



Reliability-Centered System Life Planning

Four Steps to Better Preventive Maintenance



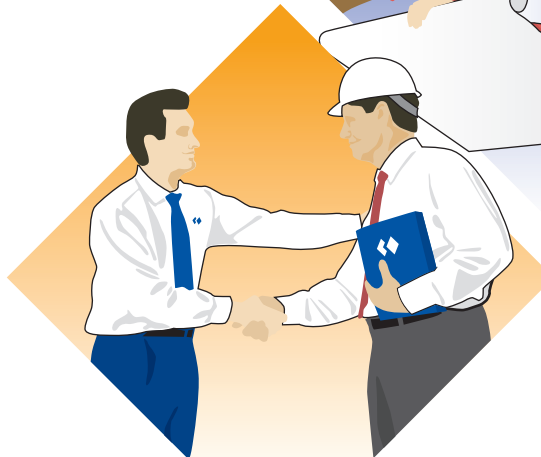
1. Interview



2. Inventory



3. Analysis



4. Report



This page intentionally left blank.



What is System Life Planning?

Reliability-Centered System Life Planning (RC-SLP) is a key component of a Reliability Centered Maintenance (RCM) strategy. RCM synthesizes reactive, preventive, predictive, and proactive maintenance practices and strategies to maximize equipment life at minimal cost.

Combining decades of process experience with rigorous statistical analysis, RCM analysis carefully considers what the control system is supposed to do, what functional failures are likely to occur, what consequences these failures are likely to have, and what can be done to prevent the failures before they occur.

RC-SLP aids the RCM program by addressing concerns of hardware degradation, software improvement, and system obsolescence with a detailed review and analysis of a customer's process control system.

As an additional benefit, RC-SLP also improves plant safety by identifying installation-related control system anomalies that may lead to hazardous situations. These may include intrinsic safety issues, power and grounding issues, software viruses, spyware, and required, but not implemented, software patches and service packs.

Once implemented as a part of an RCM program, the RC-SLP program can provide a clear and uniform standard for maintenance and reliability of systems across an entire plant or company.

To implement RCM, it is imperative that the maintenance supervisor/manager and maintenance technicians think about their facilities in terms of function. That means thinking about facility equipment in terms of systems, subsystems, components, and subcomponents.

The RC-SLP Program consists of the following components: Interview, Inventory, Analysis, and Report.



Step 1. Interview

The first step in the RC-SLP process is an interview with process engineers and operators to gain a general understanding of your control system's reliability risks. Any specific concerns with component age, application environment, network traffic, or failure rates serve as the starting point of the analysis process.

Some of the questions we ask are:

- Are there any recurrent system alarms?
- Does the system appear to operate too slowly?
- Do any of the system devices repeatedly crash?
- Are I/O boards failing at rates higher than expected?
- Are there any unexplained anomalies that have been noted in the recent past?
- When was the last time Preventive Maintenance (PM) was done on the system? What was done during the PM?
- Do you have any questions about how your system is supposed to operate?
- Are your system, network, and wiring documentation up-to-date?
- What are your standard operational and backup procedures?

The answers to these and other questions provide the starting point from which to conduct the rest of the process.



Step 2. Inventory

No Detail Too Small

RC-SLP includes a thoroughly detailed inventory of all process system components and related systems.

Hardware

Even the best-engineered hardware components will eventually fail. Fans, capacitors, surge suppressors, relays (solid state and electromechanical), voltage regulators, and other components can affect power supplies, microprocessors, communications interfaces, I/O devices, and the process control system operation as a whole.

Components Examined:

- CDCM and OCM
- All I/O boards
- Connected system components such as third party I/O and PLC's
- Conditions under which the system is installed: power, grounding, temperature, humidity, vibration, electrical noise, RFI/EMI, wiring, intrinsic safety
- Data Networks
- Spare Parts
- DEC equipment based CDCM, DCM, OCM, VXT Terminal
- Wintel equipment (NT consoles, etc) based CDCM, DCM, OCM, server
- RAID drives
- Keyboards
- Pointing Devices
- CRT and LCD monitors
- Network gear (DEC, CISCO, ATI, D-Link, Linksys, 3COM, HP, etc. routers, bridges, switches, multiport repeaters, media converters, transceivers, patch panels)
- Process Control Modules
- Multiplexers and associated boards
- I/O termination panels
- Power supplies
- Quantum Remote I/O
- Simatic 505 remote I/O
- Any other manufacturer remote I/O connected to the D/3®
- PLC's connected to the D/3®
- PLC's associated with the process but not connected to the D/3®



inventory of all process system hardware, software, networks and practices

Fields Recorded for Each Component:

- Hardware description (analog input, analog output, CPU, power supply, etc)
- Manufacturer (DEC, NovaTech, PCT, Quantum, Mitsubishi, Seiko, HP, etc.)
- Model number including dashes
- Serial number
- Date code
- Date placed in service
- Board or unit condition (clean, well-maintained, never maintained, etc)
- For I/O boards, are the boards used to connect to intrinsic safety barriers (I.S.)?
- Where the component is physically located (plant, building, room, CDCM, DCM, OCM, PCM, multiplexer, drop, base, cabinet, cabinet zone, etc.)
- Any other relevant comments (type of networking, on UPS, defective unit, used as bookshelf, etc.)
- Extreme dirt, cracked cases, worn-out keyboards or other physical defects.
- Poor maintenance practices that could lead to early failure
- Condition of power and data cables
- Any unusual noises from equipment
- Observed temperature of equipment (most equipment should operate just slightly above ambient temperature). If the equipment appears to be operating well above ambient temperature additional temperature measurements will be required.



HARDWARE DESCRIPTION	MANUFACTURER	OTHER LOCATION INFO.	MODEL NO.	SERIAL NO.	DATE CODE	DATE IN SVC.	COND.	I.S.	COMMENTS
AI BOARD	NOVATECH	PCM3 MUX 2 SLOT 3	A165150-1	1234568	N/A	1/12/96	GOOD	YES	BOARD IS DIRTY
VAX DCM	DEC	TABLE TOP – DCM 3	4000M	9876543210	N/A	1/12/96	GOOD	N/A	E0 IS AUI; E1 IS THIN-WIRE
MUX PS	TODD	PCM 3 TOP MPU LEFT	S42-8	64836485465	N/A	1/12/96	OFF-LINE	N/A	DEFECTIVE
COMM. BOARD	ALLEN-BRADLEY	A-B RACK 4	S5	734643947	9/2/89	10/23/91	FAIR	N/A	

Example Hardware Inventory

Software

Software patches designed to fix anomalies in old software programs may not be implemented in the existing process control system. These fixes need to be installed to assure optimal control system functionality. New software with additional features may also be available. Inventory of software includes:

- CPU usage
- System Alarms
- Process Alarms
- Patch levels
- D/3® Log Files
- Service Pack levels
- D/3® Licenses
- Hard Disk Utilization
- Evaluate CPU usage on all relevant nodes over a thirty minute period
- Review of:
 - System Alarms
 - Alarm History files
 - Process Alarm files
 - D/3® LOG filed
 - Dr. Watson logs
 - Microsoft Windows® service pack and patch levels and Hot Fixes
 - Applicable virus protection
 - Hard disk utilizations/fragmentation
 - D/3® licenses
 - Other D/3® patch levels

Board Conditions

It may be necessary to remove the components from service in order to record the pertinent data. In some cases this can be done while the rest of the plant is operational (when the boards are hot-swappable or the required information is visible when the component is in service). In other situations the equipment will have to be powered down while components are removed, data recorded, and the components re-inserted and re-connected. The customer must specify if and when boards and other components can be removed and inspected.

When boards are removed from service and inspected, the condition of the board will be noted. The following are documented:

- Dark marks on the board indicating component overheating
- Poor soldering indicating possible points of failure
- Extreme dirt
- Evidence of corrosion on system tracks or component leads
- Warped fiberglass board material
- Any other track or pad anomalies



Documentation and Procedures

Procedural practices affecting equipment longevity are also documented, including:

- Preventive Maintenance procedures
- System, network, and wiring documentation
- Backup procedures
- Operational procedures

Spare Parts Inventory

Includes the following:

- DEC equipment based CDCM, DCM, OCM, VXT Terminal
- Wintel equipment (NT consoles, etc) based CDCM, DCM, OCM, server
- RAID drives
- Keyboards
- Pointing Devices
- CRT and LCD monitors
- Network gear (DEC, CISCO, ATI, D-Link, Linksys, 3COM, H-P, etc. routers, bridges, switches, multiport repeaters, media converters, transceivers, patch panels)
- Process Control Modules
- Multiplexers and associated boards
- I/O termination panels
- Power supplies
- Quantum Remote I/O
- Simatic 505 remote I/O
- Any other manufacturer remote I/O connected to the D/3®
- PLC's connected to the D/3®
- PLC's associated with the process but not connected to the D/3®

The following characteristics are noted for each spare:

- Hardware description (analog input, analog output, CPU, power supply, etc) includes the following fields:
- Manufacturer (DEC, NovaTech, PCT, Quantum, Mitsubishi, Seiko, HP, etc.)
- Model number including dashes
- Serial number
- Revision level
- Date code
- Date purchased from EMC/ Rexnord / TI / GSES / NovaTech
- Board or unit condition (clean, well-maintained, never maintained, etc.)

- Where the component is physically located (plant, building, room, CDCM, DCM, OCM, PCM, multiplexer, drop, base, cabinet, cabinet zone, etc.). Storage area ambient conditions (temperature, humidity, corrosives, etc.)
- Dark marks on the board indicating component overheating
- Poor soldering
- Extreme dirt
- Evidence of corrosion on system tracks or component leads
- Warped fiberglass board material
- Any other track or pad anomalies
- Repair tags
- Poor storage techniques (boards stacked on top of one another with no physical protection, no static bags, incorrect static bags, etc.)

Network Inventory

There are many types of networks and communications supported by the D/3® system. The condition of all of these types of networks need to be addressed. Common networks are:

- D/3® Token Ring (legacy systems)
- Ethernet (coax, UTP, fiber, switched, flat)
- Modicon Remote I/O (S908)
- Modbus and Modbus Plus
- Profibus
- GPX I/O (RS232)
- TIWay
- Data Highway Plus
- Control Net
- Other industrial networks

Network inventory fields:

- Complete system map including all components and component locations
- Routers
- Firewalls
- Switches
- Repeater
- Optical fiber converters
- Bridge/multiplexers
- Modems
- Patch panels
- Network Interface Cards
- Network taps

Network Inventory Fields (cont'd)

- Printer servers and adapters
- Any other devices on the network
- Complete system map including all cabling
- Type of cabling (Ethernet coax, Ethernet twisted pair, Ethernet fiber, Profibus Purple copper, S908 coaxial, S908 fiber, TIWay Blue Hose copper, etc.)
- Lengths of cabling (approximate or measured using Time Domain Reflectometry)
- Electrical noise on cabling
- Routing of cabling (cable tray, conduit, condulets, 90 degree hard bends, above switchgear, underground, etc.)
- Power source for devices that require AC or DC power

Network Issues Identified:

- Retry rates
- Error rates
- Collisions
- Duplicate node addresses
- Broadcast storms
- Long response times
- Connected nodes (expected and unexpected)
- Switch, hub, router, repeater, bridge, multiplexer setups

All non-PCM nodes in the system may be analyzed for the following:

- Memory availability and utilization
- CPU performance and utilization
- Disk drive utilization
- Proper IP address and NIC card setup
- Any error events
- Any Doctor Watson files
- Any evidence of viruses, spyware, adware, etc.
- Levels of patches that should be installed
- Service pack levels
- Licenses installed
- Inappropriate software or system usage (for example, games, Internet protocols, Email, etc)
- PCM's CPU and memory utilization
- Unit backup program may be analyzed to assure that backups are performed as necessary and backup media are stored in accordance with industry practice
- System documentation should be analyzed for adequacy of network and wiring documentation as well as maintenance procedures
- Patch logs
- Backup procedures
- Logs of equipment repair and replacement
- Active and spare parts inventory
- Based on the analyses performed above, determine if there is a cost effective requirement for customer software and hardware upgrade of the system



State-of-the-Art System Monitoring Tools

- Ethernet Network Analyzer
- DEC LAN analysis tools in NCP and LANCP
- D/3® Status monitors
- SNMP (Simple Network Management Protocol) data on individual switch and router ports
- SNMP data through MIB (management Information Base) product
- RMON (Remote Network Monitoring) protocols
- Alarm files
- Microsoft® Network Monitor tools
- Discussion with customer about perceived network anomalies



Step 3. Analysis

A Blend of Intuition and Statistics

The key to developing an effective RCM program lies in effectively combining the intuitive and statistical approaches, each of which have their strong and weak points.

Intuition, if applied without serious reflection and review, results in arbitrary, "shoot-from-the-hip" solutions.

A rigorous statistical approach has its limits, too. The first of which is cost: developing and/or analyzing the amount of data sufficient to provide a statistical basis is an expensive task. One may also fall into the "analysis paralysis" pitfall; the more one delves into a problem the more data it seems is required to solve it.

Another limit of the statistical approach is applicability. Statistics often do not always produce definite trends, since there may not be any.

RC-SLP provides an ideal mix of statistical predictive methods and decades of control system know-how to form an economical and effective RCM program. Areas of analysis include:

Hardware

All components are reviewed for:

- Condition of boards
- Hardware replacement based on installation conditions and MTBF
- Spares levels
- Network changes
- Wiring changes
- Environmental changes
- Hardware revision levels

Software

Reviewed for:

- Recommended Service Pack levels
- Recommended Patch Levels
- Analysis of System Error Logs
- Analysis of CPU utilization and hard disk utilization
- Network utilization
- Security concerns
- Recommended upgrades

Documentation and Procedures



- Recommendations for Preventive Maintenance Procedures
- Recommendations for System Documentation
- Recommendations for Backup procedures
- Recommendation for problem logging
- Record maintenance
- Databases
- Sequence programs
- Graphics
- Operating documentation
- Path for system, hardware, and network upgrades
- Analysis and Documentation of data networks (Ethernet, Remote I/O, Modbus Plus, Data Highway Plus, Profibus, etc)
- Analysis of points of failure and system improvements to mitigate these points of failure

Single Point of Failure

As the system is being reviewed, any elements that could be considered a single point of failure are red-flagged for special attention.

For example:

- If there is one power supply and it goes offline, it will take the DCS down with it
- Non-redundant MRIOC or MRCC. If this board goes down, all connected I/O goes down with it (not the case if redundant links are used)
- Non-redundant microprocessors
- Non-redundant power supplies

Single Point of failure (cont'd)

- One 100 ampere 24 VDC power supply with no individual fuses feeding 300 DCS powered input or output points. If this power supply fails because of a shorted field point, all points fail and the plant shuts down.
- A poorly defined software interlock. For example, if communications to a node is marked "offline" for any reason an interlock shuts down a compressor which in turn causes a plant shutdown (there could be a temporary microsecond anomaly which causes the software to incorrectly report an offline condition).
- An exact number of fibers running from a switch to a PCM. If a fiber becomes damaged, there is no backup without a new cable pull which means a PCM could be offline with communications problems for a long period of time.
- Critical components (such as a PCM) in an unlocked area accessible to anyone. Anyone could enter, throw a power switch shutting the unit (and the plant) down, and then leave undetected. Definitely a security issue.

System Operating Environments

The D/3® DCS system and related components is designed to operate within certain environmental parameters as defined in the D/3® Site preparation Guide. When the D/3® is forced to operate outside of these parameters, system components may fail prematurely.

Sample Environmental Condition Evaluation Sheet

AREA DESCRIPTION	TEMP	HUMIDITY	VIBRATION	DIRT	CORROSIVES	COMMENTS
BUILDING 3 COMPUTER ROOM	72° F	45% RH	None	CLEAN	NONE	NONE
BUILDING 3 1ST FL MCC	79° F	65% RH	None	MODERATE DIRT	NONE	HUM FROM AC EQUIPMENT
BUILDING 2 RACK ROOM	82° F	42% RH	SLIGHT – BARELY PERCEPTIBLE	MODERATE DIRT	NONE	NONE
BUILDING 4 EQUIPMENT ROOM	71° F	67% RH	SOME VIBRATION-NEEDS TO BE MEASURED	FILTHY; USED CHEMICAL ABSORBENT ON FLOOR	PRESENT IN ATMOSPHERE; DISSOLVING THERMOSET PLASTICS	ROOM IS REALLY IN NEED OF CLEANING AND SEALING AGAINST AMBIENT ENVIRONMENT



Using an Environmental Condition Evaluation Sheet (shown below), the parameters indicated for the different system components are recorded.

We make note if any of the DCS components are subject to unusual Electromagnetic Interference / Radio Frequency Interference items. For example:

- Walkie-Talkie base station is located next to CDCM and plugs into same power receptacle as CDCM.
- Modicon or 505 base is located inside of motor control center cabinet next to Variable Frequency Drive.
- Analog I/O lines or Ethernet copper cables are in same cable tray as 480 volt power feeders.
- Joe Technician uses walkie-talkie while servicing running PCM microprocessor units.
- Any system component is located near wireless telemetry transmitters.
- Any system component is located near unshielded high energy electrical devices that develop electric arcs (welders, smelters, electric arc furnaces, etc).

System Power

All AC voltage levels are measured with a digital voltmeter. Measurement between hot and neutral is called transverse mode measurement. These measurements are made as RMS (root mean squared) measurements.

System Power (cont'd)

AC voltage levels should fall between 110 and 125 volts AC or 220 to 245 volts AC, 60 HZ plus or minus one HZ or 50 HZ plus or minus one HZ. While the D/3® will operate outside of these limits, continued operation of the D/3 outside of these limits may lead to accelerated degradation of system components.

All AC and DC voltages should be observed with an isolated oscilloscope. These measurements are made P-P (peak to peak). AC transverse mode waveshapes should be sinusoidal and free of major harmonics and noise spikes (there may be some minor 3rd, 5th, and 7th order harmonics and some high frequency noise present). DC systems should have electrical noise levels within power supply specifications. NOTE: UPS outputs will typically show some stepping in the waveshape. This is the way UPS systems work when they convert the internal DC back to AC. Nothing to worry about unless it is severe stepping; this indicates an output filter failure in the UPS.

Common mode measurements should be less than 2.5 volts peak to peak. NOTE: The D/3® components will operate up to 6.5 volts p-p common mode but measurements this high indicate a problem in the ground system that needs to be addressed to assure proper DCS operation.

All DC voltage levels will be measured with a digital voltmeter. Measurement between plus and minus is called transverse mode measurement. These measurements are made as DC level measurements. DC voltage levels should fall between:

- 4.9 and 5.1 volts for 5 volt systems
- 11.95 and 12.05 volts for 12 volt systems
- -11.95 and -12.05 volts for -12 volt systems
- 23.9 and 24.2 volts for 24 volt systems
- 47.6 and 48.6 volts for 48 volt systems (Elgar)
- 55 and 58 volts for EMC 48 VDC UPM systems

Measurement between neutral and ground is called common mode measurement. Common mode measurements should be less than 1 volt RMS.

System Grounding

All grounding connections to the D/3® system will be visually verified. Connection points, wire sizing, etc. will be noted. If necessary, the computer ground triad or other grounding connection may need to be measured according to the IEEE 81 standard. This information will be used in conjunction with the noise levels measured under "System Power" to determine if system grounding is adequate.

NOTE: Special considerations may apply for intrinsically safe systems.



Reliability-Centered System Life Planning Service Description

I/O Noise Measurements

High electrical noise levels on I/O systems will cause premature aging of system components, particularly on multiplexed analog input systems.

The first step in evaluating electrical noise on I/O points is to ask the customer about I/O board failures or noisy or unstable I/O points. Boards that have been in service for five years or more with stable I/O and no failures are generally indicative of no problems (although the boards may be approaching end of life based on Mean Time Between Failure – MTBF – data). These are not boards that need to be checked. However, boards that are replaced repeatedly at intervals of less than two years, or where there are points that are unstable, should be checked for noise levels.

A Minimum 60 megahertz battery operated (isolated from AC line) analog oscilloscope or a battery operated (isolated from AC line) digital phosphor storage oscilloscope (minimum 300 megahertz, 2.5 gigasamples/second) is used for these measurements. Fluke ScopeMeters may not work in this application and are not recommended by NovaTech. NovaTech recommends the Tektronix DPS3032 Digital Phosphor Oscilloscope.

The oscilloscope measures transverse and common mode noise on the I/O points in the following manner:

- Record the peak to peak measurement and any observations on noise for each point on a termination panel or I/O board.
- Connect the ground lead of the oscilloscope probe to chassis ground and record the results.
- Look for a pattern. For example, all common mode measurements except for one are 750 millivolts peak-peak. The one that is not is 2 volts peak-peak. This is the problem point. It is necessary to determine why the abnormal point is indicating such a high measurement and correct the problem.

Cabinet Fans

Cabinet and individual equipment fans need to be checked during the Inventory. Failed or slow moving fans are responsible for equipment overheating. Each fan in the system will be checked to assure that it is turning and moving air. Fans that are not operating properly will be noted. Cabinet air filters are inspected as well.



Step 4. Report

The final deliverable is a detailed report consisting of a complete inventory and recommendations for hardware, software, and networks. Thorough analysis of risks and a path for future upgrades makes it easier to implement RCM.

The RC-SLP Program is an ambitious undertaking. It may not be possible to accomplish all of the items presented in this outline within the requirements of time, budgets, and Process Automation System operational constraints. NovaTech welcomes the opportunity to work with the Customer to tailor the RC-SLP program to the Customer's specific needs.

The report provides a detailed study of the system in its current state, analysis of relative risks and recommendations for:

- Improvement of existing systems
- Minimizing future system downtime
- Future expansions/upgrades
- Further testing or additional evaluations
- A preventative maintenance program
- Record keeping for hardware and software (repairs, patches, revision levels, expansions, etc).
- Patches for software
- Maintenance agreements
- Software backup procedures
- Network configuration
- Upgrade road map – hardware and software
- Corrections for application software deficiencies (databases, sequence programs, graphics, FAT and SAT execution, version control, operating documentation)
- Hardware repair/replacement
- Hardware and software upgrades
- Proper implementation of I/O hardware.
- Board revision levels (working parts and spares)
- Power and grounding adequacy.
- Spare parts levels
- Scheduled replacement of boards as they exceed their MTBF.
- Intrinsic safety
- Network implementation (Ethernet, Modicon remote I/O, Modbus, Profibus, Fieldbus, Data Highway Plus, etc)
- Environmental conditions (temperature, vibration, contaminants in the environment, etc.)



Contact: