THE RIGHT MAINTENANCE ON THE RIGHT COMPONENTS, AT THE RIGHT TIME, WITH THE RIGHT PARTS: MAINTAINING HIGH PLANT RELIABILITY THROUGH AN EFFECTIVE MAINTENANCE PROGRAM

ABSTRACT

The objective of the maintenance program at a Nuclear Power Plant is to be pro-active and prevent unexpected failures of equipment that can impact on Nuclear or Conventional Safety and Plant Production. This does not mean that all equipment failures will be prevented; in a number of cases the most cost effective solution is to allow equipment to run to failure.

Deciding what components are critical to the plant is the first step. The industry uses guidance from INPO Advanced Process, AP913, to classify components as Critical, Non Critical or Run to Failure based on the consequence of the failure. Once this is complete, then the right maintenance program needs to be specified. This is done through utilization of experience from the industry based on the type of component. Maintenance strategies and templates have been produced for most power plant components. Each station or fleet needs then to apply the criteria, with exceptions as required, to determine the maintenance requirements and frequency for their components. This includes predictive and preventative maintenance. The more critical the component is the more rigorous the maintenance requirements.

Once the maintenance program is defined it can be implemented. This requires that the Preventative Maintenance (PM's) are updated to ensure the correct tasks are in place and the frequency is correct. Work Management will group the PM's so they can scheduled efficiently and to minimize equipment down time. The last element is to ensure that the required parts are specified and are stocked or readily available for the maintenance when it is scheduled. This is an ongoing effort since components become obsolete or suppliers go out of business or change hands.

Paul Von Hatten, Ontario Power Generation – 777 Brock Road, Pickering Ontario, L1W 4A7..
E Mail: paul.vonhatten@opg.com

THE RIGHT MAINTENANCE ON THE RIGHT COMPONENTS, AT THE RIGHT TIME, WITH THE RIGHT PARTS: MAINTAINING HIGH PLANT RELIABILITY THROUGH AN EFFECTIVE MAINTENANCE PROGRAM.

Paul VON HATTEN

1.0 INTRODUCTION

This paper provides a description and initial results of an Ontario Power Generation initiative called Maintenance and Supply Strategy Project (MSSP). The project has two different but complementary focus areas.

The first focus area is referred to as Nuclear Integrated Supply Planning (NISP). The goals of NISP are:

- Improve parts availability for maintenance
- Right size parts inventory in the warehouse to industry best practices.
- Document the strategies for implementing maintenance on important station components, and facilitate the use of model work orders for maintenance activities.

The second focus area is to implement industry best practices in the areas of Equipment Reliability, Work Management and Supply Chain Activities. These practices are defined in the Institute of Nuclear Power Operations (INPO) advanced process documents AP 913, AP 928 and AP 908 respectively which are being implemented across the nuclear power industry in North America.

Linkages between the Maintenance Program, Equipment Reliability, Work Management and Supply Chain:

A successful maintenance program will minimize unanticipated failures on equipment important to nuclear safety and plant production. It will be cost effective such that the economics are sound for the plant operator to meet the financial goals and requirements of the company and its stakeholders. It will also ensure that degraded or broken equipment can be returned to service within a timeframe commensurate with the importance of the component.

In order for the maintenance program to minimize unanticipated equipment, and ensure high levels of reliability, maintenance must be done pro actively on the right equipment at the right frequency to identify and mitigate failure. This is achieved with a combination of Predictive and Preventative maintenance. The equipment reliability program described in AP 913 focuses on ensuring that the right maintenance is specified and continually evaluated. This is done through the following steps.

- Identifying the most important equipment in the plant to focus on and designating a criticality rating to that equipment. The criticality is usually broken into three levels: Critical, where a failure will have a significant impact on safety or generation, Economic, where it is cheaper to prevent a failure than to fix it after it fails, and Run to Failure, where there is no significant impact on safety or production and no planned maintenance is carried out. The equipment can be run until it fails or is near failure and then fixed.
- Identifying how the equipment could fail, and putting surveillance programs in place to monitor for degradation. The predictive maintenance program is part of the suite of surveillance activities, which also include operator rounds and systems and component engineering programs.
- Establishing a preventative maintenance program based on industry experience, to overhaul the components before they deteriorate. This considers amongst other things the service condition and the criticality of the components.
- Putting in place a good feedback mechanism so the PM program can be adjusted to reflect actual component conditions when maintenance is done. This serves two purposes: First it ensures that maintenance frequency or scope is increased when as found condition is poor, thus reducing the risk of unanticipated failures. And second, to reduce the frequency of maintenance where the “as found” condition is good, which allows more focus to be placed where it is needed and to reduce the overall costs of the maintenance program.
- Identifying the causes of unanticipated failures on important equipment so the maintenance program can be adjusted to prevent repeat failures.
- Identifying and planning for major overhaul or change out of worn out equipment. This is important since preventative maintenance will be ineffective and may not prevent failures of components that are simply worn out.

The previous steps ensure that the right maintenance program is established and kept current. Now the maintenance has to be executed in the field in a timely and efficient manner. Work planning and scheduling are covered in the Advanced Process document AP928.

There are two aspects to consider when getting work ready to execute in the field. First is work planning which determines how the maintenance will be executed. Elements include decisions around repairing or replacing the component, what parts are going to be needed, specific procedures and instructions, post maintenance testing, pre and post requisite tasks such as work protection, scaffolding and system alignment and what resources are required to complete the work, the second aspect relates to work scheduling, or, when the maintenance will be conducted. This includes decisions around whether it can be completed when the unit is running, or shutdown, considerations related to maintaining design configuration and safety related functions, redundancy how the work will be bundled with other work, how much can be completed in a given work week or outage window considering timing and resources.

In order to efficiently plan the maintenance it is important that the maintenance approach is as consistent as possible from one time to the next. This allows for easier and consistent work week planning, cycle planning and outage planning, the following example is an illustration of how inconsistent maintenance approaches can be detrimental. A job on the cycle plan calls for overhaul of a small control valve which includes disassembly and inspection of the valve internals. Typically this job has been done with the valve in situ. This time the work planner sees there is a complete valve in stock and decides that time could be saved by swapping out the valve with a new one and overhauling it in the shop. This would require cutting out the old valve and welding in the new one and welders are added to the assessed resources. Overall the timing and resource requirements for the work week are reduced. However when the resource profiles are applied to the work week there is now a shortage of welders since this work week in the cycle plan typically uses all the available welding resources. Since the parts for the overhaul had not yet been ordered, the job cannot be modified to the original repair in situ strategy. The work has to be re scheduled.

The use of Model Work Orders is essential to ensure that maintenance is done consistently. Model work orders ensure that resources, tasks, timing and parts are consistently specified for repeat or similar work,

The third aspect supporting an effective maintenance program is parts availability. Managing the supply of spare parts is covered in the advanced process document AP908. Unavailability of spare parts results in maintenance work being re scheduled, critical plant components being out of service longer than necessary, leading to reduced redundancy, higher risk of unit transients or shutdowns, high maintenance backlogs and operator burdens, and higher risk of unanticipated equipment failures. It also contributes to inefficiencies in work control, maintenance work planning, engineering and Supply Chain as work is rescheduled, PM deferrals have to be evaluated by Engineering and the Supply Chain is challenged get parts on a rush basis.

There are a number of attributes that contribute to high parts availability. These include:

- Consistent selection of parts by maintenance planning
- Long planning horizons through the use of the work week schedule, cycle plan and outage preparation milestones. This allows parts deficiencies to be addressed in time for work execution
- Early assessment and ordering of parts by maintenance planning to take advantage of the long planning horizons.
- Effective material supply strategies including setting re order points and quantities and strategic vendor alliances to ensure consistent availability of parts.
- Pro active management of equipment obsolescence to provide engineering and Supply Chain adequate time to resolve issues before the work planning phase.

One other aspect related to overall maintenance costs is the amount of material purchased and stored in the warehouse. There are overhead costs associated with the storage of materials so the ideal situation is to stock the warehouse with only the parts that are required to operate and maintain the plant. Consistent specification of parts requirements by maintenance planners is a key factor in optimizing inventory and reducing associated overhead costs. It is also important to regularly surplus un-needed parts that get created due to design changes, or changes in parts requirements due to obsolescence. For example if due to obsolescence a particular component is upgraded in the field then all the parts necessary to maintain the old model become redundant and should be removed from the warehouse.

In summary, an effective and efficient maintenance program is much more than managing the work in the field. It requires:

- A rigorous analysis and constant review of what maintenance is needed, (AP913)
- Consistent work planning, including specification of work activities and parts requirements, and a robust and leading work scheduling process (AP928)
- An efficient and responsive Supply Chain function. (AP908)

If any of these elements are weak the consequences will be unanticipated equipment failures, poor schedule stability, high backlogs and poor plant material condition, and high maintenance related costs.

The fundamental structure of MSSP is to ensure that the key elements that support an efficient and effective maintenance program are addressed in an integrated fashion.

2.0 IMLEMENTATION OF EQUIPMENT RELIABILITY, WORK MANAGEMENT AND SUPPLY CHAIN INDUSTRY BEST PRACTICES AS DEFINED IN AP913, AP928 AND AP908.

2.1 Goal:

The goal of this element of the MSSP project is to improve plant performance and reduce costs by implementing industry best practices in these areas.
Improved plant performance would be seen through lower forced loss rates, higher capacity factors, improved plant material condition and lower maintenance backlogs. Cost reductions were anticipated in work planning, maintenance and warehouse inventory carrying costs.

2.2 Approach

In late 2007 detailed implementation plans were developed for Equipment Reliability, Work Management and Supply Chain functions. The equipment reliability (ER) plans were station specific. The Work Management and Supply Chain plans were fleet level plans that had some station specific elements. In the case of Equipment reliability a self assessment was completed to identify the gaps in the program. Each site had been implementing some aspects of AP913 for a couple of years and the plans identified the key elements of what was left to implement.

The key area addressed through the ER plans was implementation of PM templates. Additionally the plans addressed establishing other enablers such as Plant Health Committees, the Plant Reliability List and an overall governance framework for ER.

The work management plan was developed through the work management peer team and focused on aligning maintenance work through equipment grouping and implementing cycle plans

The Supply Chain plan involved a comprehensive approach to improve internal Supply Chain operation in the following areas: repairs process, surplus process, procure materials, inventory management, and warehousing.

Each station was responsible for implementing the ER plan and their portion of the Work Management Plan. Supply Chain was responsible for implementing the AP908 plan. Project milestones are monitored and reported monthly through MSSP.

2.3 Progress

All three plans are progressing on schedule with a few exceptions. Some key milestones that have substantial progress or have been achieved include

- Single Point Vulnerability studies and mitigating actions
- Improvements to system health process
- Equipment failure analysis and reviews
- PM Template implementation.
- Implementation of the Plant Reliability List to improve plant material condition.
- Establish or update PEGs to group equipment for maintenance
- Establish cycle plans
- Establish an equipment repairs process
- Establish an equipment surplus process

2.4 Observations

A fleet wide self assessment was completed in May of 2008. The purpose of this self assessment was to measure the integration and effectiveness of the implementation plans. Two significant findings came out of the self assessment.

- The Equipment reliability programs were not being consistently applied across the three sites causing overlaps, inconsistencies and inefficiency. This was partially due to lack of fleet level ER governance. Recommendations were developed to establish an ER peer team and a small fleet level ER group to provide direction, oversight and put a fleet level program in place.
- Better integration of the three programs is required to accelerate and maximize the benefits. A recommendation was developed to establish a cross functional peer team to drive integration across the three programs. This will be done by expanding the ER peer team to bring in Supply Chain, maintenance, and work control as required to address integration issues and set direction.

An example of where good integration would accelerate benefits was evident in the linkages between work scheduling and Supply Chain. In order to improve the lead time to obtain spare parts and plan work, PM work orders were set to generate 15 months in advance; however Supply Chain only addressed parts requirements a few weeks ahead of the established delivery lead times. If a problem existed with parts availability with a vendor, insufficient time would be available to address it in time, so the work would be delayed. If these two elements are not linked and coordinated then the effects of one good initiative are negated by not looking at the whole end to end process.

2.5 Future Direction for the Project:

Implementation of the three processes will continue as planned with enhanced integration through an Equipment Reliability Peer team. Self assessments will be conducted to assess implementation progress and effectiveness.

3.0 NUCLEAR INTEGRATED SUPPLY PLANNING (NISP)

NISP has been designed to enhance the implementation of the industry best practices by focusing on establishing and documenting consistent maintenance strategies and addressing spare parts gaps, and excessive warehouse inventories.

3.1 Goals

The goals of NISP are to

- Develop and document maintenance strategies for components critical to safety and generation. The strategies include repair vs. replace, preventative and elective or corrective maintenance approaches, and decisions related to internal or external repairs.
- Select a standard set of parts to complete all maintenance required on components
- Adjust the Bills of Material to ensure only the required parts are identified and to clean up outdated information.
- Provide the necessary evaluations and technical information to allow the parts to be procured. This includes finding substitute parts for obsolete equipment.
- Set reorder levels and quantities based on historic and projected demand.
- Order parts as required to establish the specified stocking levels.

3.2 Prerequisites

In 2006 a pilot project was conducted to determine the feasibility of establishing a maintenance strategy for components and then selecting and procuring the necessary parts to complete the maintenance. The project team focused on a portion of the boiler feedwater system at Pickering B. The team consisted of maintenance planners, engineering, procurement engineering and Supply Chain representatives. Over the course of several months it was shown that only about one third of the parts on the bills of materials were actually required to complete the necessary maintenance, this was achieved through use of replace as opposed to repair strategies where cost effective, and by careful selection of the parts lists. The results of the pilot were presented to the OPG leadership and a decision was made to go forward with full implementation.

A startup team was formed in early 2007 to put the project in place. The team completed the following work over an 8 week period.

- A guide was created to document the process. It included instructions for Procurement Engineering, Maintenance Planners, Engineering, and Supply Chain. It also included decision rules and guidelines for repairing vs. replacement of components,

- A software tool was developed to collect information from passport on bills of material, work history, and parts usage. The tool also recorded the maintenance strategies, parts lists, and progress of work through the process. The tool was closely linked with passport to provide current information. Examples of the NISP tool are shown in Examples 1 to 4 starting on page 14.
- The scope of the project was defined. It included all non-run to failure components in Pickering A and B and Darlington. Passive components such as pipe hangers, and components that had existing engineering programs such as heat exchangers were excluded. The scope was locked down and consisted of approximately
    - 4400 Level 1 cat id's covering 26,500 unique components at Pickering A
    - 3700 level 1 cat Id's covering 17,300 unique components at Pickering B
    - 6500 level cat id's covering 50,000 unique components at Darlington
- The project teams were formed in April 2007. They consisted of three independent teams of approximately 20 people, one for each station. The teams consisted of Maintenance Planners, Components and System Engineers, Design Engineers, Procurement Engineers, an Inventory Single Point of Contact and a project lead. The project team approach was adopted to enhance cross functional work and to separate resources from the pressures of the day to day requirements of power plant operation. The teams have operated since startup.

3.3 The NISP Process

The NISP process has 5 primary phases. Work starts with a component make and model and is identified by its Catalogue Identification (CAT ID). A key element of the process is identifying all the locations in the plant where the CAT ID is used. When this is done a strategy can be built for all locations. This is referred to as an Integrated Maintenance Strategy (IMS). In some cases more than one strategy is required, for example, when the same transmitter make model is used inside containment on a nuclear system and on the boiler feed water system. The maintenance may vary enough to warrant the creation of two separate Maintenance Strategies. These separate strategies are then rolled up into an Integrated Maintenance Strategy.

All activities in the NISP process are consistent with governing instructions and procedures. This ensures that overall fleet standards are maintained,

The following is a description of the 5 phases in the NISP process.

Phase 1: Bill of Material (BOM) Header Review. This is done by Procurement Engineering with support from Design and Engineering

- The Bill of Material (BOM) of the parent equipment is reviewed to ensure that the manufacturer and model has been authorized by design for that location, and the Level 1 CAT ID is set to ready for purchase, and its piece parts, if required, are available by the supplier.

Phase 2: Development of Maintenance Strategy (MS) and approval of a Consolidated Parts List. This is done by Maintenance Assessing with support from Engineering.

- A decision is made whether the equipment should have a repair or replace strategy.
- Piece parts are selected for equipment with repair strategies.
- A consolidated list of parts to complete all the specified maintenance is created and approved.
- Parts not required to complete the maintenance are flagged as not required and are assessed for surplus at a later phase.
- Corrective and preventive maintenance tasks are reviewed Model Work Orders are created or revised to reflect the strategy..
- The strategy, with rationale, and the consolidated parts list is documented in the NISP software tool.

Phase 3: Consolidated Parts List CAT ID Review and Strategy Approval by Procurement Engineering. This is done by Procurement Engineering

- All the selected CAT IDs are reviewed. Where necessary evaluations are performed. Item equivalencies are identified where necessary, and items requiring a design change are identified to Design Engineering, The CAT IDs are set to “Ready for Purchase”.
- Procurement Engineering approve the Integrated Maintenance Strategy. This is one of several approvals.

Phase 4: Development of Inventory Strategy and Approval of the Integrated Maintenance Strategy. This is done by the Supply Chain Inventory Single Point Of Contact with support from maintenance assessors and Supply Chain

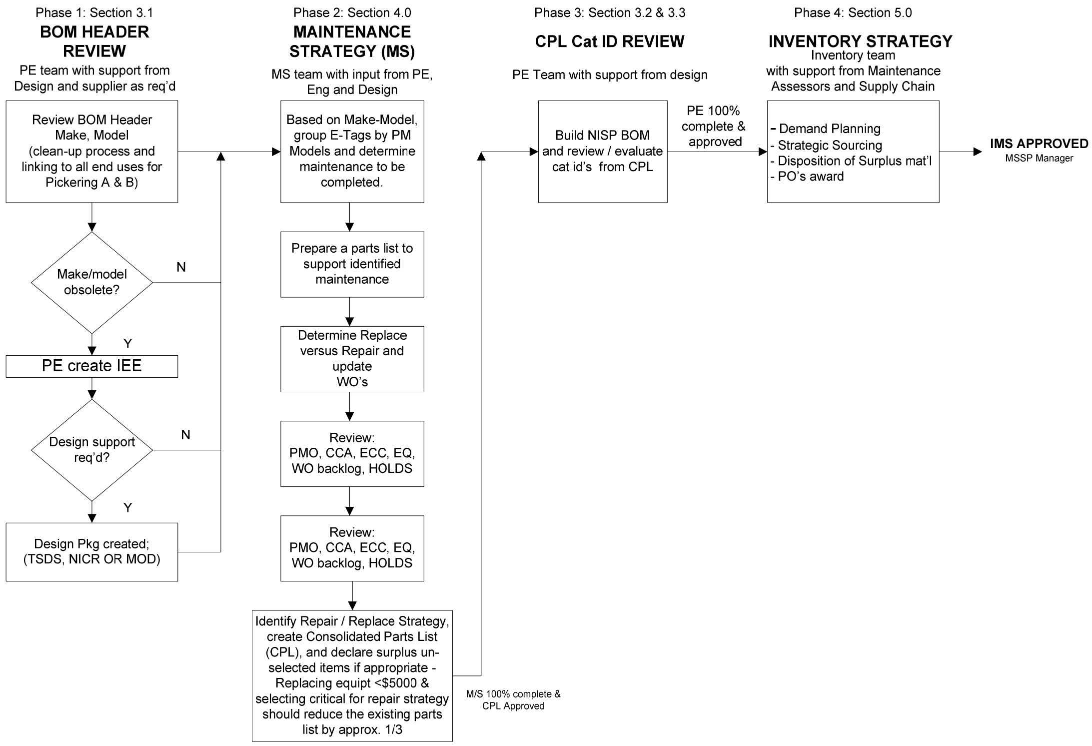
- Set re order points and quantities for selected parts in conjunction with Maintenance.
- Place a purchase order for any selected part that is below the reorder point as required.
- The other CAT IDs that are not selected in the Consolidated Parts List are reviewed to determine whether they should be stocked or declared surplus. If the parts can be declared surplus the surplus process is initiated. .
- After the Purchase Order has been placed, the Inventory strategy is approved.

Phase 5: Final approval of the Integrated Maintenance Strategy is done by the Project Manager.

- The project manager with support from the team reviews the strategy and confirms that it meets the requirements of the guide.

An overview of the process is illustrated in Figure 1.

FIGURE 1: INTEGRATED MAINTENANCE STRATEGY PROCESS FLOW



3.4 Tracking of components that have gone through the NISP process:

The NISP tool is used to track information on the strategies and the status of the strategies. Examples of the NISP tool are shown in Examples 1-4

In addition to the NISP tool which captures data and tracks progress of strategies, several flags are set in passport as the strategy progresses.

- The Master Equipment List is flagged for equipment that has a strategy developed against it. It is used to generate a requirement flag when ever a work order task is created against the equipment to indicate there is a strategy in place
- The selected parts for a given Level 1 CAT ID are flagged as NISP so Procurement Engineering and maintenance planning know that those parts have been selected through the strategy
- When the maintenance planners create or update a Model Work Order or a generated work order, that work order and its tasks are flagged with a NISP attribute. This attribute flag is generated in any subsequent task or work order that is back grounded from the original. This is used to track usage of those work orders and tasks in future work orders,

3.5 Implementation

The three project teams were formed in April 2007. After a few weeks of familiarization the teams started to produce Integrated Maintenance Strategies. Each team had a target of producing 400 strategies in 2007. Scope for the year was at the discretion of the Site Project Managers, and it tended to vary from site to site. In 2008 the production targets were increased to 800 for Darlington and 720 each for Pickering A and B.

3.6 Experience to Date

Production of Strategies: The project teams have made good progress since the project was initiated. The following are some production statistics for the fleet as of the first week of September 2008.

- 2436 Strategies Developed (16.6% of scope)
- 19910 Equipment Tags Addressed (10.4% of Scope)
- 1708 CAT IDs set to ready
- 2515 CAT IDs Re order Points (ROP) set in passport
- 438 Purchase Orders issued
- 95% of parts that have been through NISP are available for purchase.
- 89.9% of NISP Specified Parts are in Stock
- 8.4 % of Work Order Tasks being executed that are on components that have been through the NISP process.
- 0.1% holds on NISP tasks vs. 1.9% on general population of tasks in the scheduled on-line work

Improvement Opportunities: There have been a number of areas where improvements have been identified based on experience gained to date. These include

- The tracking of progress of a specific IMS can be complex. Although in a team the handoffs are minimized there are still a number of follow up items that take some time to resolve. An additional tracking application was built to allow the team to status a large number of activities. This improved the ability of the team to focus on reducing backlogs within the teams
- The development of Model Work Orders by the team was limited to the key tasks needed to maintain the equipment due to the shear size and volume of the work. The teams were not staffed to assess work package support tasks such as scaffolding, insulation, and operator preparation. When updating existing PM Models this was not an issue as the support tasks were usually in place, but for building Models for elective and corrective maintenance the Models were seen to be incomplete by the base work planning groups. This resulted in the base work planning groups continuing to background existing work packages as opposed to finishing the assessment on work orders generated from the generic models produced by the NISP teams. The process is being updated to better align the NISP output to the needs of the base work planning groups.

- For the first two years the primary measure of success has been the number of strategies produced. This was a good measure to get the project teams up and running. However depending on the component the complexity of the strategy can vary significantly. For example, a small check valve could simply require a replacement consisting of one part, on the other hand, a heat transport pump and motor will require a more complex strategy with numerous parts. The team that selected more simple components in their scope was able to meet their targets more easily where the team that selected more complex components had more difficulty meeting targets. Going forward for 2009, additional targets will be set which considers the value and complexity of the strategies, and will more closely monitor the real work. An example would be measuring the number of CAT IDs processed.
- The original scope for the project was all non run-to-failure components. On further analysis it was determined that nearly 20% of the scope had never been worked on, and up to 50% of the scope had less than 5 completed work orders completed in history. With a programmed approach to working down the scope, some components were selected which had no work demand or had never been worked on. In some of these cases the bills of material (BOM) were not in place and a significant effort was required by Procurement Engineering to build the BOMs. Additionally this work which was not directly supporting the station work program was putting a burden on workgroups such as Design Engineering, The scope is being adjusted across all three teams to focus on components that have maintenance called up in the station work program such as PM's, cycle plans, and outage scope.
- The project was designed as a one pass effort, A sustaining process is needed to keep maintenance strategies, parts requirements and parts availability aligned, Changes can occur on two fronts. The maintenance program requirements can change, thus changing the strategy and parts requirements. The other changes come from changing vendors and parts availability. For I&C components, the parts need to be reviewed every three years to ensure they are current. If this is not done pro actively then the parts issue will only surface when work packages are being prepared for execution. This can lead to schedule instability and significant emergent work for Design Engineering and Supply Chain. A sustaining process is being developed and will be implemented in 2009.

3.7 Future Direction for the Project

In 2009 the project will be handed back to the stations to manage, the transition will be in two phases:.

Phase 1- Focused Effort: The project will be carried on with dedicated staff to work down the scope. This approach was selected to ensure that the project deliverables were not subject to the emergent and day to day needs of the station. The following activities are part of Phase 1:

- Align the remaining scope to the station work program. Each station will select high value scope based on their needs.

- The teams will be scaled back to only include maintenance and engineering, Supply Chain activities will be done through their central organization
- Team operation will come under the Director of Operations and Maintenance
- Governing procedures will be updated to reflect the NISP processes and build in sustaining activities.
- More direct utilization of passport for tracking and controlling the project deliverables and outputs.
- Completion of about 400-500 high value strategies per station per year, over the next two years.

Phase 2 - Full integration of NISP process: The NISP process elements will become the way all staff do work. This will allow the program to be sustained and remaining components to be put through the process where there is good value to do so. The following activities are part of Phase 2.

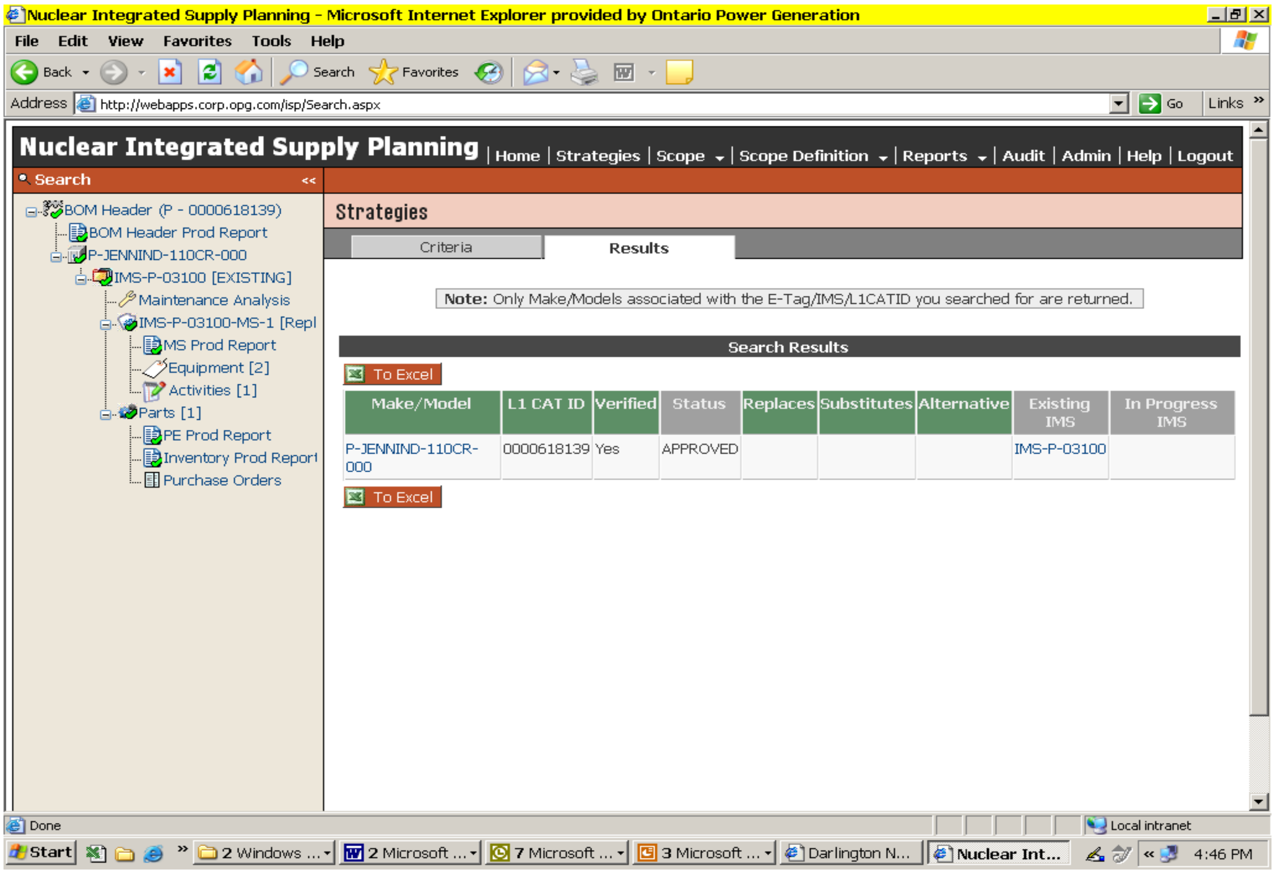
1. Full immersion of the NISP processes into the station organization. NISP becomes a way of doing business.
2. Implementations of a Critical Spares program to ensure spares are available for critical components that the stations typically do not work on.

4.0 CONCLUSIONS

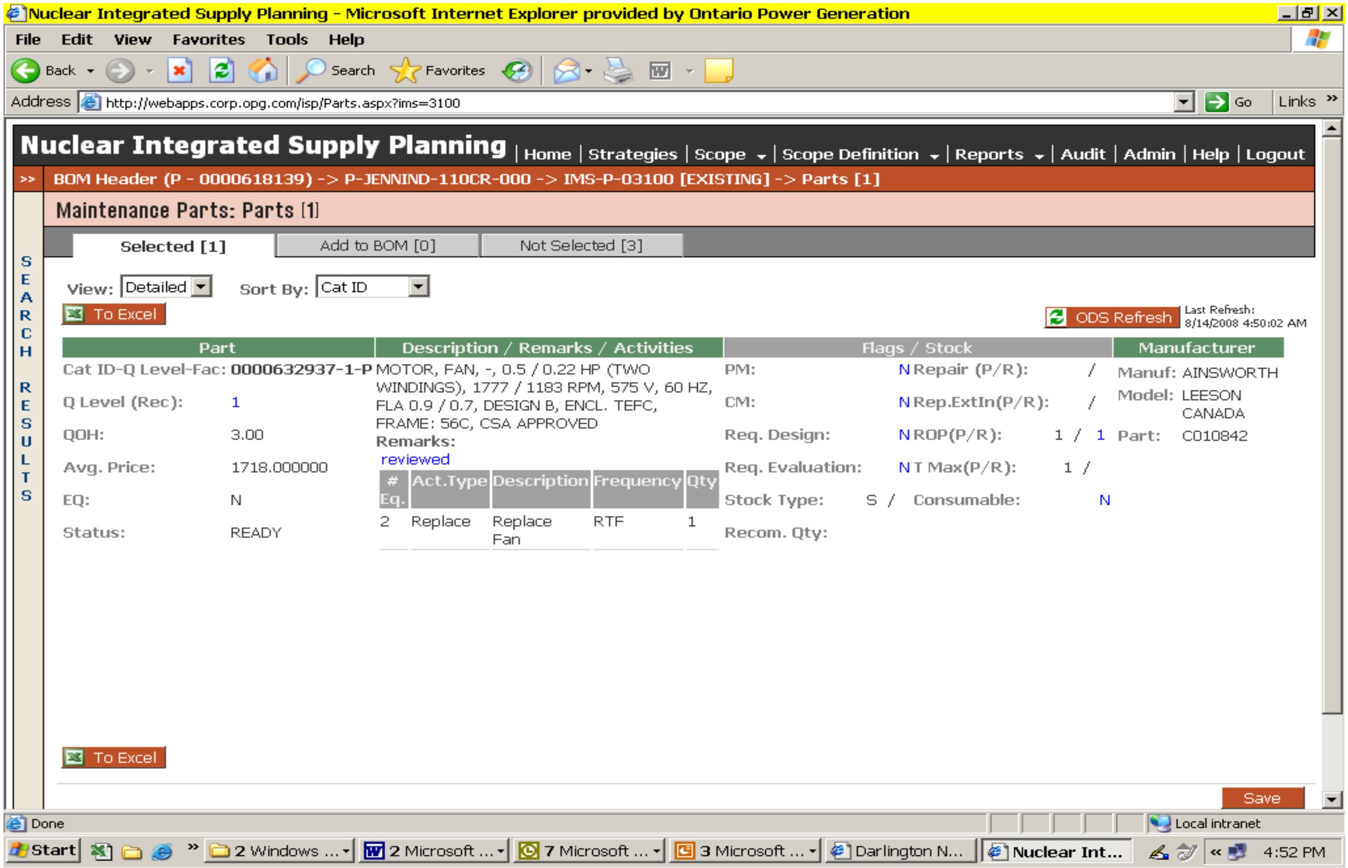
- The NISP process has provided demonstrated results in reducing parts holds and improving parts availability. It is an effective way to align maintenance requirements, maintenance practices and strategies and parts requirements.
- In a large project such as NISP it is important to establish production goals to get the project functioning. It is equally critical that scope selection and metrics are based on value added to the business.
- A sustaining NISP process is required to ensure the benefits of the project are not eroded due to changes in maintenance requirements or parts availability in the market place.
- Implementation of industry best practices such as Equipment Reliability, Work Management, and Supply Chain functions require a focus on cross-functional integration to achieve maximum benefits.
- A fleet wide approach to implementation of industry best practices is preferred to ensure consistency and efficiency. .

5.0 EXAMPLES OF THE NISP TOOL

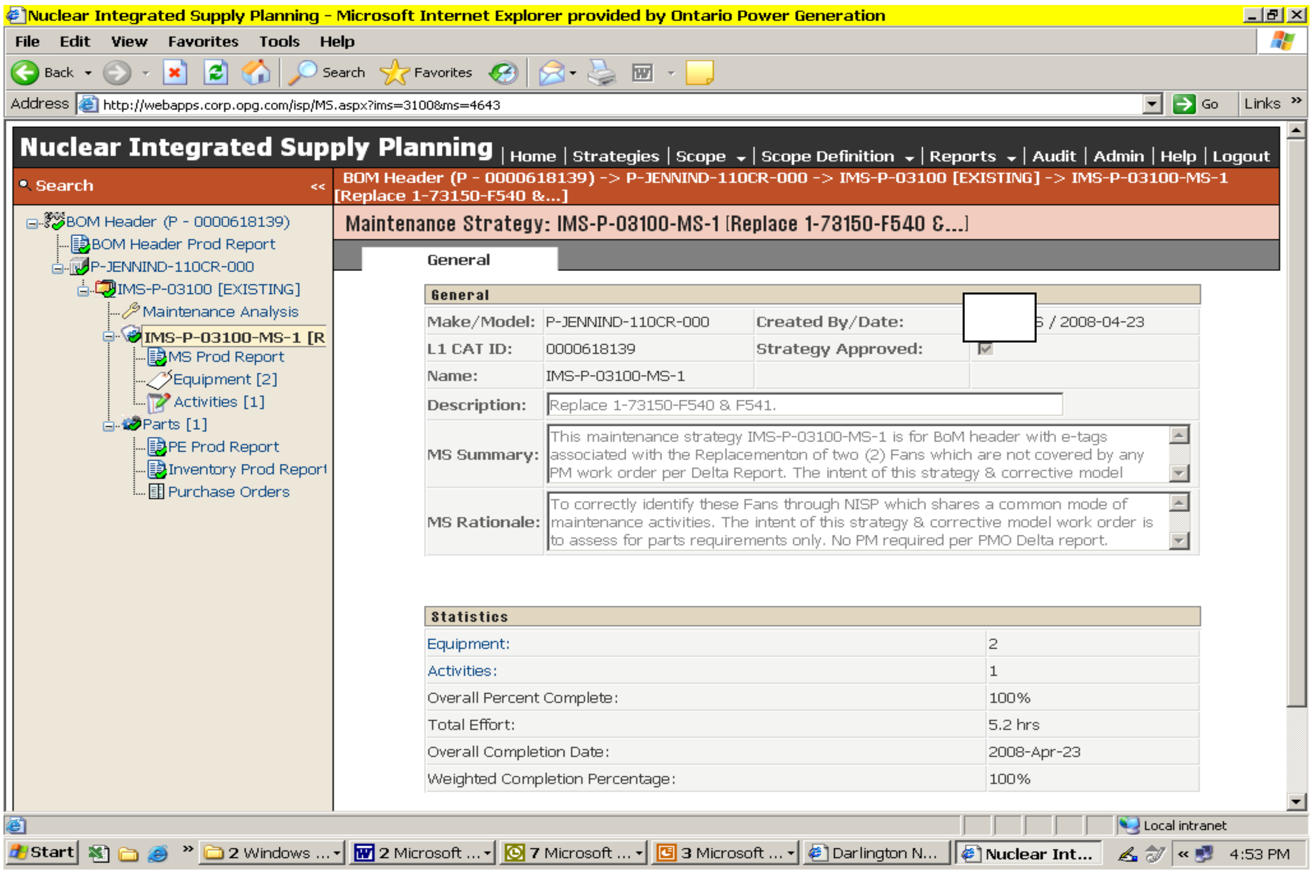
Example 1: Overview of the NISP Tool; left hand side contains the index for looking at various aspects of a given strategy



Example 2: Parts Description



Example 3: A maintenance strategy.



Example 4: A list of affected equipment that the strategy applies to.