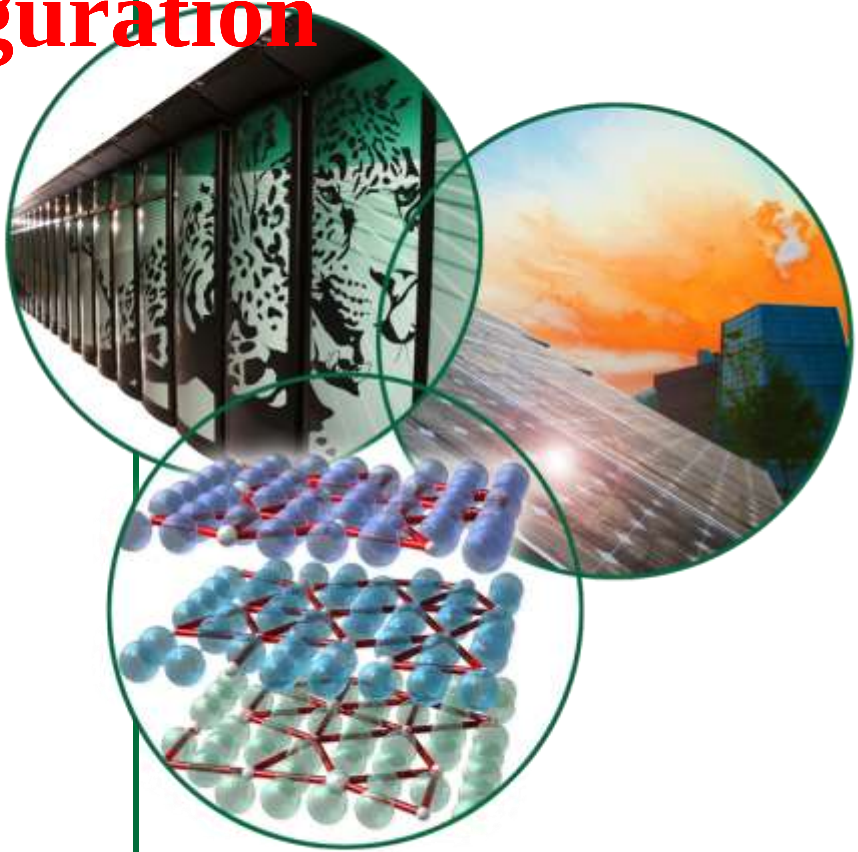
Reliability: Modeling, Vulnerability, Spares, Obsolescence and Configuration Control



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Spallation Neutron Source

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Reliability Topics

- MIS
- RAMI Modeling
- Vulnerability
- Spares
- Obsolescence
- Configuration Control

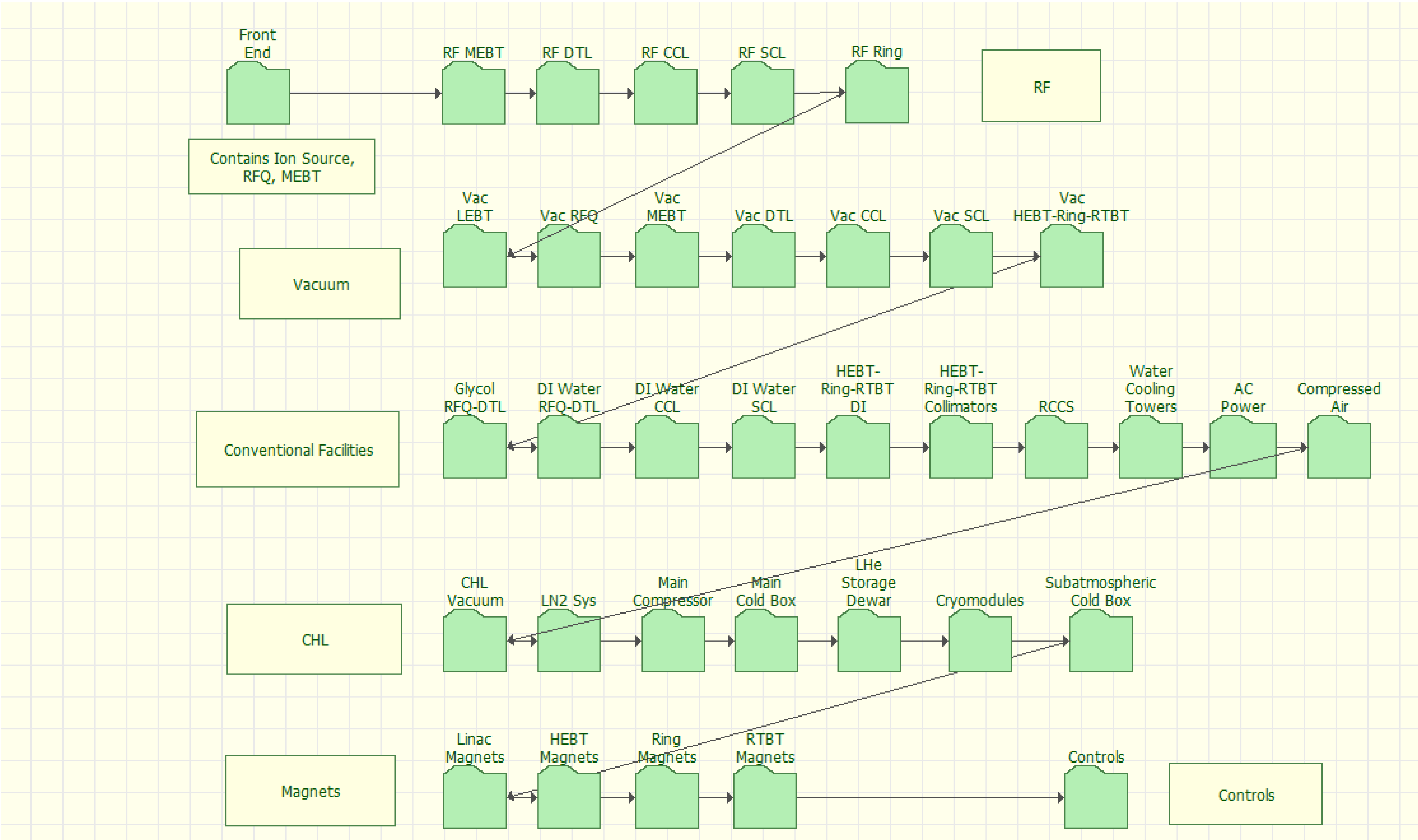
Management Information Systems (Oracle) Acquire Reliability Data

- Beam Time Accounting
  - Operations Accounting System (OAS)
  - Shift by Shift account of downtime
- Electronic Logbook
  - Narrative account of shift activities including threaded discussion of breakdown and repair
- CMMS – DataStream 7i (Infor)
  - Equipment Tracking
    - Asset Structure tables with parent-child relationships
    - “Cradle to Grave” tracking by position, location, asset
    - Asset status (Installed, In-Repair, Spare, Disposed Of)
  - Work Control
- Use the same “Data Structures” for each: System, Sub-System, Sub-Sub-System , Sub-Sub-Sub-System, Asset, Position. Location
- All 3 MIS Systems “Tied Together” through the Work Order Numbers
- **Use data to calculate actual MTBF/MTTR for installed equipment**

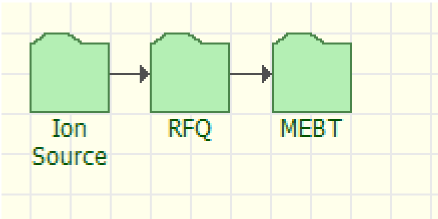
Modeling
Predict the Performance Data

- Modeling sets Your Expectations for Reliability/Availability:
- Static Model
  - Markov Chain Model
  - R(t) is Constant
    - MTBF/MTTR inputs from Vendor Information and Industrial Standards
- Monte Carlo Model
  - R(t) is an input function. You get to pick where you are on the function.
- Use Actual Performance Data to Validate the Model

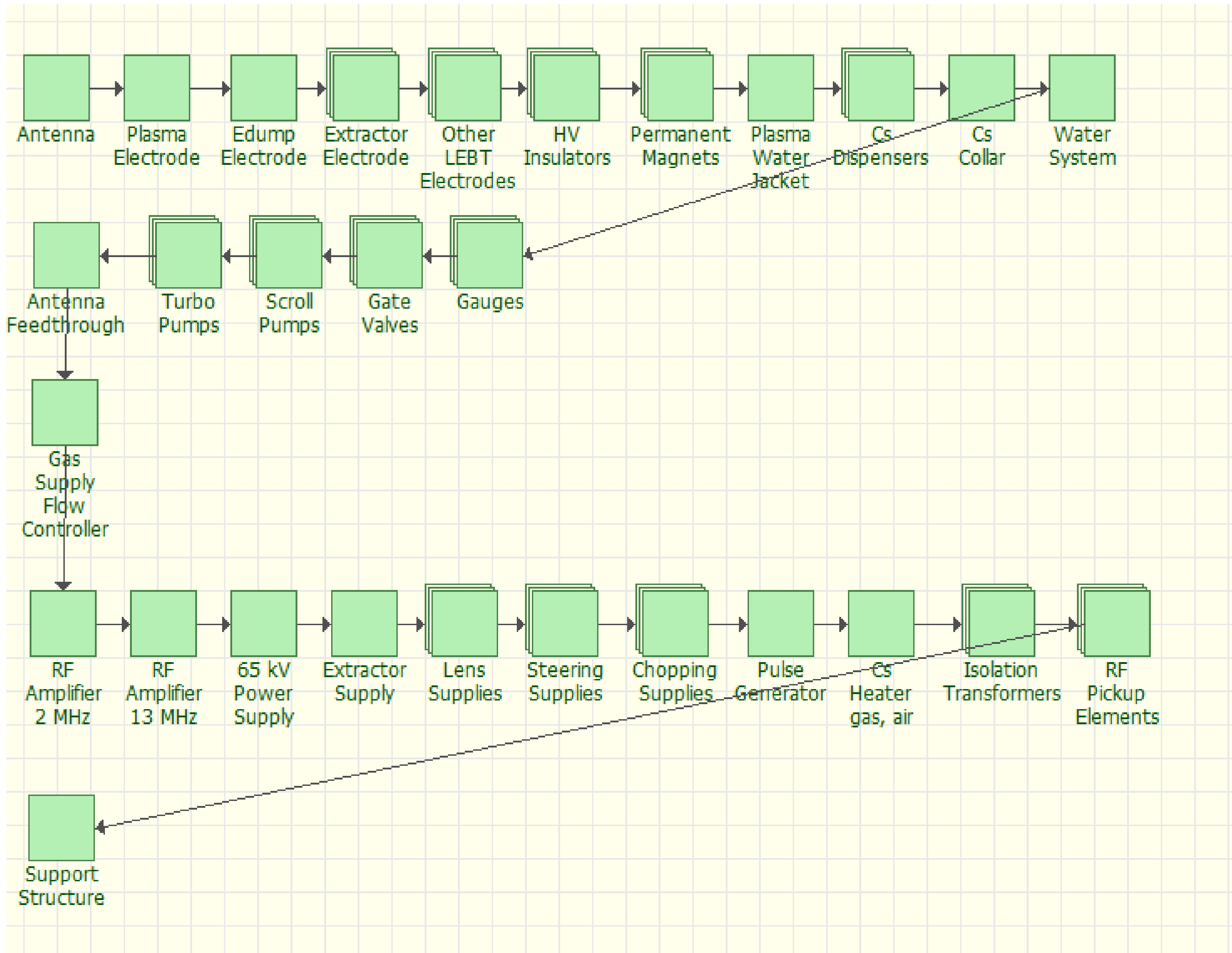
ReliaSoft BlockSim7 – Full Accelerator Complex

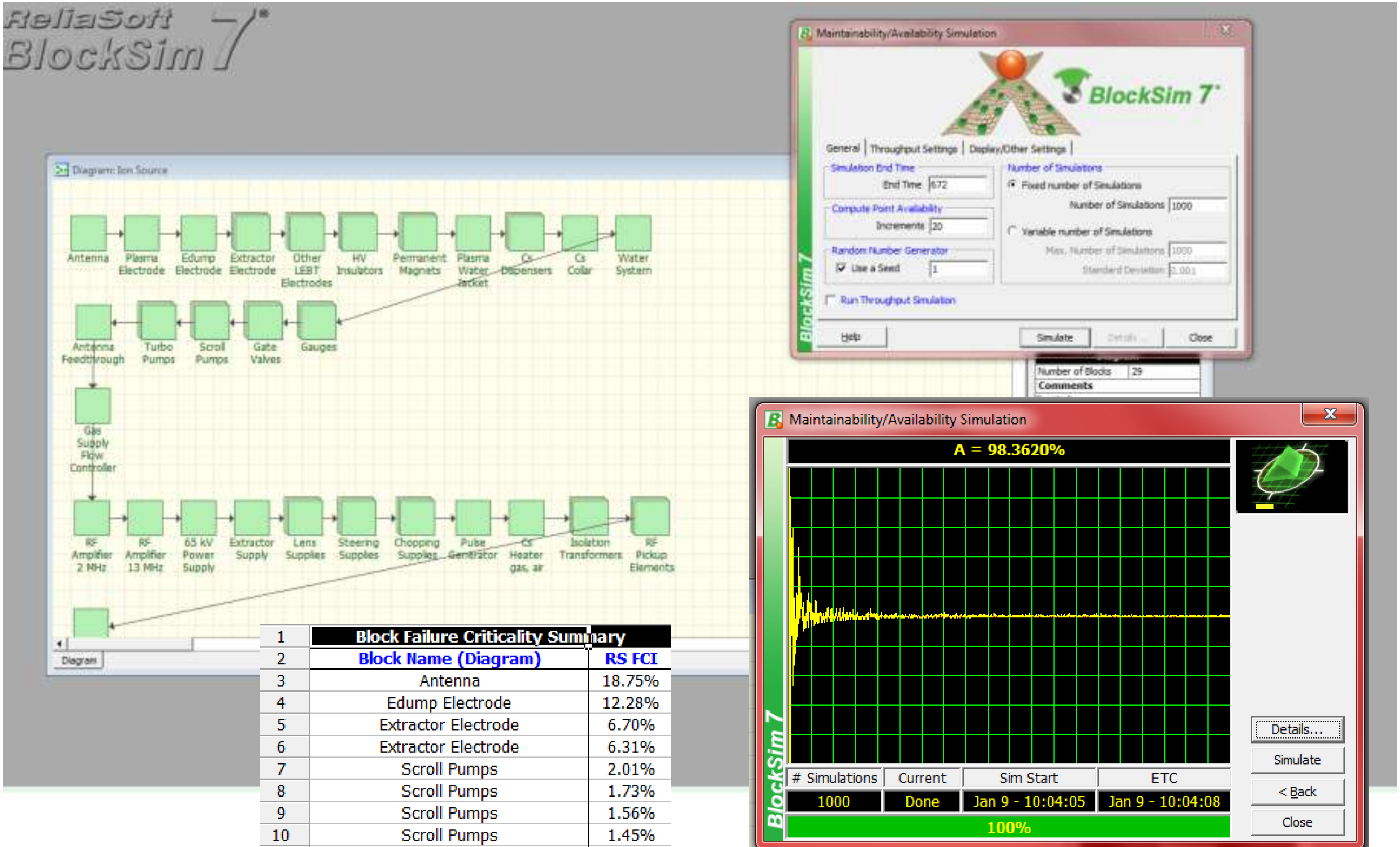


Front End and Ion Source



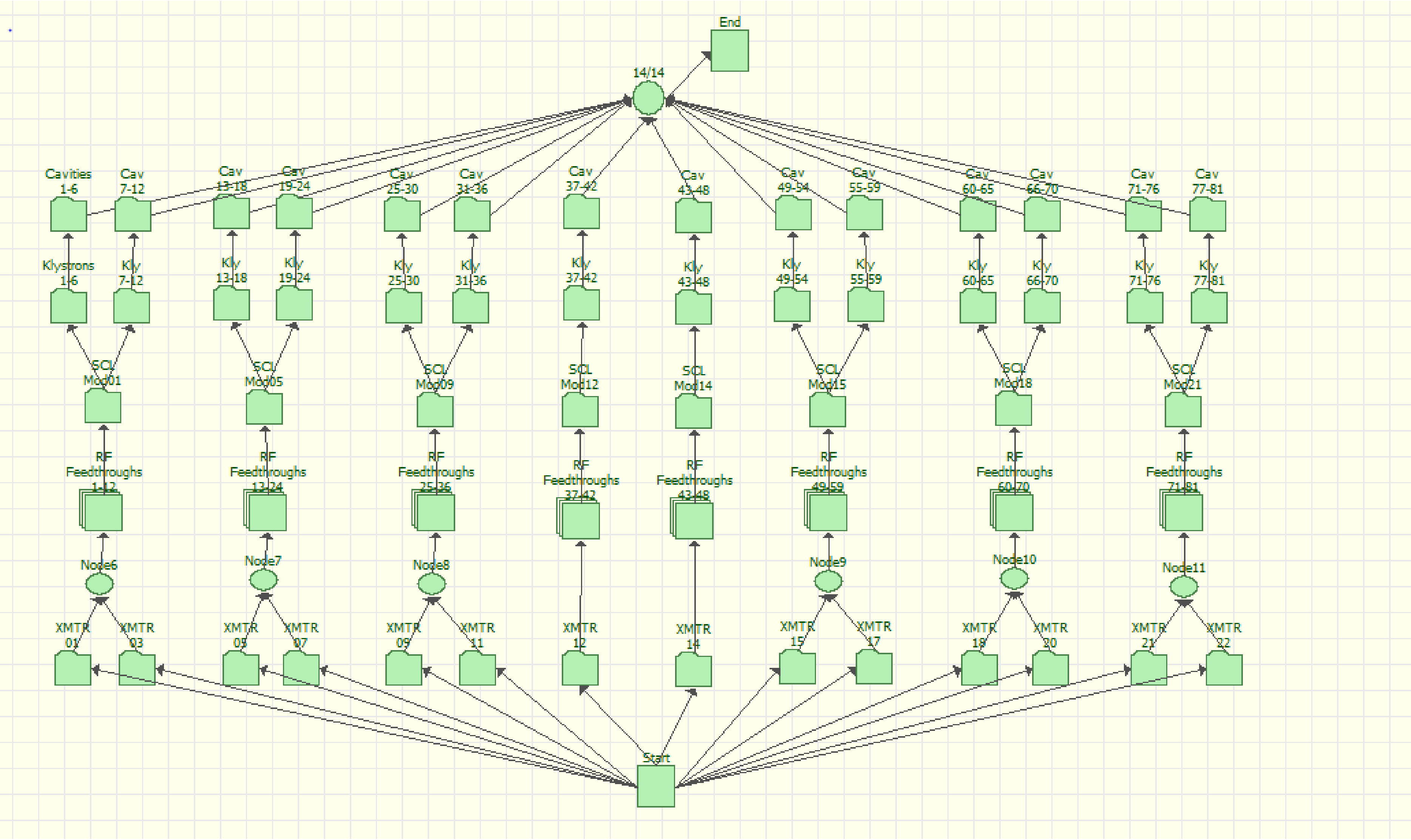
Ion Source



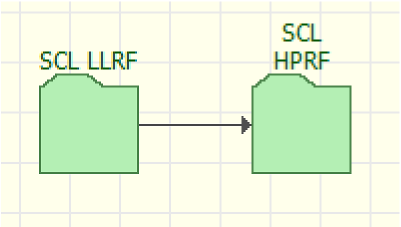


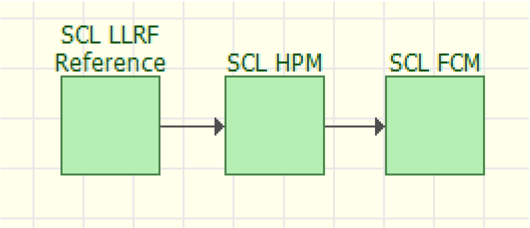
1	Block Failure Criticality Summary	
2	**Block Name (Diagram)**	**RS FCI**
3	Antenna	18.75%
4	Edump Electrode	12.28%
5	Extractor Electrode	6.70%
6	Extractor Electrode	6.31%
7	Scroll Pumps	2.01%
8	Scroll Pumps	1.73%
9	Scroll Pumps	1.56%
10	Scroll Pumps	1.45%
11	Cs Dispensers	1.12%
12	RF Pickup Elements	1.06%
13	Chopping Supplies	1.06%
14	Gas Supply Flow Controller	1.00%
15	Cs Heater gas, air	0.95%
16	Cs Dispensers	0.89%
17	Cs Dispensers	0.89%
18	Water System	0.89%
19	Lens Supplies	0.89%
20	RF Pickup Elements	0.84%

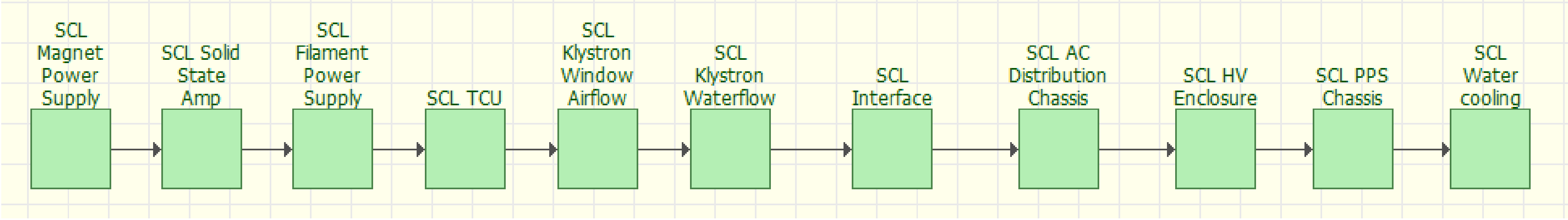
SCL RF


End
14/14
Cavities 1-6
Cav 7-12
Cav 13-18
Cav 19-24
Cav 25-30
Cav 31-36
Cav 37-42
Cav 43-48
Cav 49-54
Cav 55-59
Cav 60-65
Cav 66-70
Cav 71-76
Cav 77-81
Klystrons 1-6
Kly 7-12
Kly 13-18
Kly 19-24
Kly 25-30
Kly 31-36
Kly 37-42
Kly 43-48
Kly 49-54
Kly 55-59
Kly 60-65
Kly 66-70
Kly 71-76
Kly 77-81
SCL Mod01
SCL Mod05
SCL Mod09
SCL Mod12
SCL Mod14
SCL Mod15
SCL Mod18
SCL Mod21
RF Feedthroughs 1-12
RF Feedthroughs 13-24
RF Feedthroughs 25-36
RF Feedthroughs 37-42
RF Feedthroughs 43-48
RF Feedthroughs 49-59
RF Feedthroughs 60-70
RF Feedthroughs 71-81
Node6
Node7
Node8
Node9
Node10
Node11
XMTR 01
XMTR 03
XMTR 05
XMTR 07
XMTR 09
XMTR 11
XMTR 12
XMTR 14
XMTR 15
XMTR 17
XMTR 18
XMTR 20
XMTR 21
XMTR 22
Start

SCL Transmitter







So Far Used to:

- Run model validation calculations against the Markov Chain model with excellent results.
- Examine the “lifetime” of the 81 installed SCL Klystrons.

Vulnerability Evaluation

- An evaluation was made to address the question about the vulnerability of the accelerator systems to the failure of one or more critical elements that might put the science program in jeopardy for a long period of time.
- In this report the study was limited to those components that would jeopardize accelerator operations
- Identification of critical systems was left to those responsible for the development, operation, and maintenance of the accelerator facilities.
- There were tens of critical components identified whose failure might pose such a serious threat to operations.

Vulnerability Evaluation cont.

- The report contains a set of tables presented by accelerator type and/or subsystem with items identified by accelerator personnel that were deemed to pose a risk to operations.
- The Risk Factor was assigned based on the perceived probability for a failure, though no attempt has been made to quantitatively analyze the probability of a failure occurring. Risk is graded as:
  - High(3)
  - Medium(2)
  - Low(1)
- The Consequence Factor is assigned based on the estimated downtime for a failure. Consequence is grades as:
  - Very High(4)- Failure will cause long downtime (> 20 Weeks)
  - High(3)- Failure will cause long downtime (6-20 Weeks)
  - Medium(2)- Failure will cause medium downtime (3-6 Weeks)
  - Low(1)- Failure will cause short downtime (1-3 Weeks)
- The overall Severity is the product of the Risk Factor and the Consequence Factor.

There are 3 Severity 12 scores

System	Risk	Consequence	Severity	Failure Mode	Downtime Weeks	Mitigation	Mitigation Comment	Condition of Spares	Time to Acquire Spares	Cost to Acquire Spares
Target	3	4	12	Hg HX	26	Replace	Maintain spares	Spare HX at HFFP.	1 year	
Special Magnets-Final focus quads	3	4	12	Coil/Insulation failure, water leak	16	Replace or repair if possible	Purchase spare parts	Purchase two spare coils (one each type)	1 yr.	$500,000
Ring collimator system	4	3	12	Collimator vacuum envelope failure	12	Replace	Purchase spare	No Spares	6 months	$30,000

11 Severity 9 Items

System	Risk	Consequence	Severity	Failure Mode	Downtime Weeks	Mitigation	Mitigation Comment	Condition of Spares	Time to Acquire Spares	Cost to Acquire Spares
Extraction dump	3	3	9	Vacuum window failure	12	Replace with spare	Repair/ Purchase spare	Have not located spare	4 months	$20,000
HEBT collimator system	3	3	9	Collimator vacuum envelope failure	12	Replace with spare	Repair/ Purchase spare	No Spares	4 months	$30,000
RTBT collimator system	3	3	9	Collimator vacuum envelope failure	12	Replace with spare	Purchase spare	No Spares	2 months	
Chicane 2 Chamber (PSF)	3	3	9	Breach vacuum due to errant beam	8	Replace with spare	Purchase spare for new design	No Spares	6 months	$50,000
RTBT DH-13 Vacuum Chamber	3	3	9	Breach vacuum due to errant beam	8	Purchase spare for upgrade	Repair/ Purchase spare	No Spares exist	6 months for upgrade	$30,000
Lambertson Vacuum Chamber	3	3	9	Breach vacuum due to errant beam	8	Replace with spare	Repair	Spare on hand		
RID Septum Chamber	3	3	9	Breach vacuum due to errant beam	6	Replace with spare	Repair/ Purchase spare	Unable to locate spare	6 months	$30,000
Inj. Septum DH-10	3	3	9	Breach vacuum due to errant beam	6	Replace with spare	Replace	Spare on hand	6 months	
M. Dump Septum	3	3	9	Breach vacuum due to errant beam	6	Purchase Spare	Repair/ Purchase spare	No Spares	6 months	$30,000
Linac Dump Septum	3	3	9	Breach vacuum due to errant beam	6	Purchase Spare	Repair/ Purchase spare	No Spares	6 months	$30,000
RTBT Dump Septum	3	3	9	Breach vacuum due to errant beam	6	Purchase Spare	Repair/ Purchase spare	No Spares	6 months	$30,000

7 Severity 8 Items

System	Risk	Consequence	Severity	Failure Mode	Downtime Weeks	Mitigation	Mitigation Comment	Condition of Spares
Ring Injection Dump	2	4	8	Tooling for vacuum window replacement	52	Design, fab, and purchase tooling		No Tooling
Service Bay	2	4	8	In-cell crane cable failure	6 months	Replace cables	Ensure tooling/spares are available	No tooling No spares
Service Bay	2	4	8	Servo-manipulator cable failure	6 months	Replace cables	Ensure tooling/spares are available	No tooling No spares
Service Bay	2	4	8	Upper Intracell Door Hydraulic Actuator Failure	Unknown	Repair/Replace	Ensure tooling/spares are available	No tooling No spares
Service Bay	2	4	8	Servo-manipulator mechanical failure	Unknown	Doesn't matter during beam delivery.	One of a kind. High Bay pedestal manipulator	Have Some Spares
Service Bay	2	4	8	In-cell crane mechanical failure	Unknown	Doesn't matter during beam delivery.	One of a kind.	Have Some Spares
2K Cold Box		2	4	8	Internal Failure	30 to 50	Repair	Have Component Spares

Spares Plan

- **Types of Spares** (Spares can generally be divided into 3 types;)
  - Consumable Material. Consumable material is not spares per. se. but material that must be maintained on-hand to support the operation of equipment.
  - Consumable Spares, consist of material or equipment that is used to failure then disposed of.
  - Rotable Spares, which consists of equipment which, when it fails, is repaired or rebuilt, either in situ or after it is replaced with a spare unit. Some units have a fixed number of rebuilds associated with each individual unit

- **Classes of Spares**
  1. A "true spare" consisting of a "like for like or equivalent" "on the shelf, tested and ready to go ", "plug compatible" replacement unit.
  2. A "like for like or equivalent" that is installed in some other system that is not required for operation of the accelerator systems e.g. a Test Stand that must be removed from where it is being used so that it can be used as a replacement for the failed unit.
  3. A system structure or component that must be modified to be used as a spare.
  4. A system structure or component that must be purchased to be used as a spare.

- **Critical Equipment**
  - Critical Equipment are SSCS which are essential to the SNS Mission, which is traditionally defines as greater than 1MW beam delivery at greater than 90% availability for 4500 Hours of Neutron Science and 5000 Total Operating Hours per year and support for Neutron Science

Responsibilities

The System Engineer is responsible to recommend the type and number of spares and:

- Identify routine maintenance activities that will be required for existing equipment, new equipment and changed equipment including the spare parts and consumables that will be needed to support operation.
- Ensure that these spare parts and consumables are to be stocked are identified as part of design implementation.
- Ensure that spare part and consumable re-order limits are adequate to prevent interruption of system operation.
- Identify any shelf life issues with spare parts and consumables.
- Consider stocking a large number of spares for high technology components that might quickly become obsolete and unavailable in a short period of time.
- Identify any special requirements for the storage of spare parts and consumables
  - Identify repetitive maintenance requirements for spare parts (i.e., spare motors need to be rotated periodically)
  - Identify any special orientation, environmental conditions or special handling required during storage
- Ensure that new and replacement equipment meets or exceeds the minimum system requirements

Identify Equipment Needing Spares

- **Critical Equipment or components of Critical Equipment** which is reasonably expected to fail during the expected SNS facility lifetime of 40 years, must be identified in a Conditional Assessment.
- Staff shall **identify systems and components for configuration control based on a tailored approach** and shall develop appropriate configuration documentation to define each. This activity includes the development of a system top-down structure (Department, System, SubSystem, SubSubSystem, etc.) that summarizes the total number units and configuration documentation for the system or component and the assignment of unique identifiers, which identify units, and groups of units, in a system including manufacturer, make, model and serial numbers. Configuration identification and system information shall be maintained and readily available to all NFDD/RAD Staff. Baseline documentation shall be maintained in the Maintenance Management and Document Control Systems.

Calculate the Appropriate Number of Spares

- A Conditional Assessment using a "Tailored Approach" will ultimately contain for each identified component:
    1. The number of installed units
    2. When they were installed
    3. How they were installed (all at the same time or randomly after a number of failures)
    4. Mean Time Between Failures for this manufacturer/model (estimated at first, then validated against experience)
    5. Mean Time to Repair or Replace
- It is imperative that sufficient spares for critical equipment exist at the SNS to minimize the risk of an "out of stock" condition during repairs. A tailored approach is needed to accomplish this. In this approach, the most critical and longest time to repair or replace items will be assigned a higher level of scrutiny. This scrutiny should include a calculational basis. The result of the calculation will be a Mean Time to Out of Stock as a function of the number of spare units. RAD Management will include budgetary considerations when setting the desired limit for Mean Time to Out of Stock.

Obsolescence

- The objective of the Obsolescence Management Plan is to describe strategies for identification and mitigation of the effects of obsolescence through the SSC lifecycle. For each SSC, using a "Tailored Approach" create an Obsolescence Plan. The Obsolescence Plan must be linked to the Spares Plan.
- The objective of the plan is to achieve the optimum compromise between life cycle costs for the SSC performance, availability, maintainability and safety.
- The plan must address:
  - In-house processes, skills and infrastructure necessary for support and maintenance of the SSCs.
  - Identification of the items that present the greatest risk from obsolescence;
  - Consideration of the need for component, material or SSC requalification following item substitution as a "Like-for-Like, Equivalent" or an "Alternative" as specified in Configuration Control policies and procedures

- **Obsolescence Planning**
  - The plan must take into account the technology, complexity, cost and operational considerations of the SSC.
  - The plan should record the chosen option for each SSC, with reasons for the choice. It may be appropriate to apply different management options to different components of the same SSC and the choices should be regularly reviewed to ensure that they are still appropriate.
  - The essential factor in choosing between options is optimum value for cost over the life of the SSC while taking account of cash flow constraints.
  - Regardless of the option chosen, the associated costs should be included in the cost of ownership and recorded in the life-cycle management plan
- **The two main strategy options are:**
  - Reactive Strategy: react to problems of obsolescence as and when they occur
  - Proactive Strategy: develop and implement an obsolescence management plan in advance

- **Reactive strategy - Do nothing until the need arises, then**:
  - The SSC has been procured to satisfy an operational need, has a finite duration and no further purchases are planned.
  - The probability of obsolescence is very low, e.g. low technology SSCs;
  - The SSC is dependable and can be supported throughout its service life from available spares;
  - There are dependable OEM guarantees for Replacements, Service and Spares
  - **Parts Search Cannibalization Repair Design Change**
- **Proactive Strategy Options**
  - Design considerations
  - Technology transparency
  - Obsolescence monitoring
  - Planned system upgrades
  - Lifetime buy
- A trigger for the creation of a plan is an Obsolescence Notice from a manufacturer or vendor. We need to be tracking these notices and our chosen option…

Configuration Control

One of the worst things that you can do at a mature, operating facility is allow changes to the design basis that, though the Law of Unintended Consequences, causes a failure that prevents the facility from operating.

– Corollary – Smart People Sometimes Do Dumb Things.

Configuration Control Policy

- Configuration management (CM) is defined as a process for establishing and maintaining consistency of a configuration item's performance, functional and physical attributes, and its documented configuration with its requirements, design and operation information throughout its lifetime.
- Configuration management control begins with baselining of requirements, the Design Criteria Document (DCD and DCN) process, and ends with decommissioning of equipment in the operational SNS.
- Responsibility for Configuration Control of Systems, Structures, Components and Software (SSCS) resides with the System Engineer.

Configuration Control Objectives

- To document and provide full evidence of an SSCS's previous history (when available) and present configuration including the status of compliance of an item to its physical and functional requirements.
- To ensure that staff who operate, use, repair or maintain an SSCS or who have the potential to affect its configuration use correct, accurate, and current documentation.
- To ensure that new designs and changes to existing designs for systems, structures, components and software utilize best engineering practice, follow from an approved set of specifications, and are appropriately documented.
- To ensure that the deployment of a new SSCS or a change to an existing SSCS is authorized.
- To ensure that the impact on performance due to the deployment of a new SSCS or a change to an existing SSCS is fully understood, and that the risks associated with the deployment are considered.

Configuration Management Policy

SNS-OPM 9.A-1 SNS Configuration Management Policy

Configuration Identification

Configuration Change Management

Configuration Status Accounting

Configuration Verification and Audit

Commercial Off-The-Shelf, Non-Developmental Items, and Commercially Available Software

Procedures for Design Development and Design Change

SNS-OPM 9.A-2 SNS Design Development Procedure

SNS-OPM 9.A-3 SNS Design Change Procedure

Summary

- The SNS has an evolving Reliability Program
- We are making good progress
- We have exceeded our Near-Term goal of 90% Availability.
- We realize that we are "young" and that we have not reached Terminal Mortality or Obsolescence for many systems.
- We realize the need to manage our accelerator configuration to