RCM++ Version 2020 First Steps Example

This example provides a quick introduction to the RCM++ software by allowing you to experiment with the application's data management, analysis and reporting features.¹ These instructions were prepared with RCM++ 2020 but you can perform the same steps in previous versions back to Version 9. The appearance of a few icons and screenshots will vary slightly.



A Note About RCM Terminology in the Software: RCM++ combines RCM capabilities and FMEA capabilities together in the same software interface. Although there are many similarities between the two analysis methodologies, there are some basic differences in the terminology that affect the application interface. Note that:

- FMEA and Functional Failure Analysis: Regardless of whether you are performing an RCM analysis or an FMEA, all of the information related to the functions and failure modes will be displayed in the FMEA tab of the Analysis panel, and you will use the commands in the FMEA tab of the ribbon to manage this information. In other words, the term "FMEA" is often used within the software interface in place of "functional failure analysis."
- Functional Failures, Failure Modes and Causes: Although the property names within the software are fully configurable to fit the specific analysis terminology used by your organization, the ribbon commands, icons and window names are not. When a name is not configurable, the term "Failure" is used for the second level in the analysis hierarchy and "Cause" is used for the fourth level. If you are performing a functional failure analysis, you might refer to these levels as the "Functional Failure" and "Failure Mode."

1.1 Open an Existing Database

If you haven't started RCM++ already, choose **Start > All Programs > ReliaSoft >** and then select the RCM++ application.

When you launch RCM++, the Backstage view (File tab) is the first view you will see. This Backstage view provides a quick way to create and open databases. In ReliaSoft desktop applications, *standard databases* are Microsoft Access® databases. These are easy to create and maintain without any special IT infrastructure or support, but there are limitations to the amount of data they can store and the number of users who can access the repository simultaneously. *Enterprise databases* require implementation of Microsoft SQL Server® or Oracle® (which require separate licensing, support and maintenance), but are a more robust platform that can store much more analysis information in the same database and support access by many more simultaneous users.

^{1.} For this example, you will work with a project that contains part of an RCM analysis for a standard pump. The analysis was performed using the RCM logic diagrams published in the SAE JA1012 guidelines.

For this example, you will use a standard database that is installed with the software (called "RCM20_Examples.rgz20") that contains several sample projects. (If you are using Version 2019, the file is called "RCM19_Examples.rgz19," and so on.) To access this file, choose **File > Help**, click **Open Examples Folder**, then browse for the file in the RCM sub-folder.

Tip: To preserve the integrity of the shipped example files, the software creates a copy of the file each time you access a repository in the Examples folder. The copy has the same name as the original file and is saved in the default documents folder for your computer (e.g., My Documents\ReliaSoft\Files). Use the copy to work on the example projects and save your changes. Any changes you make in the copy will not affect the original file.

1.2 View the Project Properties

In all ReliaSoft desktop applications, *projects* give you the flexibility to manage your analyses to fit the particular needs of your organization. You can have one or many projects in the same database.

Every RCM++ analysis within a given project will have the same configurable settings, including the fields that are enabled/disabled in the interface and reports, the rating scales or questions that are available for risk assessment and the options that are available for codified information (such as FEC logic, task selection logic, etc.).

To save time and ensure consistency, these configurable settings can be set automatically based on predefined *profiles* that are managed by authorized users. They can also be viewed or modified directly in each individual project.

• Select the RCM - Pump Analysis with Simulations project in the Project Manager and choose Project > Management > Edit Project Properties to open the Project Properties window, as shown next.

💩 Edit Pr	oject Properties (Project:	RCM - Pump Ana	lysis with Simulations)	?	×					
General	Configurable Settings									
Name										
RCM - Pun	p Analysis with Simulations									
Descriptio	n									
In this project, an abbreviated RCM analysis is created for a standard pump as an exercise for the student to better understand how RCM++ is used to develop maintenance plans including task packaging.										
Remarks										
Disclaimer: to accurat	Disclaimer: Example projects are purely for illustrating software features and functionality. They are not intended to accurately represent any real physical process or real data.									
Proprietan	/ Label									
For Demor	stration Purposes only - does	not represent speci	fic equipment.		1					
FMEA Stru	cture		Select Profile from Library							
Effects Be	fore Causes	- 🖍	[Based on SAE RCM (4 Categories)]	-	- 🥒					
Draiget Cal										
RCM	egory				•					
L				Can	el					
Project Ow Last Updat	ner: HBM Prenscia ed: 11/5/2019 3:21 PM Use	er: HBM Prenscia								

As can be seen in the **Select Profile from Library** field, the configurable settings in this project are based on the SAE RCM (4 Categories) profile. This predefined profile is shipped with the software and can be used to quickly configure the project to use the data fields and logic diagrams specified in the SAE JA1012 "A Guide to the Reliability-Centered Maintenance (RCM) Standard" guidelines for RCM.

- Now click the Configurable Settings tab. This page provides one way that you can view (and edit) the configurable settings that have been copied into the current project from the predefined SAE profile. (Note that the settings are also accessible when you are working in the project by choosing Project > Management > Configurable Settings or by clicking any of the Configurable Settings icons.)
- As an example, click the View/Edit Settings icon for FEC Logic.

Tasks	
FEC Logic	_
Current Settings	- 🖍
Task Selection Logic	0
Current Settings	- 🎤

You can see that the project has been configured to use the 4-category failure effect categorization diagram from the SAE standard.



- Click **Cancel** to close the failure effect categorization logic window without saving any changes.
- If desired, you can click the other **View/Edit Settings** icons to see the rest of the configurable settings that have been predefined for this project. When you are finished exploring these settings, click **Cancel** to close the Project Properties window without saving any changes.

1.3 Open a Project

• With the RCM - Pump Analysis with Simulations project still selected in the Project Manager, open the project either by double-clicking the project name or by choosing **Project** > **Management** > **Open Project**.



The Project window is the main interface that you will use to perform your analyses. It is divided into two panels, as shown next.²

RCM - Pump Analysis with Simulation	ons ©						
📩 System Hierarchy					Properties Ask Disk	scovery F FMEA	
Name	10	1	<u>_</u>	F	Property Name	Value	^
🗉 💼 Pump_Centrifugal_MotorDrive			2	F	Identifiers		
Impeller and shaft sub- assembly				F	Image		
Key - Coupling					Name	Pump_Centrifugal_MotorDrive	
Lock nut Assembly - shaft					Category	🕪 No Category	
Key - Impeller					Part Number		
Slinger Ring - water					Supplier		
Wear plate					Application		
System Panel					Comments	-	Analysis P
					Keywords		
					Other Item Properties		
					Operation		
					Operating Time	20000 (hr)	
					Current Age	0 (hr)	
				_	Duty Cycle	1	-
The nierarchy Y Fit	erea view				Maintenance Group		~

The System panel displays the system hierarchy, which includes all items that have been defined in the project. The Analysis panel displays information and analyses associated with the item that is currently selected in the hierarchy. Depending on your preferences, these panels can be displayed side-by-side, or with one panel above the other.

1.4 View the Item Properties

The Properties tab in the Analysis panel displays the item properties fields that are enabled for the current project, along with some settings that can be used for reliability calculations (if desired) and information about when the item record was created and last updated.

You can click inside any field with blue text to edit it. Fields shown in italics cannot be edited, either because they are populated by the application or because they are based on inputs that you make elsewhere in the software.

• If the item properties are not already displayed, click the **Properties** tab at the top of the Analysis panel.

^{2.} If not all of the properties shown in this image are visible on your computer, you can show them by clearing the **Hide** reliability nodes on item properties option on the Settings page of the Application Setup window.

• As an example, click inside the **Part Number** field and type **PN9999**, as shown next.



• If desired, you can edit any of the other item properties. When you are finished exploring these properties, proceed to the next section.

1.5 View the Equipment Selection

RCM++ supports two configurable methods for evaluating potential risk and selecting which items will receive further analysis. The Risk Discovery tab displays the questions or ratings that have been defined for the current project. For this example, the project uses a set of four yes/no questions to select which equipment should receive RCM analysis.

Note: A project can also be configured to use the Risk Ranking method for equipment selection (which uses a set of configurable rating scales). This is determined by the option that is selected in the Risk Discovery area on the Configurable Settings tab of the Project Properties window (Use Risk Discovery Questions or Use Risk Discovery Ratings).

• Click the **Risk Discovery** tab in the Analysis panel to view the equipment selection analysis for the pump.

RCM - Pump Analysis with Simulati	ons	Θ									
System Hierarchy							Properties	Aisk Discovery	F FMEA		
Name	1	Ø		4	F	1 [Label	Question		/ Response	/ Comments
Pump_Centrifugal_MotorDrive Impeller and shaft sub- assembly			4	2	F		Safety	Could failure affect safety other hazardous consequ	y or have ences?	No	
Key - Coupling					_		Detectability	Could failure be undetect likely to be detected duri operation?	able or not ng normal	No	
Key - Impeller Slinger Ring - water Wear plate						Operational	Could failure have signific operational impact?	cant	Yes	Failure could interfere with the performance of othe equipment in the manufacturing line.	
							Economic	Could failure have signific economic impact?	cant	Yes	Failure could result in lost production.
🕂 Hierarchy 🌱 Filt	ered ۱	/iew					✓ Mark item for	more detailed analysis			

In this utility, you can click inside the **Response** column to toggle the answer between "Yes" and "No." The label will be displayed in green to indicate a "No" answer (not critical) or in red to indicate a "Yes" answer (critical). If desired, the team can use the **Comments** column to record any additional information relevant to the responses.

• To see the colors change, click inside the **Response** column to toggle both of the current "Yes" answers to "No." You can see that the **Mark item for more detailed analysis** check box is cleared automatically and the risk discovery icon in the System panel changes from red to green.

- Now click the check box to select the option again. You can see that the risk discovery icon in the System panel changes back to red. In other words, the application will automatically update this icon based on your answers to the selection questions, but you have the option to override this setting if desired.
- Before proceeding to the next section, click inside the **Response** column again to toggle the Operational and Economic answers back to the original "Yes" answers.

1.6 View the Functional Failure Analysis

The FMEA tab in the Analysis panel allows you to view/edit the functional failure analysis for the currently selected item.

• Click the FMEA tab to view the functional failure analysis for the pump. There are now four tabs at the bottom of the Analysis panel. Each tab displays the analysis information in a different way to facilitate data entry and decision making.



1.6.1 The Hierarchy View

The hierarchy view displays the analysis records in a hierarchical tree, which tends to be good for viewing a lot of information in a small amount of space. It can be especially useful when copying and pasting data or when scanning the analysis to find a particular section.

• If the hierarchy view is not already displayed, click the Hierarchy tab to view it.

• Double-click the "Move a given fluid..." function record at the top of the tree. The function properties window will appear, as shown next.

₩ Edit Function					×
Home Navigate					
Add Function Add Failure	Add Effect Add Cause	Configurable Settings	Spelling Attachments Change Log Cools		
Function					
Function	Move a given fluid while	maintaining an a	acceptable leak rate	at the Shaft	
Name	*				
Keywords 🕞					
Associated Records					
Item	Pump_Centrifugal_Motor	Drive			
- History					
Created By					
Date Created	4/3/2012 11:44 AM				
Last Updated By					
Last Updated	4/3/2012 11:44 AM				
Function					
			ОК	Cano	el
Editing function properties					:

- With the properties window still open, click the first functional failure ("Functional Failure: External leak rate at the Shaft...") in the FMEA hierarchy. You can see that the window updates automatically to display the properties for the record that is currently selected.
- If desired, you can continue clicking different records in the hierarchy to view their properties. Note that this approach works for any record type except tasks, which have a specialized interface to facilitate integration with other ReliaSoft applications (such as BlockSim). When you are finished exploring, click **Cancel** to close the properties window without saving any changes.
- Now create a new branch in the hierarchy by right-clicking the "Move a given fluid..." function and choosing Add Function from the shortcut menu.
- In the properties window, type "New Function" in the **Function** field and then click the **Add Failure** icon at the top of the window.



- The properties window is now prepared to define a new functional failure. In the **Functional Failure** field, type "New Functional Failure" and then click the **Add Effect** icon.
- Now you can define a new effect. In the **Effect** field, type "New Effect" and then click the **Add Cause** icon.



• Now you can define a new failure mode. In the **Failure Mode** field, type "New Failure Mode" and then click **OK** to close the properties window.

You can see that there is a new branch at the bottom of the hierarchy with the new records you just created.

E New Function		
-X New Functional Failure		
- New Effect		
⊖-? New Failure Mode		
⊢ Reliability Policy - Default (Not Set)		
- Tasks		

1.6.2 The Worksheet View

The worksheet view provides an alternative way to view/edit the same analysis information displayed in the hierarchy view. This view allows you to type directly into the worksheet cells and tab through the analysis as you would in a spreadsheet application such as Microsoft Excel®.

• To give more space in the Analysis panel before switching to the worksheet view, first choose View > Workspace Layout > Hide System Panel.

4	L

• Now click the **Worksheet** tab at the bottom of the Analysis panel.

R	CM - Pump Ana	alysis with Simulatio	ns 🛛						
	Properties	🛕 Risk Discovery	F FMEA						
Function				Functional Failure		Effect	Failure Mode		
1	Move a given f an acceptable	luid while maintaining leak rate at the Shaft	Functional Fail above the acce Failure Mo	ure: External leak rate a eptable rate ode: Packing worn	t the Shaft is	Loss of fluid to the ground / sewer	Packing Gland too tight or loss of lubrication		
2			Incorrect installation						
3			Wear Out - Normal wear						
4			Functional Fail the acceptable Failure Mo	ure: Leak rate at the Sh rate ode: Packing mis-adjust	aft is below ed (too tight)	Packing prematurely worn	Packing bolts over tightened		
5			Functional Fail Seal Failure Mo	ure: Catastrophic failur ode: Seal/Packing blowd	e of the Shaft out	Process impact and Loss of fluid to the ground / sewer	Induced - Gland Follower corrosion / failure		
6							Induced - Gland Follower stress / failure		
7	New Function		New Effect	New Failure Mode					
	Function O Attachments								
	Header		Hierarchy		Worksh	eet	F iltered		

• Double-click inside the first function description. You can see that the cell switches from "select mode" (with a blue background) to "edit mode" (with a white background and a blinking cursor so you can modify the text).

Function	
Move a given fluid while maintaining an acceptable leak rate at the Shaft	2

• Press ENTER. Note that the blinking cursor now appears in the second function description. Press ENTER again and the application will automatically create a new row so that you can type a new function description at the bottom of the worksheet, as shown next.



• This time, instead of typing the function description, you can use the Select Existing utility to reuse text that is already stored in the database. While the cell is in "edit mode," click the **Select Existing** icon.



- In the Select Existing window, look at the Project Filter, Item Filter, Record Filter and Phrase Sets dropdown lists. These lists allows you to specify the source(s) for the list of existing descriptions that you can select from.
- Look in the list of descriptions and double-click any existing description from the list. This automatically enters the selected text into the worksheet cell. This convenient feature is available for text fields throughout the application.
- If desired, you can continue to explore the worksheet view by adding and editing records. When you are finished, proceed to the next section.

1.6.3 The Filtered View

The filtered view allows you to generate sortable lists of different types of records. For example, you can view a list of all failure modes in the analysis, all tasks sorted by type, etc.

- Click the Filtered tab at the bottom of the Analysis panel.
- From the **Filter By** drop-down list at the upper right corner, choose **Causes**. The Analysis panel will change to display all of the failure modes that have been defined in the current analysis (sorted in alphabetical order by default).

RCM - Pump Ana	alysis with Simulati	ons ©								
Properties	🛕 Risk Discovery	F FMEA								
Filter By Causes -										
Failure Mode										
1 ? Incorrect in	istallation									
2 🥐 Induced - G	Gland Follower corros	ion / failure								
3 🥐 Induced - G	Gland Follower stress	/ failure								
4 🥐 New Failur	e Mode									
5 🥐 Packing bo	lts over tightened									
6 🥐 Packing Gla	and too tight or loss o	flubrication								
7 🕐 Wear Out - Normal wear										
🗌 Header		击 Hierarchy		Worksheet	Filtered					

- You can sort the records by clicking any of the column headers. You can also double-click any record to open its properties window.
- If desired, you can continue to explore the filtered view by changing the filter or sorting by different columns. When you are finished, click the **Hierarchy** tab to return to the hierarchy view.
- To show the System panel again, choose View > Workspace Layout > Split Panels.

1.7 View the Failure Effect Categorization

The FEC column displays the failure effect categorization for each failure effect. (If the FEC column is not displayed on your computer, right-click a column header in the FMEA and choose **Customize Columns**. In the Customize Columns window, select the **FEC** column, and then click **OK**.)

• With the FMEA hierarchy displayed, double-click inside the FEC column for the "Loss of fluid to the ground / sewer" effect.

RCM - Pump Analysis with Sin	nulations ©												
📩 System Hierarchy 🕞	FMRA				Properties	🔥 Risk Discovery	F FMEA						
Name 💄 🖉 🚹 🚹 F			Description					d)	FEC	^			
🖃 💼 Pump_Centrifugal_Motor	Drive		2	F	😑 🕨 Move a giv	en fluid while maintaining	g an acceptab	le leak rate at the Shaft					1
E Impeller and shaft sub-	assembly			F	-× Function rate	ial Failure: External leak r	rate at the Sh	aft is above the acceptable					
Key - Coupling					⊨. Loss	of fluid to the ground / s	ewer					2	
Lock nut Assembly - shaft			⊨-? Pa	acking Gland too tight or l	loss of lubric	ation				_	5		
Key - Impeller					- Reliability Policy - Induced - Packing Gland too tight / loss of lub								
Slinger Ring - water						式 CM - RR - Packing Gl	land Asm						
Wear plate						A 2PW [WB2 (0.612, 83	30077)]						
						Tasks							
						-🛃 Training; Mainter	nance - Prope	r Packing					
						IN - Inspection fo	or leaks						¥
🕂 Hierarchy	Filtered	/iew			- Header	🕂 Hierarchy	[Worksheet	T	Filtere	d		

The Failure Effect Categorization window displays the FEC logic diagram that is being used for all RCM analyses in the current project. There are two ways to select the category:

- 1. Answer each individual question until a category is highlighted.
- 2. Select a category directly from the Category drop-down list in the bottom right corner.

If desired, you can use the text fields on the right side of the window to record any additional information relevant to a particular response (use the **Answer** fields) or the categorization overall (use the **Remarks** field). The following picture shows the failure effect categorization that has been performed for the "Loss of fluid..." effect.



- To see the categorization change, select **No** for Question 1. When Question 3 becomes enabled, select **No** again. You will see that the "4 Hidden Economic Consequences" category is now highlighted.
- To return to the original categorization, choose 2 Evident Economic Consequences from the Category drop-down list.
- Click **Cancel** to close the window without saving any changes.

1.8 Assign the Reliability and Corrective Maintenance Policies

For this project, the team is using a combination of RCM design logic and availability/cost calculations to select the appropriate maintenance strategies. As an example, you can complete the sample analysis by entering the data for the "Wear Out - Normal wear" potential failure mode.

• Right-click the **Reliability Policy** node under the "Wear Out - Normal wear" failure mode and select **Apply Existing URD**.



A universal reliability definition (URD) is a resource that describes a set of reliability and maintainability properties. It can be shared by all analyses in a given project. You have the option to create these resources as needed while performing an analysis, or select to use resources that have already been defined.

• The Select Resource window displays a list of all the URDs that have already been created for this project. Select **Wear Out - Normal wear** and click **OK**.

۲	B		□ ×					
Ho	me	Administration				^		
Shor	w All	Show Only Unused Duplicates Display	Image: Show Local with the show Slobal with the show Slobal with the show Reference bisplay Image: Show Local with the show Slobal with the show Reference withe show Reference withe show Reference with the show Reference wit					
Show	n All		1			- + / ×		
		URD Name	Failure Model	Failure Model Information	Corrective Task	Scheduled Tasks		
т		RBC	RBC	R B C	RBC	RBC		
:	0	Broken impeller vane	Broken / chipped impeller vane	WB2 (2.96, 23463)	CM - Replace impeller	Inspect for broken / damaged imp		
1	\bigcirc	Low Risk	Very Low Risk Item	WB2 (1.48, 174994)				
1	۲	Wear Out - Normal wear	Wear Out - Normal - Model	WB2 (3.5, 8500)	CM - RR - Packing Gland Asm			
1	0	Gland Follower corrosion / failure	Gland Follower corrosion - failure	WB2 (3.63, 15850)	CM - RR - Gland Follower	OC-Inspection for corrosion		
2	0	Operator error-packing set-up	Operator error - packing set-up	WB2 (0.43, 148132107)	CM - RR - Packing Gland Asm	Training; Maintenance - Proper Pa		
	0	Induced - Packing Gland too tight	2PW	WB2 (0.612, 830077)	CM - RR - Packing Gland Asm	Training; Maintenance - Proper Pa		
	0	Gland Follower stress / failure	Gland Follower stress failure URD	WB2 (1.55, 125791)	CM - RR - Gland Follower	PM - Gland Follower		
8	0	Induced - Incorrect installation	Incorrect installation Model	WB2 (0.797, 1118435)	CM - RR - Repack, reconditio	Training; Maintenance - Proper Pa		
1	0	Impeller vane wear	Impeller - vane wear	WB2 (1.16, 105891)	CM - Replace impeller	PdM - Track Flow Rate		
1	0	Packing Gland too tight / loss of lu	2PW	WB2 (0.612, 830077)	CM - RR - Packing Gland Asm			
	is i	Show Local Resources All				<u> QK</u> <u> C</u> ancel		
URD		All All				.:		

• When you return to the FMEA hierarchy, you can see that this URD defines the probability of failure for this mode (using a 2-parameter Weibull distribution with Beta = 3.5 and Eta = 8,500 hours) and the unplanned (corrective) maintenance logistics and costs.

🗄 🥐 Wear Out - Normal wear
占 Reliability Policy - Wear Out - Normal wear
–📰 CM - RR - Packing Gland Asm
- [Wear Out - Normal - Model [WB2 (3.5, 8500)]

• Double-click the "CM - RR - Packing Gland Asm" task to open the Maintenance Task window for the corrective maintenance task, as shown next.

Maintenance Task			
Task Name			
CM - RR - Packing Gland Asm			
	•		
Corrective Properties			
🖃 🛃 Task Scheduling			
Start corrective task	Upon item failure	•	,
🖃 🌆 Basic Repair Properties			
- Task duration (hr)	Emergency Repack [3]		•
🕂 🏧 Teams for task			
- Team (Priority 1)			•
- Crew	Pump EM Crew - \$200/Hr		•
Logistic delay (hr)	Crew Response Time [NOR (0.75, 0.2)]		•
⊢ Team (Priority 2)			•
No crews are selected.			
占 📳 Spare Part Pool			•
- Pool	Pump Gland Reconditioning Kit (\$3000)		•
 Spares in pool 	Unlimited		
 Logistic time for spare acquisition 	Default - Immediate Availability		ł
Quantity requested by task	1		
🗄 🚰 Task Consequences			
E 2 Restoration			
₩ <u></u>			
<u>Us</u>	eed by 3 items 🕢 🖉 OK	Cancel	
🖁 Local Resource	Editing corrective task	propertie	29

- As you can see, the task includes the following properties:
 - The "Emergency Repack" corrective task will be performed upon item failure and the task duration is 3 hours.
 - When the pump has to be correctively repaired, there is a delay before the emergency maintenance (EM) crew can respond, and the cost for their time is \$200 per hour. The "Pump Gland Reconditioning Kit" used to repair the pump costs \$3,000.
- Click Cancel to close the window without saving any changes.

1.9 View the Maintenance Task Selection

The **Tasks** node in the FMEA hierarchy provides access to the tools available in RCM++ to assist with maintenance task selection. It also displays the maintenance tasks that have been defined in the analysis for a particular failure mode.

• To open the Task Manger window for the "Wear Out - Normal wear" failure mode, double-click the **Tasks** node under that record.

🗄 🅐 Wear Out - Normal wear
🔄 Reliability Policy - Wear Out - Normal wear
-🎢 CM - RR - Packing Gland Asm
Wear Out - Normal - Model [WB2 (3.5, 8500)]
– Tasks

The top section of the Task Manager window displays the failure effect categorization for this failure mode, along with the maintenance task selection questions that are applicable for that FEC. (This is based on the configurable maintenance task selection logic that has been defined for all RCM analyses in the current project.)

You can see that the team has indicated that a scheduled restoration task (i.e., a planned preventive maintenance) may be applicable and effective to address this potential failure mode.

🛞 Task	Manager											×
		y Y	X. V.	R		6			S			
Add Task	Add Existing Tasks	Edit Task	Delete Task	Edit URD	Edit Mode	el Edit C	Corrective Fask	Effect Categorization	Simula	te		
	Tasks	5			Related F	Records		Tools				
FEC: 2 - Ev	ident Econon	nic Conseq	uences									
		Questio	on			Yes/No		Ex	p l anati	ion		
4: Is a sche doing?	: Is a scheduled on-condition task technically feasible and worth loing? No											
5A: Is a sc doing?	heduled restor	ation task t	echnically	feasible an	d worth	Yes						
5B: Is a sc doing?	heduled discar	d task techr	nically fea	sible and w	orth	No						
Run to Fai	ilure:	(Cost per	Operating	Time 1.5	399		Availa	bility	0.9996		
Tasks												
	Name		Туре	Operatin	g Cost Co	ost per O	perating	lime	A	vailability		
[[01	0	
										UK	Cano	21
Task Mana	ger											

The preventive maintenance task that the team wants to consider for this issue has already been saved as a resource in the sample database. To select it, choose **Add Existing Tasks**.



The Select Resource window displays a list of all the scheduled maintenance tasks that have already been created for this project. Select **PM - RR - planned pump** and click **OK**.

					Select Reso	urce						×
Но	ome	Administration										^
Sho		Show Only Unused Duplicates Display	how Local how Global how Reference		Batch Add 10 🛟 Duplicate 👻 Edit	View (Delete	Trace Usage Selecto	Make Global			
Sho	w All											$F \times X$
		Task Name	Task Type		Ta	ask Freque	ncy		A Du	ction ration	Duration Informa	Model ation
т		RBC	R B C		RBC				RBC		RBC	
:		Inspect for broken / damaged i	Inspection (IN)		Fixed time interval based on calendar time Impeller inspection wear / corros				NOR (0.5, 0.1)			
1		Training; Maintenance - Proper	Training (Tra)		Fixed time inter	rval based	on calenda	endar time Training Week 4			40	
:		PdM - Track Flow Rate	PdM - Online Monitori	ing (OLM)	Fixed time inter	rval based	on calenda	ar time	Flow Rate Track	ing	NOR (0.25,	0.1)
1		OC-Inspection for corrosion	Condition Based (OC))	Fixed time inter	rval based	on item ag	ge	Impeller inspect	ion wear / corros	NOR (0.5,	0.1)
E		PM - Gland Follower	Repair/Replace (RR)		Fixed time inter	rval based	on calenda	ar time	PM - Gland Follo	wer	NOR (3, 1)	
:		IN - Inspection for leaks	Condition Based (OC))	Fixed time inter	rval based	on calenda	ar time	OC-Inspection		NOR (0.25,	0.1)
2	\checkmark	PM - RR - planned pump	Repair/Replace (RR)		Fixed time inter	rval based	on calenda	ar time	Planned Repack	and Condition	1.5	
1		Training; Maintenence	Training (Tra)		Fixed time inter	rval based	on item ag	ge	Training Week		40	
•												Þ
										ОК	Cano	:el
Sche	eduled	Tasks Show Local Resources	All									:

Notice that the task is now visible in the Tasks section of the Task Manager window. Double-click the task to view its properties.

Repair/Replace (RR)	
xed time frame based on calendar time	•
our (hr)	•
task package	
anned Repack and Condition [1.5]	
4 Crew \$180/Hr	
efault - Immediate Availability	
mp Gland Reconditioning Kit (\$3000)	
nlimited	
efault - Immediate Availability	
oy 1 item	Cancel
Editing scheduled task r	propertie
	wed time trame based on calendar time sur (hr) task package anned Repack and Condition [1.5] 4 Crew \$180/Hr afault - Immediate Availability imp Gland Reconditioning Kit (\$3000) alimited afault - Immediate Availability by 1item Image: OK Editing scheduled task p

As you can see, the spare parts logistics are the same as they were for the corrective maintenance. Notice, however, that the repair time duration is only 1.5 hours and that the planned maintenance (PM) crew is less expensive (as it is only \$180 per hour).

You will also notice that the scheduled task interval is temporarily set to 1 as a placeholder for the actual value. You can use the Failure Modes and Reliability Analysis (FMRA) interface to calculate the optimum replacement time. The FMRA interface is available in multiple ReliaSoft applications (including BlockSim, XFMEA, RCM++ and RBI) and it facilitates a variety of system reliability, availability and maintainability calculations.

After you are done viewing the properties, close the Maintenance Task and the Task Manager windows.

- To display the FMRA for the sample project, View > Show > Show FMRA.
- With the system item selected, open the Optimum Replacement window by choosing FMRA > Calculations > Optimum Replacement.

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The Optimum Replacement window displays all of the maintenance tasks that are defined in the current project. You can choose to calculate the optimum replacement time for a single task, or you can select multiple tasks to optimize together. For this example, you will perform the calculation for a single task, where the planned replacement cost is \$6,320 and the unplanned replacement cost is \$11,300.

- Select the Wear Out Normal wear failure mode and enter the planned replacement cost and the unplanned replacement cost.
- Click Calculate to open the Optimum Replacement Calculations window. Choose the Individual Blocks can use different times option, then click OK. In the Optimum Replacement window, notice that the Optimum Replacement Time column now shows the calculated result of ~7,116 hours.

				C)ptimu	ım Replaceme	nt					×
Cut			•	βη σμ	•.	1 10						
Delete Paste	Displa Parent I	y tem	Clear Values	Calculate (Cost vs Time Plo	. Create Maint ot Task(s)	enance *					
Edit	Prefere	nces	Costs		1	Fools						
Available Item Available Item Packing Gland	s too tigh		Iten	n Name	Rep	Planned lacement Cost	Un Replac	planned cement Cost	Optimum Replacement Time (hr)	Rep per	placement r Unit Time	Cost ≥ (hr)
Induced - Inco	orrect ins	\rightarrow	Wear Out -	- Normal wear		6320		11300	7115.3698		1.3147	
Wear Out - N Induced - Pac Induced - Gla Induced - Gla Induced - Gla Vane wear Broken impelle Key - Coupling Lock nut Asse Key - Impeller	rmal wear king nut nd Follow nd Follow er vane g mbly - sh											
Slinger Ring -	water	Repla	acement Cos	t Per Unit Time	(hr)	1.3147						

• Close the Optimum Replacement window, then return to the system hierarchy view and click the FMEA tab to open the FMEA.

• Open the Task Manager window, then open the "PM - RR - planned pump" task and enter the calculated time in the **Fixed interval** field.

-	🚽 Task Scheduling			
	— When is this task performed?	Fixed time frame	based on calendar time	•
	 Fixed interval 	7116		
	— Unit	Hour (hr)		•
	Override task scheduling properties	s with a task package		

• Close the Maintenance Task window, and then click **Simulate** in the Task Manager window to determine which maintenance strategy (run-to-failure or preventive maintenance) will provide better results.

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• When prompted, accept the simulation value for the hours of operation (20,000), and select to run 1,000 simulations and then click **OK**. When the simulation completes, the run-to-failure (corrective maintenance only) results are displayed above the table and the results for the preventive maintenance strategy are displayed with the task. As you can see, the availability is very similar between the run to failure and PM options, but the cost per operating time is less when using PM. For a mission of 20,000 hours, this will result in significant cost savings.

🛞 Task	Manager													×
			¥ V	R			5				S			
Add Task	Add Existing Tasks	Edit Tas	k Delete Task	Edit URD	Edit M	1odel	Edit C	orrective Task	Effect Categorizat	ion	Simulate			
	Tasks	5			Relate	ed Re	cords		т	ools				
FEC: 2 - Ev	ident Econon	nic Cons	equences											
		Ques	tion			Ye	es/No			Exp	lanation			
4: Is a sche doing?	: Is a scheduled on-condition task technica oing?				nd worth		No							
5A: Is a sch doing?	5A: Is a scheduled restoration task technically feasible and worth doing? Yes													
5B: Is a sch doing?	neduled discar	d task teo	chnically fea	sible and w	orth		No							
Run to Fai	lure:		Cost per	Operating	Time	1.530	D		Av	ailab	ility 0.9	996		
Tasks														
	Name		Туре	Operatin	ıg Cost	Cost	t per Oj	perating	lime 🛛		Avai	lability		
PM - RR - p	planned pump		RR	2.1297	E+04		1.	0648			0.9	9997		
											O	к	Can	cel
Task Mana	ger													

• Click **OK** to close the window.

1.10 Calculate System Reliability and Availability

Return to the FMRA view so you can simulate the entire system and calculate the availability with the potential failure modes and maintenance tasks that are currently specified.

• To select which columns in the FMRA to show on your computer, right-click a column header in the FMRA and choose Customize Columns. Enable only the fields that are shown in the following picture (Reliability Policy, Simulation Results Status, Operating Cost, Cost per Operating Time and Availability), then click OK.

Customize Columns			×
Column	Description	^	
Reliability Policy	How the reliability will be calculated (inherit, default or the name of the URD).		
Mirror Groups	Indicates whether the cause is a member of a mirror group.	_	
Analytical Results Status	Green when analytical results are current, red when they are not current.		
Target Reliability	Target Reliability		
Reliability (Analytical)	Displays the record's calculated reliability at the system's specified operating time.		
Probability of Failure (Analytical)	Displays the record's probability of failure at the system's specified operating time. This is the inverse of reliability (1-R).		
Mode Ratio	Normalized mode ratio of the item's probability of failure (for criticality analysis).	h
✓ Prob ofLoss	Displays a factor from 0 to 1 that describes the probability that this failure mod would result in a system failure.	e	
Criticality	Displays the calculated criticality value. (This column must be displayed when the moderatio or probability of loss is displayed.)		
Simulation Results Status	Green when simulation results are current, red when they are not current.		
Operating Cost	Displays the total costs that accrued during the simulation.		
✓ Cost per Operating Time	Displays the operating cost divided by the total operating time.	_	
TargetAvailability	TargetAvailability	_	
🗹 Availability	Displays the average availability (i.e., uptime divided by total operating time).	~	

- To give more space in the System panel before calculating the costs, choose View > Workspace Layout > Hide Analysis Panel.
- Choose FMRA > Calculations > Simulate (Availability).
- Use the same operating time of 20,000 hours and the same number of simulations (1,000), and then click **OK**. The calculated results are shown next.

RCM - Pump Analysis with Simulations					
🕂 System Hierarchy					
Name	Reliability Policy		Operating Cost	Cost per Operating Time	Availability
Pump_Centrifugal_MotorDrive	Inherit		3.7202E+05	18.6012	0.9150
⊨ ► Move a given fluid while maintaining an accepta	Inherit		1.1000E+05	5.5002	0.9994
+X Functional Failure: Ext. leak at input shaft	Inherit		7.1363E+04	3.5682	0.9997
- ? Packing Gland too tight / loss of lubrication	Induced - Packing Gland too tight / lo		2.5830E+04	1.2915	1.0000
- ? Induced - Incorrect installation	Induced - Incorrect installation	-	2.4870E+04	1.2435	1.0000
🖓 Wear Out - Normal wear	Wear Out - Normal wear		2.0664E+04	1.0332	0.9997
-X Functional Failure: Leak rate at the Shaft is b	Inherit		2.4757E+04	1.2378	1.0000
Induced - Packing nut over tightened	Operator error- packing set-up		2.4757E+04	1.2378	1.0000
⊢× Functional Failure: Catastrophic failure of the	Inherit		1.3884E+04	0.6942	0.9997
- ? Induced - Gland Follower corrosion / failure	Gland Follower corrosion / failure		1.2963E+04	0.6481	0.9998
Induced - Gland Follower stress / failure	Gland Follower stress / failure		921.5216	0.0461	1.0000

You can see that the estimated availability with the current maintenance strategy is about 92% and the cost per operating time is \$18.60. For a period of 20,000 hours, that is a total operating cost of approximately \$372,024. Packaging the tasks into more efficient intervals may provide better results, as discussed next.

1.11 Using Task Packaging

For a given project, you can use the Scheduled Task Packaging window to review all of the tasks that have been proposed to be performed at fixed intervals, choose which ones to incorporate in the final maintenance plan and, if desired, group tasks into packages for the most efficient allocation of resources.

• Return to the system hierarchy, then choose System Hierarchy > Tools > Task Packaging.

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This utility provides several flexible tools to help you select the most effective maintenance packaging plan. For this example, you will use the time clusters feature, which automatically groups tasks into a specified number of intervals.

• Under "Time - Clusters" enter **3** and click **Time - Clusters**. The utility will automatically propose the three packages shown next.

🚸 Scheduled Task Packaging (Project: RCM - Pump Analysis with Simulations)											×	
Type Zone Access T 3	rs 🔣 Ung X Del	Ungroup Selected Rem X Delete Empty Packages Star		move Level		Tools	L Pac	°© Ipdate kages ≁		O Display		
Group By		Manage Groups										
Description	Flag Task	Туре	Start Interv	al (hr)	Interval (h	ır)	End Inter	val (hr)	Zone	Access	St	atus
🖃 🎁 Interval: 730 - 2190			730		1309		2190					
— PdM - Track Flow Rate	PdM - Online Monit	oring			730							
— IN - Inspection for leaks	Condi Based	tion			1008							
Inspect for broken / damaged impeller vane	Inspe	tion			2190							
🖃 🎁 Interval: 7116 - 12650			7116		9322		126	50				
— PM - RR - planned pump	Repair ace	/Repl			7116							
 Training; Maintenance - Proper Packing 	Trainir	ng			8760							
 Training; Maintenence 	Trainir	ng			8760							
OC- Inspection for corrosion	Condi Based	tion			12650							
🖃 🎁 Interval: 330000 - 330000			330000)	330000		3300	00				
PM - Gland Follower	Repair ace	/Repl			330000							
Tasks Plot												

• Click the **Update Packages > Apply Changes** command on the ribbon to create these packages in the database to automatically override the task intervals for the affected maintenance tasks.



• Close the window, then return to the FMRA and simulate the results again. You can see that the availability is now around 93% and that the cost per operating time has decreased to \$7.15. For a period of 20,000 hours, that is a total operating cost of approximately \$143,078.

击 System Hierarchy	FMRA					
	Name	Reliability Policy		Operating Cost	Cost per Operating Time	Availability
🗄 🚞 Pump_Centrifugal_N	MotorDrive	Inherit		1.4308E+05	7.1539	0.9325
🖃 🕨 Move a given flu	id while maintaining an accepta	Inherit		1.1980E+05	5.9898	0.9914
Functional Fa	ilure: Ext. leak at input shaft	Inherit		7.8569E+04	3.9285	0.9925
? Packing Gl	and too tight / loss of lubrication	Induced - Packing Gland too tight / lo	-	2.5839E+04	1.2920	1.0000
-? Induced -	Incorrect installation	Induced - Incorrect installation	-	2.4951E+04	1.2476	1.0000
🖓 Wear Out	- Normal wear	Wear Out - Normal wear		2.7779E+04	1.3889	0.9926
-X Functional Fa	ilure: Leak rate at the Shaft is b	Inherit		2.4815E+04	1.2407	1.0000
🖓 Induced -	Packing nut over tightened	Operator error- packing set-up		2.4815E+04	1.2407	1.0000
-X Functional Fa	ilure: Catastrophic failure of the	Inherit		1.6412E+04	0.8206	0.9976
- ? Induced -	Gland Follower corrosion / failure	Gland Follower corrosion / failure		1.5502E+04	0.7751	0.9976
Induced -	Gland Follower stress / failure	Gland Follower stress / failure		909.7758	0.0455	1.0000

- To see what the results would be if there were four packages, return to the Task Packaging window. Select each package and click **Ungroup Selected**.
 - 0
- When all of the tasks are back to being unassigned, click **Delete Empty Packages** to clear the old groupings.



- Set the number of packages to 4 and click **Time Clusters** to automatically regroup the tasks into four packages.
- Click Apply Changes to save the new packages and override the task intervals.
- Close the window, then return to the FMRA and simulate the results again. You can see that the availability is now around 92%, and the cost per operating time has decreased to \$6.79. For a period of 20,000 hours, that is a total operating cost of approximately \$135,710.

📩 System Hierarchy					
Name	Reliability Policy	Operating Cost	Cost per Operating Time	Availability	^
🖃 💼 Pump_Centrifugal_MotorDrive	Inherit	1.3571E+05	6.7855	0.9222	J
- Move a given fluid while maintaining an accepta	Inherit	1.1265E+05	5.6327	0.9935	
Functional Failure: Ext. leak at input shaft	Inherit	7.3463E+04	3.6731	0.9937	
-? Packing Gland too tight / loss of lubrication	Induced - Packing Gland too tight / lo	2.5791E+04	1.2895	1.0000	
- 🤣 Induced - Incorrect installation	Induced - Incorrect installation	2.4957E+04	1.2479	1.0000	
-? Wear Out - Normal wear	Wear Out - Normal wear	2.2715E+04	1.1357	0.9938	
-X Functional Failure: Leak rate at the Shaft is b	Inherit	2.4800E+04	1.2400	1.0000	
-? Induced - Packing nut over tightened	Operator error- packing set-up	2.4800E+04	1.2400	1.0000	
⊢ Functional Failure: Catastrophic failure of the	Inherit	1.4392E+04	0.7196	0.9997	
- 🤣 Induced - Gland Follower corrosion / failure	Gland Follower corrosion / failure	1.3529E+04	0.6765	0.9997	
Induced - Gland Follower stress / failure	Gland Follower stress / failure	863.0519	0.0432	1.0000	v

• You can continue to experiment with the cost and availability calculations, if desired. When finished, proceed to the next section.

1.12 Generate a Report of the Analysis

RCM++ provides a complete set of reports for your analysis. Reports can be generated in Microsoft Word® and/or Excel, which provides maximum flexibility for customization and the ability to create HTML and/or PDF versions of the reports.

- To open the Reports window, choose **Home > Reporting > Reports**.
- The Select Items area (on the left) allows you to specify the item(s) from the system hierarchy that will be included in the report. Make sure that all seven items are selected.

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- The Available Reports area (in the middle) displays the report forms that are available to be included in the report document, while the Selected Reports area (on the right) displays the report forms that will be included in the new report you are generating now. Click the **Exclude All** icon (<<) to clear the Selected Reports area so you can start building the new report from scratch.
- In the Available Reports area, press **CTRL** and click each of the following report forms so they are all selected at the same time.
 - Under the Risk Discovery heading, select Risk Discovery Details (One per Item).
 - Under the RCM heading, select:
 - Functional Failure Analysis
 - Failure Effect Categorization (One per Effect)
 - Maintenance Task Selection (One per Cause)
 - Tasks
- Click the Select (>) icon to move all five of these report forms into the Selected Reports area.

Tip: You can also drag and drop or double-click the report form names to move them back and forth between "available" and "selected."

• Finally, select to generate the report as an **Excel Spreadsheet**. The Reports window will look like the one shown next.



• Click **Generate Report** and specify a name and location for the document. When you click **Save**, a progress bar will appear. After the report is complete, it will open automatically in Microsoft Excel. When you are finished reviewing the reports, close Excel and the Reports window.

1.13 Close the Repository

Congratulations! You have completed the First Steps Example for RCM++.

• To close the sample database, choose File > Close Repository.

Note that if you do not close the database, it will be closed automatically when you create or open a new one.