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Lessons for the next NPP projects, as learned from the Olkiluoto 3 construction experiences

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Challenges met in starting nuclear new build (1)

Loss of experience during the many years of no new construction in Western Europe and North America

- Without new orders it was not possible to keep large design staff employed and many of those having designed current plants had already retired
  - adequate design staff could be recruited and trained only after signing a contract on a new plant
- Project managers had little experience on nuclear build
- Many of the nuclear equipment manufacturers had left the business
  - it was necessary to find new manufacturers and to teach them how to work in the nuclear business: QA, regulatory control, safety culture, ...

Challenges met in starting nuclear new build (2)

New plants have ambitious goals for improved safety and economy

- Larger structures and components than in the plants of previous generation: need to explore new limits of technology
- New manufacturing technologies that needed to be qualified
- New advanced design features and technologies that had to be demonstrated to meet design targets and to function in a reliable manner

Challenges met in starting nuclear new build (3)

Business models in Western Europe and North America have changed since1970's when most of the currently operating plants were constructed:

•Vendors of 1970 s had large experienced organizations, with comprehensive in-house capability for design and manufacturing

•Today's business is based on long subcontractor (supply) chains that need to be managed

- Decentralised design work is most difficult to manage, even within the same company
- Often also the supply chain management (Vendor duty) and its oversight (Licensee duty) is conducted by consultants, not by the own staff of the main Parties

Challenges met in OL 3 schedule

The schedule of Nuclear Island is now about four years behind the original plan. Main reasons for this delay are:

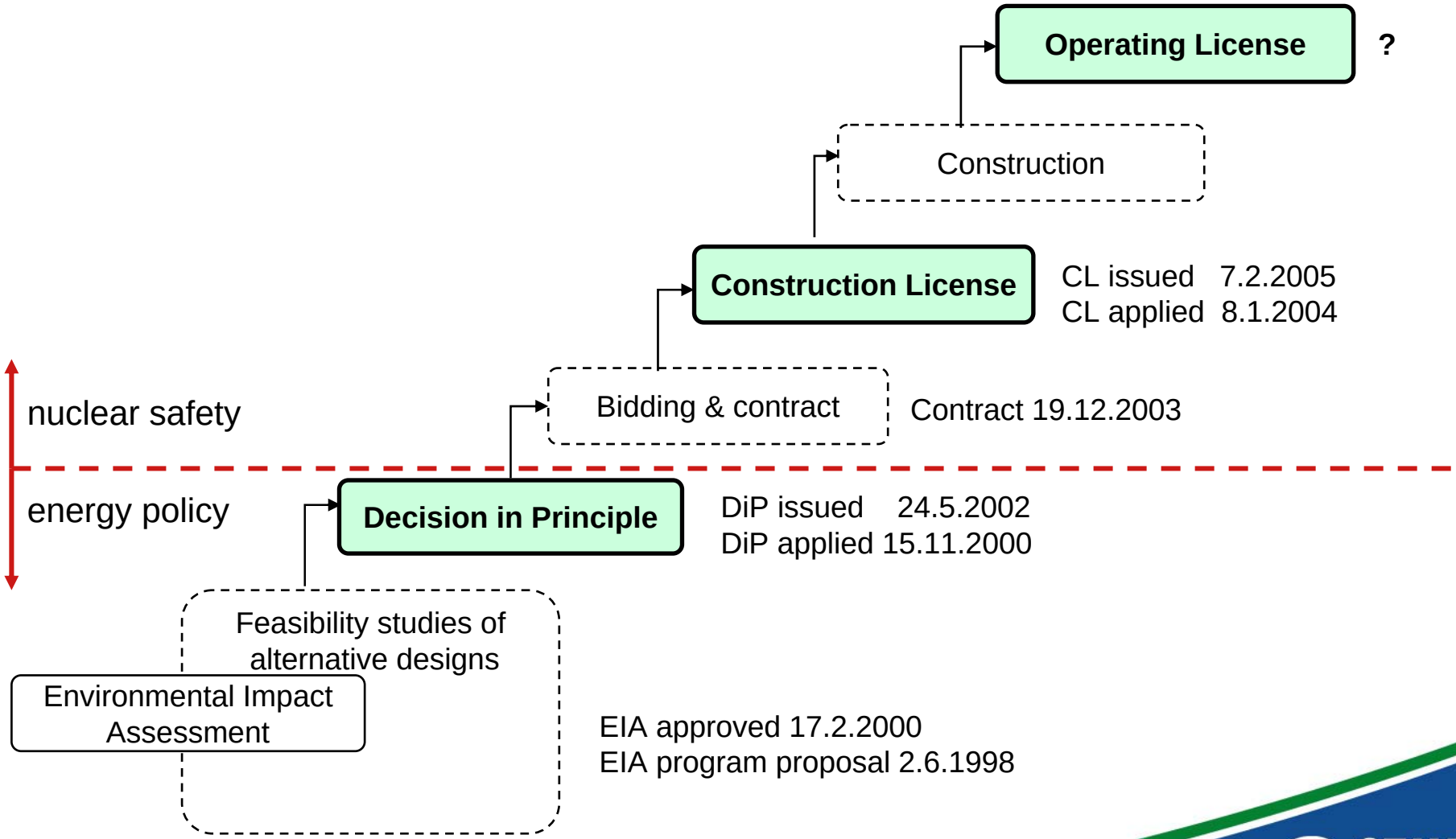
- too ambitious original schedule for a plant that is
  - first of its kind,
  - larger than any NPP built earlier, and
  - built in a changed business environment after long recess in construction
- inadequate completion of design and engineering work prior to start of construction
- lack of experience of parties in managing a large construction project

Turbine Island has been more "business as usual" and probably could have been built close to the original schedule.

Issues of importance in new build

- Schedule
- National safety regulations
- Regulatory oversight approach
- Communications between Vendor, Licensee and Regulator
- Role and responsibility of the Licensee
- Preparedness and resources of the parties
- Timely completion of design and engineering work
- Management of the construction work
- Management of the supply chain
- Qualification of technologies
- Emphasis on safety culture

Licensing schedule of Olkiluoto 3



Schedule Olkiluoto 3 versus New NPP's

	Olkiluoto 3	New NPP's
From start to DiP	3,2 y	2,5...3 y
– EIA process	-1,7 y	-1,1 y
– DiP process	-1,5 y	-1,4…1,9 y
(*Olkiluoto3 had a recess of 9 months after EIA*)		
From DiP to construction start	**2,7 y**	**5…5,5 y**
– bidding and supplier selection	-1,5 y	-2,0 y
– **design and engineering***	**none**	**-1,5 y**
– construction license review	-1,2 y	-1,5…2,0 y
From construction start to fuel loading	8 y ?	5…6 y ?
Total time	13,9 y ?	12,5…14,5 y ?

* *Intensive design and engineering work in the Olkiluoto3 project was not started before signing the contract and submitting CL application; for new NPP's one licensee contracted specific design and engineering tasks to potential suppliers six months after receiving DiP*

National safety requirements

National safety requirements, or proper references to recognized international or other countries' requirements need to be clearly specified as part of the licensing and regulatory framework.

- In case OL3, up-to-date requirements were available in STUK's YVL guides (regulatory guides) but evidently the vendor did not get full understanding of them in the early stage of the project
- For the new plants:
  - STUK is making a major revision of the set of YVL guides, aiming to provide guidance in a user friendly and easy to understand format
  - The actual requirement level is not intended to change from OL3
  - New IAEA and WENRA guidance is used to the extent possible
  - STUK will review the safety requirements written by Licensee in its call for tenders, aiming to confirm that the requirements are presented in clear and explicit manner to potential vendors

Regulatory oversight approach

Understanding of regulatory practices is essential for successful project implementation

- In OL 3, the regulatory oversight approach is different from what the Vendor has met elsewhere.
  - STUK has a unique regulatory approach involving inspection of design documentation of Safety Class 1 and 2 structures and components before approving their manufacturing – the Vendor was not used to a comprehensive pre-assessment, inspections at manufacturers and on-site, and specific hold points
- For ensuring smooth progress of NPP construction project, all parties (vendor, licensee, regulator) should be familiar with the licensing, regulatory oversight, and inspection practices both in the vendor country and in the customer country; the vendor should take regulatory actions into account in the project planning.
- STUK is considering possibilities to reduce hold points in future projects, pending the arrangements and performance of the Vendor and Licensee.

Communications between Vendor, Licensee and Regulator (1)

Early contacts between potential Vendors, Licensee and Regulator before starting the actual project facilitate the licensing process and help to avoid licensing uncertainties

- Feasibility studies of several designs were conducted in early stage of OL 3 project
  - Safety issues involving potential uncertainties to licensing were identified and thoroughly discussed before and during the DiP process; these issues could be addressed before bidding
  - Each design proposed in bidding was improved from the original version that was reviewed tentatively during the DiP process
- Similar approach has been adopted and even strengthened in the new projects

Communications between Vendor, Licensee and Regulator (2)

Regular project management meetings and direct contacts among the three Parties at management level are most useful

- Difficulties encountered in the OL 3 project have been discussed frankly and openly in the project meetings, thus promoting their timely resolution
- Movement of the Vendor's project management to the site and its continuous presence, as opposite to working mostly in home office abroad, improved significantly common understanding of current issues

Communications between Vendor, Licensee and Regulator (3)

Adequate decision making power of the Vendor's project management, and separation of contractual issues from project management needs to be emphasized

- Vendor's home office decisions turning down common expert views on technical issues, as formed in project meetings between all Parties, have been found to be detrimental to smooth progress of project.
- Raising contractual (financial) disputes among the Parties during construction should be avoided, they create difficulties to formal communication not only between Vendor and Licensee but also between the Licensee and the Regulator.

Role and responsibility of the Licensee (1)

Licensee is responsible for the safety of its plant when it starts to operate, and it needs to verify during design and construction that it gets a plant which is safe to operate.

- Roles and responsibilities of Licensee and Vendor need to be agreed unambiguously in the main contract.
- Licensee must have detailed oversight of the construction of its plant – a turn key project is not different in this respect.
- Licensee management needs to be committed to build and implement
  - a strong quality management system (QMS) on the company level and in addition project-specific quality assurance plans (QAP) for complicated key supplies (e.g., diesel generator supply)
  - a high safety culture already during the construction time.

Safety culture cannot be turned on overnight at the plant start-up !

Role and responsibility of the Licensee (2)

In specific, the Licensee shall

- have human resources with adequate competence to conduct, possibly with support of a qualified expert organisation, its own safety assessment as needed to verify that the plant and its SSC's meet safety and quality requirements,
- have its own requirement management system and an independent capability to verify and prove that all requirements are met, with support of a third party where necessary,
- have a system for reporting and resolving all non-conformances identified in quality controls,
- have an opportunity to require use of proven state-of-the-art technology in manufacturing and construction (not only to accept final products that meet minimum agreed quality requirements),
- have an opportunity to verify and require that the Vendor uses only sub-contractors with adequate qualifications.

Preparedness and resources of the parties (1)

Adequate preparedness and resources of all parties must be ensured and verified before starting the project implementation

- It is obvious that the progress of OL3 project has been undermined by shortage of skilled resources
  - After the construction start, the Vendor had to recruit a large number of designers for all areas, and to acquire an experienced construction management organisation; in this respect the situation has improved with time.
  - A persistent concern on the Vendor side seems to be shortage of skilled designers of digital I&C systems, and respectively on the Licensee side shortage of skilled reviewers of these systems; this is an area of engineering which suffers a general lack of competent and experienced persons
  - Progress of the project could have been promoted by larger and better managed resources to supervise the supplier chains.

Preparedness and resources of the parties (2)

In the new projects it is important to ensure that the Licensee and the Vendor organisations have, in their own staff, adequate:

- project management and quality management skills
- experience from management of a large construction project
- knowledge and experience in all technical areas relevant for nuclear safety: civil, mechanical, electrical, and I&C engineering, and nuclear technologies (water chemistry, nuclear fuel, reactor physics, thermo-hydraulics, safety analysis)
- skills and arrangements to make independent assessment of the design and safety analysis
- skills and arrangements to verify achievement of required quality and to control correction of quality non-conformances

Preparedness and resources of the parties (3)

In addition, the Vendor needs to have at its disposal for each NPP project:

- experienced generalists who have broad technical knowledge across the areas relevant to NPP design and safety (“Chief Engineers”)
- experienced designers who have a realistic view on the actual challenges involved in implementation and can set the requirements to constructors / manufacturers in an optimum manner
- manufacturers and constructors who have proven capability to meet designer’s intent and related specifications

Timely completion of design and engineering work (1)

Importance of timely completion of design and engineering work cannot be too much emphasised as a necessary condition for controlled implementation of the project in targeted schedule.

- Starting construction activities without approved design documentation and without a construction plan and schedule will
  - delay the start of construction activities at full speed
  - cause continuous pressures to all involved organizations
  - lead to attempts to reschedule manufacturing and construction steps, thus making project management complicated
  - lead to reduced quality due to time pressure and often require corrections and reassessment

Timely completion of design and engineering work (2)

In the new plants it may not be meaningful to require that all details of design, such as choice of components, shop drawings for manufacturing and specifications for each construction step are done before construction start.

However, in the new NPP projects a target to be emphasised is that before starting construction it is necessary to have approved design documentation and a construction plan and schedule for at least six months ahead at all time.

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Timely completion of design and engineering work (3)

In its new YVL Guide, STUK specifies the level to which the systems should be designed before applying for Construction Permit.

At least the following should be presented in the CP application:

- plant layout and architectural drawings of buildings,
- systems design basis, system descriptions, process diagrams and 3D-drawings of main fluid systems and systems providing or supporting basic safety functions,
- key design parameters of main equipment,
- fluid systems design and their protection limits to the extent that is needed for deterministic safety analysis of anticipated transient and postulated accidents,
- I&C systems architecture,
- electrical systems architecture,
- loads for design of buildings.

Management of the construction work

In making contracts for construction, one should not underestimate the importance of proven experience from management of large projects.

- Vendor needs to know how to find a competent contractor for construction, how to verify its competence and how to manage it.
- Licensee needs to know how to assess the Vendor's choice and how to conduct oversight of the construction organisation's work.
- Construction organisation needs to have the following experience and skills

– how to schedule the work,

– how to organize the construction site,

– what resources are needed and when.

Management of the supply chain (1)

For contracting suppliers and sub-suppliers with no previous experience from the nuclear field, Vendor needs to ensure that all relevant nuclear specific work practices are clearly brought out in each call for tender. These may include:

- requirements on design documentation to be provided for approval before manufacturing,
- oversight (audits, inspections, ...) to be conducted by several different organisations during manufacturing,
- expectations on safety culture.

If the nuclear specific work practices are not recognized and understood by the sub-contractors at the time of signing the contract, difficulties are to be expected in a later stage.

Management of the supply chain (2)

Vendor needs to ensure the expected performance of the entire supply chain by a contract that addresses management of each step of the supply chain. The contract needs to include requirements both on the product and on the work practices (especially provision for a project specific QA Plan for each sub-supply).

- All requirements, including management of sub-suppliers, need to be clearly specified in the top level contract between the Vendor and its main supplier.
- Relevant requirements need to be communicated unchanged to each sub-supplier in the contracts made along the supply chain; these requirements shall be written in terms that are understandable to all parties involved.
- Means to ensure correct and accurate transfer of information on agreed changes in design or requirements need to be specified.
- Reporting on deviations and corrective measures needs to be specified.

Vendor and Licensee shall have an opportunity to review the safety and quality relevant requirements in the contracts.

Management of the supply chain (3)

- In OL 3 project the Vendor has been active in training new players to the nuclear field and in auditing organisations that participate the project as suppliers. However, it has not always been successful in managing the supply chain or monitoring the performance beyond its main supplier.
- In some supply chains, following concerns have been noticed:
  - Some suppliers not aware or attentive to the relevant technical or quality standards or nuclear specific requirements.
  - Some suppliers not aware or attentive to the required safety culture.
  - Information on design changes agreed by the Vendor and Licensee, and approved by the Regulator, but not transferred to the manufacturer.
  - Lack of interaction between designers at different levels and ignorance on related safety analysis.
  - Identical components / parts have been purchased through separate supply chains from the same manufacturer to systems that are intended and believed to provide diversity for managing key safety functions (e.g., identical air coolers for two different sets of diesel generators, making them vulnerable to common cause failure in very low temperature)

Management of the supply chain (4)

Evaluation of the manufacturers' ability needs to involve observations at the level of shop floors.

- It has been learned that the real competence of manufacturers is not easy to judge through auditing only and the Certificates issued to a company do not always tell the real truth.
- Evaluation of shop organisation, available tools and products supplied by the shop earlier are better indicators of supplier's expected capability.

Management of the supply chain (5)

Both the Vendor and the Licensee need to verify that each important supply chain functions as expected.

- Interaction between designers who work in different parts of the supply chain but contribute to the design of the same system or component needs to be ensured.
- Graded approach to oversight of manufacturers is necessary; oversight requirements for each sub-supplier should be specified in the contracts
  - A systematic oversight plan, including hold-points and focusing on compliance with QA Plan, is commendable for supplies with high safety relevance
- Management of comprehensive supplies that involve different technical areas need a separate sub-project organisation by both Vendor and Licensee, with competence in each relevant area, e.g. supply of
  - diesel generators, reactor building main crane, fuel loading machine, main coolant pumps

Qualification of technologies

Qualification of new construction or manufacturing methods takes time – it should be done before the project starts.

- New advanced safety features were not easily implemented at OL 3
  - Many components had to be re-manufactured to achieve specified quality and to ensure 60 years lifetime
  - New welding methods applied to main components required practice before achieving the specified material properties in the weld and in the heat affected zone and avoiding faults that need corrections
  - Construction of massive concrete structures required full scale tests to demonstrate casting methods of structural parts, especially casting of concrete with specified properties into a dense grid of rebars was an issue
  - One of the two proposed main digital I&C platforms could not be qualified according to current standards although it has good operating record in conventional applications – this requires further changes in the I&C architecture

Emphasis on safety culture

Strong message and transparent actions and decisions are expected from the management of the Vendor and the Licensee to promote safety culture: ***"safety and quality have higher priority than costs and schedule"*** .

Management needs to demonstrate their attitude in

- choice of qualified subcontractors
- state-of-the-art tools and methods
- uncompromising compliance with the agreed requirements
- walk downs by management
- taking into account safety concerns expressed by workers and answering their questions

Conclusions

Starting new build is demanding because much of the earlier experience and resources have been lost from the nuclear industry.

Adequate time has to be allocated to good preparation of the project before actual construction start:

- making design as early as needed for smooth construction,
- resolving potential regulatory uncertainties,
- qualifying the new design features and technologies,
- building competent organizations,
- specifying responsibilities of parties,
- ensuring availability of qualified designers, constructors, and manufacturers to implement the project, and
- providing quality management systems that emphasise strong management of supplier chains.