New Build CANDU In Canada – Development And Application Of Information Management Systems For Latest Construction Technology

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Abstract

In the wake of recent events representing growing nuclear energy interest in Canada, AECL and Hitachi are sharing each other's expertise as each company has its own unique and unrivalled capability in managing new build construction projects. This paper addresses some of the key strategies used to execute successfully a New CANDU build project, by focusing on recent developments and implementations in the construction and project management fields and by highlighting the use of cutting edge information technology. These strategies are designed to achieve and maximize their benefit to the New Build CANDU project team, to AECL/Hitachi as well as customers, partners and suppliers.

1. Introduction

An ever-increasing demand for power, growing concerns about fuel supply and the increasing awareness of the environmental benefits of clean nuclear power, form the foundation for a worldwide nuclear energy renaissance.

In addition, the strong economic and safety performance of nuclear power in Canada have contributed to the increasing interest in building the next generation of new nuclear power plants. The following recent events reflect this growing nuclear energy interest in Canada:

1) In December, 2005, The Ontario Power Authority advised the Ontario Government that there will be a 15,000 MW gap by 2015 and recommended maintaining level of nuclear power supply at ~50% which requires new nuclear.
2) In June, 2006, the Ontario government directed Ontario Power Generation to begin the work needed for an environmental assessment for the construction of new units.
3) In August and September, 2006, Bruce Power and OPG respectively started the federal approvals process with the Canadian Nuclear Safety Commission by filing an application for a Site Preparation License for new units at their existing Bruce and Darlington Nuclear sites.

In order to fulfill these robust expectations for new build nuclear projects, Atomic Energy of Canada Limited (AECL) and Hitachi Canada Ltd. together with Hitachi, Ltd. (Hitachi), whereas each has its own experience in successfully managing nuclear power plant construction projects, are sharing each other's expertise using a broader basis of resources focused on one goal: a successful new build CANDU project in Canada.
This paper describes two state-of-the-art technologies and their potential applications to a new build CANDU project in Canada:

- Integrated information management applications, and

- Advanced construction technologies supported by information management systems – Modularization and other cutting-edge technologies

Specifically, this paper includes an evolutionary strategy that emphasizes the importance of integrating information systems managed by the diverse disciplines and project organizations involved in a CANDU build project. This strategy is designed to achieve and maximize benefit from shared use of engineering and information management applications by the project team, as well as customers, partners and suppliers.

2. Latest Construction Achievement and Track Records

AECL and Hitachi bring the best of each member's skills in managing nuclear power plant construction projects based on their past achievements and track records. This section summarizes such achievements and track records by highlighting the most recent nuclear construction projects.

- Latest CANDUs: Qinshan – China / Cernavoda-2 – Romania / Wolsong – Korea
- Latest full turn-key ABWR: Shika-2 – Japan

2.1 Qinshan – China / Cernavoda-2 – Romania / Wolsong – Korea

Since 1996, AECL, together with its key partners including Hitachi, has completed six power plants, and currently has one under construction. These achievements showcase the following advantages of CANDU reactors and projects:

- Delivery On Time, On Budget:
  All of the six power plants were delivered on budget and on or ahead of schedule.
- Advantage CANDU – Performance:
  The operating experience of all CANDU 6 plants has been world class. For year-end 2006, the global CANDU 6 fleet achieved an average annual Capacity Factor of approaching 90%.

The Cernavoda site in Romania is a five-unit CANDU 6 station. Unit 1 has been in operation since 1996; Unit 2 is now under construction with an expected in service date of Fall 2007.

Wolsong 2, 3 & 4 in South Korea were completed within budget and on schedule in 1997, 1998 and 1999 respectively. KHNP (Korea Hydro Nuclear Power Co.) was the Project Manager for Wolsong Units 2, 3 and 4, and AECL was the Prime Contractor for Design and Equipment supply.

The Qinshan CANDU project in China was the most successful nuclear project in China and established a benchmark against which all nuclear projects will be measured in the future. AECL provided the design and equipment for the nuclear steam plant (NSP) and was responsible for overall project management and construction management of the NSP. Hitachi supplied the steam turbines, generators, and other major BOP components as well as several NSP equipments under subcontracts to AECL.

The Qinshan and the Cernavoda 2 projects have been the first nuclear projects where an integrated set of project enterprise systems has been leveraged to substantially impact the delivery costs and schedules. On the Qinshan and Cernavoda-2 projects, significant benefits were realized because the project participants used a common set of shared "project enterprise-wide execution and delivery" systems. AECL's present project execution environment is based on four highly integrated core systems:

- Intergraph's 3D plant modelling and schematic design suite
- AECL's Supply Chain management system (CMMS)
- AECL's Document Production and Control System (TRAK)
- AECL's IntEC equipment design and management (MEDB), cable & wiring and DCC/DCS signal management system

Both Qinshan units were delivered ahead of schedule and the budget targets were achieved in large part due to the extensive use of the above four systems during all project phases.

2.2 Shika Unit No. 2 - Latest ABWR in Japan

The Shika Nuclear Power Station Unit No.2 of the Hokuriku Electric Power Company, Inc. is the first Advanced BWR unit built in Japan by a single EPC (Engineering, Procurement and Construction) contractor, except the civil structure and construction, and it is among the largest nuclear power generating units within Japan. The construction proceeded on schedule and the plant entered its commercial operation in March 2006 as planned. Hitachi, Ltd. supplied the entire plant from design, fabrication to construction including the reactor and steam turbine generation system. In the design and construction of the plant, the most advanced technologies were applied in order to match the civil site construction process with the Mechanical & Electrical installation to supply a safe, reliable and economical power plant.

Hitachi has been applying advanced construction methods in order to reduce construction schedules and expenses in actual nuclear power plant construction projects as follows:

- Performing more detailed pre-construction engineering to minimize rework at site. This reduces coordination efforts and indirect costs through the sharing of temporary facilities.
- Electronic sharing of engineering concepts between utilities and contractors during the pre-engineering phase to improve the collaboration efforts.
- Utilizing the over twenty years of experience in modularization to improve safety and quality, as well as a reduction of the construction site workforce.
- Application of a "living" 3D-CAD system at all stages of engineering and construction, using "as designed" and "as built" information. This process allowed for more effective construction engineering and improved records of construction activities.

With these concepts, coupled with other proven technologies, Hitachi achieved an approximately 25% reduction of peak construction staff levels as compared to the first ABWR's. Furthermore, the overall construction period was shortened considerably while maintaining high standards for safety and quality.

3. Construction Technology Highlights

Integrated information management will provide cutting-edge solutions for system and equipment design, 3D plant design, supply chain management, and document control as well as highly sophisticated engineering and construction schedule control. Such integrated information management systems facilitate the engineering and management processes through the entire project lifecycle. Furthermore, it also enables even broader application of advanced construction technologies as the result of detailed pre-construction engineering in every aspect of construction from very early stage of plant engineering.

3.1 Integrated construction management with information technology

3.1.1. Background

Back in 1984, the AECL executive team challenged the organization to find tools and methodologies that will provide revolutionary breakthroughs in productivity increases and project schedule reductions. AECL was not content to move to evolutionary conventional computer aided drafting available at that time.

With 3D modeling installed at AECL as a core engineering tool supplanting 2D drafting, AECL tackled instrumentation, control and electrical (ICE) engineering. However, with no “off-the-shelf” software available that met AECL’s needs, AECL developed IntEC, its own equipment, cabling and wiring system. IntEC was successfully used to design and build units 2, 3 & 4 at Wolsong, Units 1 & 2 at Qinshan and unit 2 at Cernavoda. IntEC became a commercial success as well. The CANDU utilities quickly recognized IntEC’s benefits and capabilities. Following the initial sale of IntEC to KEPCO, AECL sold IntEC to Hydro Quebec for G-2, OPG for Darlington, Bruce Power for Fuel Handling (units 1-8) and New Brunswick Power (NBP-N) for Point Lepreau.

At the start of Qinshan, CADD (Computer Aided Design and Drafting) and IntEC were firmly established and in use at AECL. The next challenge was for engineering tools to drive down costs and reduce non-conformances. To achieve this goal, information would need to be made available to the right people at the right time, and this meant improving the documentation systems used on the AECL projects. With the advent of electronic tools used to author and produce the project documentation, Electronic Document Management and Control (EDMS/EDCS) systems became business imperatives. The need to properly manage, distribute and archive the many hundred of thousands of formal and informal documents produced on CANDU projects, resulted in the implementation of TRAK, a comprehensive, state-of-the-art, fully integrated documentation system. TRAK is currently used across the company, at all of its sites by over 3,000 users. It facilitates documentation processes as well as QA processes for New Build, Re-tube/Refurbishment projects, Engineering Services, Development projects, operating facilities (NLBU), R&D, etc. with TRAK incorporating the best practices of commercial products but tuned to the “CANDU-way” of document management.

Material Management has always been a major challenge for any project of the magnitude of CANDU project. With no “off-the-shelf “product available to meet its needs, AECL developed the CANDU Material Management System, CMMS. CMMS was used on the Wolsong 2, 3,4, Cernavoda 1, Qinshan and Cernavoda 2 projects and is currently used on the Re-tube/refurbishment projects. Unlike commercial material management systems, CMMS supports AECL’s stringent design verification, quality assurance and control procedures that are core to the procurement of nuclear grade equipment and components. CMMS is a seamless, single-point of access of information for all materials throughout the project lifecycle, from engineering through procurement, receiving, warehousing, construction and operation.

Design Data, Documents and Materials are the tripod supporting all engineering and procurement activities. On Qinshan, the first steps towards a mission critical multi-disciplinary enterprise information system began to emerge through the data sharing among the four systems, CADDS, TRAK, CMMS and IntEC.

3.1.2. Business Processes

During the design phase of a CANDU plant, several computer applications are used to render the design and validate it through analysis. Much the design is performed using a "intelligent" CADD applications. The current systems used to design the New Build CANDU are INTERGRAPH's Smart Plant Enterprise for plant design, TEKLA civil detailing modules and Unigraphic's Solid Edge 3D modeling for component design.

Throughout the design phase the material requirements are captured in CMMS via data sharing with CADDS and links are created to both IntEC and TRAK. This intelligent linking allows data to be located in a variety of different ways, using a single piece of design information.

During the construction phase as well as in the commissioning stage of the CANDU plant, the four core applications become the main source of data. TRAK is used to deliver and manage documentation issued to site and thereby create the construction and commissioning history of the plant. This is a key activity defined in the codes applicable to building a CANDU Nuclear plant.

When handing-over of a plant to the client, it has historically necessitated a transfer of voluminous amounts of hard-copy documentation. For the Qinshan project, this task was simplified by handing over the three major systems: TRAK, CMMS and IntEC.

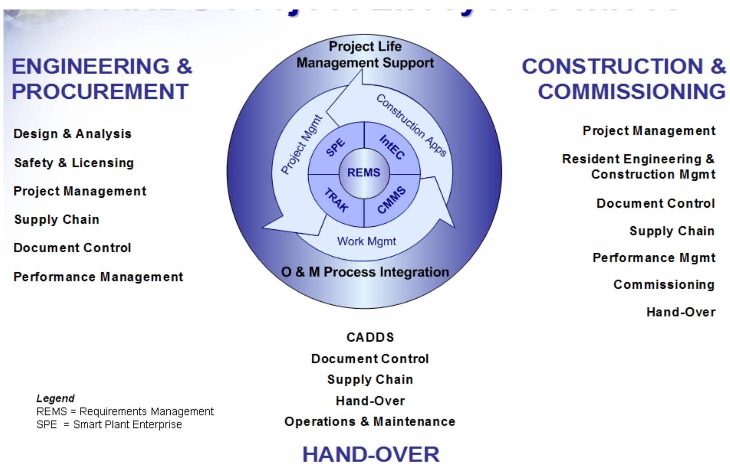


Figure 1 AECL - Electronic Tools Application Integration

AECL has benefited from significant side-benefits from its investments in electronic engineering tools; over and above the gains in productivity and non-conformance cost avoidance gained in past build projects. Our customers and partners seek AECL's software applications for their own use. Since the first sale of IntEC to KOPEC in 1989, every CANDU operator is running IntEC (Argentina is presently acquiring IntEC). China and Romania are using TRAK and CMMS as well. Today the Engineering Tools branch within AECL is well positioned to advance AECL's pioneering leadership in exploiting emerging information technologies for the benefit of the CANDU.

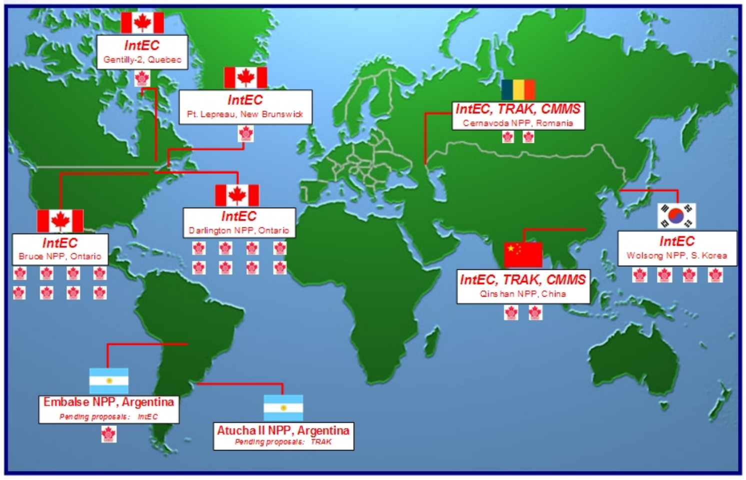


Figure 2 AECL - Electronic Tools in Use at Operating CANDU Plants

3.2 Improved construction technologies using information management systems

Since the beginning, Hitachi has never been satisfied with its past achievements and track record and has undertaken never-ending development and improvements in all aspects of its technology. Construction technology is no exception, indeed it is one of the areas where Hitachi has reaped some of its greatest paybacks for its investment into intensive development and improvement. This desire to improve is in no small part thanks to Hitachi's continuous experience in new build projects over the last three decades.

Shika No. 2 is the latest testament of Hitachi's achievements, completing this latest ABWR on schedule and on budget. Hitachi's endeavour to maximize construction efficiency was embodied in this tremendous success by full exercise of advanced construction technologies including, but not limited to, the instalment of over 200 modular units within Shika No.2.

The coming ABWR projects, of which earliest site construction started in 2006, will continue down the same path started by Shika No.2, enabling Hitachi to enter into a new era of nuclear plant construction. Using all the advanced construction techniques which allowed Shika No.2 to be a success, and furthering the technology through the use of the new concepts of:

- Hybrid Room Modularization
- Modularization Assessment System
- Radio Frequency Identification (RFID) Applications

Hitachi will once again set the standard for new build construction projects. As can be seen in Figure 3, the next series of ABWR projects will represent the 4th Generation of Hitachi's construction technology to be employed.

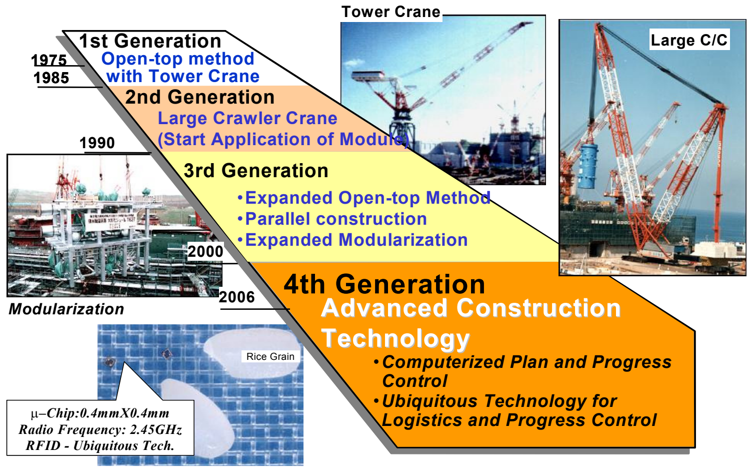
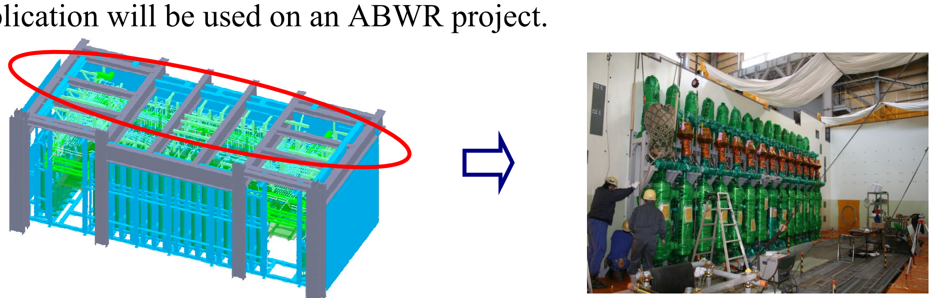


Figure 3 Development of Construction Technology within Hitachi

3.2.1. Hybrid Room Modularization

Hybrid Room Modularization Technology is so named to reflect the merging of civil structures with the mechanical/electrical components during modularization. This concept envisions full assembly of civil structures and mechanical/electrical components at an off-site manufacturing facility in place of conventional in-situ installation. Such civil structures include substantially everything which is needed to create an area where mechanical & electrical components, which would typically be modularized, are installed. In addition to the general advantages of modularization, this advancement in modularization serves greatly to benefit both the civil constructors and the mechanical/electrical suppliers/installers. Further to conventional modularization, this method requires more intensive coordination between civil, mechanical & electrical groups from the conceptual design stage to final construction/installation at site. Figure 4 shows a brief overview of how this application will be used on an ABWR project.



3D-CAD Model Actual Fabrication at Dedicated Modularization Factory

Figure 4 Application of Hybrid Room Modularization

3.2.2. Modularization Assessment System

Hitachi has led the industry in achieving benefits from modularization application by intensively increasing the number of module and by pursuing the largest practical size which a module can be made. Hitachi has realized during its new build projects experiences, that there is a limit to which these simple approaches can provide additional advantage. With this in mind, Hitachi has undertaken the challenge to quantify the effect of modularization technology application on a construction project using an electronic model, called the Modularization Assessment System (MAS).

MAS has been under development for some time and is now ready for trial use on an ABWR project. A limited number of modules have been selected to serve as validation tests to verify the theoretical predications of MAS. Once fully validated, MAS will be used to more accurately determine whether any given module design is of true benefit to the overall construction project. This will allow a definitive line to be drawn between "beneficial modularization" and "modularization for the sake of modularization". MAS is designed to allow customization to suit any new build project, not just nuclear, taking into account specific inputs and parameters for the project and the construction site.

3.2.3. Radio Frequency Identification (RFID) Applications

The construction of a nuclear power plant requires numerous components, parts, and bulk material which can amount to numbers in the millions of individual pieces, all of which need to be under control. The rigorous requirements of traceability from manufacturer, to temporary storage, to site installation require considerable amount of time and resources and can greatly influence the economics of a new build project.

In order to cope with this challenging issue, Hitachi has introduced the use of use of Radio Frequency Identification (RFID) microchip technology. RFID is a fundamental technology whose ever expanding functionality and versatility has led to its application in nuclear material tracking and control. Japanese refer to RFID as the realization of "Ubiquitous Society": Everyone can know everything all the time.

Simply put, a RFID microchip tag is placed on every component used in the construction of the nuclear power station. The RFID is programmed with the basic information to identify the item and the ability to broadcast its location anywhere within the construction site. Therefore, everyone knows where everything is, all the time. A few examples of where Hitachi envisions RFID technology will offer improvements in the construction of next ABWR's are:

- Shipping/Receiving and Warehouse Management
- Installation Sequence Management
- Wire Connection Management System

It is expected that as the project progresses, more and more uses for RFID technology will be found, leading to even greater improvements on Hitachi's next new build project.

4. New Build CANDU Projects

As a step towards a successful new CANDU build opportunity in Canada, AECL and Hitachi are sharing each other's expertise as each company has its own unique and unrivalled capability in managing new build projects.

To maximize advantages from such joint activities, the companies recognize the importance of enhancing common infrastructures such as information management systems, supply chains, manufacturing bases, etc. Collaboration and partnering will be essential components of all major new build projects in the 21st century and the New Build CANDU project has to be a manifestation of this global trend. In particular, effective collaboration rests on a common, multi-disciplinary, project-wide information network accessible and used by all partners. AECL, with its deep experience and state-of-the-art skills as well as with its partnering with Hitachi is well positioned to build this next generation information network for the new nuclear plant market-place.

4.1 Collaboration amongst Project Participants

The collaboration requires external organizations to adopt the same tools and processes. Given the current web-based tools and integrated encryption methods, the implementation team would be looking at easier ways to propel information integration and tool implementation amongst all partners involved in CANDU New Build project.

4.1.1. Path forward – Enhancements of computer aided engineering technologies

AECL and Hitachi are not resting on their laurels following the success of their recent nuclear projects, but are rather continuing to push computer aided engineering technology through enhancements and new cutting edge tools for use on the New Build CANDU project. Some of these path forward strategic initiatives are:

a. Requirements Management System

Advances in computing, networking, enterprise information systems and AECL's remarkable past achievements continue to drive AECL's commitment to further investments in engineering tools. For example, on the New Build CANDU project, AECL is implementing a "Requirements Management System". This system captures information elements within a document and checks consistency of this information across documents. Relationships and linkages between information elements are formed. Changes to these information elements flag the need for changes to related documents, enforcing information consistency.

This technology was first applied within the pharmaceutical industry as an aid to manage their regulatory licensing documentation. AECL is pioneering its use in nuclear engineering projects.

b. Smart CANDU

Part of AECL's business strategy is to engage customers in an on-going service relationship following the plant handover. Consequently, AECL, under its Smart CANDU initiative, is preparing a suite of value-added processes, information products and technology. The goals of the Smart CANDU initiative are to improve plant operability, reduce outage frequency and duration, reduce operating margins, and reduce operations, maintenance and administrative costs.

c. Continued Commercialization of the Core Applications

A strategic move forward will be the continued improvements of the core application in consultation with AECL's key clients in an effort to further penetrate the operations and maintenance phase of the CANDU plant life cycle. These developments will be done in a coordinated effort with the Smart CANDU initiative.

d. Evolution to a New CADD Modelling Suite

AECL has moved forward in the CADD technology area by implementing the "data-centric" Smart Plant Enterprise from INTERGRAPH on the New Build CANDU project. In data centric-systems, all the information resides in relational databases, including the graphic data. This facilitates significant advances in the following areas:

- Greater design consistency, for example from Flowsheets through to piping isometric and Bill of Material

- Improved Configuration Management and Revision Control
- Design and operating data readily accessible to procurement and project management applications
- Better support of global work sharing

4.1.2. Path Forward – Project stakeholders structure

A key part of the success in the implementation of a project is how the parties involved in the contract to interact with each other in the execution of their work. The relationship between the Owner and the Contractor, and subcontractors/suppliers/sub-suppliers has to focus on building a close cooperation. Members should perform their corresponding project tasks in adherence to the contract. Issues are dealt with in an open and timely manner. Each party must take all the necessary measures in order to support the Project schedule while commercial issues are being dealt with in parallel. The building of trust at the senior management level as well as at the working level among all parties contributes significantly to the success of a Project. Communication is the key competency for all projects.

Fig. 5 provides an illustration of how the Project information structure could be organized, in regards to the sharing of electronic information, for a CANDU New Build project. It would be imperative that this structure is linked to the contract structures among the parties. The Project management structure is modeled to the five layers described below and it should be executed at each level for integrated information based management.

- Tier 1: Owner. This will include deliverables of integrated information management from the Prime Contractor, which in turn will be utilized for Operation and Maintenance of the plant.
- Tier 2: Contractor. Project information of engineering, construction, documentation, and schedule are to be finally integrated at this level. Contractor's in-house or third party engineering and management tools are fully implemented here to ensure consistency with the Owner as well as with subcontractors and suppliers.
- Tier 3: Subcontractors. The subcontractors for the BOP, BNSP and/or NSP will provide design, supply and construction. Project management at joint-work level is to be executed here based on the mutually agreed Work Breakdown Structure (WBS) that will include integrating and transferring deliverables to the Contractor.
- Tier 4: Suppliers. Underneath the Subcontractors and as per an agreed upon Division of Responsibility (DOR), each party will perform engineering and procurement works within its own organization. It should be noted that detailed level engineering and information might be kept at this Tier and not necessarily transferred to a higher level.
- Tier 5: Sub-suppliers. Each sub-supplier will execute its subcontracted work based on the agreed upon terms. At this level, common project tools may or may not be used by the sub-suppliers, depending on the scope of supply.

It should be noted that project common IT tools implementation has two critical directions as illustrated in this model. The first one is the "*horizontal*" implementation within each Tier, consortium, or organization among CANDU New Build project. . For this direction, the common tools are to be implemented mainly for the benefit of each group of the users, which will include engineering and project management processes executed within each Tier. The second is the "*Vertical*" implementation between Tiers which will include integration and interface coordination between sets of two or more groups. Vertical integration targets enhancement of the integration capabilities and quality throughout the entire project, leading to the establishment of a "win-win" situation for all Tiers.

During the pre-project planning phase of a CANDU New Build project, the Contractor and subcontractors will take the lead to develop the project management structure so that every project participant will be well positioned for the New Build project when it is launched. This structure will be well established and strengthened by activities as listed below, and even more sophisticated project implementation may be achieved for any forthcoming Canadian CANDU New Build to be shared by all project participants:

- Refine DOR in depth for engineering / management activities
- Identify the leverage areas of integration throughout the processes with interfaces between parties
- Select engineering / management tools to be applied
- Develop implementation plan including infrastructure
- Standardize project procedures such as equipment identification and documentations

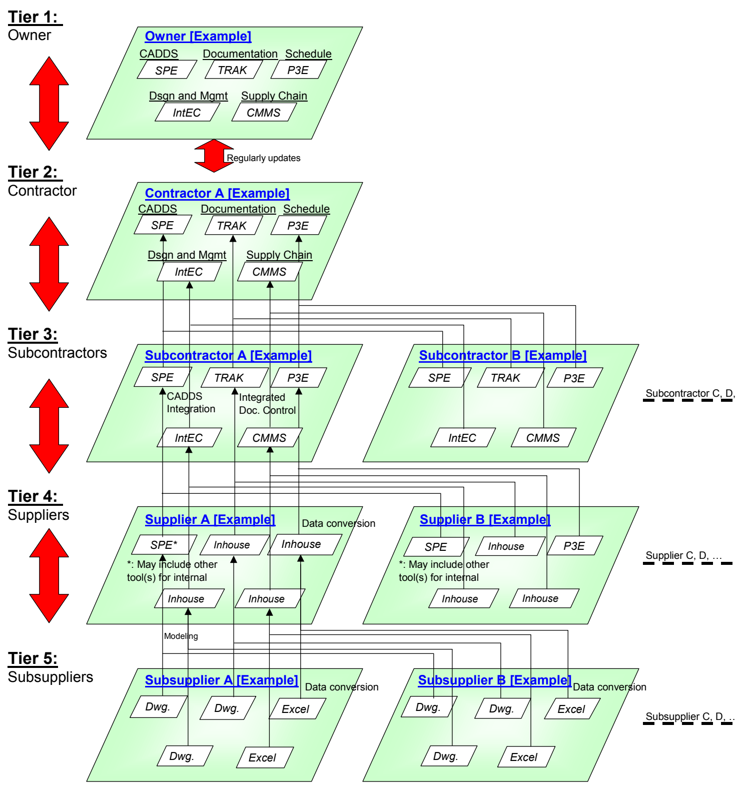


Figure 5 – Simplified Project Information Structure for CANDU New Build

5. Conclusion

AECL and Hitachi have shared expertise and experience in information technology that can be used to build new nuclear plants in Canada on a very competitive basis.

Hitachi's experience in advanced construction technology being applied to the upcoming ABWR in Japan would be of great benefit when applied in the construction of a New Build CANDU project.

AECL's main business factor driving the application of Information Technology to the delivery of the New Build CANDU product is to reduce project delivery costs, while continuing to improve quality and further minimize the construction schedule.

The New Build CANDU success will be achieved by delivering a suite of products that:

- Derive maximum business value from the information managed using common engineering and project management information products/processes, engineering equipment data and operating data available through the plant control and information systems included in the Smart CANDU product, and
- Benefit from the application of recent advances in construction technology to be customized for new build project in Canada, and
- Benefit from the sharing of common infrastructures bringing advantages not only to AECL/Hitachi, but also to their customers, partners and suppliers.

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