INDUSTRY PARTNERSHIP: ADDING VALUE TO NUCLEAR REFURBISHMENT AND MAINTENANCE

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1. Introduction

The Point Lepreau Generating Station was the first CANDU 6 unit to be licensed for operation, beginning commercial operation in 1983. It is now become the first CANDU 6 to undergo full refurbishment. As part of the overall project, all 380 fuel channels and associated feeders will be removed and replaced. In order to undertake this project, it was necessary for AECL to design and develop over fifty "first-of-a-kind tools" for fuel channel and calandria tube replacement. This paper outlines the complexity of the retube tooling project and the industry partnership strategy for the engineered tooling systems development.

2. Retubing a CANDU 6 Reactor

The scope of the Point Lepreau CANDU 6 retube project includes the large-scale replacement of all reactor fuel channels, calandria tubes and feeder components (Figure 1).

The process to replace the fuel channels and calandria tubes is as follows:

Removal Process

- Remove Feeders
- Remove positioning assembly
- Cut end fitting from annulus bellows
- Cut pressure tube
- Remove end fittings
- Remove pressure tube
- Release and remove calandria tube insert
- Remove calandria tube
- Transfer all removed material to the waste storage facility

Inspection and Installation process

- Install upper Feeders
- Inspect calandria vessel and remove any debris
- Inspect calandria tube sheet bore
- Inspect bellows
- Inspect lattice tube

- Prepare fuel channel components for installation
- Install calandria tube
- Roll and inspect calandria tube insert
- Insert fuel channel sub-assembly and verify position with Tubesheet and Datum plane measurement system
- Install annulus spacers and verify position
- Install second end fitting
- Inspect end fitting to pressure tube rolled joint
- Weld end fittings to bellows
- Install positioning assemblies
- Install lower Feeders

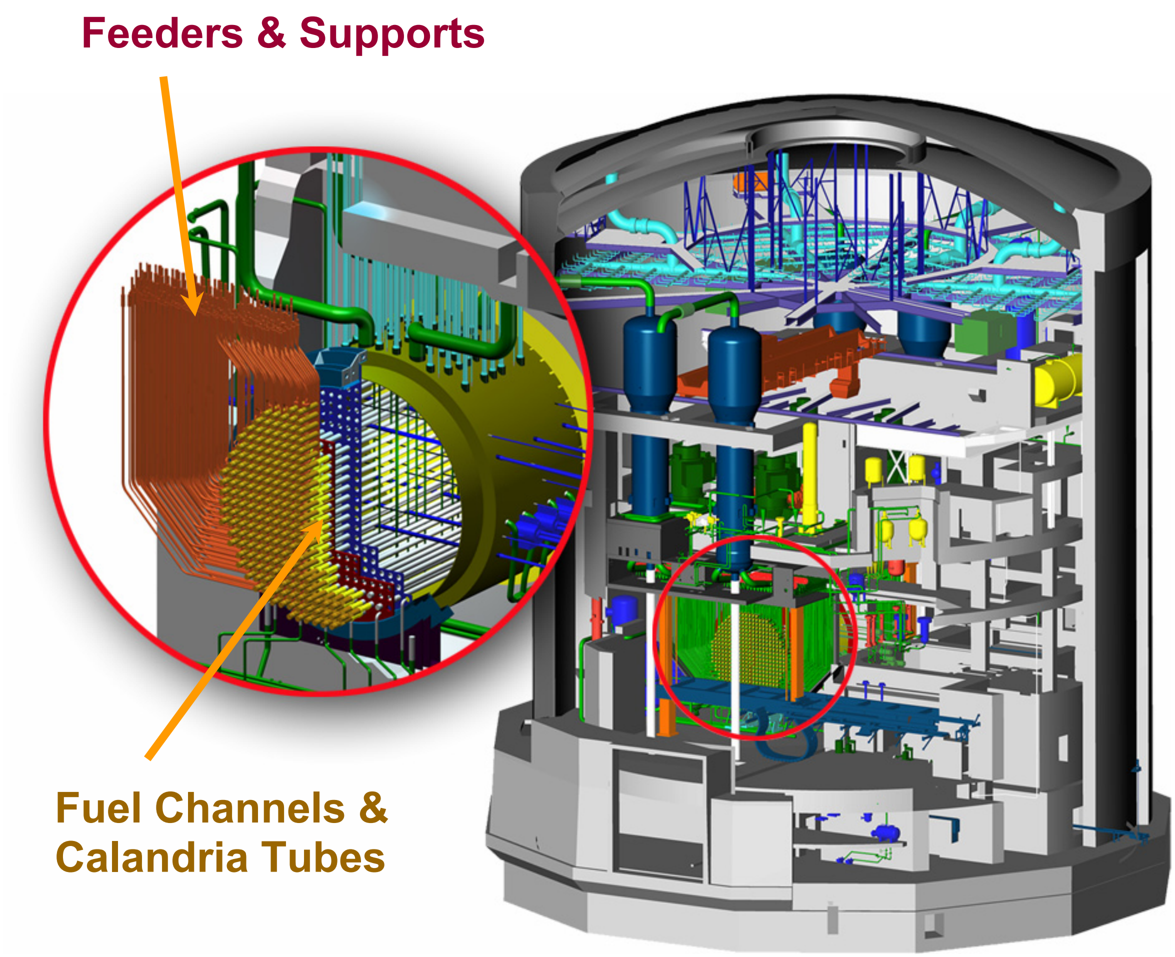


Figure 1- Retubing Major Component Replacement Scope

3. Tooling Scope and Schedule

The schedule represented the greatest challenge for tool delivery. The project officially started August 2005 and the complete tools were delivered at the AECL Saint John facilities for training in late 2007 and early 2008. When the mobilization, packing, and shipping periods are taken into consideration, there was effectively about 24 months for the tools to be designed built and delivered to site.

The major scope of work in this period included the following:

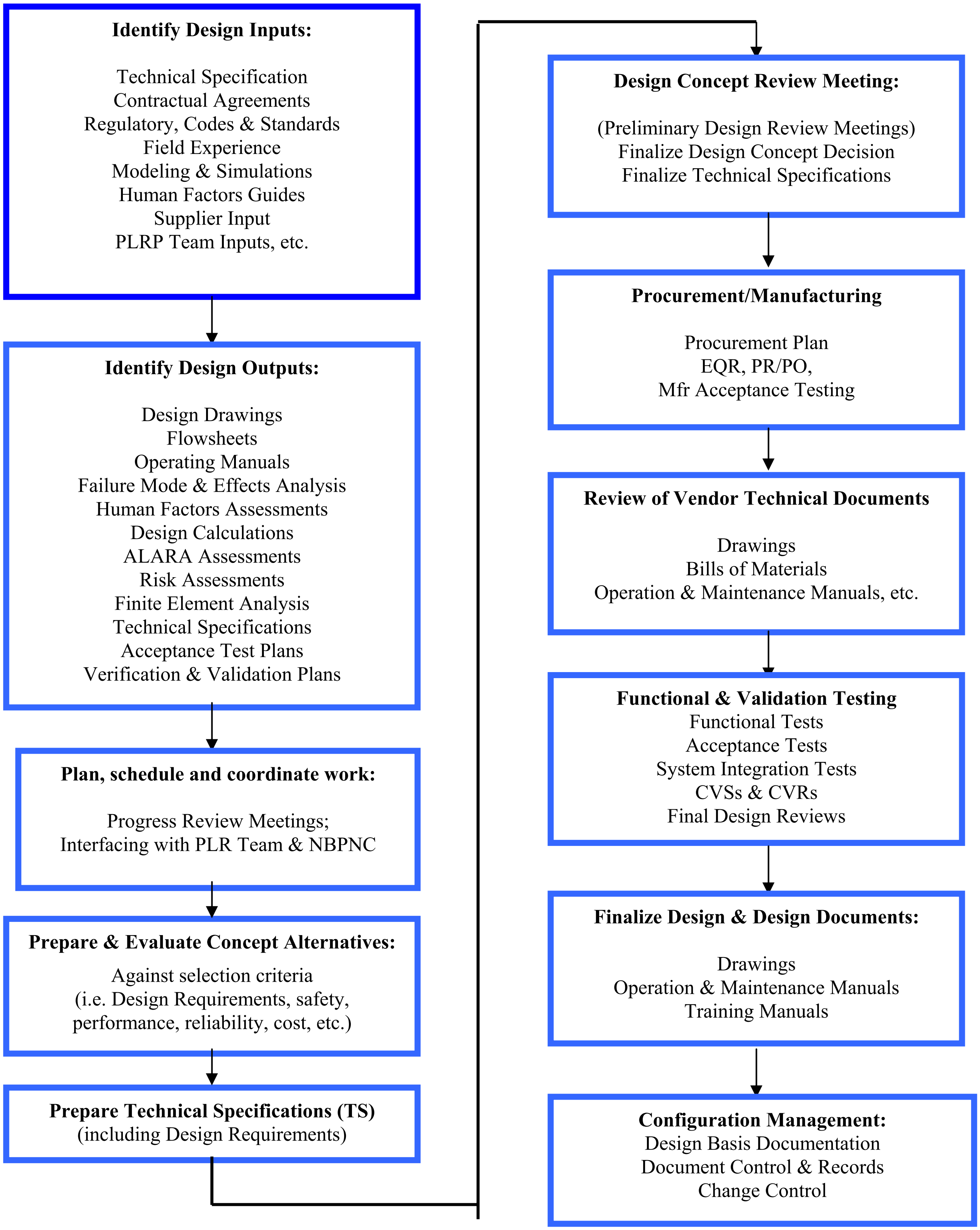
- Concept design and formal design reviews
- Detailed design and formal design reviews
- Proof of principle and prototype testing
- Manufacture
- Functional Testing and Acceptance Testing
- Integration and Integration Testing
- Packing and shipping

The client and end user of the specialized tooling is the AECL Point Lepreau Site Implementation team. The general Tooling Systems Requirements (TSRs) was defined by the AECL Retube Pre-Site Program department, they were also involved with the tooling design review process. The specific toolsets and equipment to be designed and delivered by AECL Retube Systems comprise of the following main toolsets:

- Fuel Channel Removal Tooling
- Calandria Tube Removal Tooling
- Inspection Tooling
- Calandria Tube Installation tooling
- Fuel Channel Installation tooling
- Annulus Gas System tooling
- Contingency Tooling; and
- Common Tooling

The overall project design workflow is illustrated in Figure 2 and is based on AECL's overall quality assurance framework.

Design Workflow - Figure 2



4. Number of Tools

In total there are approximately one hundred engineered tools (fifty are first-of-a-kind) for removal, installation and inspection processes. The most critical tools that were first-of-a-kind were the removal and inspection tools. Even though some of the installation tools were of new design, most were derivatives of tools used for new reactor construction.

5. Tool Delivery Challenge: AECL Perspective

Soon after the contract was signed in August 2005 a level 4 tooling schedule was prepared in conjunction with a resource plan. From this it was clear that the traditional AECL strategy of doing the design, assembly and testing process in-house, using machine shops to manufacture the components and in-house personnel for assembly, electrical and controls integration would not meet the schedule with our available resources.

Therefore, several new suppliers had to be qualified and a design-build strategy implemented in a relatively short time frame. Potential suppliers from New Brunswick and Southern Ontario were sourced and evaluated for capabilities, experience and project management. Since most of the complex tools required substantial automation, suppliers from the automotive sector, that were going through a down turn in their business, were looked at in detail, and eventually choosen to do much of this work. ATS Automation Tooling Systems was chief among these new suppliers and would eventually be contracted to build the lion's share of the tools.

Although the automotive suppliers were extremely adept at designing and building automation systems there was an obvious discomfort at moving into the nuclear industry as the perception was that the nuclear industry introduced many risks and unknowns, perceived beauracracy, regulation and nuclear issues such as radiation and nuclear quality standards.

It became readily apparent that AECL could not have a typical customer-supplier relationship with these new suppliers to the nuclear sector. They had never been exposed to the nuclear sector and had no knowledge of nuclear reactors, nuclear systems and radiological environments. As they could not be relied on to independently design nuclear tooling, AECL developed partnerships with them to provide specialist training and design support, which established the pre-requisite infrastructure for a successful project. This also provided the "comfort zone" required to engage and improve the confidence of the senior management of these new suppliers.

AECL then moved rapidly to the conceptual design phase in parallel with qualified suppliers. The complexity of the tools determined at what phase of design a contract would be put in place with suppliers. For tools based on existing designs, AECL designed the tools and released manufacturing drawings for supplier to "build to print". For relatively simple new tools, AECL released the concept design as part of the tender package and the suppliers proceeded to finish the detailed design and to build. For tools of high complexity, AECL provided the concept and approximately 30% of the detail design. In order to reduce risk a decision was made that the contracts would be spit into two phases, the production of the first set of tools and after successful testing the remaining production tools would be built. Tenders were issued and suppliers were selected based on their proposal, experience and ability to deliver. Regardless of the relative split of responsibility for the design process between AECL and the suppliers, the design workflow was strictly adhered to, and suppliers were directly integrated into AECL design review process.

5. Tool Delivery Challenge: ATS Perspective

ATS is a global Canadian automation company with headquarters in Cambridge, Ontario. ATS has been in business for 30 years and provides manufacturing solutions to Fortune 500 companies in the automotive, energy, pharmaceutical, electronics, and consumer product packaging sectors.

When AECL first approached ATS in early 2006 they had done a small amount of work in the nuclear sector (fuel pellet grinding and fuel bundle welding automation) but not on the scale of the Point Lepreau Retube opportunity. While the project seemed both interesting and significant in scope, there were two main areas of concern on the part of ATS management.

a) Capacity/Capability
   There was some initial concern over whether this retube project was a good 'fit' for ATS and whether they had the capacity to take on all the work that AECL could eventually award. The capacity issue was quickly put to bed due to the significant downturn in the automotive sector that the entire automation industry was experiencing at the time. When ATS started in 1978, automotive comprised 100% of its business and even with diversification into other sectors it still comprised about 30% of its business by 2005. It appeared that the AECL business (and other future nuclear sector business) had the potential to make up for the lost automotive sector business.
   The issue of 'fit' was not as obvious. Most of ATS's business could be described at turnkey automated manufacturing lines – component feeders, conveyor, robotics, etc – whose purpose is to produce finished parts as an output and operate for several years. The Retube equipment would be large, precision tooling designed to perform a specific suite of tasks on the reactor face for a comparatively brief period of time. Upon closer analysis ATS determined that although the purpose and outputs of the retube tools were different from traditional automation projects the skills and capabilities required to design and build them were the same. AECL was really looking for industry standard engineering, project management, heavy machining and milling, assembly, and quality systems. These were core ATS capabilities – just applied to a slightly different type of finished automation.

b) Risk
   There was also some concern regarding risk associated with entering nuclear sector manufacturing. ATS was unfamiliar with the regulatory landscape, special quality

programs, and documentation requirements. But ATS did have a history of entering new automation markets over the years, some of which were highly regulated. In particular, some years earlier they had entered the highly regulated pharmaceutical and medical device sector (FDA).

More importantly, the partnership model adopted by AECL was critical in mitigating any risk associated with entering the unfamiliar world of nuclear systems and regulations. Also, AECL brought ATS on board relatively slowly – working very closely with ATS on a few contracts to flesh out design concepts and conduct simple Proof-of-Principle (POP) studies. Once the partnership showed early success, more complex design and build projects were awarded.

6. Project Execution: Partnership Approach in Action

In order for the partnership approach to be successful it was important to put in place systems, procedures, and communications protocols to ensure that the AECL and ATS teams could work successfully together to execute the projects. Some elements of the program/project management methodology are:

- Dedicated AECL and ATS Program Managers
- Dedicated Single Point of Contact (SPOC) for each individual project
- Bi-weekly project status reports generated by ATS Project Managers and circulated to all key AECL team members
- Daily shop-floor meeting during critical assembly/testing phases of projects
- Maintaining team member consistency across projects to gain efficiencies and foster greater ownership in the overall program.
- Weekly high level management review meetings. Specific project-related issues as well as program level issues were discussed and quickly resolved before they could become serious.
- Regular team-building events for AECL/ATS team members. Designed to let key team members interact informally, outside the pressures of the work environment.
- Documented procedures for data security and IP control
- Secure FTP servers for secure data transfer.

7. Testing

Three basic categories of testing were performed: proof of principle testing, functional/acceptance testing, and integration testing.

Proof of principle testing was done during the design phase to prove critical design features. This was required as the first-off tools were manufactured within one year of the start of design and time for building and testing a prototype was not available. Proof of principle testing typically consisted of bench testing on key assemblies or components. For example, a combination of testing on a lathe and then bench testing was done to determine the Bellows Cutting Tool forces and behaviour with a high degree of confidence.

Functional testing, also called acceptance testing, was done to prove that the completed tool functions as required. This testing is done on each individual tool and incorporates a full range of testing such as a complete tool cycle, checks on tool interlocks, and testing of critical drives at their full design load.

Integration testing is completed on the first-off tools, after functional testing is complete. The tools for the different steps and phases of the retube operations are assembled as sets, and tested to confirm the tools in the sets all interface properly. For example, the Volume Reduction System is mounted on the Heavy Workable, which is supported on the Fuel Channel Platform as part of Fuel Channel Removal Tooling integration testing.

Again, AECL in the interest of schedule determined it best to use 10,000 square feet on the ATS shop floor to build a mock reactor and perform all integration testing operations. If any of the largest and heaviest tools, such as the Volume Reduction System or End Fitting Transfer Station, required immediate rework, it could easily be performed on the premises using ATS equipment and toolmakers without incurring the schedule delay and expense associated with shipping the tooling between AECL and ATS.

Design issues and modifications identified through functional and integration testing have been incorporated into the remaining production tooling. Formal design change control procedures have been utilized to ensure that the design basis documentation for all tooling is accurately maintained.

In addition to verifying the tooling Operating and Maintenance Manuals, Integration Testing provided an opportunity to develop and refine tooling Training Manuals which were delivered along with the tooling.

8. Logistics, Training, and Site support

The partnership approach has extended to AECL and ATS working together beyond the design, build and test of the Retube equipment. The true measure of a successful program would be the successful conclusion of the Point Lepreau Retube, not just the delivery of the equipment. To help ensure that success the two companies are working together in a few other areas.

a) Logistics Planning and Shipping
Working closely with the AECL Sheridan park team as well as the St. John, NB office (SJO) the crating, temporary storage, and shipping of all the tools have been done through the ATS facility in Cambridge. This has resulted in the efficient and cost-effective movement of equipment to the SJO.

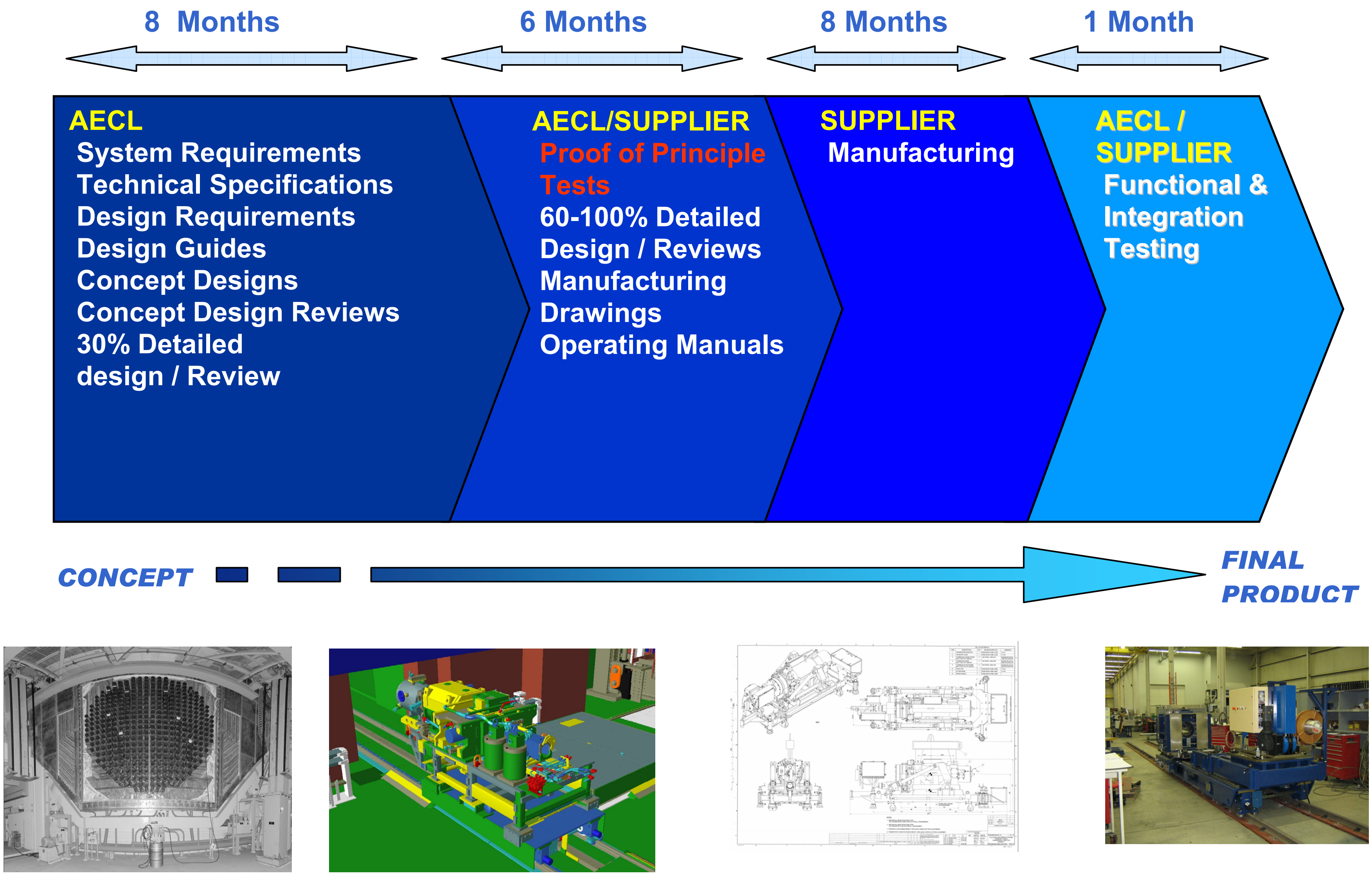
b) Training
ATS has a dedicated training department and has worked with AECL to develop course materials and deliver 'train-the-trainer' equipment training to AECL team members. ATS has also worked with SJO to deliver supplemental technical training directly to their staff both at ATS and at SJO.

c) Site Support
AECL and ATS will work together to support the installation and use of the equipment at site during the Retube process. The ATS support will consist of 24-7 telephone support accompanied by a well documented escalation plan for remote online support as well as travel to site. ATS technical staff will also work closely with AECL staff at site during the installation and initial use of all tools.

9. Retube Tooling Current Status

The overall Retube Tooling Design/Manufacture Cycle is illustrated in Figure 5. Design, build, Functional/Acceptance testing and Integration Testing have all been completed and tools have been shipped to SJO awaiting use in the Retube process.
Tooling design basis documentation such as Design requirements, Technical Specifications, Design Review Reports, drawings, test results, Operation and Maintenance manuals, and Training Manuals are maintained in the AECL official records system.

Figure 5 - AECL Retube Tooling Design / Manufacture Cycle



11. Conclusion

The Point Lepreau Retube first-off tooling was designed, manufactured and tested in less than two years. Design controls were incorporated to ensure that all design requirements, along with industry best practices such as conventional risk assessments, ALARA principles, and human factors were incorporated into the design. The key to this achievement was AECL working in close partnership with ATS and the other automotive, non-nuclear commercial industries. This partnership approach builds on the strengths of AECL and its partners. It has also broadened the nuclear technological base and introduced some additional capacity and competition into the supply chain. The Canadian nuclear industry, the Canadian automotive/commercial industry and CANDU owners worldwide all stand to benefit from this business model for retube tooling development and supply. The model could also be successfully applied to ongoing reactor maintenance projects requiring design and/or build of specialized equipment. Figure 6 and 7 show the Volume Reduction system and the End Fitting and Shield Plug Transfer Station undergoing testing.

Figure 6 – Volume Reduction System

Figure 7 – End Fitting & Shield Plug Transfer Station