Construction Experience of the Jordan Research and Training Reactor

Dec. 2025.

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Overall

~1985: New Engineers for HANARO Construction Project

- KAERI: Handling of HANARO Construction

  KEPCO: Handling of Hanbit-3 Construction

- 1995: Initial Critical of HANARO & Hanbit-3
  - KAERI: Study on New RRs

    KEPCO: Construction of Many Domestic NPPs + Design of APR1400

- 2009: First chances to export RR & NPPs

  4 Dec.: KDC became the preferred bidder of JRTR construction.

  27 Dec.: KEPCO contracted 4 Barakah units with ENEC.

- 2017: Turnover of JRTR to JAEC

Motivation to Study New RRs

- 1998: IAEA RCA selected Korea as the lead country of RR sector.
  → HANARO became focal point of technical cooperation.
- 1999: Japan renamed 'Nuclear Cooperation in Asia' to FNCA.
  → HANARO team actively participated in technical sessions of RR.

➢ HANARO engineers began to understand RR status in the region better!

✓ Resolving Problems in HANARO Operation

✓ Superior Performance of Atomized Fuel

✓ Expected Completion of Major HANARO Utilization Facilities in around 2010

➢ 2003: Initiation of a Project to Study New RRs

Activities Relevant to New RRs

- Design of high-performance compact cores, etc. using U-Mo pin type fuel
- Talks with a few Asian countries for potential replacement of aged reactors
- 2005: Cross visits between HANARO & HFR
- April 2006: NRG asked KAERI for the participation in the Pallas project.
- Sep. 2007: NRG invited KAERI to Pallas bidding.
    - HANARO level task → KAERI level
    - Formation of a consortium with industry
    - 11 May 2009: Submission of vender documents
    - 24 June 2009: Failed to become the preferred bidder
    - 15 Jan. 2010: NRG stopped the bidding.
- 2009: JRTR bidding

JRTR Bidding

15 Jan. 2009: Jordan Atomic Energy Commission (JAEC) issued Request For Proposal (RFP) of JRTR, but KAERI was not included in their vender list.

- By chance, KAERI was informed about the JRTR.
- KAERI requested JAEC the RFP.
- KAERI – DAEWOO E&C Consortium (KDC) was formed.
- KAERI changed from pin to plate type fuel for the JRTR.
- 17 May 2009: Submission of vender documents
- 4 Dec. 2009: KDC became the preferred bidder.

❖ Interest of Korean government & industry in RR export promoted through the Pallas
→ Very helpful for the success of JRTR bidding

Expected Role of JRTR - Overall

Effectively utilize JRTR for;

- Ongoing nuclear power program of Jordan
- Enhancing level of sci. & tech. indispensable for the national development

❖ Through the JRTR construction process as well!

Expected Role of JRTR – Nuclear Power

- Increasing population and industrial development → Rapidly increasing electricity demand
- No oil or gas resource economically available
- Energy import: ~ 97% of total energy demand and ~ 22% of GDP in 2008

→ Ongoing nuclear power program

  - A preferred vendor for the construction of 1 GW scale NPP
  - Construction plan: 2015 ~ 2022

JRTR

✓ Develop Human Resource for Successful Construction and Operation of the NPP

✓ Establish Infrastructure Ensuring NPP Safety to Protect People

Human Resource Development for NPP

- Students of JUST(Jordan Univ. of Sci. Tech.) nuclear engineering dept. had been graduating.
- Many trainees including the graduates had been dispatched abroad: Korea, France, Russia, China, Japan, etc.
- JRTR construction project also includes education and training program for the operation staff of JRTR
    - Direct participation of trained personnel in the construction, commissioning and operation of JRTR → Accumulate practical experiences and knowledge
    - ➢ Become the key members of Jordan nuclear projects!

➢ Utilize JRTR for the nuclear training after construction.

Expected Role of JRTR – Sci. & Tech.

- Enhance the level of sci. & tech.: Neutron beam applications, RI production, NAA, NTD of silicon, Various basic and applied research.
- SESAME (**S**ynchrotron-Light for **E**xperimental **S**cience and **A**pplication in the **M**iddle **E**ast)
    - Member States: Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian Authority, Turkey
    - Commenced in 1999 → Official project under the auspices of UNESCO in 2002 with its target operation from 2015
    - The first synchrotron light source in the Middle East
    - ➢ Promote peace in the region as the "Door Opener" by providing a common utilization field to scientists of member states openly hostile.

➢ JRTR: Best neutron beams among RRs of all SESAME member states

→ Expand co-utilization to other JRTR applications.

JRTR RFP

- Due of offer: 15 April 2009
- Full power operation: 2012
  - Preparation of vendor documents: ~ 2 months
  - Only DAEWOO E&C was willing to participate. → KDC

1) Design & construction of JRTR for 5 MW reactor and related buildings, RI production facility, Education & training center
2) Education & training of Jordan staff for the facility operation - Operators of reactor & reactor utilization facilities.

❖ Radwaste treatment facility (RTF) was not included in the scope of supply.

Initial Stage of JRTR Construction

- Hot time for Pallas bidding → Small group of HANARO team for the conceptual design
  - ❖ Pin type fuel → Plate type
- 17 May 2009: Submission of vendor documents
- 4 Dec. 2009: JAEC declared KDC preferred bidder.
- 30 March 2010: Contract signing
- 1 August 2010: Official launch of the project
- 23 Nov. 2010: Ground-breaking ceremony with the king of Jordan
- Accommodation building for KDC staff
- Education & training center: Utilized for KDC offices until turn over to JAEC

Arab Spring

- Began in late 2010 → Jordan and Syriah in Jan. 2011
  - ✓ Jordan: Nonviolent protests calling for fixing the existing regime rather than its change
    - Violent protest of local residents against JRTR construction
  - ✓ Syria: Escalated to full-scale civil-war
    - Lots of refugees into Irbid Governorate
    - Shortest distance to the border ~ 11km: Occasional sounds of shelling until the end of project
    - During a certain time period: explosions in between the site and the border, with visible rising smokes → JAEC made a contingency plan to evacuate workers.

➢ Anxiety to stakeholders of the JRTR project, especially to workers in the site

➢ Little impact to the project implementation


Haifa
JRTR
SESAME
Amman
عمّان
WEST BANK
Jerusalem
Turaif
طريف
STRIP
Be'er Sheva
Jordan
Al Qurayyat
القريات
Israel
Tubarjal
طبرجل
Ma'an
معان
Meegowa
ميقوع
Aqaba
العقبة
Haql

Fukushima Accident

- JRTR site: Far from sea shore and around 600m elevation → No tsunami
- Core: Always in the water of sufficiently large pool → No safety concern from black out
- However, the accident which had been considered not likely to occur actually occurred in Fukushima and its consequence was tremendous. → Reconsider safety of JRTR!
- New guidelines were not available yet.
- JAEC, IAEA experts and KDC discussed about enhancement of the JRTR safety.
- 30 July 2011: Application of construction permit to JNRC along the project schedule

Safety Assessment for Construction Permit

- ✓ Existing safety principles for the global reactors were in doubt.
- ✓ Nuclear safety related legislation of Jordan was incomplete.
- ✓ Experience and capability of JNRC was not sufficient.
- ✓ Assistance of IAEA + Special agreement with KINS (Korea Institute of Nuclear Safety) + US Consulting Company
    - Basically, Korean law and rules for JRTR regulation
    - Participation of many KINS experts
    - Education and training of JNRC staff by KINS

- ➢ Much longer time than the original project schedule
- ➢ Created additional items of safety enhancement.

- ❖ 2014: JNRC moved to Radiation & Nuclear sector of Energy and Minerals Regulatory Commission (EMRC).

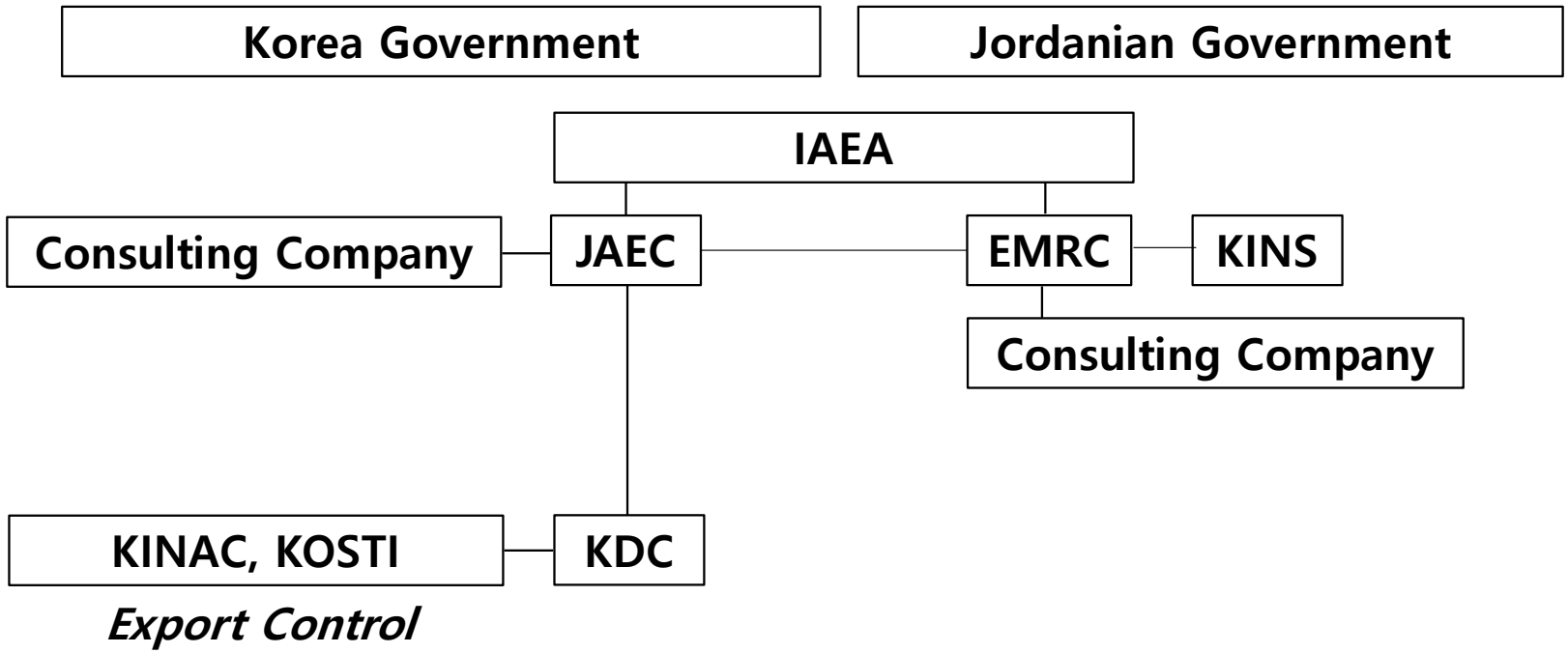
Consulting Contract of JAEC

- JAEC contracted with a French consulting company.
- The company began advice from the end of 2012 and review from the beginning.

➢ Lots of questions & recommendations for additional enhancement of safety

❖ Its consulting ended before fuel loading.

Project Implementation Scheme



Project Delay & Additional Cost

- 6 Dec. 2012: Start of limited works
- 12 May 2013: First concrete
- 15 August 2013: Construction permit

➢ Delay of project schedule: 16.5 months

➢ JAEC agreed to postpone the target date of completion for 14.5 months.

- JAEC decided to build the RTF beside JRTR site. → Requested KDC to design and to construct it too.
- JAEC agreed to increase the project cost for the RTF and additional items for the safety enhancement, but not for the additional cost caused by the elongated project period.

Education & Training of JAEC Staff

- Education from Jan. 2012 at KAERI
  → Began to participate in the reactor design and construction
- Last batch education at KAERI: Candidates for reactor operators
  → 7 May 2015: Began to participate in the commissioning tests
  → EMRC requested KINS to implement the exam for RO licenses.
  → Sufficient ROs for the initial fuel loading on 21 April 2016
  → ~ 1 year after: SRO exam
  ❖ JAEC requested EMRC to authorize HANARO SROs for the JRTR SROs.

Commissioning

- JAEC did not allow KDC to hire workers from third countries.

➢ Experienced workers for the commissioning and maintenance of systems were not sufficient in Jordan

→ JAEC allowed DAEWOO to hire third country workers.

→ After turnover, JAEC temporally hired many of them for the JRTR maintenance.

- No demi-water supplier in Jordan

→ DAEWOO got it from a power plant operated by KEPCO(~200km distant).

→ A water tank truck could make only one round trip in a day.

- From the fuel arrival at the site: Gendarmeries began to control access to the site.
  - Independent of JAEC
  - Access control to the site especially for the transport of equipment became much stricter than before.

RPT & Nuclear Analyses

- Under the control of HAHARO SROs
- 31 Oct. 2016: End of RPT
  - → JAEC temporally hired three specialists retired from KAERI.
  - ✓ Two of them had HAHARO SRO licenses.
  - ✓ Led JAEC departments for reactor operation, mechanics and I&C, respectively
- Monte Carlo code McCARD + ENDF B-VII.0 for the JRTR nuclear design
- ENDF B-VII.1 became available from Nov. 2011.
- JAEC: MCNP6 + ENDF B-VII.1 for their review calculations.

➢ Practically same results in the criticality and neutron reaction rate distributions

RPT Results

- Confirmed excellent accuracy of design
  - Criticality < 1mk difference
  - Neutron reaction rates in the fuel region: σ = 2.64% for 165 points

- $|\rho_{ex}^{M} - \rho_{ex}^{D}|$ > acceptance criterion 10%

  → No fault in the design and experiments → NCR with 'Use As Is' → A hot issue

  → JAEC reevaluated ρ_{ex}^{M} from raw data: Delayed neutron data from ENDF/B-VII.1

  → Satisfied the acceptance criterion

  → KAERI could not say the delayed neutron data of ENDF/B-VII.0 problematic.

  → Later on, they devised a logical way of correction to the problematic experimental data to deduce a better ρ_{ex}^{M} .

Initial Operation

- 7 Dec. 2016: JRTR inauguration
- 26 Feb. 2017: EMRC authorized conditional JRTR operation.
- JAEC prepared ‘Initial Operation Test’ (IOT) plan and modified RPT procedures to reflect changes in situation and reactor conditions from the previous RPT period.
- JAEC strongly requested to measure the neutron reaction rate distribution for all fuel assemblies and to include the neutron spectrum measurement.

  → KAERI prepared additional materials and devices for the two tests.
- All tests were planned, analyzed and implemented by the responsibility of JAEC with the assistance of KDC when necessary.
- 15 June 2017: Turn over of JRTR to JAEC except RTF and RI production facility
- 15 Oct. 2017: Turn over of RTF and RI production facility
- 12 Nov. 2017: Final JRTR operation permit

Closing Remarks

- Several-years study for new RRs + works already in progress to bid Pallas: Significantly contributed to the success of JRTR bidding.
- Fukushima accident during the early stage of the project: Induced significant increase of cost and period of the project.

  → No responsibility of both sides was agreed.
- After final turnover, KDC assisted JAEC's JRTR operation and continued cooperation.

➢ The project had been implemented under the spirit of mutual benefit with strong backing of both governments.

- JAEC temporally hired three specialists retired from KAERI to lead initial JRTR operation and several third country workers of KDC for system maintenance. JAEC staff gradually took over all responsibilities.
- 28 Nov. 2018: Dr. Khaled Toukan, Chairman of JAEC addressed the success of JRTR project at the Ministerial Conference on Nuclear Science and Technology at the IAEA.
- 24 - 28 March 2019: JAEC hosted RRFM/IGORR

Recent Status of JRTR

- 7 March 2024: Dr. Khaled Toukan announced;
  - JRTR is operated entirely by Jordanian personnel.
  - It is a key pillar of progress in peaceful nuclear energy applications, not only at the Jordanian level but also at the regional level.
  - Plans for expanding its utilization through producing other medical RIs namely, Tc-99m and Ho-166, and for undertaking NTD.
- The planned nuclear power project has not been accomplished.

  → They are making strides towards the introduction of SMRs to produce both electricity and drinking water.

  → The infrastructure and experience of Jordan accumulated through the construction and operation of JRTR: Beneficial for their SMR project if it is realized.

Thanks!