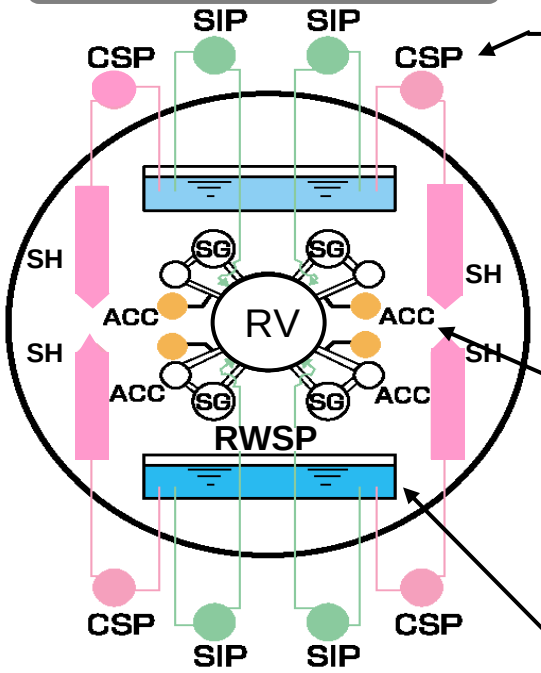


Reduction of primary build.volume 20%



Enhanced Safety of APWR
- ECCS Configuration -

System Configuration



ACC : Advanced Accumulator
SIP : Safety Injection Pump
LHSIP : Low Head SIP
CSP : Containment Spray Pump
SH : Spray Header
RV : Reactor Vessel
RWSP : Refueling Water Storage Pit

4 train ; DVI*1 design for SIP
→ Independent and Redundant
→ Simplified configuration
50%-capacity pumps

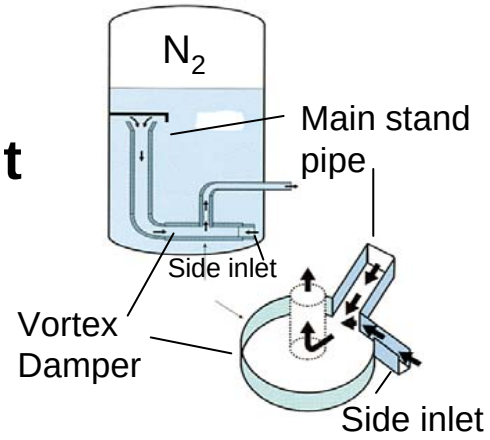
Advanced Accumulator
→Prolonged injection term
Elimination of LHSIP

In-containment RWSP
→ CDF*2 can be reduced
1/10 of current 4-loop plant

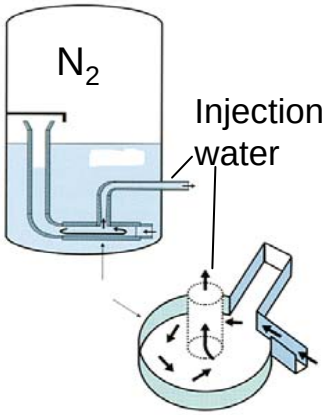
*** 1 : Direct Vessel Injection**

*** 2 : Core Damage Frequency**

Principle of Advanced Acc.



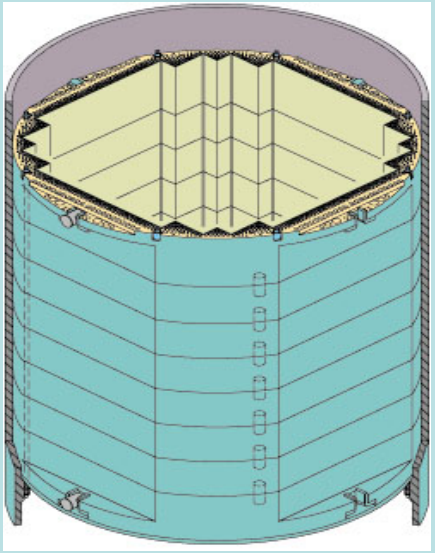
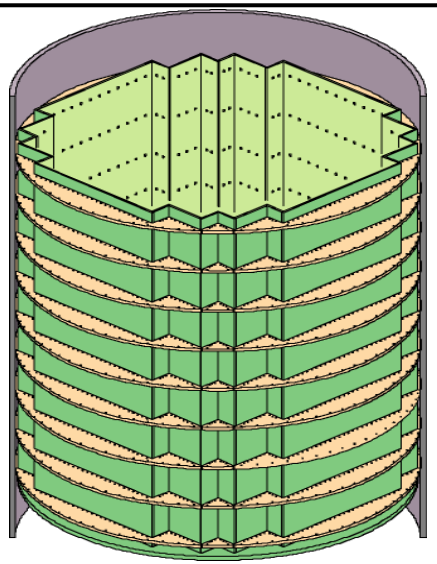
Large flow phase

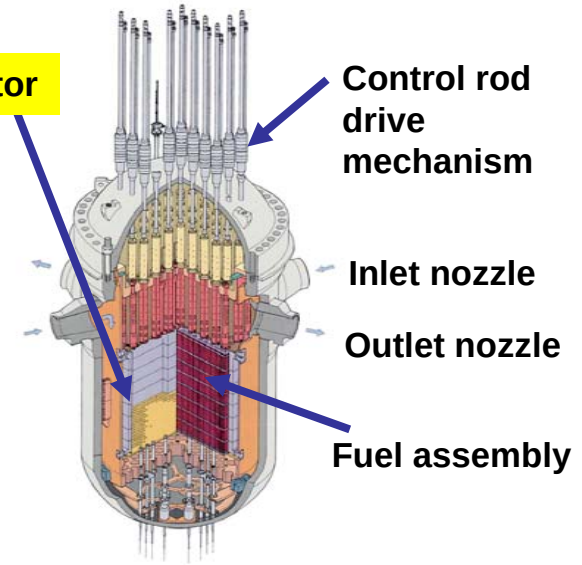


Small flow phase

Enhanced Reliability of APWR

- APWR Reactor Internals -

	APWR (Neutron Reflector)	Current 4 Loop (Baffle/Former)
Structure		
Number of Bolts	approx. 50 (Out of Core Region)	approx. 2,000
FCC	approx. 1% Reduction	Base
Neutron Exposure	approx. 1/3 (w/o Neutron Pads)	Base



Reactor Internals

Operation and Maintenance of APWR

- Improved Operability by Digital I&C Systems -

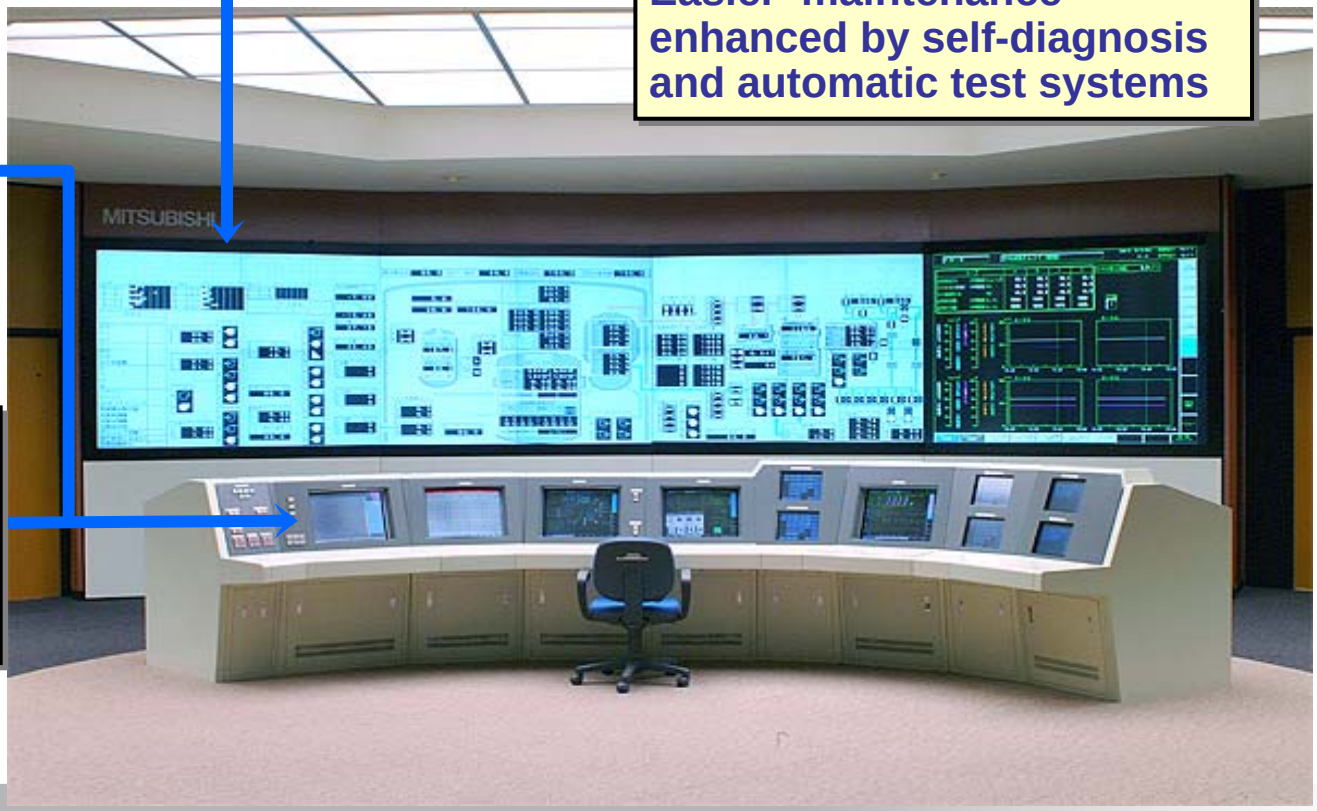
Improvement on human-system interface and reliability

Advanced Control Room

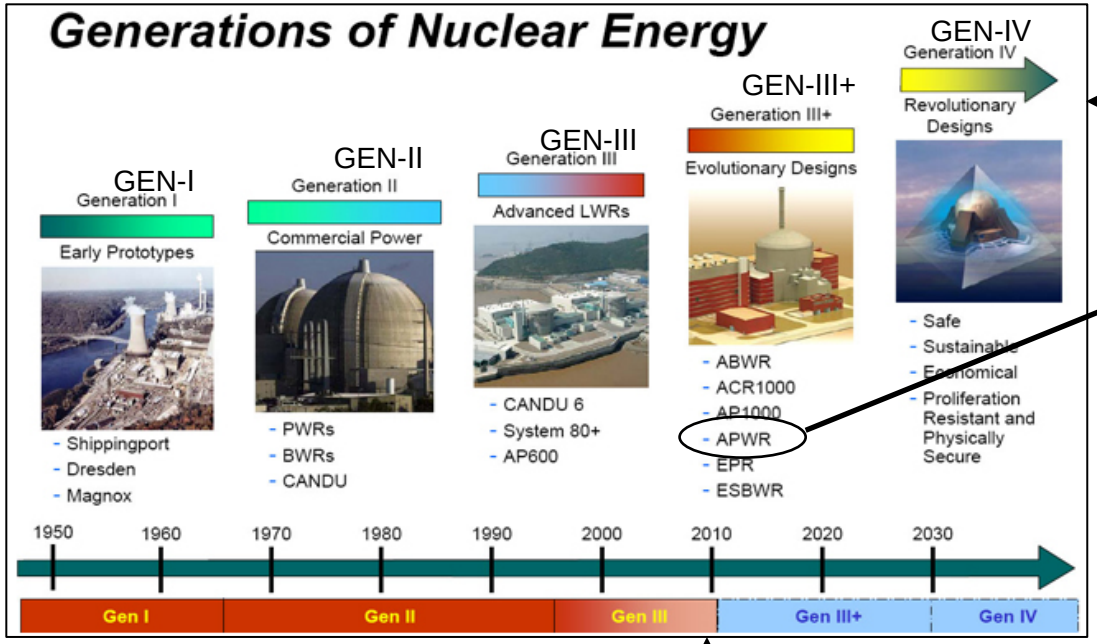
- Large Display Panel
- Compact Operator Console
- Soft Operation
  - **Improved monitoring and operational performance by integrating controls and information display**

All Digital I&C

- **Easier maintenance enhanced by self-diagnosis and automatic test systems**

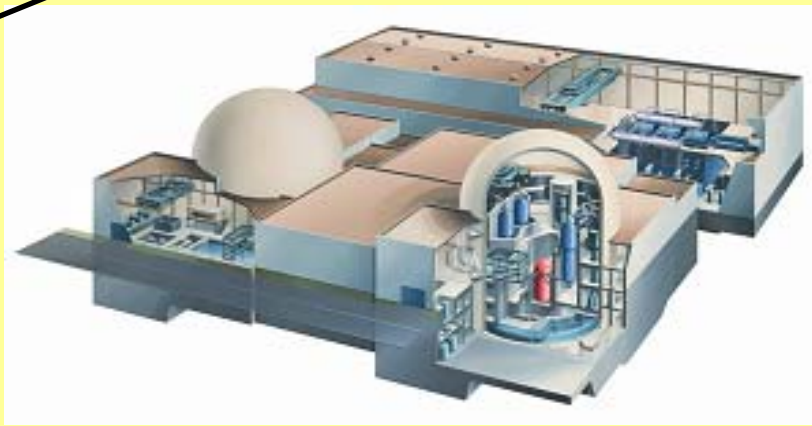


APWR is GEN-III+ Plant



Cited from The Generation IVForum (GIF) HP
http://www.gen-4.org/Technology/evolution.htm

GEN-III+ APWR



Tomari-3
Commercial Operation: Dec. 2009

Preoccupation of Evolutional Design

Evolutionary Designs of APWR

- Internals with Neutron Reflector
- Advanced Accumulator (Passive Safety)
- Refueling Water Storage Pit in CV
- **All Digital I&C**
- **Advanced Control Room**
- **SG with High Corrosion Resistance**
- **3-D Design Turbine Blade**
- etc

Latest Construction Experience: Tomari 3

- **Approval for Reactor Establishment License: July, 2003**
- **Commercial Operation: December, 2009**

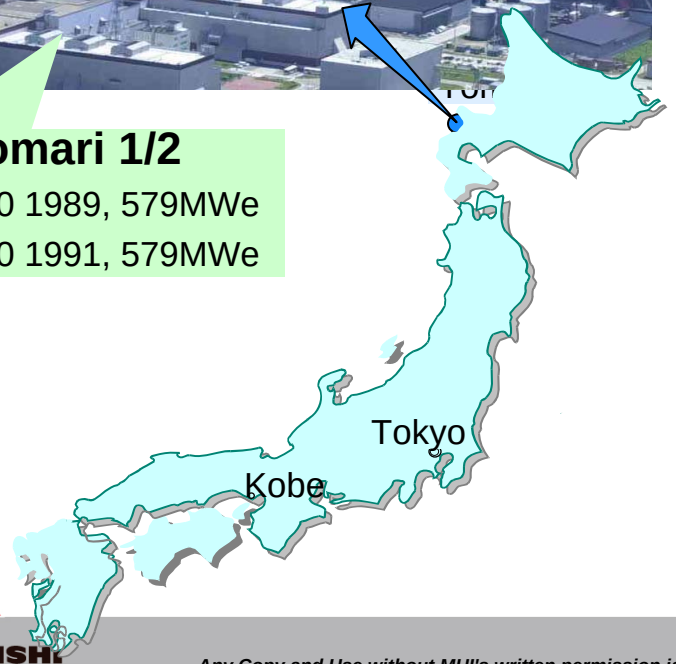
Under Start-up Test

Tomari 3

Tomari 1/2

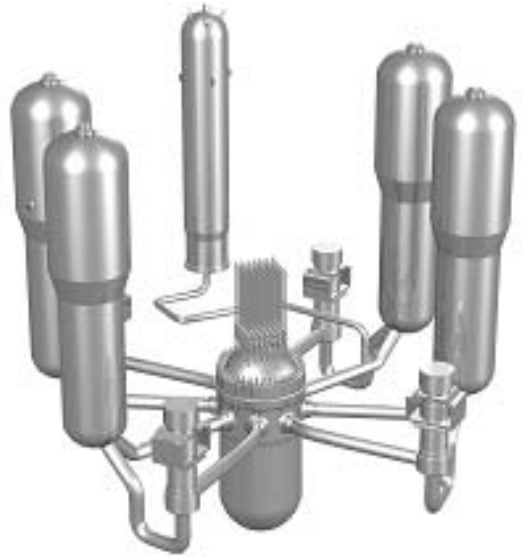
unit1;C/0 1989, 579MWe

unit2;C/0 1991, 579MWe

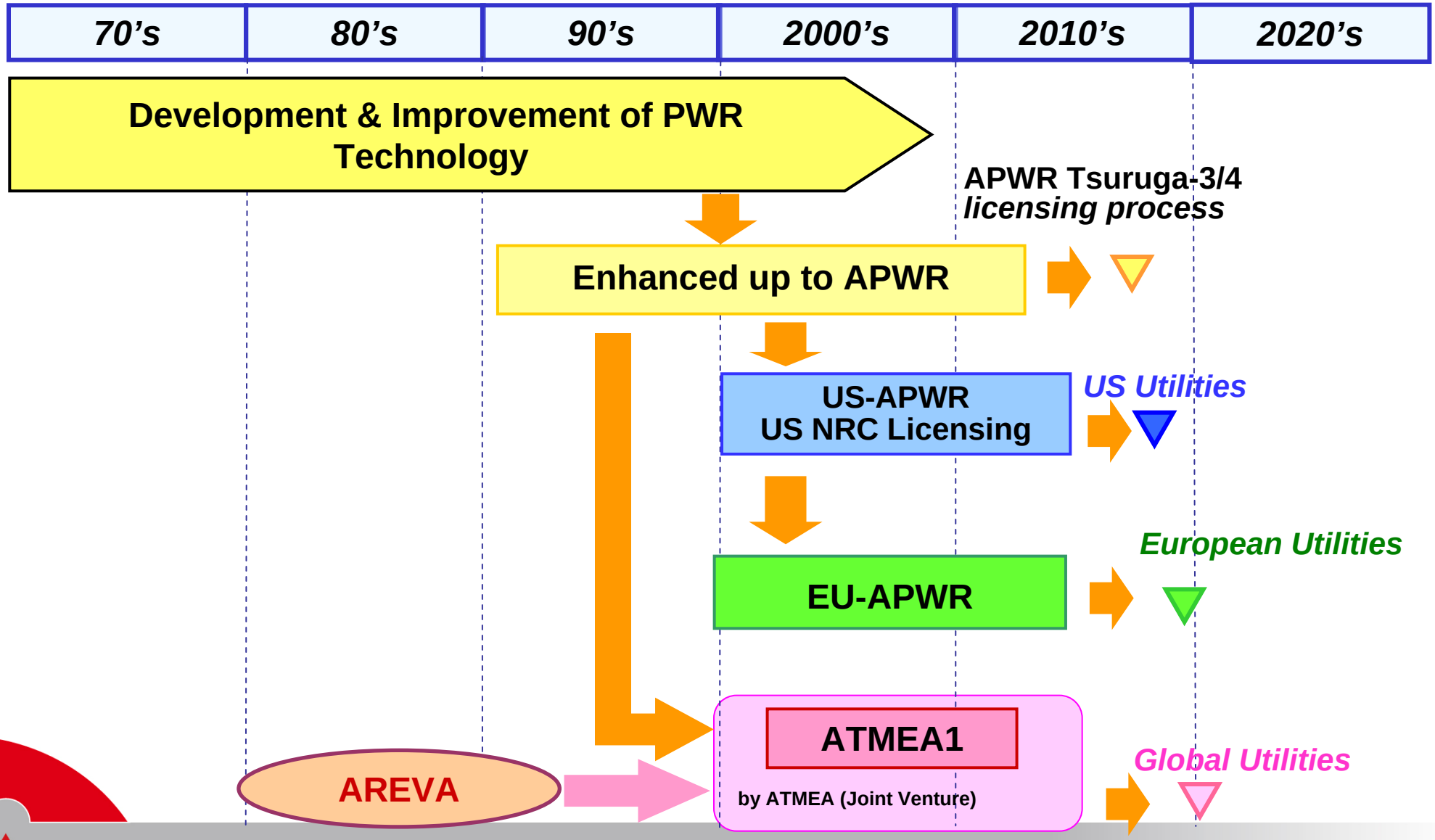


	Tomari Unit 3
Utility	Hokkaido Electric Power Co., Inc.
Output of Thermal Power	2,660 MWt
Output of Electric Power	912 MWe
Reactor	Mitsubishi 3 Loop PWR
Fuel	Low Enriched UO_2 17×17–12ft
Condenser Cooling	Sea Water
Layout	Single Unit
Commercial Operation	December 2009
Cycle	50 Hz

Contents

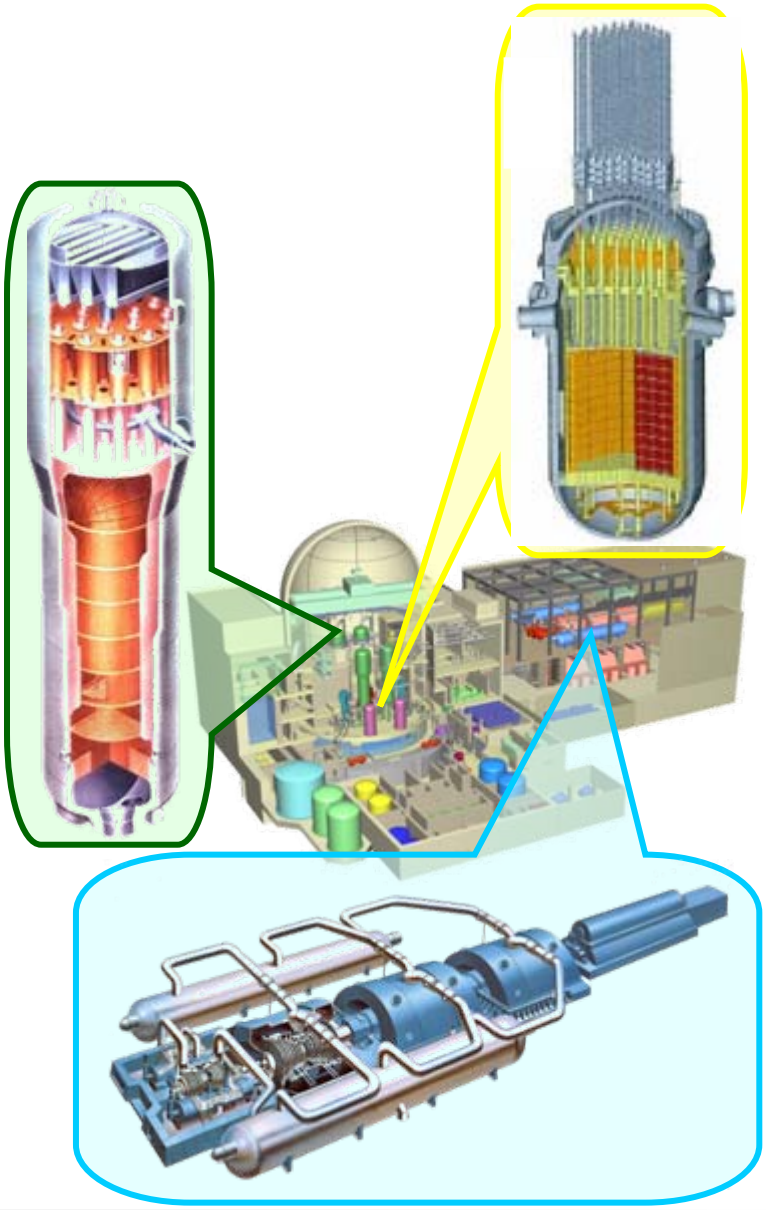


GIII+ Reactors Development



US/EU-APWR : 1700MWe Gen-III+ PWR

- **The World Largest Class Output 1,700MWe Based on "Our Own" Technologies**

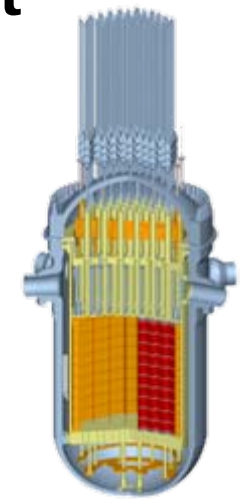


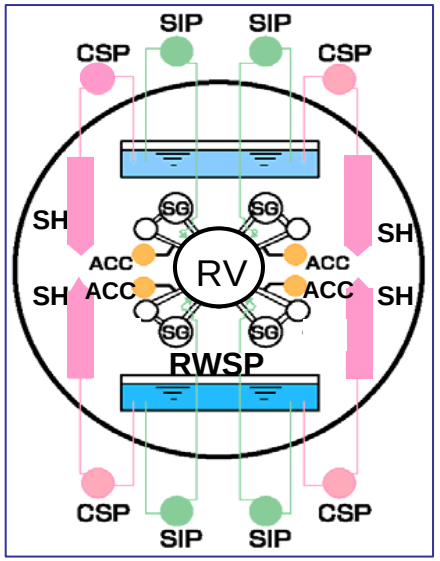
- ✓ ***Thermal Efficiency Max 37% (NET) note,***
- ✓ ***Enhanced SG Heat Transfer Area (91,500ft²/unit) with Triangular Lattice of SG Tubes,***
- ✓ ***High-Performance Steam-Water Separators Generate High Quality Steam,***
- ✓ ***High Performance LP-Turbine System with 70-inch Class Integral Shroud Blades.***
- ✓ ***14-ft Fuels Creates Additional Thermal Margin, Making 24-Month Extended Cycle Operation with keeping Fuel Economy.***

note) it's depend on site condition

US/EU-APWR : 1700MWe Gen-III+ PWR

Safe, Reliable and Economical Plant





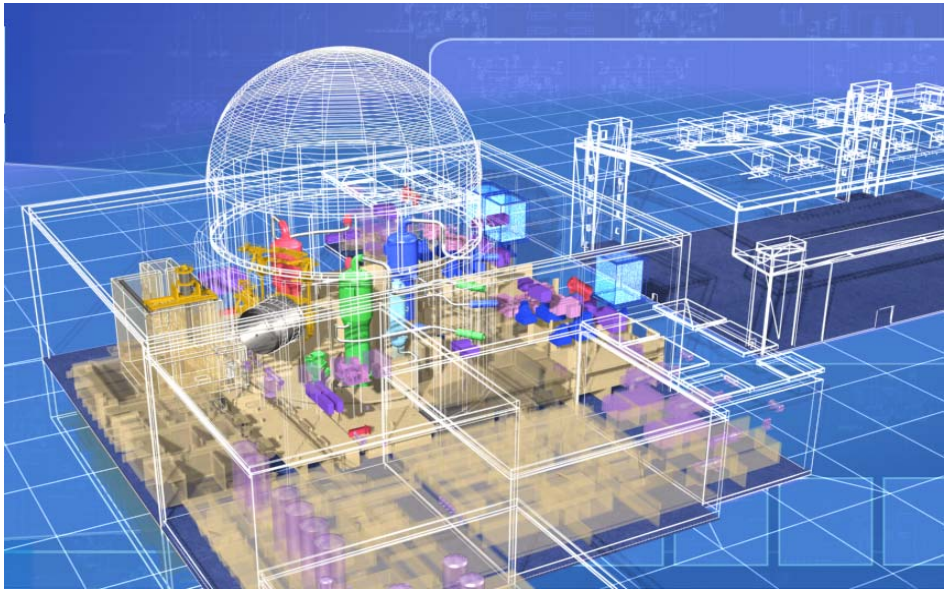
- ✓ ***Top Mounted ICIS* Eliminating Penetrations at the RV Bottom,**
- ✓ ***Full 4-Train Safety Systems*, with *Best Mix of Passive and Active Systems* Allowing *On-Line Maintenance* (OLM),**
- ✓ ***Full Digital I&C* Technology with Japanese Domestic Experiences.**
- ✓ ***Due Consideration on Protection against Airplane Crash* and Long-term Containment Integrity against *Severe Accidents*.**

ATMEA1: The mid-sized Gen-III+ PWR(1)

ATMEA1 is a midsize PWR developed by ATMEA which is a joint venture established by MHI and AREVA.

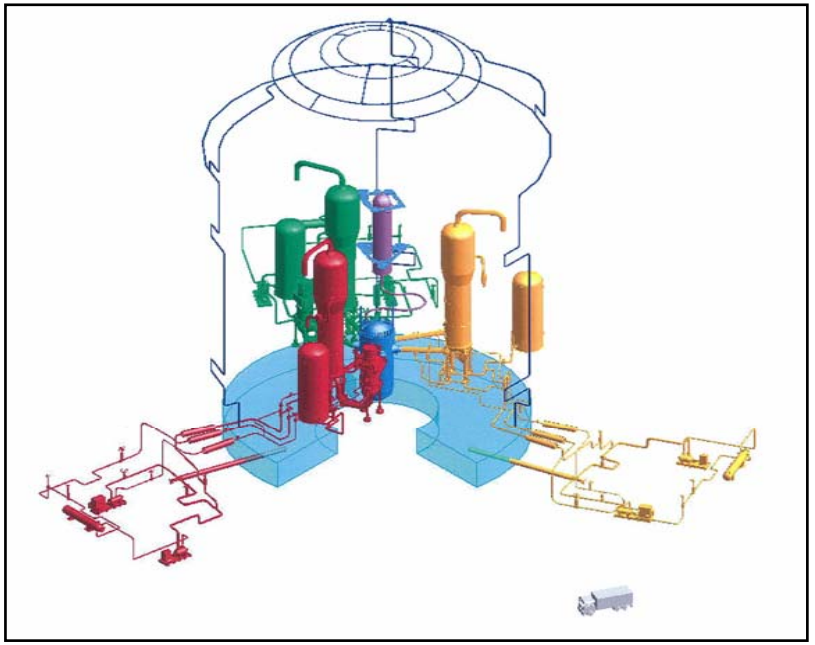
World Wide Compliance with Regulations and Utilities requirements

-The IAEA's Fundamental Safety Principles Review has been completed



ATMEA1: The mid-sized Gen.-III+PWR(2)

- **Superior operation performance by reliable and proven technologies**



- ✓ ***Electrical output : 1,100MWe (NET)***
- ✓ ***Thermal efficiency : 37% (NET)***
- ✓ ***Plant availability : more than 95%***
- ✓ ***Primary system : 3-loop***
- ✓ ***3-train reliable active safety system with advanced accumulators and in-containment water storage***
- ✓ ***Operation flexibility (12 to 24-month operation cycle length, Load-follow and frequency control, MOX loading)***

Conclusions

- ***MHI has abundant experiences to deliver total PWR plants and to render excellent services to secure highest reliability.***
- ***MHI's successful performance of integrating and managing the projects owes to the fact that all major activities, such as conceptual design, engineering, manufacture of main components, construction, commissioning and maintenance, are made by own resources and technologies.***
- ***These resources and technologies have been developed, maintained and enhanced through over 40 years continuous dedications for nuclear power plants and MHI is ready to contribute them through the application of Mitsubishi PWR in the world.***

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