Solving the Impossible

Chrono™ User Guide

V 2.1 – October 2021

Chrono™
Moneyball for Project Management

Solving the Impossible

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Introduction: What is Chrono™ and What it Helps You Do

Chrono™ is a software tool that augments Microsoft Project® to help users build and maintain more credible schedules. The tool helps manage schedule risk in three ways:

1. Supporting three-point estimates helps identify tasks with significant variance affecting the timeline that might be candidates for further risk review and mitigation
2. Using statistical methods to emulate a Monte Carlo simulation of a project, Chrono™ helps predict schedules more reliably and provide an approximate statistical confidence for milestone dates based on the estimates provided – an excellent visual aid for discussions of schedule and risk with executives
3. By tracking schedule trends over time, Chrono™ uses Earned Schedule Management to provide feedback on how well a project is tracking against its predictions, allowing early intervention when necessary

The traditional scheduling practices that project managers have learned and used over the last 50 years are fundamentally flawed (for background see Why Traditional Schedules Fail) and produce overly optimistic predictions. This presents itself as schedules that seem credible but are nearly impossible to achieve as planned. A solution to this problem is schedule simulation using Monte Carlo methods, which produces more robust and credible predictions.

Although tools have been available for years to support Monte Carlo simulations, historically they have been expensive, complex, cumbersome, hard to use, and slow (simulations can take minutes or hours depending on the size and complexity of the project being analyzed). The "secret sauce" of Chrono™ is a mathematical acceleration of Monte Carlo – our patented TriCoBi™ algorithm – that decreases simulation time to seconds, providing project managers with real time results. Chrono™ integrates this technology into a tool most project managers already use, Microsoft Project™, and provides a simplified interface that provides easy access to Chrono™ features. Most computation is performed in the cloud and historical schedule information is securely retained there to facilitate trend analysis.

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Chrono™ leapfrogs last generation schedule risk management tools that were unavailable to most organizations and teams because they were expensive and hard to use. We built Chrono™ for ourselves, to help us manage our projects. Our goal was to make the tool cost-effective, fast, and simple to use. Our Chrono™ tool helps project managers better identify and address schedule risks and provide more sophisticated and useful schedule forecasts to sponsoring executives to support more informed decision making.

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Tutorial #1 – Building and Validating an Integrated Master Schedule

INTRODUCTION

This first tutorial shows how to build and validate an Integrated Master Schedule (IMS) in Chrono™. Schedules need to be "well-formed," so that they can be properly simulated and result in actionable information that can properly guide a program or project.

This section assumes that the user is familiar with standard scheduling principles as described in the Project Management Institute's (PMI) PMBOK® Guide and has a working knowledge of Microsoft Project®.

The basic scheduling knowledge required for this section include the following:

- **Task** – the unit of work for resource allocation, estimation, scheduling and tracking
- **Summary Task** – a collection of tasks
- **Work Breakdown Structure (WBS)** – the collection of all tasks and summary tasks for a project and the hierarchical relationships
- **Task-Level Assumptions** – assertions made about uncertainties surrounding a task to facilitate planning and estimation, for example: "We assume the needed parts will be in stock/on hand"
- **Network Diagram** – a visual depiction of the project schedule that shows the order and dependencies of all tasks
- **Deliverable** – the work products created by each task
- **Acceptance Criteria** - the details of how a task will be measured to confirm that it is complete or meets the *definition of done*. This acceptance criteria must be agreed to in advance of estimating or performing work on the task

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PLANNING STEPS

The planning process can expand, or contract based on the size and complexity of a project but follows a basic process flow that can be shown in the series of planning steps listed below. This tutorial assumes that the user understands this process flow and will be able to follow it as needed to build out their schedule.

1. Scope – Identify Tasks
2. Create Preliminary Schedule
    A. Approximate Task Durations
    B. Determine Task Dependencies
    C. Enter Data to Build Preliminary Schedule
3. Refine Estimates
    A. Develop 3-Point Estimates
    B. Update Tasks with 3-Point Estimates
4. Optimize and Adjust for Risk
    A. Run TriCoBi™ Simulation
    B. Review Nominal and Goal Confidence Levels
    C. Change the Commitment Milestone and Rerun the Simulation
    D. Optimize Plans
5. Review Plans with Sponsor
6. Update Project Plan per Sponsor's Review
7. Final Project Plan Review with Sponsor and Team

Scope – Identify Tasks

A common method used to identify tasks and create the Work Breakdown Structure (WBS) is to have a brainstorming session with the core project team and Subject Matter Experts (SMEs). In this session they would discuss the work products representing the value to be created for the end goal of the project and describe the tasks necessary to create those work products.

These tasks are then placed in a hierarchy called a Work Breakdown Structure which consists of the "tasks" (work items) and "summaries" which represent collections of tasks

and summaries. Summaries are used to organize tasks, much like folders might be used to organize files on a hard disk.

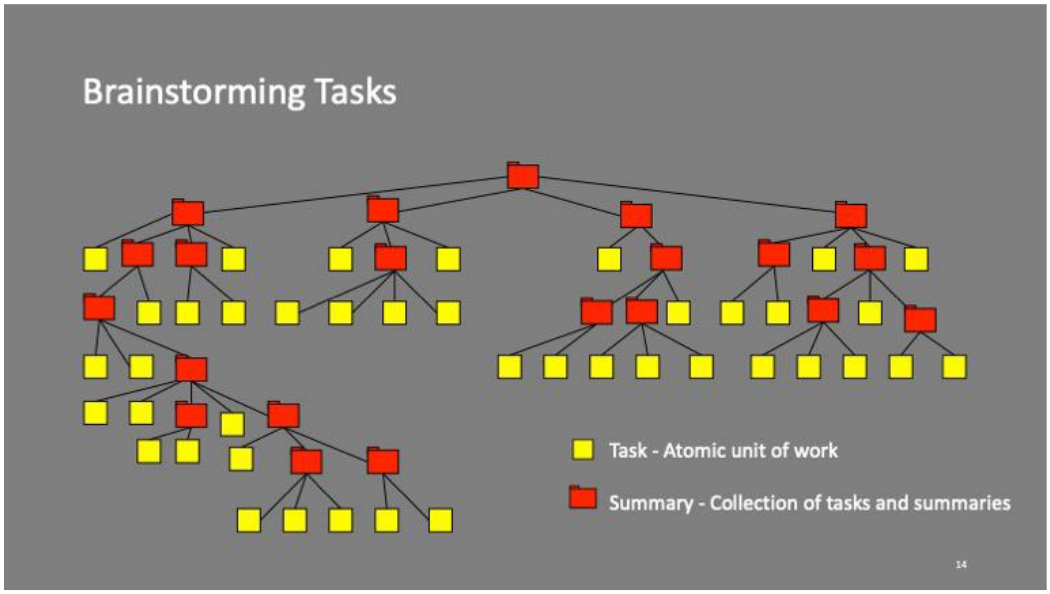

Figure 1 Work Breakdown Structure Framework

Create Preliminary Schedule

Creating the preliminary schedule consists of three steps:

1. Approximate Task Durations
2. Determine Task Dependencies
3. Enter data into Microsoft Project®

Each of these are discussed in the sections below. We assume you are using Microsoft Project® to create the preliminary schedule.

Approximate Task Durations

The first step in building a schedule is to create initial duration estimates for identified tasks. These initial durations or rough estimates are a first guess at the time needed to complete each task and should be an honest best guess – not optimistic or pessimistic. These durations will be used for the preliminary schedule development and later they will be replaced with a 3-Point risk adjusted estimate used to determine the overall project schedule. The team should develop approximate task durations in a manner comfortable for the team. Some common methods used by teams include expert opinion, analogy, and

planning poker. The team should record any assumptions made when approximating durations. These can be revisited later in the planning process as part of refining estimates, assigning resources, and managing risk.

Determine Task Dependencies

The goal of this step is to determine the logical sequence of the identified tasks. Sequence is often represented as a network diagram that describes the task dependencies. The network diagram consists of 3 basic elements:

1. Milestones – Milestones represent significant moments in time for the project. At a minimum, all projects should include a Start and Finish milestone. The Start milestone represents the beginning of project work. The finish milestone represents the completion of all project work.
2. Tasks – Tasks are the elementary unity of work for scheduling, assignment, and tracking.
3. Dependencies – The arrows that show the relationship among the tasks, usually described as "Finish to Start", meaning "Task A must be finished before Task X can Start".

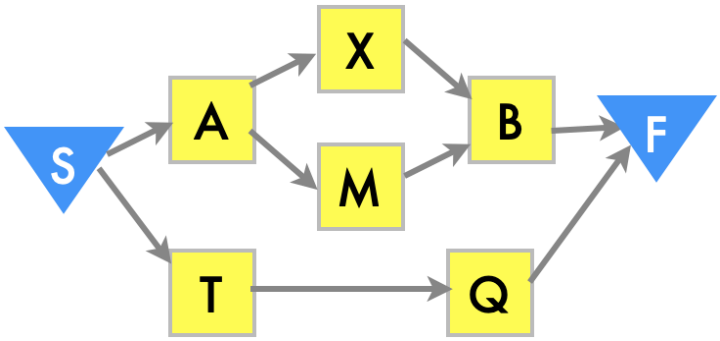

Figure 2 Example Network Diagram

Determining the logical relationships among tasks can be challenging and is best approached as a team effort. Conceptually what happens is an assumption is made about the start date of the project and the start milestone is created. Next, tasks that could begin as soon as the project starts without input from other tasks are listed as successors to the start milestone. Then other tasks are added showing their dependencies upon prior

tasks until all tasks are accounted for. Finally, a finish milestone is created as a successor to any task that doesn't already have a successor.

When the network diagram is complete, the following should be true:

1. There is a start milestone scheduled to occur at a fixed date in the future when we assume the project work will begin.
2. All tasks have at least one successor (task or milestone that is dependent on that task finishing before it can start).
3. All tasks have at least one predecessor (task or milestone that must be completed before this task may begin).
4. There is a finish milestone tied to the completion of the last tasks in the project. When the finish milestone occurs, all project work should be complete.

While discussing and capturing task dependencies it is common to discover tasks that were initially missed and must be created, are redundant and can be eliminated or redefined to avoid redundancy, and tasks that might be either decomposed further for better granularity or consolidated with other tasks for simplicity.

At this point in schedule development, don't worry about the resources necessary to do the work. The preliminary schedule is about capturing the logical sequence of the tasks. Resource considerations are addressed later.

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Enter Data to Build Preliminary Schedule

After creating the network diagram as described above, we are ready to use the scheduling tool. For our tutorial, the preliminary schedule is created by entering the tasks, durations, and dependencies into a scheduling tool like Microsoft Project®.

For the purposes of this tutorial, the following project data table will be used for the initial project Gantt.

Task ID	Task Name	Duration	Predecessors
1	Start Milestone	0	
2	**Prototype Development**		
3	Prototype Design	45	1
4	Buy Prototype LL (Long-Lead) Parts	35	3SS+30
5	Buy Remaining Prototype Parts	30	3
6	Initial Prototype Build	20	4
7	Final Assembly of Prototypes	10	5,6
8	Test & Evaluation	20	7
9	**Final Product Development**		
10	Final Product Design	35	8SS+15
11	Final Design Review	0	10
12	Buy LL Parts for Qual Units and Production	30	8
13	Buy Remaining Parts for Qual Units	30	11
14	Initial Assembly of POR (Plan of Record) Units	20	12
15	Final Assembly of POR Units	15	13,14
16	Conduct Qual Tests	20	15
17	Verify Final Design Iterations	30	15SS+10
18	Conduct Launch Readiness Review	0	16,17
19	Buy Remaining Production Parts	30	16
20	Start Production		18,19
21	Commitment Milestone		20

Figure 3 Source data for example

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Steps to create initial Microsoft Project Gantt Chart for the tutorial:

1) Open Microsoft Project® and create a Blank Project.
2) Confirm that Chrono™ is installed and functioning by assuring that the Chrono™ tab is visible near the File tab across the top of the application.
3) Observe that Chrono™ adds some initial milestones and a first task place holder to your blank schedule when it is created.
4) If needed, go to the File > Options > General > Project view setting and change the Date format to include hours. Example: 1/28/09 12:33PM.
5) Update the Start Milestone to begin 2/3/20 8:00 AM (if you use this exact date and time for the tutorial then your output should match the examples below), and update the corresponding project start date in the Project Information dialog from the Project tab.
6) Insert 17 tasks below TaskID #2 (TaskID #2 task name is "Put your first task here").
7) Select and indent TaskID #3-#8 to promote TaskID #2 to a summary task.
8) Select and indent TaskID #10-#17 to promote TaskID #9 to a summary task.
9) Copy the task names from tasks #2 through #19 from the table above into the corresponding task name fields in the Microsoft Project® table.
10) Copy the durations from TaskID #3-#8 and #10-#19 into the Durations column of the MS Project table.
11) Clear the predecessor in TaskID #2. Copy the predecessors from tasks #3-#8 and #10-#20 into the Predecessors column of the MS Project table.
12) Rename task #20 to "Start Production". Confirm that it has a duration of zero.
13) Save your work and name the file "Tutorial Project #1.mpp"
14) Click the "View Entire Project" button on the Chrono™ Tools ribbon.

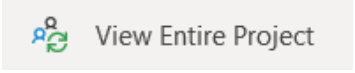


Figure 3 Button for Viewing Entire Project Width

15) Click the "Align Commit" button on the Chrono™ Tools ribbon, and choose "Yes" for End of Day

Figure 4 Button to Align Commit to Goal

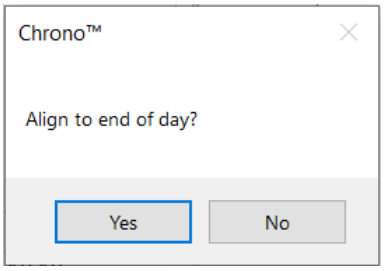
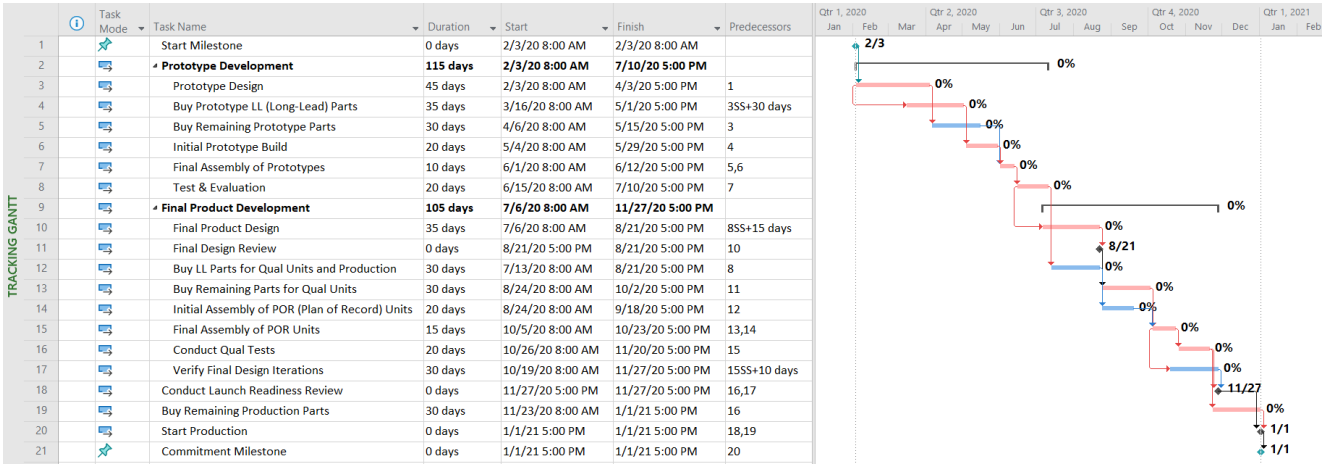


Figure 5 Pop-up to Align Commit to End of Work-Day



TRACKING GANTT

	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Start Milestone	0 days	2/3/20 8:00 AM	2/3/20 8:00 AM	
2		**Prototype Development**	**115 days**	**2/3/20 8:00 AM**	**7/10/20 5:00 PM**	
3		Prototype Design	45 days	2/3/20 8:00 AM	4/3/20 5:00 PM	1
4		Buy Prototype LL (Long-Lead) Parts	35 days	3/16/20 8:00 AM	5/1/20 5:00 PM	3SS+30 days
5		Buy Remaining Prototype Parts	30 days	4/6/20 8:00 AM	5/15/20 5:00 PM	3
6		Initial Prototype Build	20 days	5/4/20 8:00 AM	5/29/20 5:00 PM	4
7		Final Assembly of Prototypes	10 days	6/1/20 8:00 AM	6/12/20 5:00 PM	5,6
8		Test & Evaluation	20 days	6/15/20 8:00 AM	7/10/20 5:00 PM	7
9		**Final Product Development**	**105 days**	**7/6/20 8:00 AM**	**11/27/20 5:00 PM**	
10		Final Product Design	35 days	7/6/20 8:00 AM	8/21/20 5:00 PM	8SS+15 days
11		Final Design Review	0 days	8/21/20 5:00 PM	8/21/20 5:00 PM	10
12		Buy LL Parts for Qual Units and Production	30 days	7/13/20 8:00 AM	8/21/20 5:00 PM	8
13		Buy Remaining Parts for Qual Units	30 days	8/24/20 8:00 AM	10/2/20 5:00 PM	11
14		Initial Assembly of POR (Plan of Record) Units	20 days	8/24/20 8:00 AM	9/18/20 5:00 PM	12
15		Final Assembly of POR Units	15 days	10/5/20 8:00 AM	10/23/20 5:00 PM	13,14
16		Conduct Qual Tests	20 days	10/26/20 8:00 AM	11/20/20 5:00 PM	15
17		Verify Final Design Iterations	30 days	10/19/20 8:00 AM	11/27/20 5:00 PM	15SS+10 days
18		Conduct Launch Readiness Review	0 days	11/27/20 5:00 PM	11/27/20 5:00 PM	16,17
19		Buy Remaining Production Parts	30 days	11/23/20 8:00 AM	1/1/21 5:00 PM	16
20		Start Production	0 days	1/1/21 5:00 PM	1/1/21 5:00 PM	18,19
21		Commitment Milestone	0 days	1/1/21 5:00 PM	1/1/21 5:00 PM	20

Figure 6 Preliminary Schedule

16) View the Gantt chart. It should look like the following figure and have 1/1/21 5:00 PM as the Commitment Milestone.

The project schedule needs to be "well-formed" for it to be simulated. The Chrono™ "Validate Project" wizard is used to perform the project validation, assuring that all tasks have a predecessor and successor, start as soon as the task logic allows, and that summaries do not have predecessors or successors or fixed dates. Click the "Validate Project" button on the Chrono™ Tools ribbon to run the validation:

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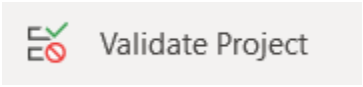

Figure 7 Button to Initiate the Schedule Validation Check

The project should validate properly and present a "Validate Project – Passed" message to the user.

The details of what validation does are discussed here.

Clear the predecessor from task #8 to cause a validation failure. This will result in task #7 having no successor. Run the "Validate Project" wizard again. See the wizard message showing the integrity error in the project structure:

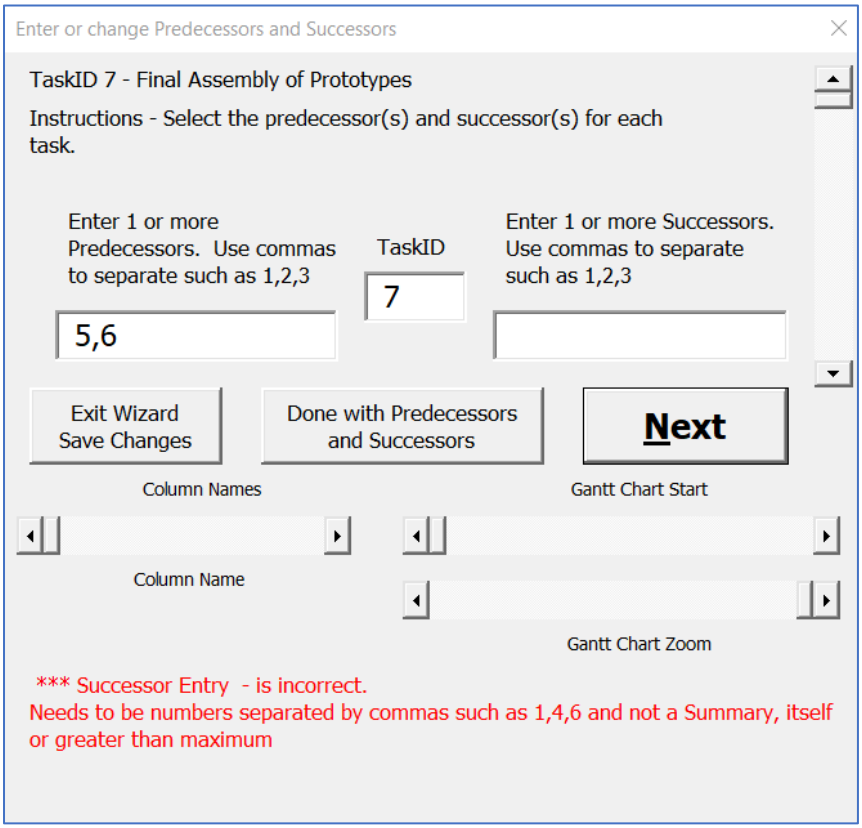

Figure 8 Validate Project Error Dialog

Since predecessors and successors are directly related, fix the issue by inserting "8" as a successor to task #7 in the dialog and pushing "Next". This will make task #8 the successor of task #7 restoring the schedule integrity. The wizard should now complete validation successfully and display the "Project Validation – Passed" message.

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Refine Estimates

Next, we will review and refine the estimates, working with the team to develop 3-point estimates that give us insights into the likely variability of task durations.

Develop 3-Point Estimates

Chrono™ helps create realistic schedules by utilizing the information normally hidden in the natural variance of task estimates. To support this analysis, three estimates are created for tasks with a known risk of duration variability. These estimates and their definitions are:

- Best-Case Estimate – the shortest reasonable duration that resources and technology would allow the task to be finished. This is how quickly we could get this done if things went very right.
- Nominal-Case Estimate – the most likely duration of the task according to history or expert opinion. The nominal estimate assumes that things go reasonably well, but not perfectly – and there are no significant surprises. Microsoft Project® labels this simply, "Duration".
- Worst-Case Estimate – the longest reasonable duration of the task absent extraordinary problems. Typically, this would be characterized by the estimator as the longest the task would reasonably take barring natural disaster or other disruption.

Ideally, we obtain the best-case and worst-case estimates by engaging the same people who developed the original task duration estimates. For each task, discuss what would have to go right for the duration to be shortened assuming the resources and project priorities remained the same, and what that optimistic but credible best-case duration would be. Then discuss what kinds of things could go wrong with the tasks that would delay completion and ask what the pessimistic or worst-case duration would be. In both cases, limit the discussion to things that are controlled by the team or normal things that impact the team and have some reasonable likelihood of happening during the project.

Examples:

A. When discussing the best-case duration, a subject matter expert (SME) might say, "If we had all of the needed parts in stock at the beginning of the task and

we could focus on it full time, we might be able to build the prototype in as little as 8 days rather than 10."

B. When discussing the worst-case duration, the SME might say, "Expanding the server room could be delayed if there were insufficient power on the designated electrical circuits or if cooling the new equipment exceeded the capacity of the existing HVAC unit." Either of these situations would extend the nominal 30 day estimate to as much as 45 days.

C. When discussing the worst-case duration, a SME might say, "If there is another pandemic this estimate goes out the window." To which a project manager could reply, "Let's focus on the normal things that go wrong with tasks like this. Pandemic delays are beyond the scope of our estimation exercise and we can deal with them as part of our overall risk management strategy."

When teams revisit task durations to develop best-case and worst-case estimates, they sometimes find they can also justify changing the nominal or expected case duration. Often a team will feel more comfortable shortening the nominal durations when given the opportunity to capture the worst-case durations, effectively removing internalized or hidden task duration risk buffers. The result is a much more credible 3-point estimate for each task.

For additional discussion of 3-point estimates, see 3-Point Estimates.

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Update Tasks with 3-Point Estimates

The next step in our tutorial is to run the "Chrono™ Wizard" to add the best-case and worst-case duration estimates to each task. Use the following project data table for the best-case and worse-case task durations in the tutorial update. This should assure that your output matches the illustrations below.

Task ID	Task Name	Best-case Duration	Nominal Duration	Worst-case Duration
3	Prototype Design	40	45	60
4	Buy Prototype LL (Long-Lead) Parts	35	35	35
5	Buy Remaining Prototype Parts	30	30	40
6	Initial Prototype Build	15	20	25
7	Final Assembly of Prototypes	8	10	20
8	Test & Evaluation	15	20	40
10	Final Product Design	30	35	50
12	Buy LL Parts for Qual Units and Production	30	30	30
13	Buy Remaining Parts for Qual Units	30	30	40
14	Initial Assembly of POR (Plan of Record) Units	15	20	25
15	Final Assembly of POR Units	8	15	20
16	Conduct Qual Tests	15	20	50
17	Verify Final Design Iterations	20	30	40
19	Buy Remaining Production Parts	30	30	40

Figure 9 Project Data Table for Inputs

Steps to add updates project tasks with 3-point estimates:

1) Launch the "Chrono™ Wizard" by clicking on the button the Chrono™ Tools ribbon.

Figure 10 Button for Initiating the Chrono™ Wizard

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2) Note the TaskID in top right corner of the wizard. For the tutorial TaskID #3 should be shown. You can navigate to a different task by entering the task number in the TaskID box or using the slider next to the data entry box.

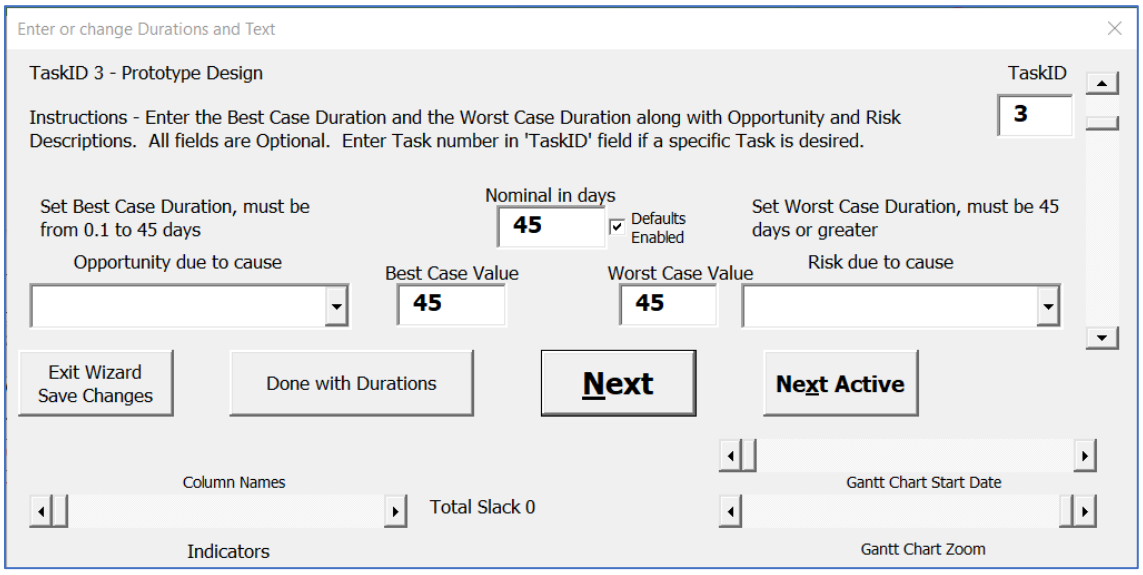

Figure 11 Wizard Data Entry Pop-up with Single Nominal Duration Entered

3) Update the best-case value and worst-case value from the data table. Optionally, you can add a text description reason for the possible the best-case scenario in the Opportunity field using a drop-down item or as a text input. Optionally add the reason for the possible worst-case scenario in the Risk field.

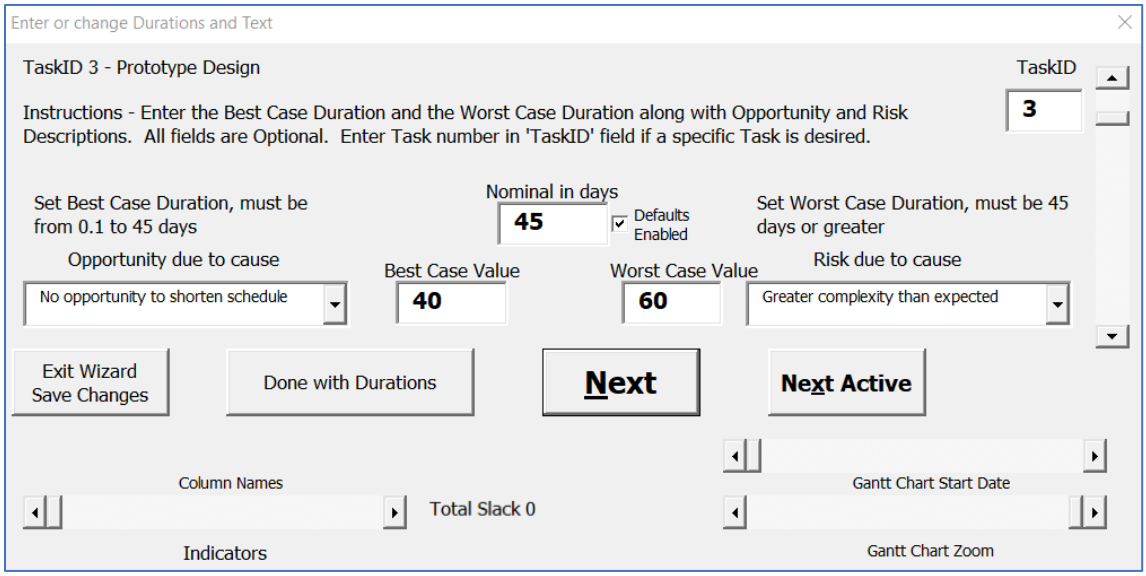

Figure 12 Wizard Data Entry Pop-up with 3-point Duration Estimates Entered

4) Click the "Next" button to commit the changes and move to the next TaskID
5) Repeat the process for all tasks that have 3-point estimates. For the purposes of the tutorial, enter the rest of the best-case and worst-case durations from the table above.
6) After updating the durations, the Chrono™ Wizard will present the opportunity to update the predecessors and successors again. No changes are needed for the tutorial.
7) Close the wizard by completing the update sequence or by clicking on the "Exit Wizard Save Changes" button or the "Done with Durations" button.

Optimize and Adjust for Risk

The next step in planning the project is the run the TriCoBi™ Simulation. This simulation provides a functional equivalent to a Monte Carlo simulation but orders of magnitude faster - allowing for What-If analysis in seconds rather than minutes or hours.

The results of the simulation will provide insights into opportunities to address schedule risk.

Run TriCoBi™ Simulation

Like a Monte Carlo simulation, the TriCoBi™ simulation combines the probabilistic distributions for each 3-point estimate into a combined probabilistic distribution for the whole project schedule. The probability of each possible completion date for the project is summed up and presented on an "S-curve" where the confidence-level of every possible end-date is presented.

The steps to run the TriCoBi™ Simulation:

1) In the Chrono™ Settings portion of the Chrono ribbon, select "Defaults". This will display the Default Settings dialog and allow you to select the triangle probability type. For purposes of our tutorial, select the distribution type of TriGen™ then "Save" the changes.

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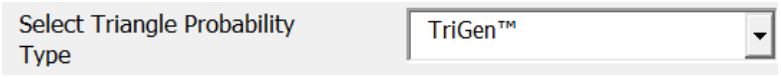

Figure 13 Default Section for Changing Probability Type

(Note: See the appendix here for an explanation of the different triangles and how this setting impacts the simulated timeline.)

2) Click the "Run TriCoBi™ Simulation" button in the Chrono™ Tools ribbon. The warning triangle on the left of the button is present whenever the simulation needs to be run because of changes in the project data since the last simulation was run.

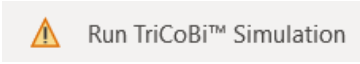

Figure 14 Button for Running Simulation

3) Project validation will automatically run and, if successful, then the simulation will proceed. When the simulation is finished, choose to display the probability chart by selecting "Yes" on the dialog presented.

Review Nominal and Goal Confidence Levels

The project's Commitment Milestone (TaskID #21) probability distribution and confidence-level S-curve are presented the default web browser. Notice that the Nominal confidence-level is 1%. This shows that the expected durations of the tasks provided by the subject matter experts has a 99% change of failing to hit non-simulated original timeline calculated by Microsoft Project® in the Preliminary Schedule above.

Confidence-Level	%Confidence	Date
Nominal Confidence	1%	1/1/2021
Commit Confidence	1%	1/1/2021
Goal Confidence	70%	3/4/2021
Medium Risk Confidence	50%	2/18/2021
High Risk Confidence	30%	2/8/2021

Figure 15 Chrono Distribution Output Information Box

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Generally, we recommend that teams present their estimated timeline to the business using the TriGen™ distribution type and confidence-level of 70% or higher. Some managers prefer to present a 75% confidence-level to the business for organizational commitments.

The output above shows that the original timeline calculated by Microsoft Project® using traditional critical path method (CPM) and the nominal estimates resulted in an end date of January 1, 2021. When the simulation factors in the expected duration variance reflected by 3-point estimates it generates a more realistic end date of March 4, 2021. In summary, this example shows how an 11-month schedule created in good faith by experts can be off by 2 months (nearly 20%) due the difficulty of combining tasks that have an expected natural variance.

For more information about Monte Carlo simulation compared to traditional critical path method schedules, see appendix here.

Change the Commitment Milestone and Rerun the Simulation

The next step in our tutorial is to change the Commitment Milestone and rerun the simulation.

Steps to update the Commitment Milestone:

1) Navigate to the Microsoft Project® schedule
2) Select "Goal Confidence @ 70%" button on the Chrono™ Gantt Chart Views ribbon.

Figure 16 Button for Viewing Goal Confidence Gantt

3) Note the green check mark on Goal Confidence indicating that this is the Gantt chart currently being displayed.

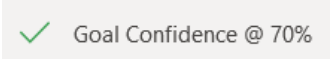


Figure 17 Button with Green check mark

4) Observe that the Gantt chart tasks have been moved to reflect the 70% confidence-level timeline.

5) Click the "Align Commit" button on the Chrono™ Gantt Chart Views ribbon. This fixes the start of the Commitment Milestone to align with the completion of its predecessor, in our tutorial this is the Start Production milestone which is scheduled to occur on 3/4/2021 at the 70% confidence level.

Figure 18 Button to Align Commit to Gantt End Milestone

6) Select "Yes" on the "Align to end of day?" question.

7) Note that the "Run TriCoBi™ Simulation" button in the Chrono™ Tools ribbon has the yellow warning triangle signifying that the TriCoBi™ Simulation needs to be run again.

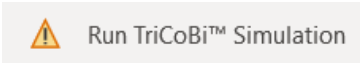


Figure 19 Simulation Button with Yellow Warning Sign

8) Re-run the TriCoBi™ Simulation.

9) Notice that the warning triangle on the "Run TriCoBi™ Simulation" button is gone signifying the project dates for the various Gantt views for each confidence level are up to date.

Figure 20 Simulation Button without Warning

10) Select "Yes" to display the probability charts on the dialog presented.

11) See the Commit Confidence date is now on March 4, 2021 with a 72% probability. (The difference between the 70% Goal Confidence and the 72% Commit Confidence is the "Align to end of day" setting above.)

Solving the Impossible

Confidence-Level	%Confidence	Date
Nominal Confidence	1%	1/1/2021
Commit Confidence	72%	3/4/2021
Goal Confidence	70%	3/4/2021
Medium Risk Confidence	50%	2/18/2021
High Risk Confidence	30%	2/8/2021

Figure 21 Output Distribution Box with new Dates

12) Review the project distribution curve for the Commitment Milestone. Hovering the curser over the Commit Confidence diamond shows the confidence-level to be 71.69% for an end of day March 4, 2021 project end date.

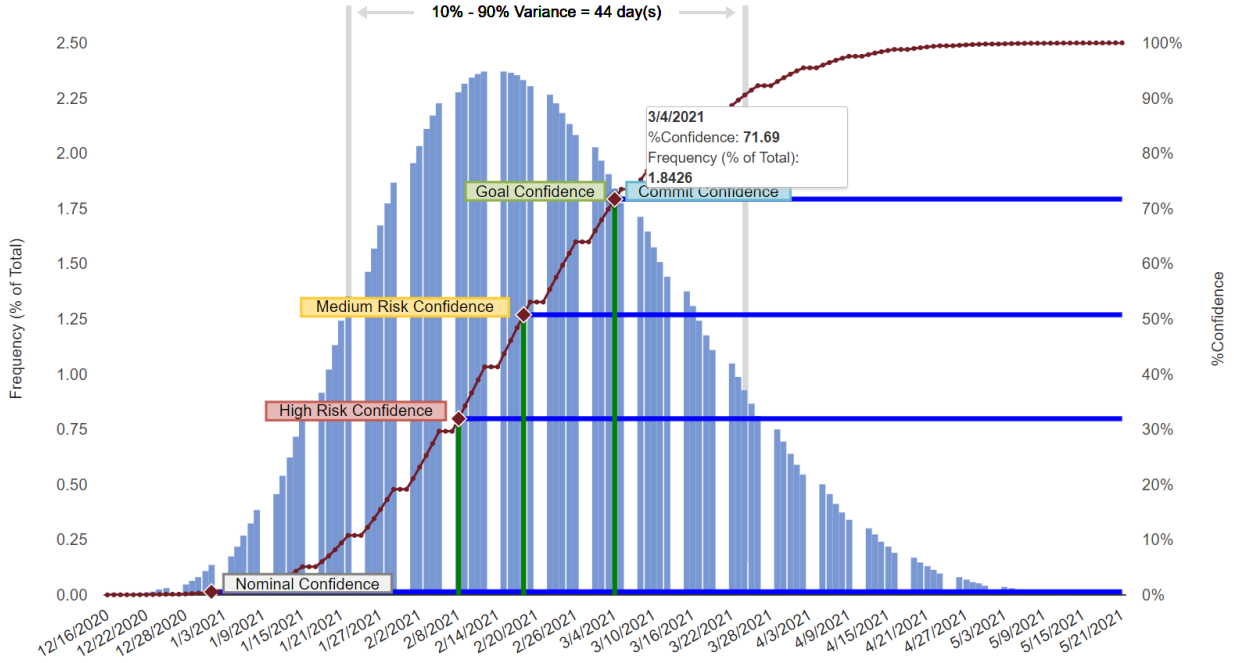


Figure 22 Probability Distribution Chart

13) Navigate back the Microsoft Project® schedule.

14) Select "Goal Confidence @ 70%" button on the Chrono™ Gantt Chart Views ribbon.

Figure 23 Goal Confidence Gantt Chart Button

Solving the Impossible

15) Click the "View Entire Project" button to have the Gantt chart scaled to fit into the space available on your computer display.

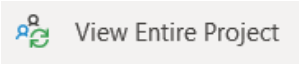
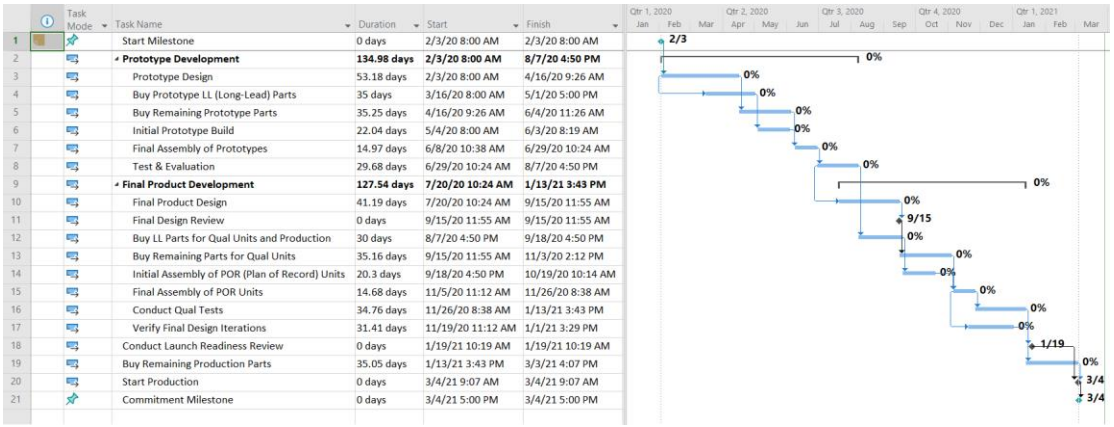


Figure 24 The View Entire Project Button

16) See the full schedule in the Project Gantt showing the 70% confidence-level dates for each task as well as the overall timeline.



	Task Mode	Task Name	Duration	Start	Finish
1		Start Milestone	0 days	2/3/20 8:00 AM	2/3/20 8:00 AM
2		**Prototype Development**	**134.98 days**	**2/3/20 8:00 AM**	**8/7/20 4:50 PM**
3		Prototype Design	53.18 days	2/3/20 8:00 AM	4/16/20 9:26 AM
4		Buy Prototype LL (Long-Lead) Parts	35 days	3/16/20 8:00 AM	5/1/20 5:00 PM
5		Buy Remaining Prototype Parts	35.25 days	4/16/20 9:26 AM	6/4/20 11:26 AM
6		Initial Prototype Build	22.04 days	5/4/20 8:00 AM	6/3/20 8:19 AM
7		Final Assembly of Prototypes	14.97 days	6/8/20 10:38 AM	6/29/20 10:24 AM
8		Test & Evaluation	29.68 days	6/29/20 10:24 AM	8/7/20 4:50 PM
9		**Final Product Development**	**127.54 days**	**7/20/20 10:24 AM**	**1/13/21 3:43 PM**
10		Final Product Design	41.19 days	7/20/20 10:24 AM	9/15/20 11:55 AM
11		Final Design Review	0 days	9/15/20 11:55 AM	9/15/20 11:55 AM
12		Buy LL Parts for Qual Units and Production	30 days	8/7/20 4:50 PM	9/18/20 4:50 PM
13		Buy Remaining Parts for Qual Units	35.16 days	9/15/20 11:55 AM	11/3/20 2:12 PM
14		Initial Assembly of POR (Plan of Record) Units	20.3 days	9/18/20 4:50 PM	10/19/20 10:14 AM
15		Final Assembly of POR Units	14.68 days	11/5/20 11:12 AM	11/26/20 8:38 AM
16		Conduct Qual Tests	34.76 days	11/26/20 8:38 AM	1/13/21 3:43 PM
17		Verify Final Design Iterations	31.41 days	11/19/20 11:12 AM	1/1/21 3:29 PM
18		Conduct Launch Readiness Review	0 days	1/19/21 10:19 AM	1/19/21 10:19 AM
19		Buy Remaining Production Parts	35.05 days	1/13/21 3:43 PM	3/3/21 4:07 PM
20		Start Production	0 days	3/4/21 9:07 AM	3/4/21 9:07 AM
21		Commitment Milestone	0 days	3/4/21 5:00 PM	3/4/21 5:00 PM

Figure 25 Full Gantt Chart - Revised

17) Select from the Project menu "File > Save" to protect the work to this point.

18) Select from the Project menu "File > Save As" to create a backup copy of the work. (Use the file name "Tutorial Project #2.mpp".[1])

19) Perform the next steps in the tutorial with the "Tutorial Project #2.mpp" file.

[1] Important point: Never use the operating system copy command to make a copy of a Microsoft Project® file that has been used with Chrono™, instead use "Save As…" in the application menu. Microsoft creates a unique identifier for each project file when you create a new project or do a "Save As…" that is hidden inside the file. Chrono™ uses that to identify your project and save historical information in the cloud. If you make a copy of a file using the operating system, then both files will have the same (no longer unique) identifier, and this will confuse and potentially corrupt the historical data retained about your project that is used to track trends.

Solving the Impossible

Optimize Plans

Project plan optimization involves trying to adjust the scope, schedule, and resources of the project in the context of known risks to achieve the project objectives and provide options to the sponsor if that can't be accomplished credibly. Chrono™ assists with schedule optimization and schedule risk management by helping project managers create realistic schedules through probabilistic simulations that identify opportunities and risks that can the addressed directly by the organization. The tools for this include identification of the merge bias interactions that impact the schedule and the tornado chart that the shows the tasks that have the largest potential positive or negative impact variance on the project schedule. Often, an organization may seek to compress a timeline by adjusting the resources applied to the program. This might include adjusting team sizes and skill sets or expediting capital purchases that could have a positive impact on the schedule.

Observe the impact of Merge Bias by selecting the "Merge Bias" tab on the web-based Chrono™ Chart. This shows that the merge bias contributes to likely schedule delays on three tasks. See Appendix here for ideas about how to optimize a schedule for merge bias. For this tutorial we will accept the current merge bias.

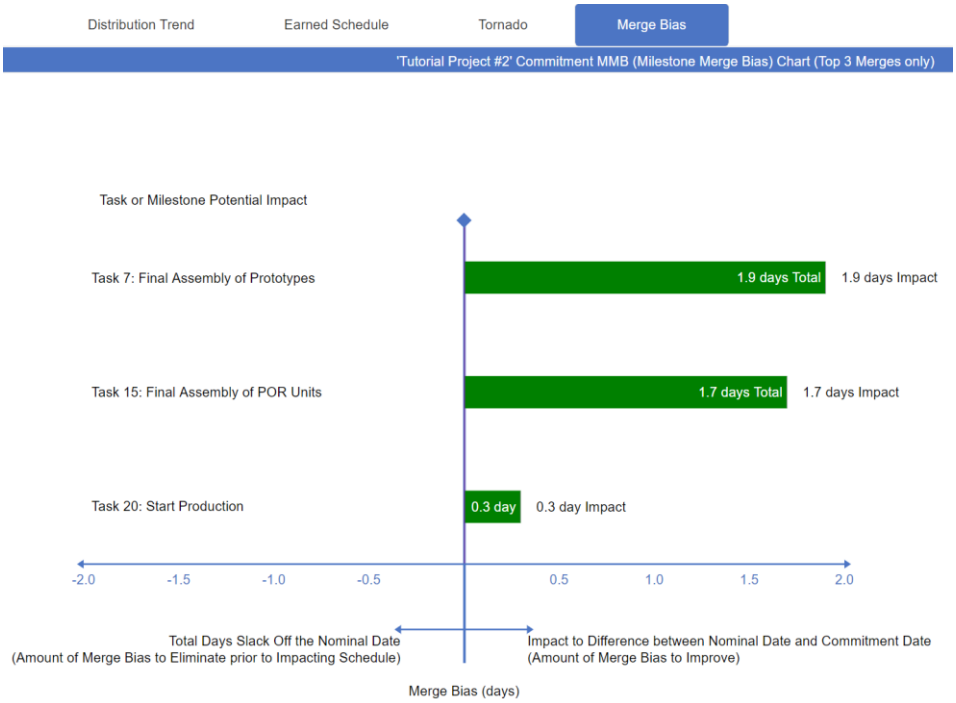


Figure 26 Merge Bias Chart

Solving the Impossible

1) Look for opportunities to optimize the schedule and mitigate schedule risks by reviewing the Tornado tab on the web-based Chrono™ Chart. The chart identifies tasks that are contributing the most to extending the schedule. In our tutorial example, the Tornado chart shows a significant opportunity to pull in the schedule by reducing the variance on the "Conduct Qual Tests" shown in TaskID #16 on the chart below. The chart also shows six additional risks that, if mitigated, could help reduce the overall schedule duration further.

2) When working to shorten a schedule we recommend reviewing the tornado chart items one by one and acting to reduce their variance in addition to reviewing overall task logic to confirm dependencies and reviewing the critical path for opportunities to better allocate resources for schedule optimization.

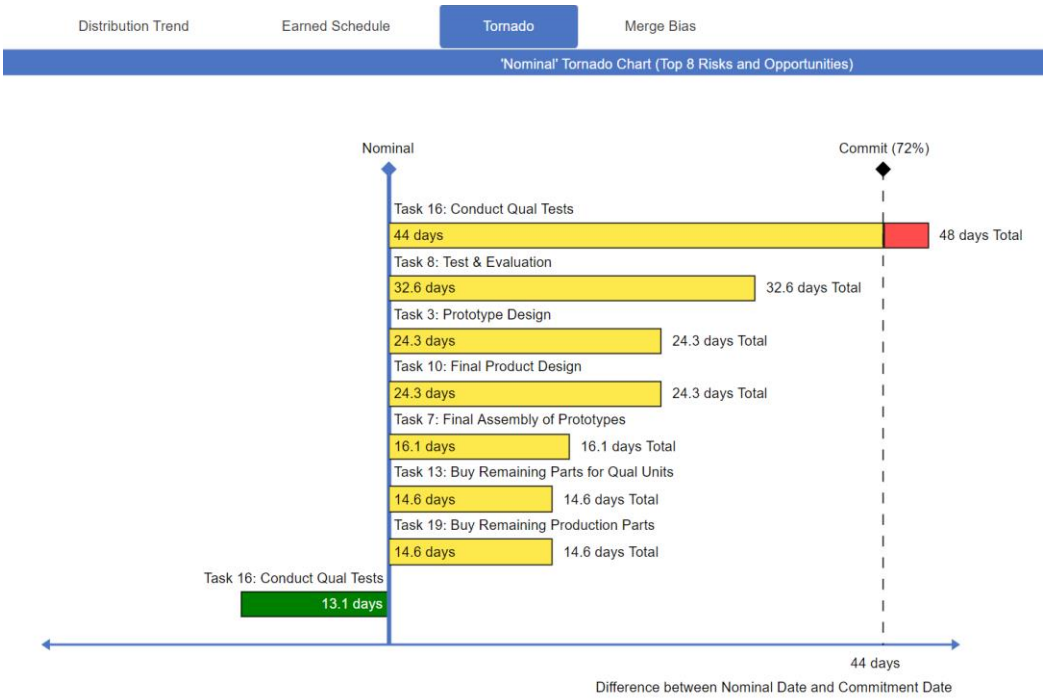


Figure 27 Tornado Chart

Review Plans with Sponsor

Once plans have been optimized as much as possible within the bounds authorized by the project charter, budget, schedule, and resource plans are normally presented to the project

sponsor for review and discussion, along with identified risks and remedies and any recommendations for changes in the original project charter/definition constraints or goals.

Chrono™ components that may aid that review include:

- Probabilistic distribution chart – Helps visualize the uncertainty of the scheduled end date
- Tornado chart – Identify tasks with significant positive or negative variance that might be targets for further optimization
- Merge bias chart (if it has significant impact on the timeline) – Helps explain hot spots of schedule variance

The initial sponsor review typically results in discussions of potential remedies for out of bound conditions in the current plans and possibly agreements to change the project constraints, assumptions, or definition. If the project plans are deemed acceptable, this review presents an opportunity for a Go/No-go conversation.

Update Project Plan per Sponsor's Review

If the sponsor requests additional optimization this might include adding, deleting, or changing tasks, adjusting budgets, changing schedule targets, modifying personnel assignments, or adjusting assumptions underlying aspects of the plan. Chrono™ can continue to play an ongoing role in modeling schedules and schedule risk. Users can adjust 3-point estimates as needed, run schedule simulations and review the results with the team as part of schedule refinement.

Final Project Plan Review with Sponsor and Team

When the last bout of optimization has been performed and before the schedule is approved and the initial baseline established, we recommend a final review of the schedule with the project sponsor and team to establish buy-in.

Make clear to the team that they will be striving to deliver according to the nominal-case estimates schedule they provided for their tasks. The team should understand that some variance is expected, and that the organization has taken that into account. Both the team and sponsor should understand that organizational commitments for project deliverables will be based on the timing from the commitment confidence which will usually be set to 70% or higher.

Solving the Impossible

Tutorial #2 – How and Why to Set Baselines

Once the team and the sponsor have agreed to a project schedule and there is a decision to begin the project on an agreed upon date, it is time to set the project baseline. The project baseline is a snapshot of the approved schedule that will be used as a benchmark to gauge schedule performance as the project progresses.

WHAT IS A "BASELINE"?

Think of the baseline as a line drawn at the base of each task in the Gantt chart in permanent ink. Task durations and start dates may fluctuate and cause the task to move as status is entered or estimates are changed, but once the baseline is established and saved it persists (until explicitly updated) and indicates when the task was scheduled to occur when the baseline was set. Comparing the baseline to the position of the task bar helps to visually identify variance between when the tasks occurred or are currently scheduled to occur and when they were planned to occur when the baseline was set.

The baseline function in Chrono™ is customized and replaces the standard Microsoft Project® baseline function. Do not set a baseline when using Chrono except through the procedure below.

SETTING A BASELINE

These are the steps to set the Chrono™ specific baseline:

1) Confirm/adjust the date of the Start milestone. No change is required for this tutorial.
2) Select "Set Project Baselines" button on the Chrono™ Tools ribbon.

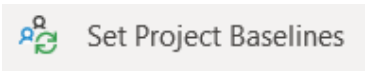


Figure 28 Button for Setting the Project Baselines

3) Select "Yes" to the sponsor approval question.

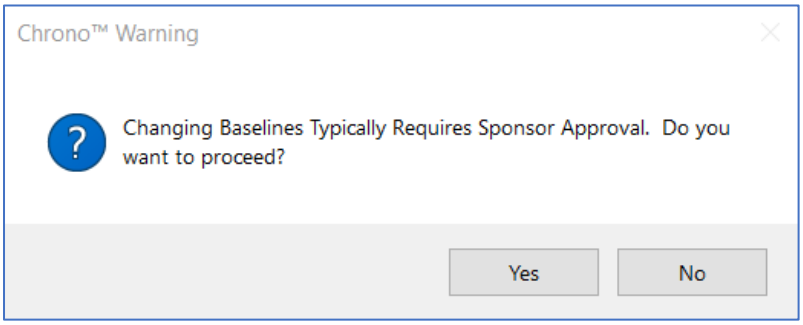


Figure 29 Chrono Warning to Verify User is Ready to Set Baselines

4) The screen will flash as an additional backup file is stored for the baselines.
5) Baselines are set for both the Nominal Durations and the Goal Confidence Durations.
6) The TriCoBi™ Simulation is rerun.
7) Choose to see the web graphics.
8) See that the baseline is set in the top right side of the header. The modified date should reflect the current date and time.

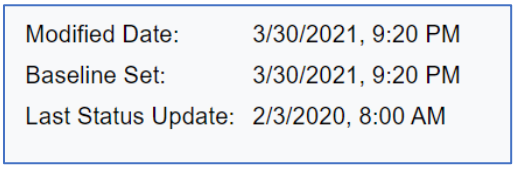


Figure 30 Baseline Information in Output Header

WHAT CHRONO™ RISK CONFIDENCE INFORMATION MEANS

1) See the *Distribution Trend* chart which should be showing:
    a. Initial project status date is February 3, 2020 (the date of the project start milestone)
    b. The baseline confidence level is 72% This means that if the current 3-point estimates and task dependencies are generally correct, Chrono™ analysis predicts that there is a 72% chance of completing the Commitment Milestone on or before the Goal Confidence schedule target.
    c. End-date variance (the interval between the 10% likely date and the 90% likely date) is 44 days. This means that project has an 80% chance of

completing within the middle 44-day period. We usually use this confidence interval quantity of days to understand how well the risks are reducing over time. Each time the project is updated the number of days within the 10% to 90% confidence interval should be reduced. The reductions start small in the beginning and get larger as the project nears completion, signifying that more of the project tasks are complete and the opportunities for variance are decreasing.

d. Goal confidence band is set to 70%. This means that the project has a 70% chance of completing on or before the date the corresponds to the 70% confidence-level. We have found that a 70% or higher confidence level is both attainable and sufficiently aggressive to minimize program costs. There are always exceptions to this rule, so the project manager will need to determine what goal confidence level is the best fit for their organization and adjust that factor in the Defaults dialog.

e. Medium risk confidence band is set to 50%. This factor is typically used for two different purposes. The first is used to schedule internal hand-offs within the organization such as the hand-off between a hardware team and a firmware team working on the same product, where it is important to be both aggressive on the schedule and still establish a fairly reliable hand-off date.

f. The second is used a warning flag for the entire project. If the confidence level of the commitment date reaches 50%, then the project is entering a level of uncertainty in its delivery timing that must be fully understood. Reaching this confidence level from a starting level of 70% suggests that something major has changed from the project planning assumptions such as the productivity of the team, or more risks are materializing than expected. If after exploring the confidence level variance action is needed, then it should be taken promptly as changes in a program typically grow more expensive over time.

g. High risk confidence level band 30%. This factor is also typically used for two different purposes. The first is used as an alternative to the nominal or critical path confidence level for planning aggressive task executions within a single team with no external hand-offs. The second use is as a critical warning flag for the entire project. If the confidence level of the commitment date falls to 30%, then it is unlikely that a normal recovery plan can recover the project slippage and more proactive steps by the organization will needed to realign the project to its business objectives.

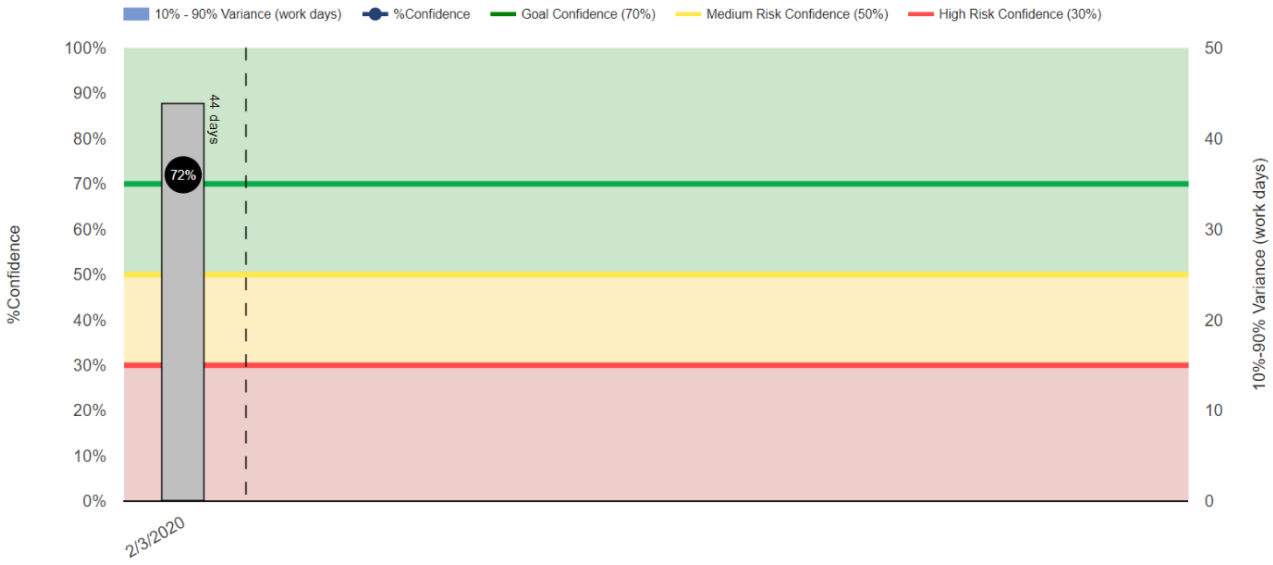


Figure 31 Distribution Trend Chart with Baseline SRA (Schedule Risk Analysis) Data

2) The Earned Schedule Management (ESM) tab provides baseline, Earned Schedule, projected, and actual burnup charts for both the goal confidence level and the nominal confidence level. Monitor both the slope of these lines and the extension of the lines to understand a possible change in the project end date and monitor the health of a projects. In the tutorial example, these charts show the project ready for its first schedule update with actuals (no actuals are shown yet).

Solving the Impossible

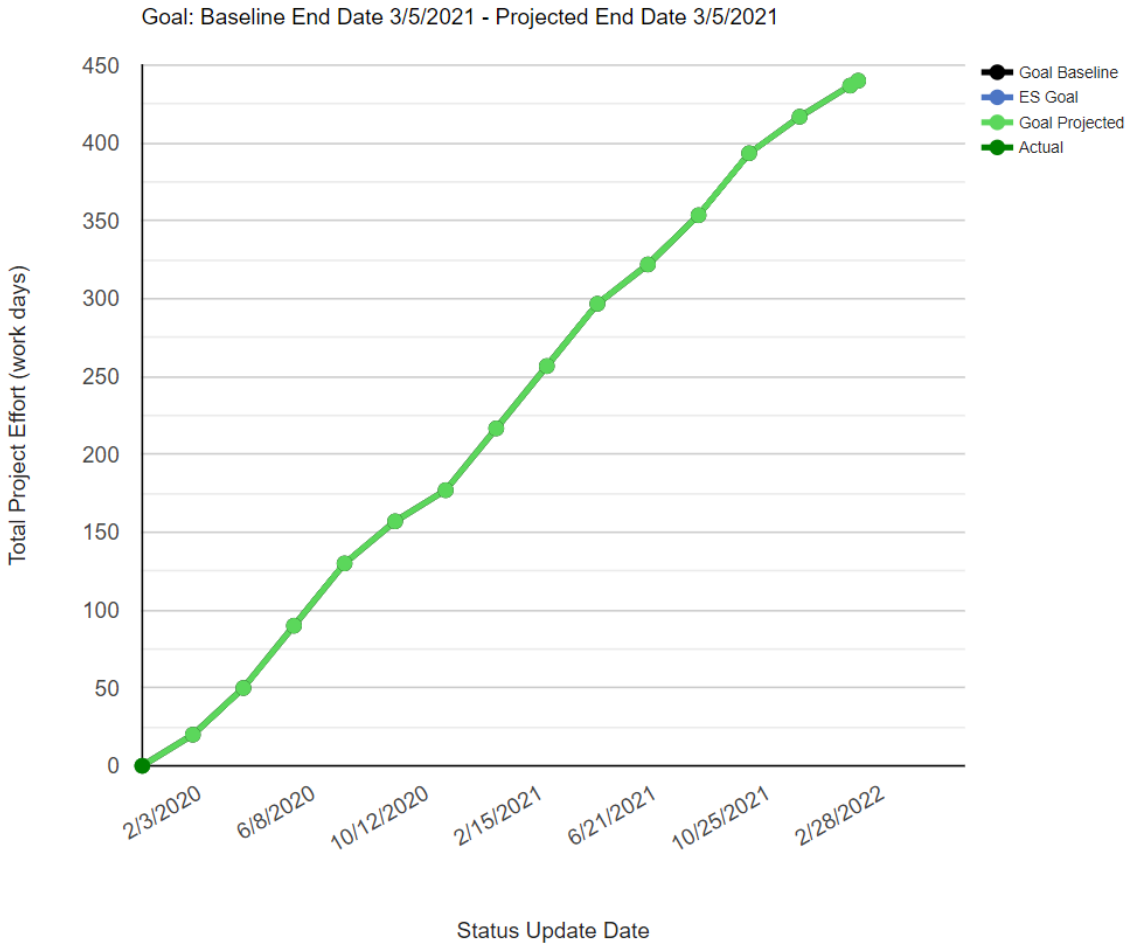


Figure 32 Goal Baseline Earned Schedule Chart

Solving the Impossible

Tutorial #3 – Tracking Projects with Earned Schedule Management

Starting with a realistic schedule is a great way to launch what we hope will be a successful project. Once project work begins, the next challenge is monitoring status to determine whether the project remains on track to meet its schedule objectives.

Because gathering status data and pro-actively mapping schedule trends is difficult and time consuming without the right tools, many projects simply track and report on historical performance. This is rather like driving your car with your windshield blacked out, watching your rear-view mirror to see what is behind you.

Chrono™ tracks completion of historical tasks and monitors consumption of the risk buffers (the difference between the Nominal Schedule and the baselined Goal Confidence Schedule) to calculate the likelihood of achieving schedule commitments after each status update. This is done using a process called Earned Schedule Management (ESM).

DISCIPLINED EXECUTION FOR PROJECTS

If an organization cares about project schedule performance, then tracking a project based on what has been completed at various milestone stages is necessary but insufficient. A tracking metric that focuses exclusively on what has been completed in the past is called a "lagging indicator." While lagging indicators reflect history, they do not provide insights into future consequences or guidance on what needs to happen to improve performance. A smoke alarm is an example of a lagging indicator. It does not prevent fires; it merely identifies when the smoke from a fire is detected.

Leading indicators are predictive, designed to track progress of historical events (lagging indicators) and forecast the consequences of that performance on future tasks. An example of a leading indicator: my car monitors fuel consumption, fuel tank capacity, and distance traveled to provide me with a constant prediction of how many miles I can go with the fuel remaining in my tank at the current rate of consumption.

In this way, leading indicators and lagging indicators go hand in hand. The lagging indicators track the completion of historical tasks and milestones and the leading

indicators calculate trends from lagging indicator performance to predict whether the project is on pace to hit future milestones at their forecast time.

As work progresses and actual task performance is recorded (hopefully in the range defined by 3-point estimates), a consistent analytical method must be used to measure progress and predict the impact of variance. The metric used to track progress is not the time already invested in a task, but instead the time remaining to complete the task. Periodic status collection will gather from team members the currently estimated time required to complete all unfinished tasks.

EARNED SCHEDULE MANAGEMENT AND RECOVERING FROM PROJECT SLIPPAGE

The statistical schedule management approach Chrono™ uses to combine the "time remaining status" information for incomplete tasks is called Earned Schedule Management. It is similar to more traditional Earned Value Management (EVM) but uses task durations instead of monetary measures. The ESM process provides a view into the project's progress in terms of its current velocity or pace.

As a project manager, it is important to know if project velocity is steady, slowing or accelerating. Lagging indicators alone do not provide insights to understanding the project's velocity, but ESM leading indicators do.

Historically, the best project managers gauged the velocity of a project based on clues obtained by informally monitoring the project's leading indicators. These project managers knew when to take action because of their intuitive sense of the project's velocity. The ESM feature of Chrono™ takes the remaining duration for each task and calculates the project's current velocity. The project manager can then use this information to confirm the project is on track to meet its timeline or determine that one or more impediments are impacting project performance. The project manager can then act early to avoid a major schedule slip before recovery is impossible.

TRACKING PROJECTS IN CHRONO™

Tracking a project using ESM in Chrono™ requires that an initial baseline be established. The project can then record updates chronologically from any time after the start date. We

recommend users select a frequent and consistent time interval for status updates (perhaps weekly or bi-monthly?) so that the corresponding graphics are uniform and intuitive.

For the first update in the tutorial perform the following steps:

1) Select the "Project Progress Update" button from the Chrono™ Tools ribbon.

Figure 33 Project Progress Update Button to Initiate Wizard

2) Enter 2/28/2020 5:00 PM in the Set Status Date input box and click on the "Set Status Date" button. Note the Status Date will now be updated in the dialog.

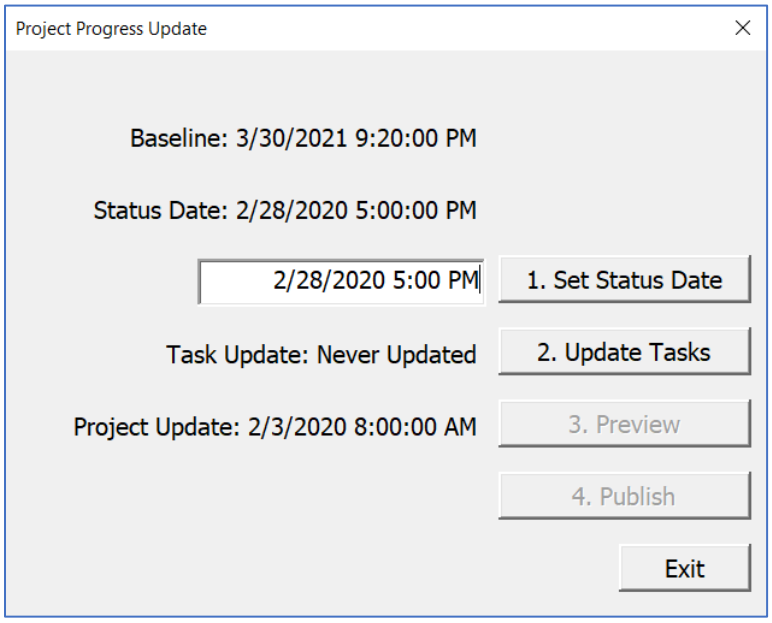


Figure 34 Project Progress Update Dialog & Input Box – Pre-Update

3) Select button "Update Tasks" on the dialog.

4) The update tasks dialog displays the time remaining for each task that requires an update. For this tutorial change the remaining days on TaskID #3 from 25 to 35 days and hit "Next". This change indicates that an issue has impacted the schedule of TaskID #3 causing a delay.

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5) A child window will be displayed asking if you wish to accept the recalculated Best-Case and Worst-Case values. For our tutorial, click "Accept Changes" without further edits:

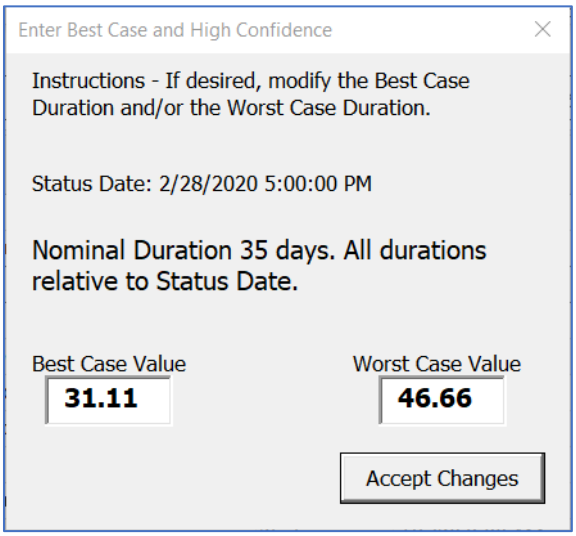

Figure 35 Best-Case and Worst-Case Adjustiments Window

6) Click the "Preview" button to view the changes to the project and determine if additional changes may be necessary. The dialog will automatically exit and the TriCoBi™ simulation will be run so that you can observe the results of the update.

7) For purposes of the tutorial, we will make one more change. While you are learning to use Chrono™ you may find the wizards helpful. Once you are familiar with the tool, you may find it more convenient to update the data in Microsoft Project® directly. Change the duration of TaskID #8 from 20 to 30 days in the duration field of the task in Microsoft Project®. This change indicates that a second issue has negatively impacted the schedule.

8) Click the "Run TriCoBi™ Simulation" to manually preview the how the changes have impacted the timeline.

9) Publish the schedule when satisfied with the updates by clicking on the "Project Progress Update" button and then clicking on the "Publish" button.

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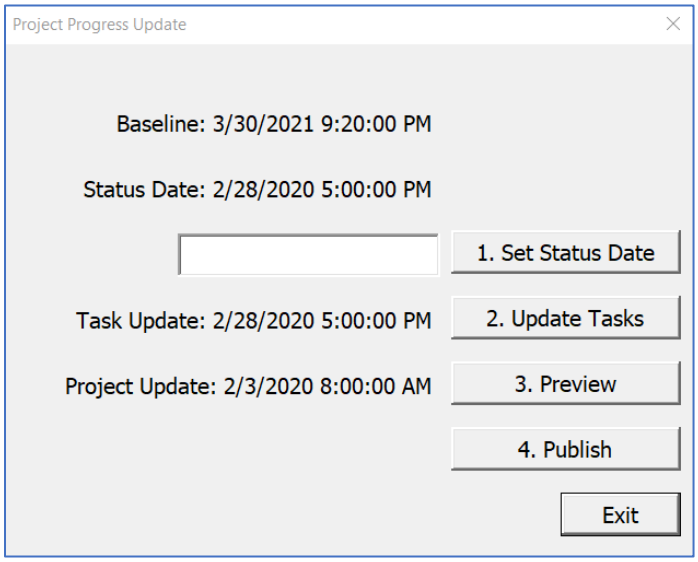


Figure 36 Project Progress Update Dialog & Input Box – Post-Update

10) Choose "Yes" on the accept change warning dialog. The screen will flash as a backup file is stored for future reference. Notice the backup files created with setting baselines and publishing have a naming convention that extends the original file name with three digits, such as "Tutorial Project #2_000.mpp", "Tutorial Project #2_001.mpp", Tutorial Project #2_002.mpp", etc.

UNDERSTANDING WHAT ESM AND CHRONO™ REFLECT ABOUT STATUS

1) Choose to display the probability chart and see how the commit confidence-level has been lowered and the 70% goal confidence-level date has been extended.

Solving the Impossible

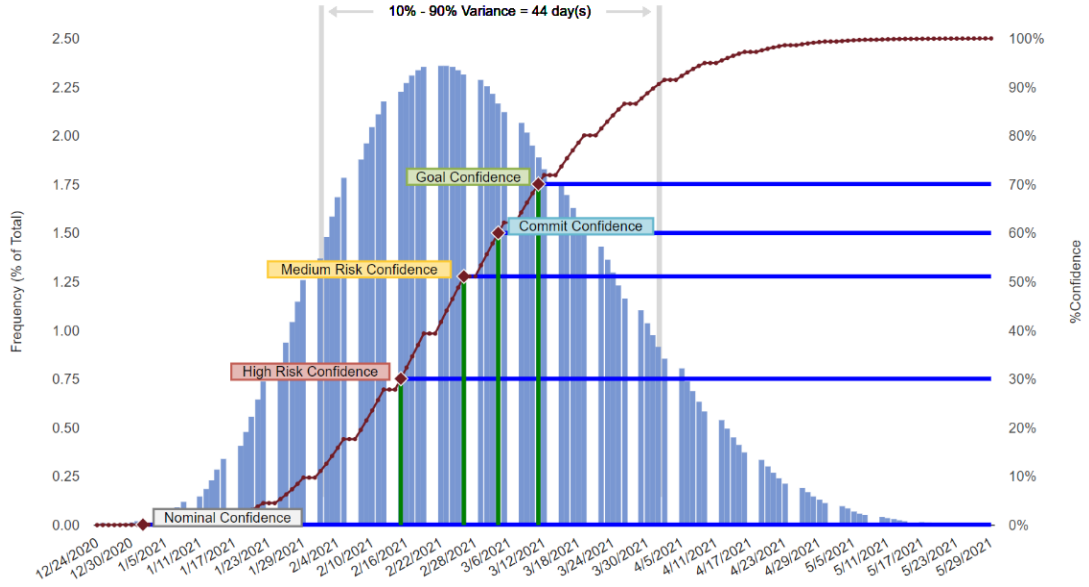


Figure 37 Primary Simulation Output - Commitment Milestone

Confidence-Level	%Confidence	Date
Nominal Confidence	0%	1/1/2021
Commit Confidence	60%	3/4/2021
Goal Confidence	70%	3/11/2021
Medium Risk Confidence	50%	2/26/2021
High Risk Confidence	30%	2/15/2021

Figure 38 Distribution Output Data Box

2) Next check on the Distribution Trend chart. Note the new bar on the right represents the update.

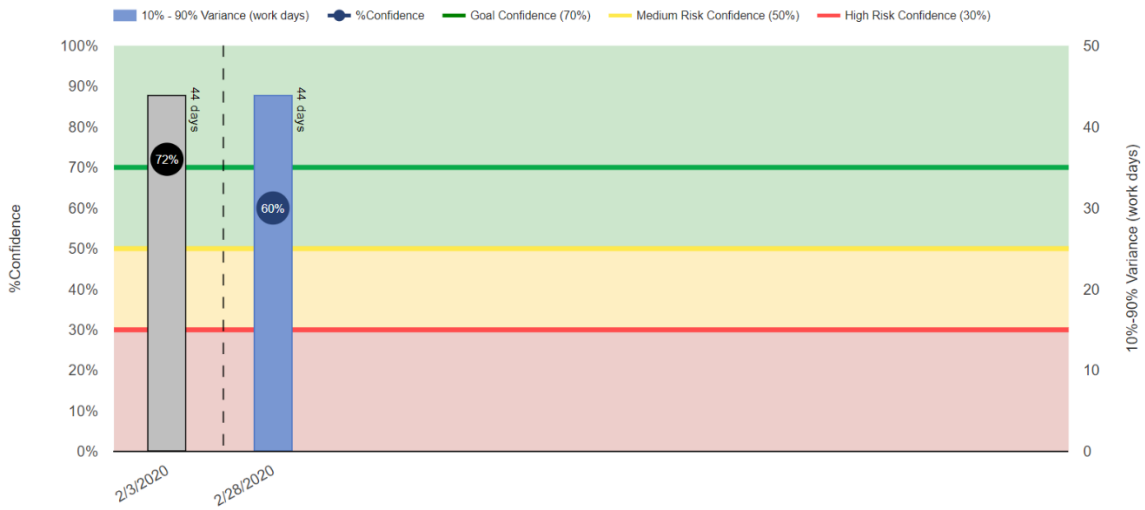


Figure 39 Distribution Trend Showing Baseline and First Status Update Data

3) Next check on the Earned Schedule Management (ESM) charts. Remember these charts have the built-in leading indicators that go beyond the 3-point estimate probability distribution and use the velocity calculated from the most recent status update to forecast the project end date at the given confidence level.

Earned Schedule Management is about forecasting the future based on current trends. When a project starts to slip the project's change in velocity is reflected in the Schedule Performance Index value shown in the charts below. An SPI value of 1.0 means the project is running at the velocity originally estimated and reflected in the project baseline. Since we have both goal-baseline and a nominal baseline, we have corresponding SPI values.

When measuring project performance for important business deadlines, we recommend tracking SPI on a weekly basis. SPI values of 1.0 or greater means that the project is tracking to meet or beat the business commitments. SPI values of less than 1.0 mean that the project has begun slipping and the recovery plan should be put in place as soon as possible. The reason it's always urgent to start a recovery plan when SPI is less than one is because changes in schedules are always least expensive early in the project rather than late in the project. More to the point, if project slips are not detected and acted upon early in the project, it becomes increasingly difficult to recover the schedule.

An added benefit of monitoring SPI is that first-line managers and project leads have found that they can use the SPI factor to identify subtle issues like employee engagement and hidden project complexity issues that might not be verbalized by their teams.

In tutorial data entered above, TaskID #3 and TaskID #8 were both extended by 10 days each during the first 4 weeks of the project. Note how this negative performance has extended the burn-up for the Goal Projected line. The total project duration is now estimated at over 500 days. The project is not off to a good start.

Solving the Impossible

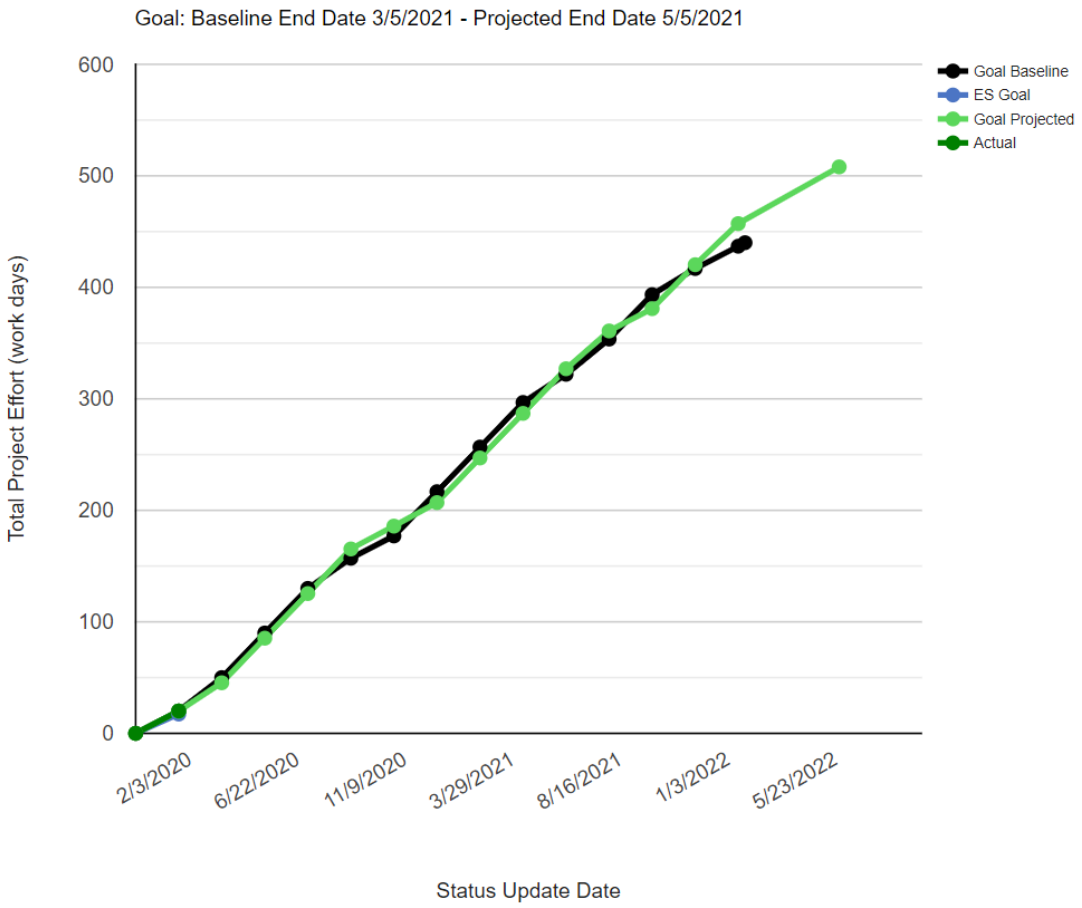
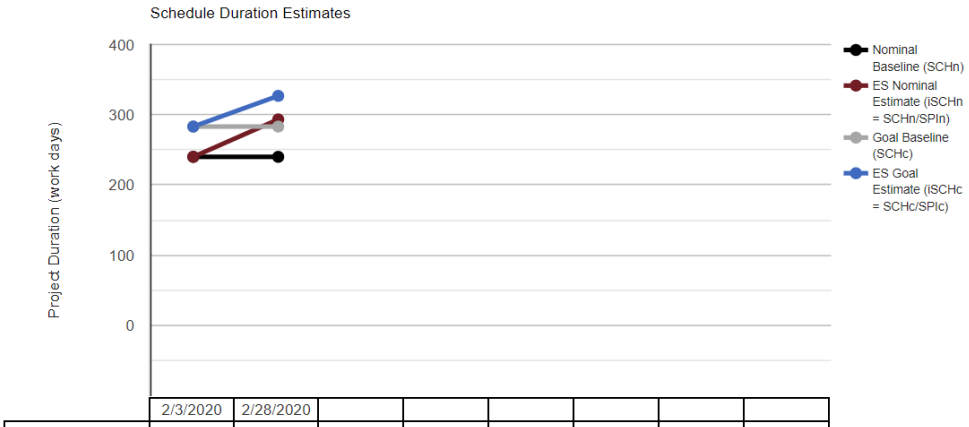


Figure 40 Goal Baseline vs. Projected Earned Schedule Chart after First Update

You can access Schedule Duration Estimates and Schedule Performance Index (SPI) values from the vertical tabs along the left side of the Earned Schedule tab of the browser display. Note how the SPI has changed from the neutral starting position of 1.0 downward to 0.87 for the Project Goal. The result is an ESM forecasted extension of 43 business days to the project - creating an ESM projected end-date of May 5, 2021.

Check that again, the SPI factor predicts that a 10-workday slip on two separate tasks early in the project results in a 43-workday slip in project completion. The message is to monitor SPI closely to keep steering the project to the targeted goal dates similar to how a sailor might monitor their compass or GPS to stay on course to their destination.

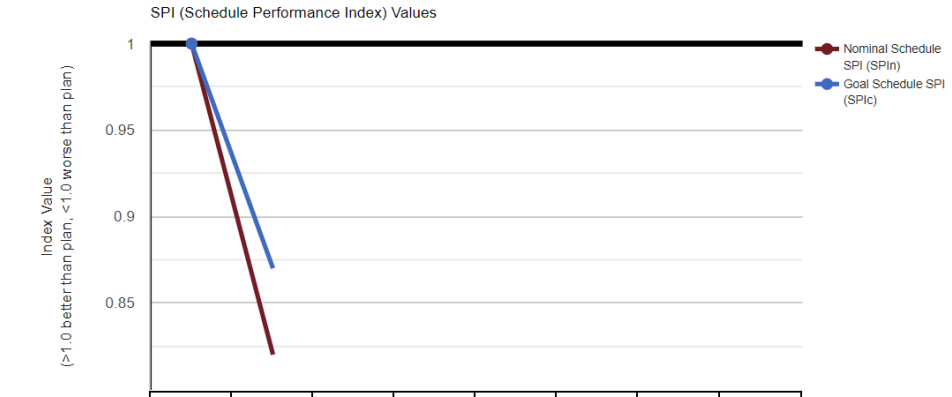
Solving the Impossible



	2/3/2020	2/28/2020						
Nominal Baseline (SCHn)	240.00	240.00						1/4/2021
ES Nominal Estimate (iSCHn = SCHn/SPIn)	240.00	293.33						3/19/2021
Goal Baseline (SCHc)	283.14	283.14						3/5/2021
ES Goal Estimate (iSCHc = SCHc/SPIc)	283.14	326.89						5/5/2021

Status Update Date

Figure 41 ES Total Time Baseline and Projected Metrics after First Update



	2/3/2020	2/28/2020						
Nominal Schedule SPI (SPIn)	1.00	0.82						
Goal Schedule SPI (SPIc)	1.00	0.87						

Status Update Date

Figure 42 ES SPI (Schedule Performance Indicators) Metrics after First Update

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4) After seeing the negative performance of project with the ESM leading indicator, the project manager will need to consider some early and aggressive actions to recover the schedule and get the trend back on track to the original forecasted 70% confidence date. The impact of this schedule recovery action will be shown in the next project update.

5) Select "Project Progress Update" and set the date to 3/27/2020 5:00 PM.

6) Select "Update Tasks"

7) Change the remaining dates on TaskID #3 from 15 to 10 due the results of the project manager's aggressive recover plan.

8) Accept the remaining dates for TaskID #4.

9) Select "Publish" and choose "Yes" on the accept change warning dialog.

10) See the distribution chart showing that the Commit confidence has recovered and is now over 74% based on the original end-date of 3/4/2021.

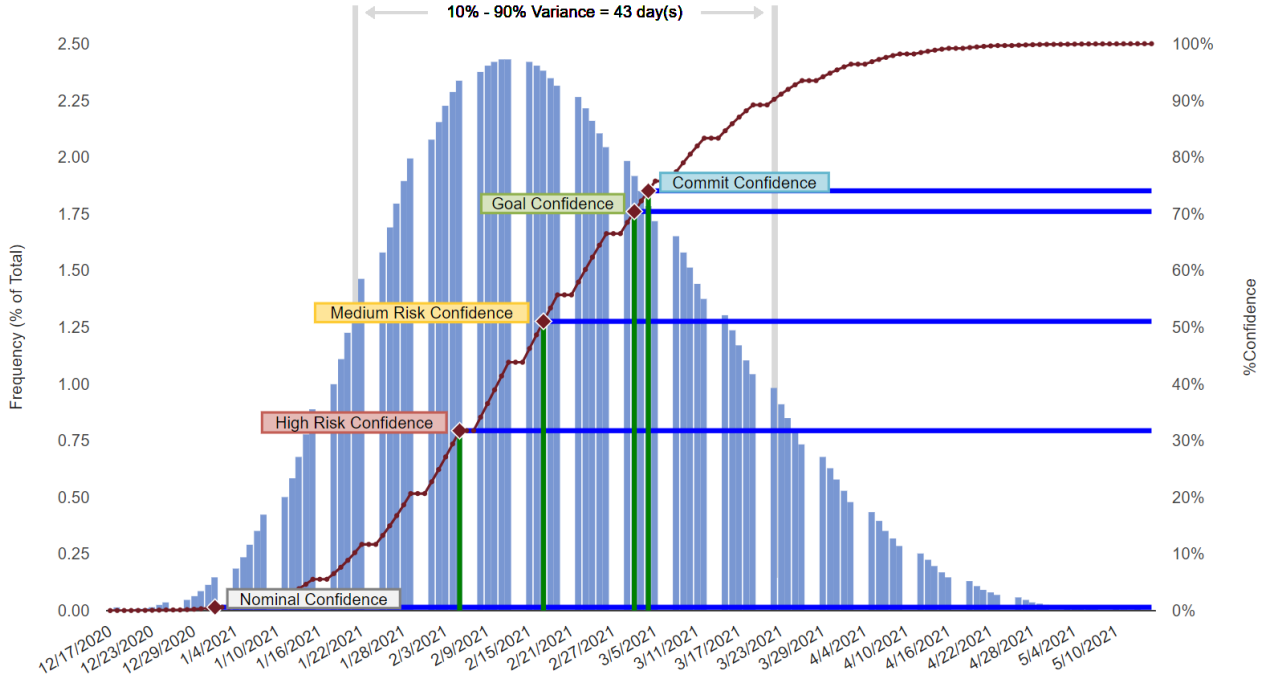

Figure 43 Output Distribution after Second Update

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Confidence-Level	%Confidence	Date
Nominal Confidence	1%	1/1/2021
Commit Confidence	74%	3/4/2021
Goal Confidence	70%	3/2/2021
Medium Risk Confidence	50%	2/17/2021
High Risk Confidence	30%	2/5/2021

Figure 44 Output Data Table after Second Update

11) Check the Distribution Trend to view the changes in the Commit confidence-level.

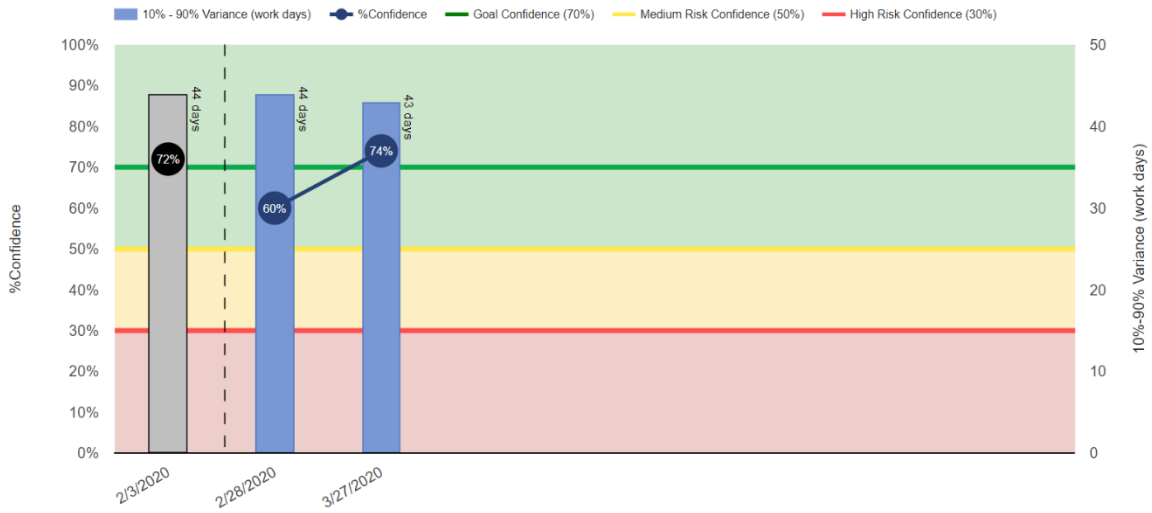

Figure 45 Distribution Trend Chart after Second Update

12) Next check on the Earned Schedule Management (ESM) charts, to see how well the project manager's recovery plan worked using the SPI as the primary lead indicator.

13) See that the updated Goal Project is now within the Goal Baseline on the burn-up chart.

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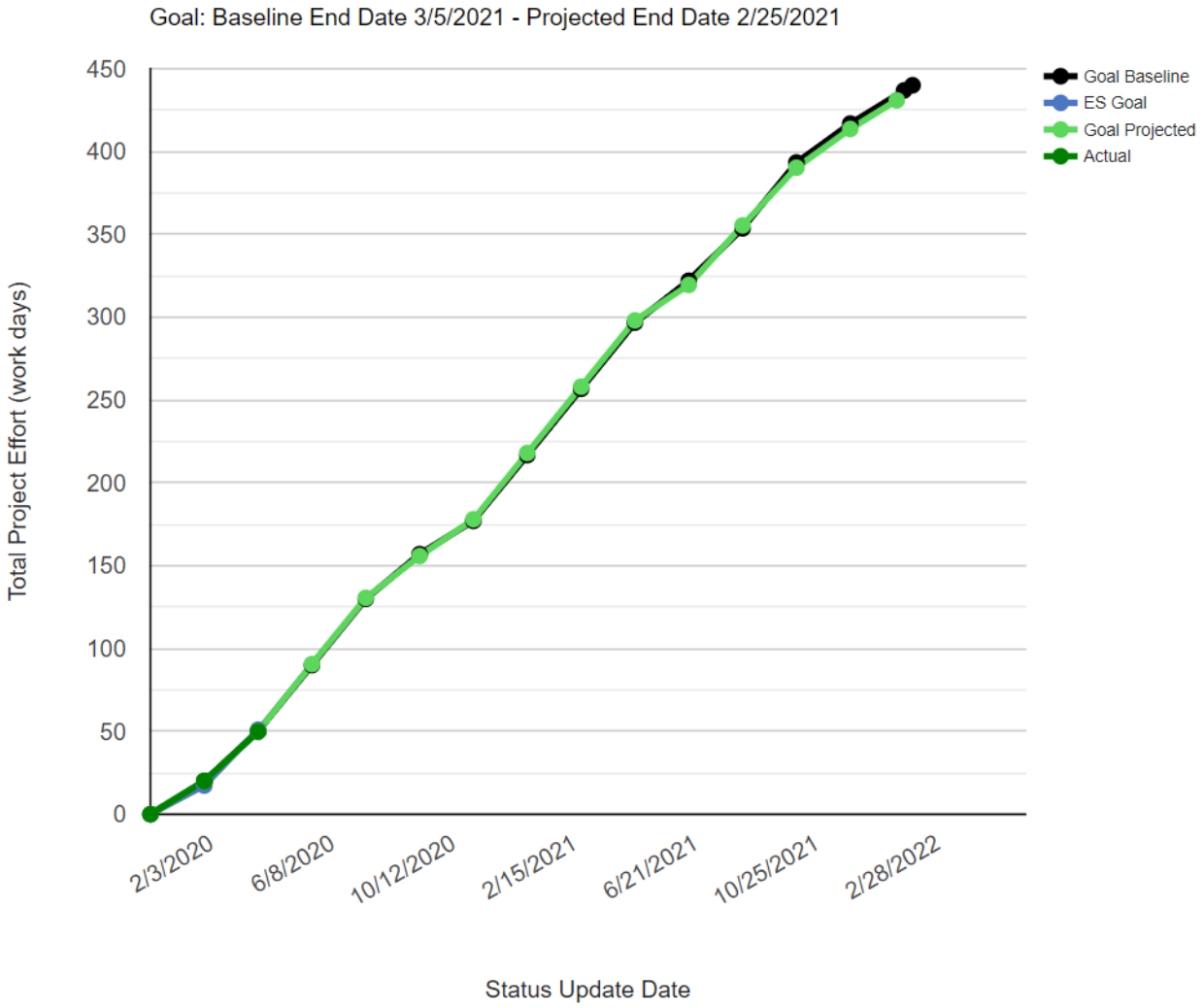
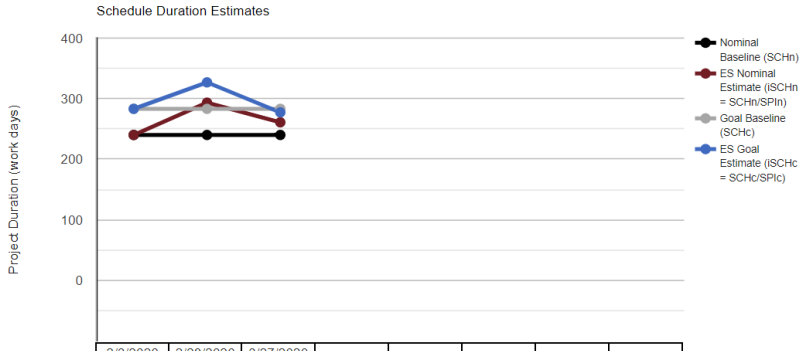


Figure 46 Goal Baseline and Projected after Second Update

The SPI has change through the aggressive action of the project manager from 0.87 to 1.02 resulting in a new ESM forecasted end date of 2/25/2021.

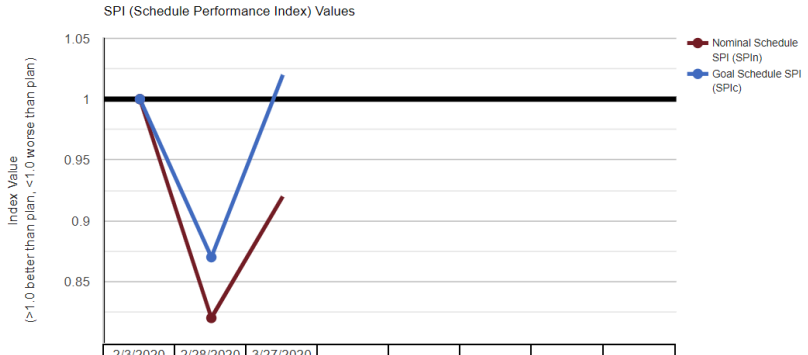
Solving the Impossible



	2/3/2020	2/28/2020	3/27/2020					
Nominal Baseline (SCHn)	240.00	240.00	240.00					1/4/2021
ES Nominal Estimate (iSCHn = SCHn/SPIn)	240.00	293.33	260.87					2/2/2021
Goal Baseline (SCHc)	283.14	283.14	283.14					3/5/2021
ES Goal Estimate (iSCHc = SCHc/SPIc)	283.14	326.89	277.31					2/25/2021

Figure 47 End Date and Time Projections vs. Baselines

Ideally, the project manager will now continue to monitor the Goal SPI and the ESM forecasted end-date and as much as possible take the actions required to keep SPI equal or greater than 1.0 and to keep the ESM forecasted end-date near or earlier than the ESM Goal Baseline target of 3/5/2021.



	2/3/2020	2/28/2020	3/27/2020					
Nominal Schedule SPI (SPIn)	1.00	0.82	0.92					
Goal Schedule SPI (SPIc)	1.00	0.87	1.02					

Figure 48 SPI (Schedule Performance Indece Trends for Nominal and Goal

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CAVEATS TO TRACKING WITH EARNED SCHEDULE MANAGEMENT

In some cases, the tracking a project strictly with ESM can miss some critical information. The ESM computation can include in its calculations the tasks that are not on or near the critical path, but are trending significantly late per the project baseline.

Until these non-critical path tasks slip so late that they become critical path or near critical path tasks, then they would not impact the schedule end date. However, they would impact the SPI of the ESM. Therefore, if the ESM schedule forecast end date is moving out because of these non-critical path items, then there are two options to consider to help determine a more accurate forecasted end date. The first is to re-baseline the schedule and reset the timing on the non-critical path items to match the current trends. The second is to balance the ESM schedule forecast with the probabilistic estimation forecasted end date.

CAVEATS TO TRACKING WITH ONLY A PROBABILISTIC SCHEDULE END DATE

It is also important to understand the limitations of tracking a project by the probabilistic end date created from the original 3-point estimates. While this forecasted end date is kept current with each Project Update entry, it does not provide an update to the project velocity. The project velocity represented in the probabilistic schedule end date is the original project velocity from the planning stage of the project.

Therefore, if the project velocity significantly changes after the project start date, it will be important to make sure the SPI for ESM remains valid by carefully monitoring the caveats for ESM. If the project velicoty significantly changes for any reason and it is not possible to keep the SPI accurte, then it would be best to re-evaluate the remaining 3-point estimates and re-baseline the project.

RE-BASELINING THE SCHEDULE

If at any point the project charter or plans change significantly enough for the original schedule to no longer be valid, then the updated project schedule should be re-baselined.

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A two-step process is recommended to re-baseline a schedule. The first step is to duplicate the project schedule using the Chrono™ customized "Save As" function in Microsoft Project®. The second step is to use the "Set Project Baselines" function in the Chrono™ Tool ribbon to set the baseline. It is important to understand that the both the ESM values and the cloud-based history of the project will be cleared when re-baselining as schedule. The principal option when re-baselining a schedule is whether or not keep the percent complete values for each task.

Typically, when re-baselining the percent completes for each task are retained. If a project is being used as a template for a new project, then it is typical to clear the task progress.

Re-baseline the project schedule with the following steps:

1) "Select File > Save" to save the project file to confirm that the original file is preserved.

2) "Select File > Save As" to create a new project file to hold the re-baselined project schedule. Use the file name "Tutorial Project #3.mpp".

3) Select the "Retain" option in the "Save As" dialog for the purposes of creating a re-baselined project schedule.

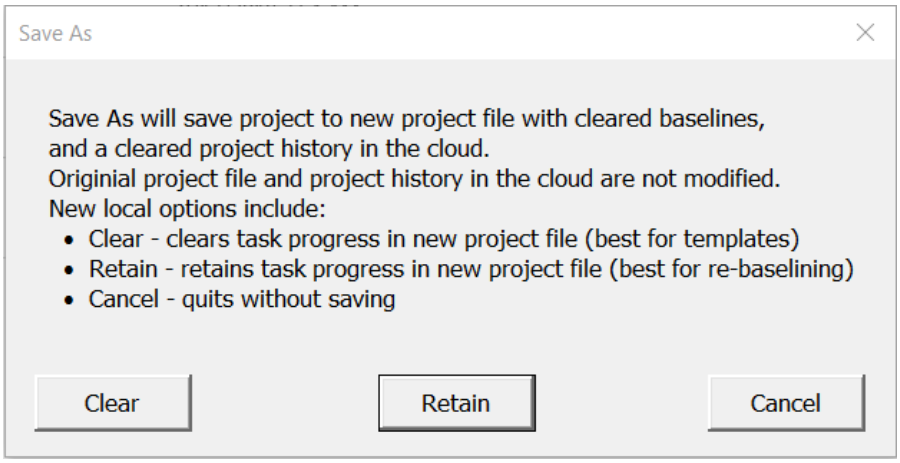

Figure 49 Options for Clearing IMS Data

4) Select "Run TriCoBi™ Simulation".

5) Choose "Goal Confidence" on the Chrono™ Gantt Chart Views ribbon.

6) Click the "Align Commit" button on the Chrono™ Gantt Chart Views ribbon, and choose "Yes" for End of Day

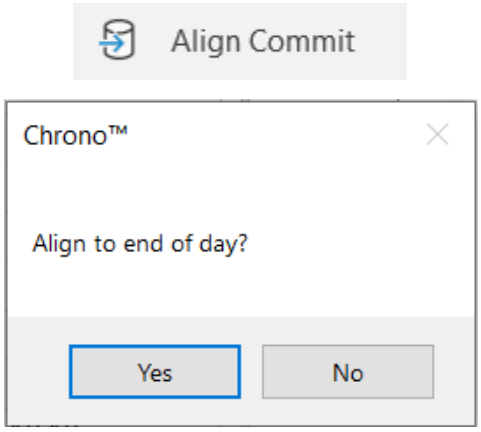

Figure 50 Sequence for Aligning the Commit Milestone

7) Note that the "Run TriCoBi™ Simulation" button in the Chrono™ Tools ribbon has the yellow warning triangle signifying that the TriCoBi™ Simulation needs to be run again.

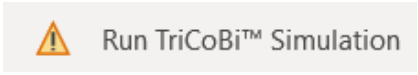

Figure 51 Simulation Button's Warning Triangle

8) Re-run the TriCoBi™ Simulation.

9) Select "Set Project Baselines" button on the Chrono™ Tools ribbon.

Figure 52 Set Project Baselines Button

10) Select "Yes" to the sponsor approval question.

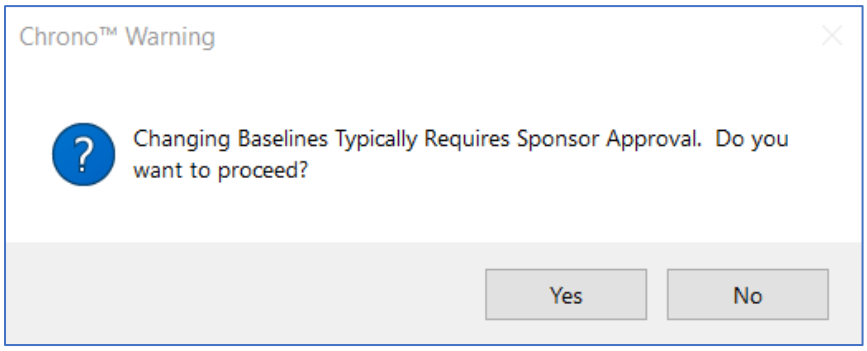

Figure 53 Precaution Pop-up for Changing Baselines

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11) The screen will flash as an additional backup file is stored for the baselines.

12) Baselines are set for both the Nominal Durations and the Goal Confidence Durations.

13) The TriCoBi™ Simulation is rerun.

14) Choose to see the web graphics.

15) See that the baseline is set in the top right side of the header.

16) See the updated project end-dates for each confidence level.

Confidence-Level	%Confidence	Date
Nominal Confidence	1%	1/1/2021
Commit Confidence	70%	3/2/2021
Goal Confidence	70%	3/2/2021
Medium Risk Confidence	50%	2/17/2021
High Risk Confidence	30%	2/5/2021

Figure 54 Simulation Output Data Box

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Why Traditional Schedules Fail: Basics of Schedule Risk Management

The Problem

We have something we need to accomplish. We build a to-do list of the steps, develop credible estimates, commit arithmetic and determine the approximate time required to do the project. We often find the project takes longer than we predict. The process seems reasonable, why are we late so often?

The answer is risk. This article explores how estimation risk affects a schedule and what you can do to create better schedules and more effectively communicate schedule risks to executives.

A simple example project to illustrate: Imagine you have been hired to frame and pour the foundation for a house being constructed. Let's assume you identify the following tasks and believe that the estimates for the task are reasonable:

Project – Create Slab House Foundation:

A) Get Materials (2 days) – obtain wood and pipes for framing and plumbing
B) Frame Foundation (5 days) – build wooden frame to pour concrete into
C) Install Plumbing (5 days) – place drains & sewage pipes prior to cement pour
D) Pour Foundation (3 days) – pour cement and wait for it to cure

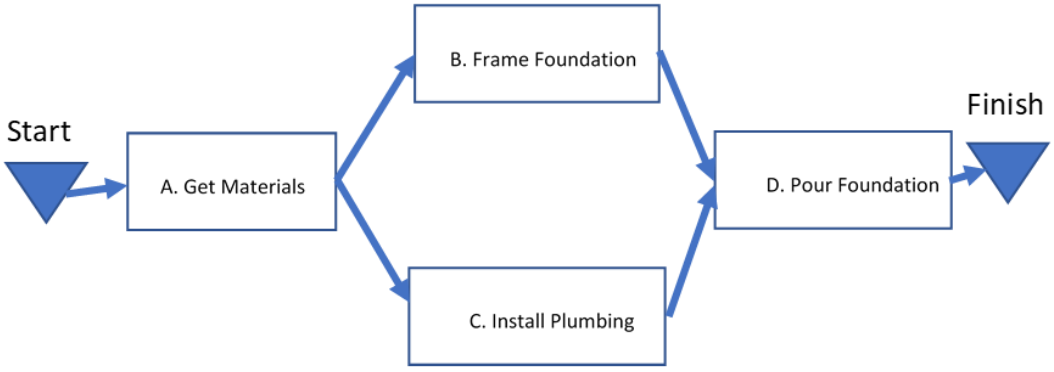

Figure 55 Basic Network Diagram

Assume these estimates are reasonable. Assume we have the resources to run tasks B & C in parallel. How many workdays will it take to finish the project?

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D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
Get Materials									
		Frame Foundation							
		Install Plumbing							
							Pour Foundation		

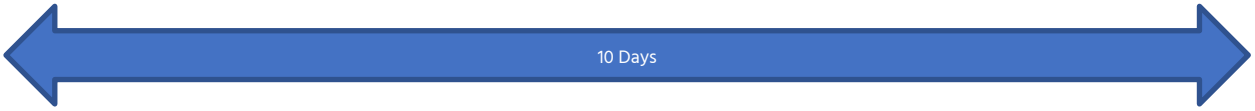

Figure 56 Simple Project Timeline

We can do the math to calculate an end date, but our experience says this will often be optimistic, particularly as projects get larger and more complex. Why? The estimates are reasonable. We are following traditional scheduling practices. What are we missing?

The estimates are reasonable, but how likely is it that these tasks take EXACTLY the amount of time we estimated. Pretty rare. Some might take a day longer or a day less. We might be able to get all the materials in a single day, or a part we need might be out of stock. One of the workers might get sick. Rain might delay concrete curing.

A number of problems could delay the tasks in even this simple project. Is it a problem with the estimates? Not really. Estimates are predictions based on the best information available when we make them. We don't have perfect information about the future, so we make what we hope are reasonable assumptions about the availability of materials, the productivity of the team, and the availability of concrete. Things might go a little faster or might take a little longer, but we call them "estimates" rather than "accurate predictions of the future" because we know there is uncertainty in all predictions.

Risk = uncertainty

Let's look specifically at tasks B and C. We estimated that these would each take 5 days and that they could be done in parallel. There may be a problem hiding here. If the same people are doing both tasks, having the tasks occur in parallel assumes that people can be in two places at once. Even if your estimates were good, you may already be in trouble. These estimates depend upon some general assumptions about resource availability, materials, humans, and cement mixers.

Solving the Impossible

There is a subtle structural problem that may come into play as well. Note that we have depicted that both tasks B and C must be complete before you can pour the foundation. When a task like Pour Foundation is dependent upon multiple predecessors, we describe it as a "**merge node**" in the task network.

Merge nodes must wait for all of their predecessors to complete, which increases the chances they will be late because any of the predecessors that run late cause the merge node to be late. Merge nodes play the unfortunate role of amplifying schedule slippage through a task network. This effect is surprisingly significant.

Imagine that estimates for tasks B & C both have a 50% chance of being "right" – predicting the date on or before the task will complete. That says there is a 50% chance of exceeding the estimate – that translates into a 75% chance that task D starts late, as shown in the following picture:

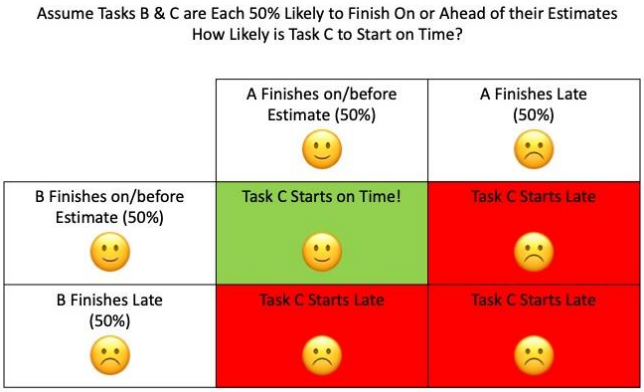

Figure 57 Merge Node Effects

Why Not "Pad" the Estimate?

Our first instinct is often to "pad" the estimates. We imagine it will take 2 days to get our materials, but we call it 3 days "just to be sure". We think it may take 5 days to frame the foundation, but we call it 7 to avoid being responsible for the schedule slipping. Sadly, padding our estimates like this can hurt us in several ways:

1) An executive who thinks our end date is too far in the future and discovers obvious padding may deduce that we are either incompetent or lying. "Seven days to frame a foundation? In MY day we could do that in 4 or 5."

2) It may result in poorly informed business decisions that cause us to lose the business. The client may say, "I wanted to go with contractor X, but their schedule said this was going to take 15 workdays and contractor Y says they can do it in 10."

3) If we can complete a task sooner, we may not be able to take advantage of the windfall because resources to do the other tasks aren't scheduled to be available. If we can frame the foundation and get the plumbing installed in 5 days, but we padded the schedule to 7, then the cement mixer we scheduled may not be able to shift to earlier delivery. Padding may seem like a natural solution, but it causes more problems than it solves.

A Better Approach to Estimates

Developing credible estimates is hard. It asks us to make informed guesses about the product we are building, the team that is building it, and the future context in which it will be built. These are all uncertain.

Here's a counterintuitive solution: Instead of asking for one estimate predicting the cost and schedule of a piece of work, ask for three:

1) Best Case - If you did tasks of similar size & complexity 10 times, what is the best realistic case you can imagine (e.g., things don't go perfectly, but they go smoothly)?

2) Likely/Nominal Case - What is your best guess about the time and resources normally be required to perform a task of this size and complexity?

3) Worst Case - If you did similar tasks 10 times, what would likely be the effort and duration of the most frustrated of your 10 attempts? What estimate do you feel very confident you can deliver, absent significant drama?

The three-point estimate relieves the team from the pressure of trying to accurately predict the future and instead asks for a range of possibilities they think are credible, based on their experience and the best information available.

This reinforces for both the estimator, and anyone reviewing the estimate that estimation is not an exact science. It also calls attention to tasks where the team has a great deal of

uncertainty, as defined by tasks with a large spread between the best and worst case. This method fosters a conversation about what, if anything, can be done to reduce that uncertainty (prototyping, further research, more design) prior to providing information to executives.

Remember, these are estimates, not hard and fast predictions of the future. In the hands of responsible decision-makers, thoughtful estimates can do a lot to identify risks and set expectations.

Visualizing 3-Point Estimates

Let's go back to our foundation example and show you how the results of 3-point estimates can be shown to executives to better communicate schedule risk. The same task list is presented below. I have included estimates for best case, likely case, and worst case.

Project – Create Slab House Foundation:

A) Get Materials (1,2,3 days) – obtain wood and pipes for framing and plumbing
B) Frame Foundation (4,5,8 days) – build wooden frame to pour concrete into
C) Install Plumbing (3,5,9 days) – place drains & sewage pipes prior to cement pour
D) Pour Foundation (2,3,7 days) – pour cement and wait for it to cure

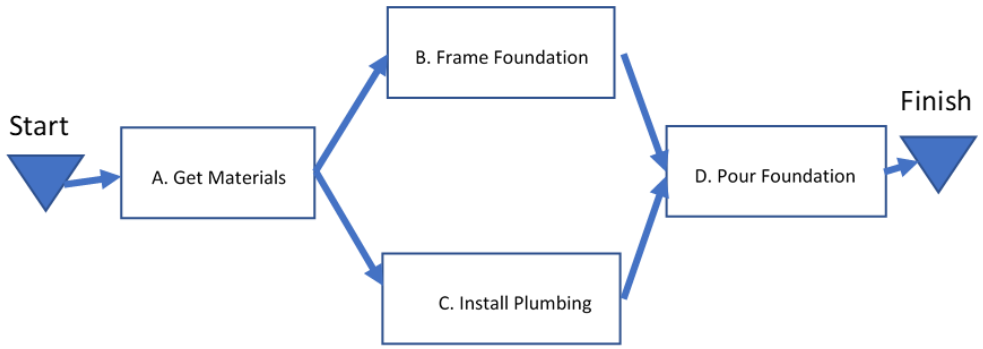

Figure 58 Network Diagram

If we assume the best case when we build our schedule, we get a duration of 7 days – this is overly optimistic because it is unlikely that everything would go so smoothly for all four tasks, but it describes the absolute soonest we can imagine the project being competed with the resources assigned.

If we show the likely case, we get a duration of 10 workdays - the same as the earlier schedule, which experience says would be a challenge and likely late.

Solving the Impossible

If we show the worst case, we get a duration of 19 days - and we have the same problems we described above for padded estimates.

Let's visualize the duration of each task as a probability distribution (a curve showing likely outcomes)? The tasks might look like this:

Get Materials (1,2,3)

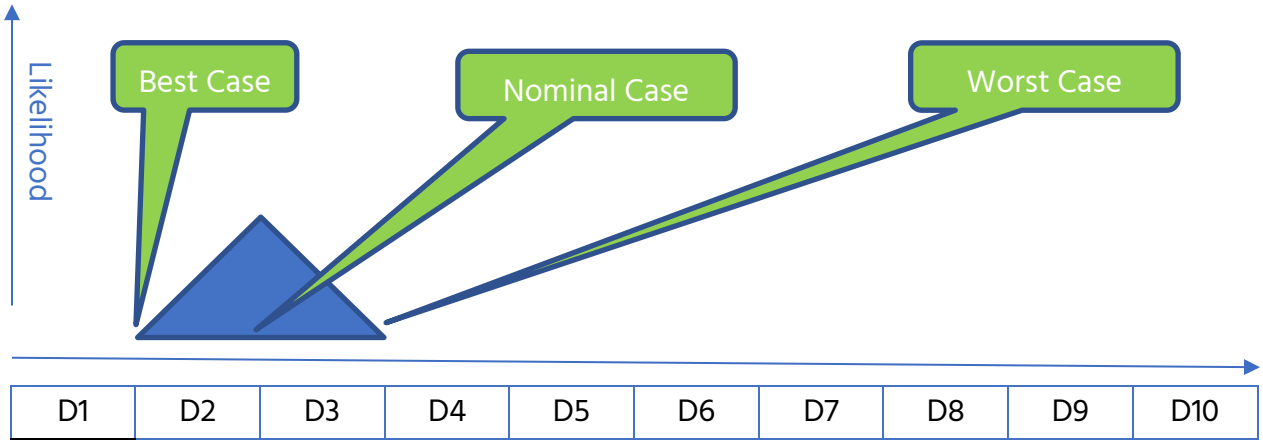

Figure 59 3-Point Timeline Estimate for Get Materials

Finishing by the end of day 1 is possible, but very unlikely. The most likely estimate would be to finish at the end of day 2. Interesting to note that half of the outcomes shown by this curve occur in day 3, although it appears unlikely that all of day 3 would be required to complete the task.

Frame Foundation (4,5,8)

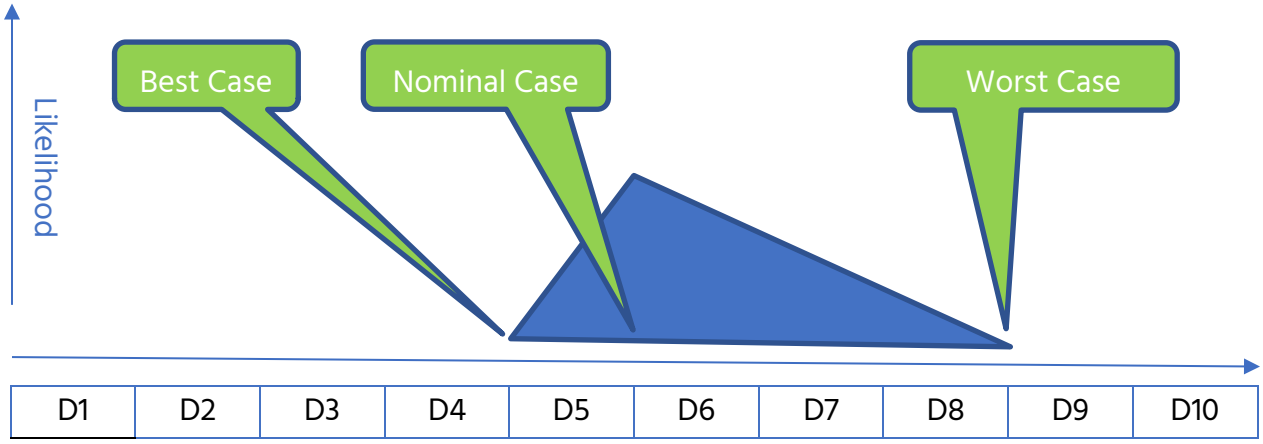

Figure 60 3-Point Timeline Estimate for Frame Foundation

Solving the Impossible

Note that most of this shape represents that task finishing after day 5. This might prompt a question about what the estimator imagines might go wrong that would lead to this delay (like bad weather), but we will explore that later.

Install Plumbing (3,5,9)

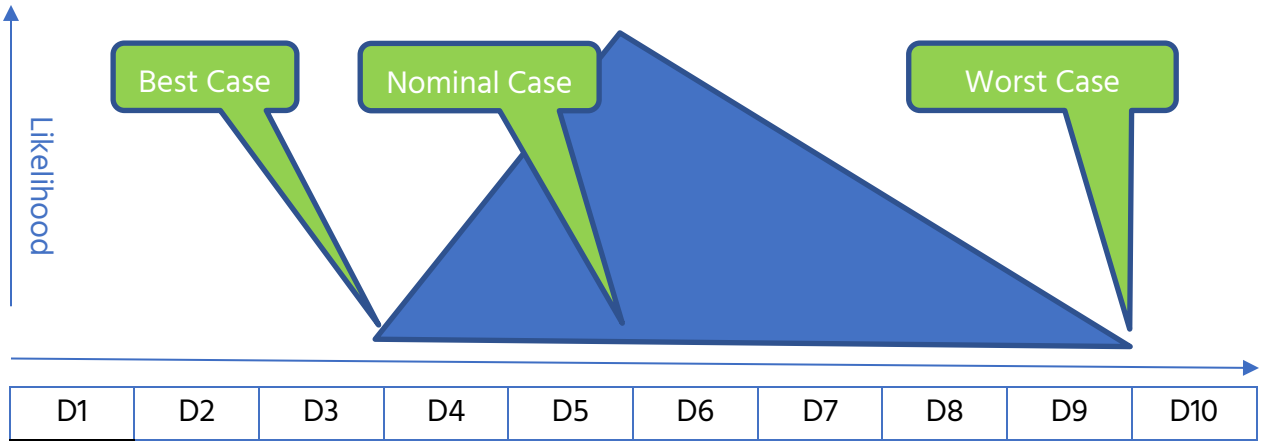

Figure 61 3-Point Timeline Estimate for Install Plumbing

Pour Foundation (2,3,7)

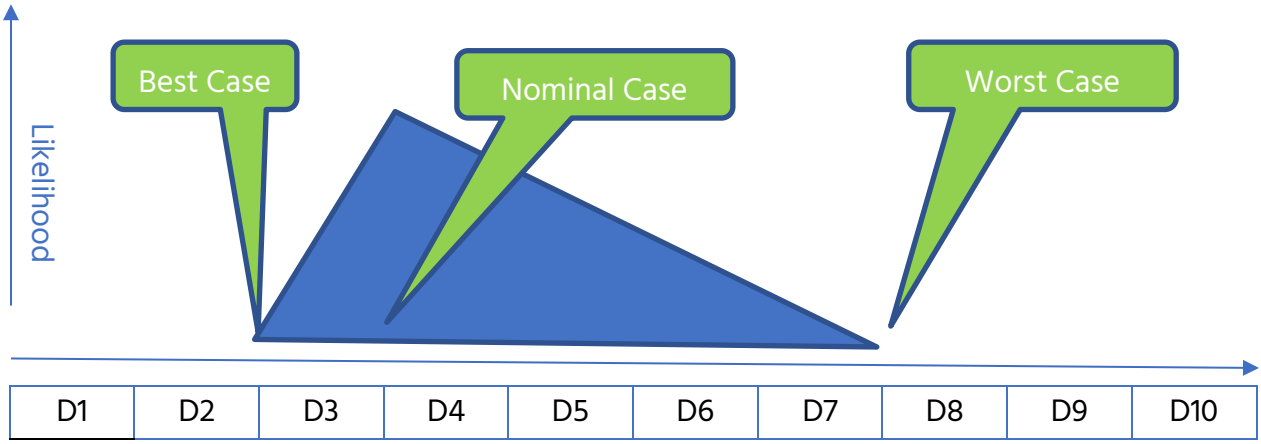

Figure 62 3-Point Timeline Estimate for Pour Foundation

These images help visualize the problem with single point estimates. Although the likely case may be a reasonable estimate, there are many outcomes that exceed it.

A key idea here is that some tasks might finish early, but it is unlikely that ALL tasks will finish early. Some tasks may exceed their expected duration, but if the estimates are credible it is unlikely that they ALL extend to the maximum "High Confidence" boundary. It

would be helpful to combine the information from the 3-point estimates of all four tasks into something that we could show an executive to help them understand when the project was likely to be complete.

(Drum roll please…)

We can do this with a mathematical process called a "Monte Carlo Simulation". Without going into the math, this is like hiring a thousand identical teams to do the same project a thousand times and graphing the resulting completion times.

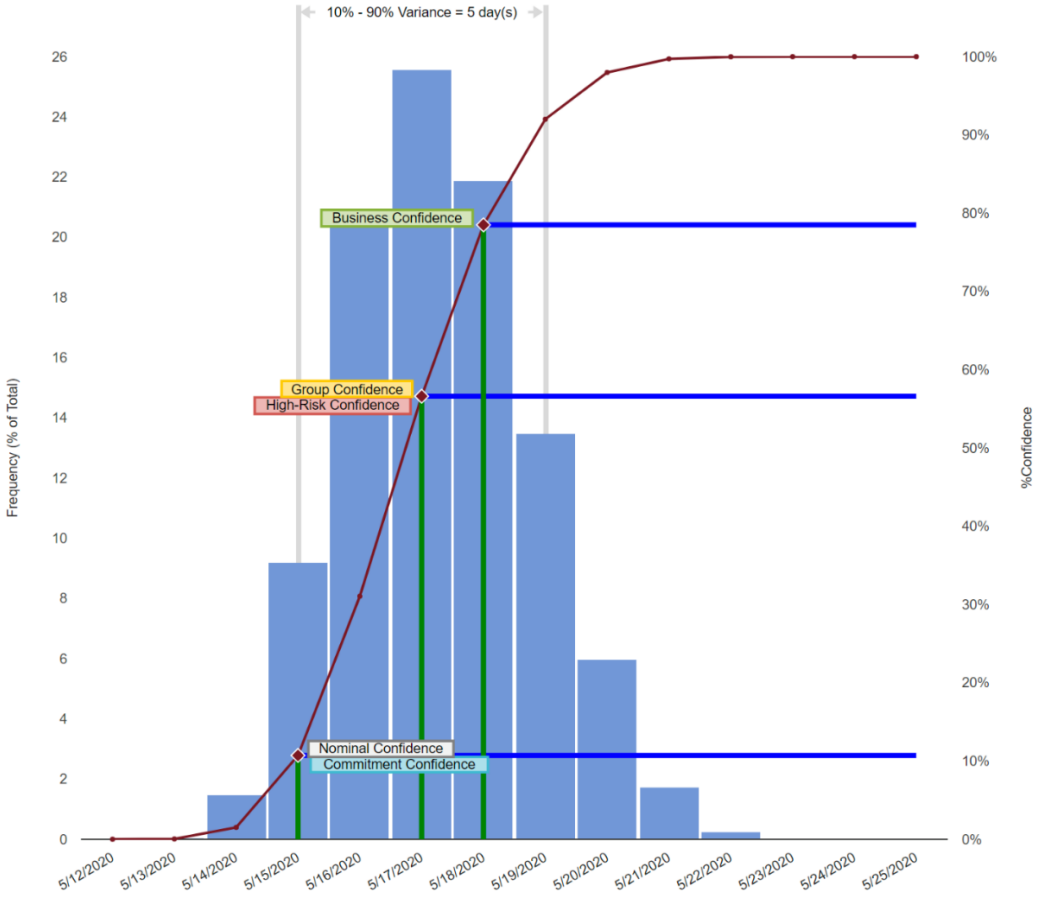

Figure 63 Simulation Output Distribution

As you can see above, the output of this simulation shows the approximate likelihood of achieving various project completion dates. The left vertical access describes the frequency of the date bars of the histogram. If you look at the histogram bar for 5/15 you will see that it occurred about 9% of the time in the simulations. The right vertical access describes the cumulative probability of achieving the date corresponding to the purple

line. If you look at the 50% mark and go left you will see the purple line on 5/17, meaning that the schedule extended beyond 5/17 about 50% of the time and finished on or before 5/17 about 50% of the time.

Our project began on May 5th and the best-case scenario would be the project finishing in 7 days at the end of the day on May 11th or start of May 12th (my example schedule assumes we are working 8 hours per day 7 days a week - the 7 days of work would occur on May 5, 6, 7, 8, 9, 10, & 11). None of the simulations finished before the 14th. Clearly assuming the best case for all tasks is overly optimistic.

Remember the initial schedule we built with the first set of nominal estimates? Those were the best honest prediction of the team and traditional scheduling suggested the project would finish at close of business on the 15th. The simulation only saw that outcome or better (right axis) about 11% of the time. Our intuition that this wasn't enough time seems correct.

What about the late outcomes? Although normal scheduling techniques would suggest that 5/15 was the projected end date, over 10% of the end dates in the simulation finish on or after 5/19, four or more days after our projected end date.

How is this helpful?

Remember that we went down this rabbit hole trying to honestly answer the question, "When will the foundation be ready?" We agreed that estimates were difficult and rarely accurate and were trying to find a better way to predict the end date without arbitrary padding. When we asked the team for 3-point estimates, they were able to give us their best honest guess (likely case), as well as the best case and the high confidence estimate to establish boundaries and help us understand the variability they predict based upon their experience.

Using this data to create the chart, we can now have a conversation about schedule risk. Is it possible we could do the project by 5/14? Yes, but it is extremely unlikely. Less than a 2% chance. We now have a visual aid for the project sponsor. According to the chart about 90% of the time we expect the project to complete on or before 5/19, barring circumstances we can't anticipate. This allows a sponsor to discuss how much risk they are willing to take.

Solving the Impossible

For example, if the plan calls for an expensive crew to show up to build the building once the foundation is complete and they must be paid whether the foundation is in place or not, the sponsor can decide whether to risk having them show up May 15th (90 percent chance of missing that date) or schedule them for May 18th (80% chance of the foundation being complete).

The process that culminates in this chart helps to communicate the uncertainty of the schedule prediction much more effectively than specifying a specific date. If you were relying on someone to tell you how long they thought a project was going to take, would you rather they gave you a date or initiated a conversation about likely dates and confidence levels?

Solving the Impossible

Using 3-Point Estimates for Less Stressful, Better Quality Estimates

Estimates are needed to inform decision-makers about whether it is worth solving a problem as it is currently understood. It might seem counterintuitive, but instead of asking for one estimate of cost and schedule, ask for three. Here's an approach to doing that and an explanation about why it might be more informative and less stressful.

Although I disagree with the fervent #noestimates crowd about several of their arguments, they make some valid points. In a world where the ultimate project outcome is not clearly defined up front and a project is an exercise in discovery, the notion of "precise estimates" is laughable.

We part ways when people assert that no estimate is better than a crude one.

If my car starts acting strangely and I take it to the shop, I expect one of two conversations:

1) The service rep recognizes the problem and can tell me with 80% confidence about how long it will take and what it will cost to remedy the problem, *assuming their prediction about the problem is correct and no other issues are discovered.*
2) The service rep looks puzzled, says, "There are several things that could cause that," and suggests a cost and time estimate—not to resolve the problem, but to *diagnose* it.

Estimates serve a number of purposes, but one of the most important is to inform decision-makers about whether it is worth solving a problem as it is currently understood. How would you feel if the service rep said, "I don't know what the issue is, but give me your credit card and we'll start diagnostics. I'll call you if we figure out the cause!"

Developing credible estimates is hard. It asks us to make informed guesses about the product or service we are building, the team that is building it, and the future. These are all uncertain—for instance, I doubt any of the project managers I coach had "unexpected quarantine" on their "assumptions about the future" bingo card, but here we are.

Solving the Impossible

Here's a counterintuitive technique: Instead of asking for one estimate predicting the cost and schedule of a task, ask for three. Three-point estimates are more useful and usually less stressful than their single-point alternative.
Here are the three prompting questions to get your team started:

1) If your team performed tasks of similar size and complexity 10 times, what is the best realistic case you can imagine in terms of time and resources (e.g., things don't go perfectly, but they go smoothly and well)?
2) What is your best guess about the time and resources that would normally be required to perform this task? If we imagine doing the task 10 times, this would be the most likely outcome in terms of time and cost.
3) What would likely be the effort and duration of the most frustrated of your 10 attempts? What is the longest you can imagine it taking, absent some external drama? What are some of the things that could go wrong that would drive the worst case?

The opportunity to provide three-point estimate relieves the team from the pressure of trying to accurately predict the future and instead asks for a range of possibilities they think are credible, based on their experience and the best information currently available.

This approach reinforces that estimation is not an exact science. It also encourages a conversation about risk – uncertainty the team has about the task and things that could drive it toward being late. Uncertainty is underscored for tasks with a large spread between the best and worst case. This gives project managers and team leaders opportunities to discuss what might be done to reduce that uncertainty (prototyping, further research, more design).

Using schedule risk management tools like Chrono™, three-point estimates, particularly for high-risk tasks – tasks with a significant variance between the best-case and worst-case estimates – helps create more realistic schedules.

Solving the Impossible

The DCMA 14 Point Metrics Check

Some schedules represent credible task logic and can be used for tracking progress, and some are art projects that may be pleasing to the eye but are mostly worthless. Tired of dealing with vendors and programs that were trying to manage complex and expensive efforts using art projects, the US Defense Contract Management Agency (DCMA) developed and distributed objective criteria for evaluating schedules both quantitatively and qualitatively in 2005.

The metrics were adopted first by the US Department of defense (DOD), and are now required of their subcontractors by some major defense contractors. While not hard and fast rules, schedules that comply with the guidelines tend to be more credible and manageable, and schedules that do not comport with the guidelines are unlikely to be useful for understanding or tracking changes in a credible way.

Chrono™ provides a mechanism to assess compliance with the DCMA 14-Point assessment. This chapter explains the standard and how Chrono™ users can review the assessment of their schedule.

1. **Logic** – It's generally considered best practice for all tasks in a schedule to have at least one predecessor and at least one successor. This does not include summaries or milestones. The actual test looks at tasks that are not marked 100% complete to have at least one predecessor and one successor. The threshold for compliance is that no more than 5% of tasks should be without both predecessor and successor. It is a good rule of thumb that all tasks have predecessors and successor.
2. **Leads** – This metric measures the percentage of tasks that have a negative lag between them. An example would be task B scheduled to start 3 days before the end of task A. Although most scheduling tools allow this, using leads confounds efforts to calculate project float (or slack) and the critical path. The standard is that no tasks should have leads. Usually when someone suggests a lead is needed, tasks can be further decomposed so that traditional Finish to Start relationships can capture and better represent task logic.
3. **Lags** – The Lag metric is the percentage of project tasks that have a positive lag between them. Lag is a positive delay on a dependency. If we said task B can start

3 days after task A finishes, then we have defined a 3-day lag between A and B. The threshold for this metric is no more than 5% of all task relationships should contain lags. A better practice is to have a named task in the dependency chain to explain what is being waited for; for example, perhaps Task A was to paint the table and Task B was to set the table. Inserting a 3-day task for "Dry the Paint" between the two would eliminate the lag and better document the task logic.

Although a lag between finishing task A and starting task B is not advised, starting task B "x" days after task A starts (a Start-to-Start relationship type) is more acceptable provided "x" is not greater than the task A total duration.

4. **Relationship Types** – The metric is the percentage of all project tasks that use Finish to Start relationships. Most schedule logic can be represented with Finish to Start dependencies, but in some circumstances Start to Start and Finish to Finish dependencies may be appropriate; for example, a quality assurance task may not be able to start until the work being assessed has begun. The threshold for this metric is 90%. No fewer than 90% of the relationships in the schedule should be Finish to Start.

5. **Hard Constraints** – A hard constraint is a specified fixed date for a task to begin or end (Must Finish on, Must Start On). Hard constraints can mask progress/performance issues and thwart schedule analysis because they stop a schedule from responding to delays of predecessors. The metric is the number of unfinished tasks with hard constraints. The threshold is that no more than 5% of incomplete activities in the schedule may use hard constraints.

6. **High Float** – This metric measures the percentage of unfinished tasks that have total float greater than 44 working days. While high float might be a good indicator that there is slack in a schedule, it can also indicate that task logic is missing; the assumption being that it is rare that a task can slip more than 2 months without affecting the end date. The threshold for this metric is that no more than 5% of the unfinished tasks in a schedule should have High Float.

7. **Negative Float** – Negative Float occurs when the schedule predicts that a critical or contractual milestone will be missed, or a slipping task collides with a hard constraint. Essentially, negative float suggest that the schedule will not achieve its

objectives and is usually a sign that intervention is necessary. The threshold for negative float is zero. Any task with negative float will fail this test.

8. **High Duration** – This metric counts the number of unfinished tasks with duration greater than 44 workdays (2 months). High duration tasks are problematic in many cases because it is challenging to monitor progress. The remedy is often to further decompose the task into smaller, well defined tasks with shorter durations. The threshold for this metric is that no more than 5% of the unfinished tasks in the schedule should have duration greater than 44 workdays.
9. **Invalid Dates** – The metric for invalid dates examines both forecast and actual task start and finish dates. Tasks forecasted to finish in the past (earlier than the project status date) or reported as having started in the future (later than the current status date) are deemed invalid. The threshold for the Invalid Dates metric is that zero tasks in the schedule should reflect an invalid date because this undermines the credibility of the entire schedule.
10. **Resources** – This optional metric represents the percentage of unfinished tasks that have resources associated with them. Organizations that wish to use this metric can have it enforce that 100% of the unfinished tasks identify a resource.
11. **Missed Tasks** – The missed task metric tracks the number of baselined tasks that were scheduled to finish on or before the status date but have not been marked complete. This does not include tasks that are forecasted to be late after the status date, it is only retrospective. The threshold for this metric is that no more than 5% of the tasks in the schedule should reflect missed dates.
12. **Critical Path Test** – This is a pass/fail metric that evaluates the integrity of task logic in the schedule. The first step is to identify the critical path in the task network, then the first task(s) in the network have a slip introduced and the resulting slip in the project end date should slip by the same amount. If the slip inserted at the beginning is the same as the slip observed at the end, the test is passed, else the test is failed. This test identifies bad task logic or hard constraints that are making the schedule unresponsive.
13. **Critical Path Length Index (CPLI)** – This is a measure of the efficiency required to achieve a schedule milestone at the assigned time, defined as the sum of the

remaining project duration in workdays on the critical path plus total float (the difference between the forecast and baseline finish dates of the finish milestone), divided by the remaining project duration. CPLI = 1.0 indicates that the project must execute exactly as planned to complete on time. CPLI > 1.0 indicates that there is some schedule margin remaining. CPLI < 1.0 suggests the project is not on track to achieve its goal. The threshold for this metric is CPLI < 0.95 which indicates the project does not appear to be on track to achieve its schedule goals.

14. **Baseline Execution Index (BEI)** – This metric evaluates the project team's schedule performance against the baseline plan. It is calculated by dividing the total number of tasks completed by the total number of baselined to have been completed by the project status date. BEI = 1.0 indicates the project team appears to be executing according to plan. BEI > 1.0 indicates that the project team is performing ahead of plan. BEI < 1.0 suggests that the project team is behind schedule. The passing threshold for this metric is BEI not less than 0.95.

Although the DCMA assessment is not a widely recognized industry standard, it generally represents good scheduling practice. Whether or not your organization is required to use it, you may find this analysis helps to identify issues with schedule logic and performance that should be investigated. Satisfying these targets doesn't mean that a schedule is credible or correct but failing to meet these goals indicates that a thorough schedule review to understand why the standards weren't met might be in order.

At any time, users can select the metrics button on the Chrono™ toolbar to display the results of the 14-Point assessment. The metric information is stored in the Commitment Milestone's "Note" section.

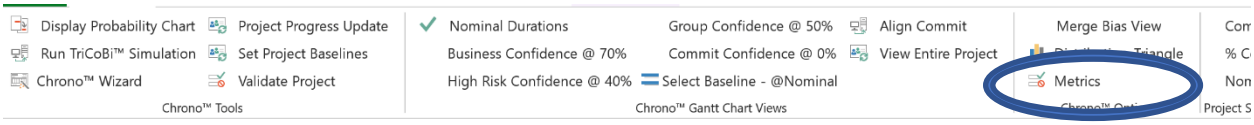

Figure 64 The Metrics Button

Note that the Chrono™ Validation Wizard has both some less stringent and more stringent requirements relative to the DCMA 14-point Metric, so an IMS can be considered "valid" by Chrono™ standards, but may "Fail" the DCMA 14-point Metric standards. An asterisk next to the score indicates a failed test, as shown below.

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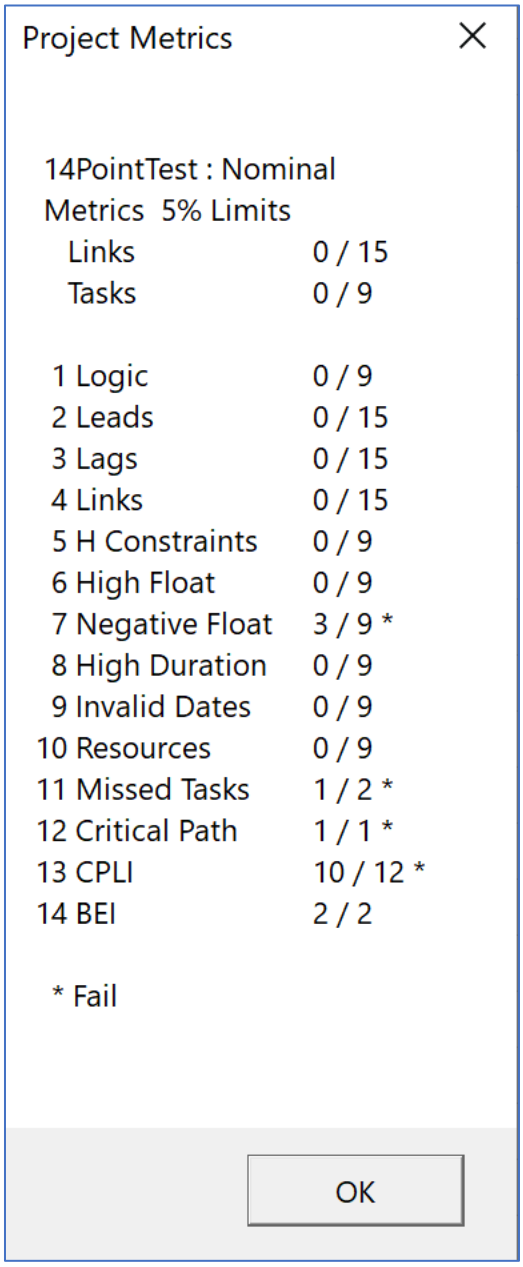

Figure 65 Example of the DCMA 14-point Metric Scorecard Produced by Chrono™

A quick reference for the DCMA 14-Point Metric and the Chrono™ implementation can be found on the next page.

Chrono™
Moneyball for Project Management

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	IMS Analysis Check-List Items	DCMA 14-Point Metric	Chrono™ Comparison*
1	**Logic (inter-dependencies)**	Minimal missing Logic Links.	+
		# of tasks without predecessors and / or successors should not exceed 5%.	0 Exceptions per Chrono™ Wizard
2	**Leads (negative lag)**	Should not be used.	+
		Negative time is not demonstrable and should not be encouraged.	0 Exceptions per Chrono™ Wizard
3	**Lags**	Minimal usage allowed.	
		Should not be used to manipulate float/slack or to restrain the schedule. Should not exceed 5%.	SS+ Allowed by Chrono™ Wizard
4	**Relationship Types**		+
	Finish-to-Start (FS)	Encouraged (>90%)	Chrono™ Default
	Start-to-Finish (SF)	Counter-intuitive: only rarely used, if Justified	Not allowed by Chrono™
	Start-to-Start (SS)	OK	Allowed by Chrono™
	Finish-to-Finish (FF)	OK	Not allowed by Chrono™
5	**Hard Constraints**	No more than 5% of tasks should have Hard Constraints.	+
	Hard: Must-Finish-On (MFO), Must-Start-On (MSO), Start No-Later-Than (SNLT) & Finish-No-Later-Than (FNLT)	Hard constraints prevent schedule from being logic-driven.	Not allowed for Tasks in Chrono™ Can Accomplish in Chrono™ with Milestones
	Soft: As-Soon-As-Possible (ASAP), Start-No-Earlier-Than (SNET), & Finish-No-Earlier-Than (FNET)	Soft constraints are OK.	Chrono™ Default
6	**High Float**	No more than 5% of tasks with Total Float/Slack in excess of 44 days (2 months).	Computed by Chrono™ but not prevented (more specific to Earned Value Management)
		May be a result of missing predecessors and/or successors.	Not Specifically Imposed by Chrono™ (could easily add)
7	**Negative Float**	Tasks should not have negative float.	Milestones are Exempt
		A task which has less than 0 Float/Slack does not support the Critical Path (CP).	Not allowed by Chrono™
8	**High Duration**	<5% of tasks with a Baseline duration >44 working days (2 months), within rolling wave planning window.	Computed by Chrono™ but not prevented (more specific to Earned Value Management)
		Helps to break large tasks into 2 or more smaller tasks - makes schedule more manageable.	Not Specifically Imposed by Chrono™ (could easily add)
9	**Invalid Dates**	Cannot forecast starts and/or finishes before the project Status date.	
		Not logical or appropriate to back-date.	0 Exceptions per Chrono™ Wizard
10	**Resources**	All tasks with durations greater than zero have dollars or hours assigned.	Specific to Earned Value Management
		If IMS is required to be resource-loaded.	Not Specifically Imposed by Chrono™ (not Planned or needed for ES)
11	**Missed Tasks**	No more than 5% of tasks should be late at a status update.	+
		% of tasks which were suppose to be completed by the baseline status date, but have forecasted finish dates after the status date.	0 Exceptions per Chrono™ Wizard
12	**Critical Path Test**	Change in Critical Path task duration extension must result in same number of negative float/slack days for completion task/milestone.	+
		This is a test for broken logic somewhere in the IMS network.	0 Exceptions per Chrono™ Wizard
13	**Critical Path Length Index (CPLI)**	CPLI < .95 is an indicator of inefficiencies to be investigated.	
		CPLI = (remaining duration of CP + TF)/(remaining duration of CP).	Specifically Calculated by Chrono™
14	**Baseline Execution Index (BEI)**	Metric measuring task throughput (>1 is good, and <1 is bad).	
		BEI cum = (total # of tasks complete) / (total # of tasks completed before status date + total # of tasks missing baseline finish date).	Specifically Calculated by Chrono™
		Provides insight into the realism of program cost, resource and schedule estimates.	

+	Chrono™ Exceeds this metric guideline
	Chrono™ Meets this metric guideline
	Not Implemented but could (or do not have to due to ES vs EV Implementation)

Exclusions from above metrics:
- Completed Tasks
- LOE (Level of Effort) Tasks
- Summary Tasks
- Milestones

Figure 66 Comparison of Chrono™ Wizard and DCMA 14-Point Metrics

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The Chrono™ Toolbar

Chrono™ functions will primarily be accessed by using the Chrono™ toolbar that exists in the Chrono™ tab installed in Microsoft Project®. The tutorial will help you understand the commands in context. This section is intended to serve as a reference to the toolbar and will go a little deeper than the tutorial in some cases.

Organization

The selections from the toolbar will be discussed from top to bottom, left to right. The main headings are the labels under the different sections of the toolbar.

Quick Tip Before We Begin

If you hover your mouse over a button on the toolbar, a quick reminder of what the button does will be displayed.

1.0 Chrono™ Tools

1.1 Display Probability Chart = Pushing this button causes your browser to fetch and display the most recent Probability Chart previously generated for the project. If the simulation has never been run for this project, pressing this button causes the simulation to be run. You must have internet access to fetch the chart/run the simulation.

1.2 Run TriCoBi™ Simulation = Pushing this button initiates validation of the schedule and execution of the simulation if the validation is successful. When the simulation is complete, you will be asked if you wish to review the results. You must have internet access to run the simulation and display the results. The results are displayed by your default browser. Note: If you just got Chrono™ and are noodling around and the distribution chart just shows a single vertical bar, it's likely you haven't entered 3-point estimates for tasks so there is only a single point distribution to calculate and display.

1.3 Chrono™ Wizard = Initiates the wizard to help you build a valid schedule and capture three-point estimates. The wizard walks you through tasks collecting dependency and estimate information. It also lets you capture risk and

opportunity information. There is a separate section of this document that explains the wizard in more detail. Many users discontinue use of the wizard once they are familiar with Chrono™, but the wizard will be invoked if and when structural errors in the schedule are recognized after trying to Validate Project (to help in troubleshooting). The Chrono™ Wizard does not require an internet connection.

1.4 Project Progress Update = Initiates a wizard to update project status compared to the current baseline. This function is not useful until a Chrono™ baseline has been set. The details of the wizard are described in a separate section of this document. Note that setting a project baseline using Microsoft Project® menus (versus the process described below in 1.5) will not enable you to use this feature.

1.5 Set Project Baselines = This button sets and records the Nominal (Critical Path) and Goal Confidence baselines for the current project in the Chrono™ cloud. Baselines cannot be set until the project has been validated and a simulation has been run to calculate the Goal Confidence Baseline, and the Microsoft Project® file has been saved locally. Setting the baseline requires internet access and causes your project to be validated and the simulation to be run. It also results in a backup of your project file being created locally.

1.6 Validate Project = This button causes the project schedule to be validated against Chrono™ criteria that is aligned with the DCMA 14-point metrics. If issues are detected that thwart validation, the Chrono™ wizard will be activated and direct your attention to the first task that caused the problem. Validation is done locally and does not require an internet connection. The DCMA 14-point metrics are detailed in a different section of this document.

2.0 Chrono™ Gantt Chart Views

The currently displayed view (Nominal Durations is the default) will have a green check mark next to it. Pressing these buttons changes the attributes of the Gantt Chart displayed.

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2.1 Nominal Durations = This button causes a display of the Gantt Chart that reflects Nominal (a.k.a. traditional Critical Path) task schedule. This is the default Gantt Chart. This button is helpful if you have been using other Gantt Chart Views and want to return to the basic Critical Path view that ignores simulation results.

2.2 Goal Confidence @ 70% = Pressing this button causes one or both behaviors;

1) If the project has never had a simulation run or if the schedule has been changed since the last simulation run (indicated by a red flag next to the button), it causes a validation and simulation to run and then…
2) The Gantt Chart representing the Goal Confidence task durations will be shown on the Gantt Chart. The pre-set Goal Confidence default is 70% and can be changed in the Defaults setting (see 5.1).

2.3 High Risk Confidence @ 30% = Pressing this button causes one or both behaviors;

1) If the project has never had a simulation run or if the schedule has been changed since the last simulation run (indicated by a red flag next to the button), it causes a validation and simulation run and then…
2) The Gantt Chart representing the High-Risk Confidence task durations will be shown on the Gantt Chart. The pre-set High-Risk Confidence default is 30% and can be changed in the Defaults setting (see 5.1).

2.4 Medium Risk Confidence @ 50% = Pressing this button causes one or both behaviors;

1) If the project has never had a simulation run or if the schedule has been changed since the last simulation run (indicated by a red flag next to the button), it causes a validation and simulation run and then…
2) The Gantt Chart representing the Medium Risk Confidence task durations will be shown on the Gantt Chart. The pre-set Medium Risk Confidence default is 50% and can be changed in the Defaults setting (see 5.1).

2.5 Commit Confidence @ XX% = Pressing this button causes one or both behaviors;

1) If the project has never had a simulation run or if the schedule has been changed since the last simulation run (indicated by a red flag next to the button), it causes a validation and simulation run and then…

2) The Gantt Chart representing the Commit Confidence (based on the XX% value at the date selected for that manually scheduled end milestone) task durations will be shown on the Gantt Chart.

2.6 Select Baseline - @XXXXXX = Allows the user to display either the Nominal (Critical Path) or Goal Confidence Baseline. Select the baseline that you wish to have displayed. The right side of this button indicates which baseline is currently being displayed.

2.7 Align Commit = The first time the simulation is run, the Commitment Milestone should be set to the Critical Path end date represented by the Auto Scheduled Confidence Milestone/project finish. The "Align Commit" button resets and fixes the Commitment Milestone to the end date consistent with the currently displayed Gantt chart schedule end date preceding the Commitment Milestone (I.e., Finish date of its Predecessor). This is an alternative to manually adjusting the Commitment Milestone. Note: If the Confidence Milestone calculation places it at the end of the business day (1700 hours being the default), the Commitment Milestone will be placed "right after" the Confidence Milestone which will be start of the next business day (0800 being the default). "Align Commit" moves it to the end of the business day of the Confidence Milestone.

2.8 View Entire Project = This button adjusts the scaling of the Gantt Chart being displayed so that it fits within the Gantt Chart area width (I.e., schedule span) currently displayed.

3.0 Chrono™ Options

3.1 Merge Bias View = This option toggles whether phantom tasks should be displayed that reflect the buffer calculated for merge bias effect. If the green check mark is present, then the phantom tasks are displayed. Merge bias is the

statistical delay projected for one or more tasks that merge into a common successor. Merge bias is not displayed in the Nominal view and the button shows a strikethrough while in that view.

3.2 Distribution-XXXXX = This is an indicator of which distribution is being used for the Chrono™ Simulation. At this writing, there are two options **Triangle** (the default) or **TriGen**™. Your distribution choice must be set before a project is baselined because changing after that would invalidate prior baselines. For a detailed discussion of the differences, see this Appendix.

3.2.1 **Triangle** calculates a probability distribution function using the Best-Case Duration as the early bound, the Nominal Duration as the mode, and Worst-Case Duration as the upper bound.

3.2.2 The **TriGen**™ option creates a slightly broader distribution function, establishing the Best-Case Duration as 10% likely, the Nominal Duration as the mode, and the Worst-Case duration as 90% likely. This allows a small chance that a task might finish before the Best-Case or after the Worst-Case. This option allows project managers to enable estimators to be more comfortable with providing reasonable estimates of Best- and Worst-Case durations without taking into account catastrophe's (I.e., earthquakes, wars, building fires, ……).

3.3 Metrics = This button displays the results of the DCMA 14-Point evaluation criteria (described in the prior section).

4.0 **Project Summary Info** – Last Update [date of last update]

4.1 Commit Date [Date/Time] = This displays the Commit Milestone date/time extracted from the most recent Goal Confidence Baseline. This assumes that the Goal Confidence Commitment Milestone extracted from the last baseline is always the target end date of the project. This value persists no matter which Gannt Chart View is currently being displayed.

4.2 % Confidence at Commit Date XX% = The is the currently projected probability of achieving the Commit Date. The Commit Date is defined as the Commitment

Milestone of the most recently save Goal Confidence Schedule. It will change as project updates and new baselines occur.

4.3 Nominal Confidence XX% = This is the currently projected probability of achieving the Nominal (or Critical Path) Commitment Milestone.

5.0 **Chrono™ Settings**, Ver. XXXXXX

5.1 Defaults = This button allows you to modify the Chrono™ Default values. These include the ability to have Chrono™ automatically calculate the Best-Case Durations and Worst-Case Durations as a percentage of the Nominal Duration. This also allows users to override some of the "Validate Project" task dependency rules. This is where the user can choose the Triangle Probability Type. These defaults must be set before the first simulation run.

5.2 Contact and Help = This button provides links to additional resources on the RTConfidence web site for Help, general information, email support, feature requests, and issue reporting.

5.3 Info = Details about Chrono™ include the current release and when this license is due to expire.

Chrono™ Settings & What They Mean: Establishing Defaults

Chrono™ options fall into three categories:

1) Selectively overriding some of the schedule validity checks for the DCMA 14-Point analysis or Chrono™ to match local practice
2) Adjusting the estimate and distribution curves used to run the Chrono™ simulation
3) Changing some of the labels that Chrono™ uses for different confidence levels

These options are set by users through the **Default** button in the Chrono™ tab, which displays the default settings dialog.

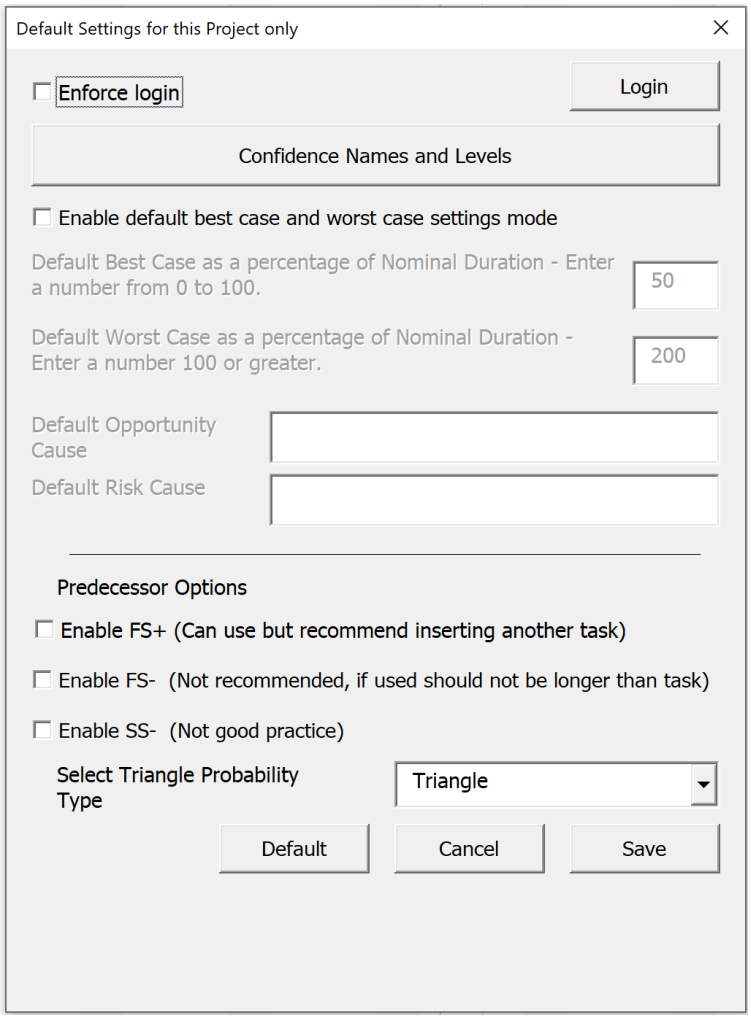

*Figure 67 The Chrono™ **Default** Setting Dialog Box*

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Overriding Validity Checks

Prior to running a simulation, Chrono™ conducts a schedule validity check. This can be initiated without running a simulation by pressing the **Validate Project** button in the toolbar. Validation flags issues with the schedule that fail the Chrono™ IMS structure criteria (closely aligned to the DCMA 14-Point check) and poor scheduling practices that can cause unexpected or misleading schedule simulation results.

We have a short description of the DCMA 14-Point metric check in this Appendix. After you run a simulation, the **Metrics** button will display the DCMA stats from the evaluation of your schedule. The only test that you can normally "fail" and have your simulation complete successfully is the "Resource" test, which Chrono™ treats as informational.

Some of the DCMA tests must be passed or the simulation cannot run or cannot produce valid output. Some of the DCMA tests represent good practices, but don't prohibit the simulation.

The **Defaults** button in the Chrono™ tab is where the validation override settings can be accessed. Here you can allow the following schedule conditions/issues to be ignored:

- **Finish to Start + Lag**
  While positive lag on a Finish to Start relationship is legal in MS Project™, it is discouraged, and flagged by Chrono™ as an error during validation. DCMA allows no more than 5% of the incomplete tasks to have FS+Lag dependencies. Chrono™ normally does not allow any. The suggested approach would be to add a dummy task to represent and explain the rational for the lag, e.g., rather than "Paint the Chair" followed by a 1-day lag to allow the paint to dry before "Pack and Ship Chair", insert a 1-day task titled "Paint on Chair Dries" with normal Finish to Start relationships. Users may elect to have Chrono™ not flag lags as errors that cause validation to fail, although the **Metrics** display button will still show that the schedule failed to meet the Lag Check.
- **Finish to Start – Lag (Lead)**
  Negative lag is weird. Although allowed in MS Project™, it is usually considered a bad scheduling practice. It is a way of saying "2 days before Task A finishes, task B should start". DCMA does not allow any negative lags because they can confound

calculation of Float and the Critical Path. Usually, tasks can be decomposed further to eliminate the need for negative lag. If necessary, users may elect to have Chrono™ not flag negative lags as an error that block validation, although the **Metrics** display button will still show that the schedule failed to meet the "Lead" Check.

- **Start to Start – (Lead)**
  Start to Start dependencies with a negative lag (or "lead") is not considered good scheduling practice and normally would be flagged as an error by Chrono™ during validation that would cause validation to fail. DCMA does not allow any negative lags because they can confound calculation of Float and the Critical Path. Saying Task A has a SS-1w with Task B is saying that Task A should start 1 week before Task B starts. Task A thereby requiring a crystal ball to know when to start. There is usually a way to decompose the tasks to better represent what you are trying to capture that doesn't jeopardize calculation of the critical path and schedule float. You can tell Chrono™ not to fail validation with this error in the **Defaults**. The **Metrics** report will still show the failed DCMA test.

Adjusting Estimate and Distribution Curves & Default Risk/Opportunity Causes

The Chrono™ schedule simulation takes the project task network and task estimates as input to a simulated Monte Carlo process. As users gain proficiency with Chrono™ they will likely gather 3-point estimates for tasks with significant schedule risk. To facilitate "quick and dirty" schedule assessment without requiring data entry of 3-point estimates, Chrono™ allows a shortcut: the definition of a "default" Best-Case and Worst-Case duration estimate calculated as a percentage of the Nominal estimate.

Once Best-Case, Nominal (or "Likely Case"), and Worst-Case Duration estimates are assigned, Chrono™ offers users two different probability distribution options, Triangle and TriGen™. Died-in-the-wool engineers sometime have issues with a 0% confidence Best-Case duration estimate (for it cannot be met, by definition). They sometime have issues with a 100% confident Worst-Case duration estimate (can people really be 100% confident?) The creators of Chrono™ have found that the TriGen™ option enables that population of estimators to get past the 0% and 100% stigma.

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Note: Defaults for these values must be set before the project is baselined. Because changing these defaults after baselining would invalidate status reporting history and trends, the choices are locked for a given project once the project has been baselined.

Finally, you can establish defaults for Risk and Opportunity causes that will be associated with the Best-Case and Worst-Case duration estimates.

The **Defaults** button in the Chrono™ tab is where these settings can be accessed.

Changing the labels Chrono™ uses for confidence levels

Chrono™ was initially developed by the authors for their own use. They used terms familiar to themselves for their duration estimates, "Best-Case", "Nominal-Case", "Worst-Case". When the tool was originally built, they intended to inflict these labels on all users.

Project managers who later joined the Chrono™ team found these labels counter-intuitive in some cases and suggested that the tool be modified to allow user customizable labels. You're welcome.

Chrono™ Used/Reserved Data Fields

Chrono™ keeps project information in two places:

1) Tucked into corners of your local MS Project file
2) History and trend information is stored in the cloud when you run a simulation

This appendix describes the columns that Chrono™ uses in your MS Project file. These columns are normally available to users, but rarely used. If you use Chrono™, we reserve them, and they are not available for your use and should not be modified.

Before importing an existing file into Chrono™, you should assure that the file is not using these fields (they are normally blank). If you are building a new project file using Chrono™, Chrono™ will prohibit you from using these fields (if you find a way around the prohibitions and use or change the fields, the results will be unpredictable).

MS Project has two types of information that it stores about your project:

- Task Level information
- Project Level information

The following Task fields are reserved for Chrono™ use:

Baseline Duration
Baseline9 Duration
Baseline10 Duration
Duration1
Duration2
Duration3
Duration4
Duration5
Duration6
Duration7
Flag12
Flag13
Flag15
Number11
Number12
Text10
Text11

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Text13
Text14
Text15
Text16
Text17
Notes[2]

The following Project Summary fields are reserved for Chrono™ use:

Flag5
Flag6
Flag7
Flag8
Flag9
Flag10
Flag11
Number3
Number4
Number5
Number6
Number7
Number8
Number9
Number10
Number11
Number12
Number13
Number14
Number15
Text3

Text4
Text5
Text6
Text7
Text8
Text9
Text10
Text11
Text12
Text13
Text14
Text15
Text16
Text17
Text18
Text19
Text20
Text21
Text25
Text26

[2] The Notes column of the Commitment Milestone contains a copy of Metrics output and the Notes column of the Start Milestone contains the URL for the Schedule Distribution report to facilitate sharing. "Notes" for other tasks are not used by Chrono™.

Chrono™ Limitations

Microsoft Project® (MSP) is a complex and sophisticated project management tool. Chrono™ is a sophisticated schedule risk management tool that interacts with MSP to support better user scheduling and decision making. Because Chrono™ lives on top of MSP rather than inside, there are several constraints that Chrono™ users must be aware of to use Chrono™ effectively.

Chrono™ assumes that users are running a current and "vanilla" (unmodified) version of MSP, otherwise results are unpredictable. We suggest users familiarize themselves with this list of assumptions and limitations. If you encounter issues using Chrono™ check this list first for clues about how they might be resolved.

1) An internet connection is needed to run a schedule simulation - Although you can enter data in MSP with Chrono™ installed and validate the schedule, you cannot set a baseline or run a simulation without an internet connection.
2) Chrono™ is the only macro that can be installed and used in your MSP implementation. A portion of Chrono™ is implemented as an MSP macro that is installed when you install the tool. Some macros don't play well with others. As a consequence, having other macros installed in your MSP implementation is not supported and may lead to unpredictable results.
3) Global.mpt is replaced when Chrono™ is installed - To preserve any data in your existing Global.mpt file, when Chrono™ is installed or updated, the current Global.mpt file is renamed and a new one is created that includes the latest Chrono™ components.
4) Chrono™ supports only one calendar - Microsoft Project® can support multiple calendars that specify workdays and work times being associated with different tasks within a schedule. These include a global calendar, individual resource calendars, even task level calendars and exceptions. If an MSP schedule refers to multiple calendars, results are unpredictable. The principal reason for this limitation is that the SRA (Schedule Risk Analysis) probability charts and ES (Earned Schedule) calculations need all the tasks to use the same workdays and times to produce valid results.

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5) Store your calendar in the MSP file - If you have only one calendar associated with your project, it can be stored in three places:
    a. In the Global.mpt file (Global Calendar) – This will affect all schedules, but will be in danger of being archived when Chrono™ updates are installed – NOT RECOMMENDED
    b. In a local template file (*.mpt) from which an MSP file may be created – this copies the template calendar into the MSP file at creation where it can be further modified as needed. Allows creation of standard holidays and work hours one time in the template without the danger of Chrono™ archiving the template (as the Global.mpt can be).
    c. In the MSP file itself – This calendar will only apply to the project being edited.
6) Avoid using Chrono™ reserved columns/fields – MSP has many optional columns that exist but are reserved for the user. Chrono™ uses several of these (see detailed list here) to store estimation and baseline data. Users may also use "Enterprise Fields".
7) Importing existing files can be a problem – Chrono™ supports import of existing MSP files from the 2013, 2017 and 2019 versions, assuming that they don't violate other constraints on this list and are "well formed". Files that have existing baselines or tasks that are partially complete can cause issues. The safest way to import existing files is to open them and copy and paste task and dependency information into a fresh MSP file.
8) Chrono™ doesn't currently facilitate managing resources and costs – Resource and cost information shown in MSP will be based on the nominal schedule only.
9) Chrono™ currently supports schedules with < 1000 tasks with variable durations – The data file that Chrono™ exchanges with the cloud is large and we are working to overcome a data timeout that occurs when attempting to send larger files.
10) Chrono™ doesn't currently support actively using Summaries – Summaries that are made "active" (i.e., given predecessors and/or successors, and/or explicit durations)

may cause issues which cannot be remedied by Chrono™ and might not be salvageable for use with Chrono™.

11) Chrono™ cannot work with versions of MS Windows™ earlier than Version 10.

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Chrono™ Validations/Well Formed Schedules

Whether a schedule with 3-point estimates is simulated with the Monte Carlo or TriCoBi™ algorithms, the structure of the schedule must be "well formed" or the simulation will either fail or worse, the results would not be representative of the project risks and the expected outcome. The Chrono™ Validate Project wizard was designed to help users confirm that their schedules are well-formed and are likely to provide accurate simulation results.

The Validate Project wizard is available to launch on the current schedule using the button on the Chrono ribbon. It will also launch automatically when changes the schedule require a restimulation to present accurate simulation results.

The validation process driven by the wizard goes through the following steps:

1) validation places the schedule in Nominal
2) validates the starting and ending milestones
3) configures merge tasks
4) runs an auto-validation or at least a manual task check
5) checks each tasks' duration
6) checks each tasks' predecessors and successors.
7) If the project validates, then the durations are then backed up.
8) Starting and ending milestones are added if necessary.
9) Merge bias tasks are inserted if in Merge Bias View.

Newly opened files will automatically run the Validate Project wizard. The Metrics button in the Chrono™ ribbon will also automatically run the Validate Project wizard as part of the metrics collection process and will provide a warning of any schedule issues found.

The Project Validation wizard checks the following items and warns for any issues, noting the number of failures and first task failure:

- Project File Options Schedule does not match Project Calendar
- First task before project start
- Summary Tasks with predecessors and successors

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For incomplete tasks:

- Manual duration tasks (only manual milestones allowed)
- Task starts before predecessors end
- Task constraints other than as soon as possible
- Task calendar differs from project calendar
- Task, other than start and manual milestones, lacks predecessors
- Task links with FF (Finish to Finish), SF (Start to Finish) which are not allowed
- Task links FS (Finish to Start)+, FS (Finish to Start)-, SS (Start to Start) which are not allowed unless enabled under Defaults
- Task links SS (Start to Start)+ with lag time greater than task duration
- Task, other than end and manual milestones, lacks successors
- Task successors start before task will complete
- Task incomplete but successors started or complete
- Task with only SS successors
- Task complete but started before predecessors complete
- More than 50 predecessors or successors

Other validation rules:

- Only manual milestones are allowed.
- Manual task check will warn of manual duration tasks before making them all auto-scheduled.
- Manual duration validation checks for each task that has Best <= Nominal <= Worst with 0 denoting default equality.

Manual predecessor and successor checks for each task:

- do not exist for summaries
- do exist and are valid for duration tasks, I.e. not absent, blank, or a summary

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- are within the main schedule and not isolated by itself
- have appropriate links, i.e. not FF or SF, not FS+, FS-, or SS- unless enabled under Defaults
- not SS+ with lag time greater than task duration
- not SS only successors, and successors of an incomplete task are not started or complete.

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Triangle vs. TriGen™ - What's the Difference?

In Chrono™ the duration of tasks are represented by continuous probability distributions. Two types of probability distributions are made available for task duration estimates — the standard triangle distribution and the proprietary TriGen™ distribution. All tasks in the project that are characterized with "3-point" distributions will use the same distribution type as set in the defaults dialog.

TRIANGLE DISTRIBUTIONS

The triangle distribution used in Chrono™ is the standard triangle probability distribution that has a probability density function shaped like a triangle as defined in numerous statistics textbooks with readily available explanations on various web sites. The triangle distribution is applied to project tasks with best case duration being the minimum value, the likely/nominal case duration being the peak value, and the worst case duration being the maximum value of the triangle. In project science, we call these three durations the three points of the 3-point estimate.

In the figure below, the best case duration is 10, the likely/nominal duration is the "mode" of the triangle (or in this case 20 days), and the worst case duration is 40 days. The frequency axis shows the probability density function value of the task duration along the continuous range from the best case duration to the worst case duration.

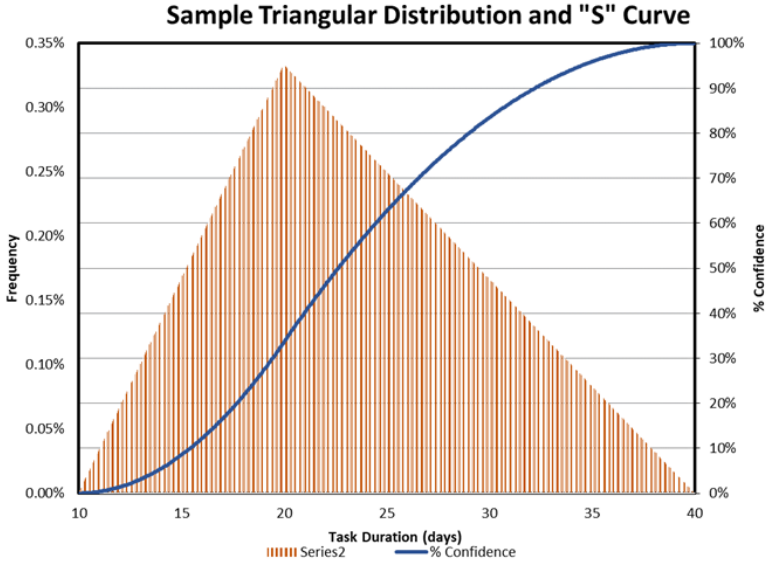

Figure 68 Sample Triangular Distribution Function

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Just as the triangle in a 3-point estimate is represented by the probability density function, the cumulation of the frequencies across the duration range of the triangle is represented by the cumulative distribution function, which we refer to as the "S" curve. The value units of the S-curve are in percent confidence representing the probability of a task being completed on or before the corresponding time duration value.
Therefore, at any point in time along the project schedule, the probability of a task being completed on or before a specific date is shown in the "S" curve. In the case above the probability of the task being completed with a duration of 10 or less is zero. The probability of a task being completed at a duration of 40 is 100%. It is often misunderstood that the peak value represents a 50% probability, but that is not true.

If you think about it, you may understand that many more things can go wrong on a project than go right. Consequently, it is natural to understand that as triangle distributions are applied to project science that the probability of completing the likely/nominal case task within a specific duration is typically well under 50%. In the case of our example above the likely/nominal case has a probability of about 33% -- this is basically calculated as [(Nominal Duration – Best Case Duration)/(Worst Case Duration – Best Case Duration)] or 10/30 = 0.3333 = ~33%.This common misunderstanding is the root of many scheduling problems, but with the right tools the actual probabilities are straight forward to calculate.

TRIGEN™ DISTRIBUTIONS

During a series of applications 3-point estimates to business-critical project schedules we found that some engineering and development teams had a very difficult time determining the actual best case where the probability hits zero and the worst case where the probabilities hits 100%. There tended to be a mention of miracles, earthquakes, and fires when we talked about extremes of 0% and 100% likelihood completion of tasks. While we did have a fire in a lab once, that broke the schedule and required a re-baselining activity.

Solving the general problem of helping the technical team become comfortable with giving a best case estimate, we simply ask the team to give a duration estimate that has a 10% likelihood of occurring. Correspondingly we asked the team to provide a duration with a 90% likelihood to be the worst case estimate. The team felt that these 3-point estimates

represented their reality and we were happy that the did not include any miracles, fires or earthquakes.

The TriGen™ distribution is represented in the Chrono™ with a triangle distribution that is created by reducing the duration of the 10% estimate (best case) provided by the team to a zero probability using the slope of the line between likely/nominal duration and the 10% duration. Correspondingly the 90% duration (worst case) is extended using the slope of the line between the likely/nominal point and the 90% duration point to give duration with a 100% probability.

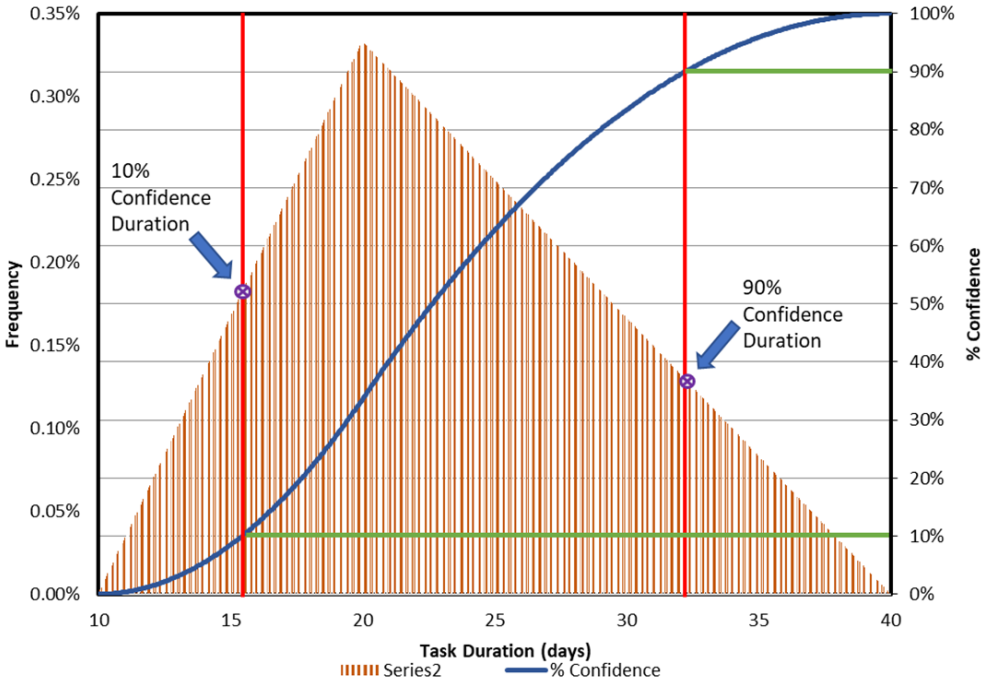

Figure 69 Sample Triangle Made from TriGen Inputs

The example above shows that a best case of 15 and a worst case of about 32 with the same likely/nominal duration of 20 provide an equivalent probability distribution as a triangle distribution of best case 10, likely 20 and worst case 40.

Whether to use the triangle distribution or TriGen™ distribution is up to the project team. We recommend that the team uses which ever distribution that most closely matches their project's characteristics

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Optimizing a Schedule for Merge Bias

There is another scheduling phenomenon referred to as "merge bias," which might not be noticed on a Gantt chart, but its affects can be surprising when the project schedule simulation results are inspected. Basically, it has to do with having more than one closely time-matched network of tasks merging into the same subsequent task.

For example, if you have three critical paths at a particular point in your schedule and each critical path has the same end-date probability distribution with a 50% probability of meeting schedule, the resulting probability of meeting schedule drops to 12.5% (0.5*0.5*0.5).

Multiple "near-critical" paths have the same basic effect, as shown in the figure below, which depicts project simulation results for one task and then a simulation of two additional tasks close to the critical path. Comparing these distributions and their corresponding S-curves, we can see the probability drop from 50% to 20% due the near proximity of the three task end-dates.

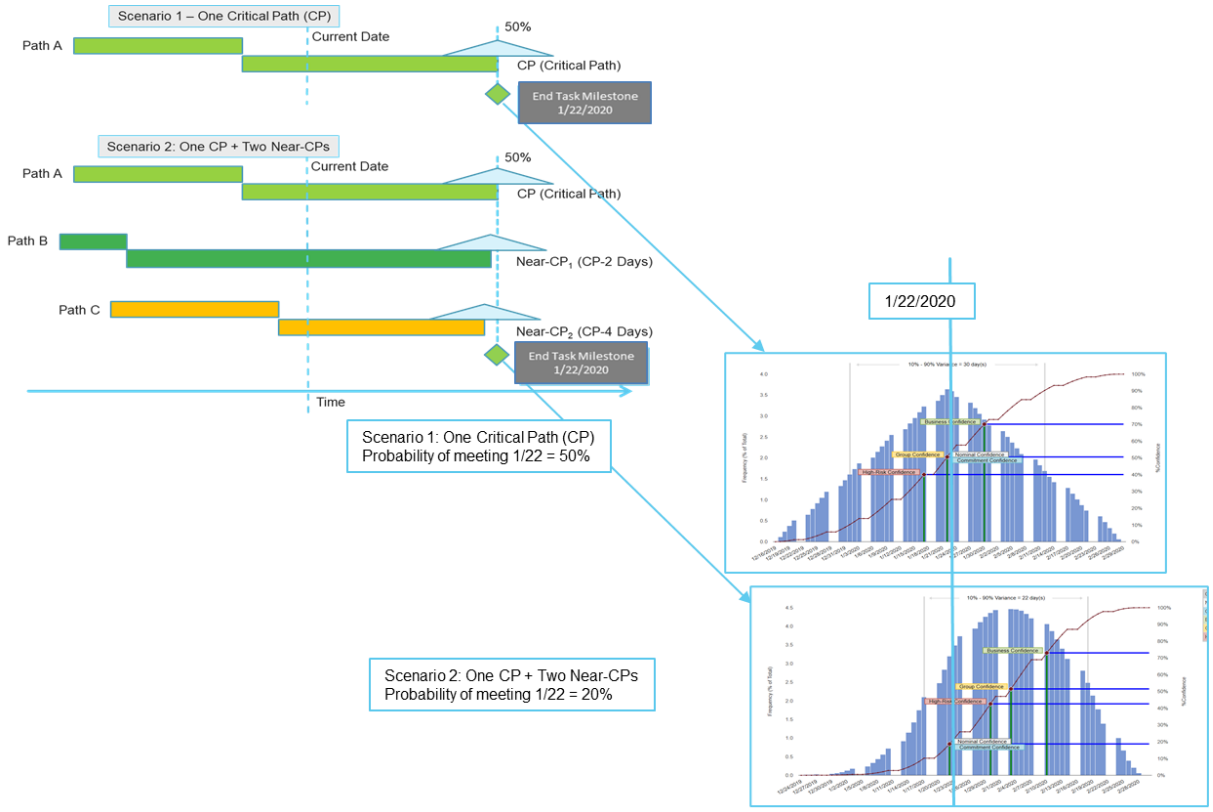

Figure 70 Simulation Results for Example "Merge Bias" Scenarios

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The probability function of the single task shows the standard triangle distribution. The probability function of the three tasks combined in probability function derived from the simulation show a bell curve.

The S-curve of the single task shows the likely/nominal confidence level of 50% for a 1/22 end date. The S-curve of three near critical path tasks shows a confidence level of 20% for the 1/22 date. This example plays out all the time in project scheduling much to the surprise of the project teams. Being aware of this effect in the planning and executing processes can literally save your project from a pending disaster.

Chrono™ the TriCoBi™ simulation highlights this problem with its merge bias chart. The process for optimizing for merge bias includes the project team finding ways to reduce near critical path tasks and then running what-if scenarios to mitigate the schedule risk.

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Chrono Schedule Duplication Options (Save As Function)

The "Save As" dialog provides the ability to duplicate the project for various purposes. Chrono™ projects have two components. The first component is a local Microsoft Project® file stored on the user's personal computer. The second component is a secure database entry in the Chrono™ cloud service. The cloud data base entry is tied with a reference link directly to the corresponding local Project file. If the Project file is copied over to a second computer, when the file is opened on the second computer and the TriCoBi™ simulation is run, the original database record in the Chrono™ cloud service will be accessed and any project updates provided will be saved in the cloud as if the updates were made from the original file and the original personal computer.

Caution must be taken to prevent multiple simultaneous project updates from occurring the same time from different computers. This unsynchronized practice would result in the Chono™ cloud service being out of synchronization with both local Project data files to the two separate personal computers. The one-to-one relationship between the Chrono™ cloud database entry and the local Project data file must be always preserved to ensure proper data synchronization.

The "Save As" function duplicates the original Project file and creates a new storage location in the cloud to correspond with the new local Project file. The original Project file and the corresponding original project history are not modified by the "Save As" function. Also the "Save As" function clears the baseline data in the new Project file.

The "Save As" function is typically use for either creating project templates for new projects or for re-baseline on-going projects.

CREATING NEW PROJECT SCHEDULE TEMPLATE

The steps to create a template for a new project are as follows:

1) Select "File > Save" to save the Project file to confirm that the original file is preserved.
2) Select "Save As" to save the Project file to a different name for the template.
3) Select the "Clear" option in the "Save As" dialog to clear out all "percent complete" task updates.

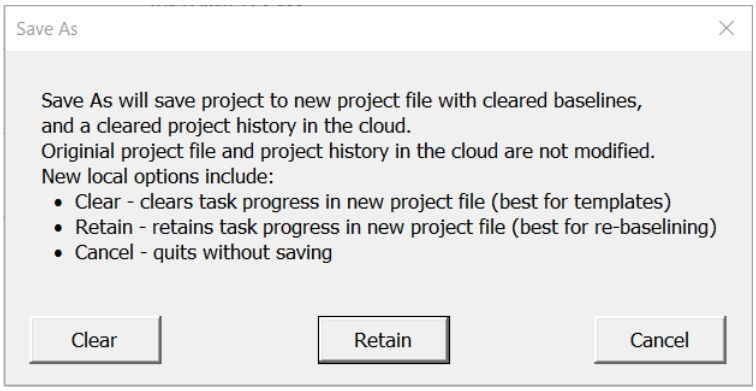

Figure 71 Save_As Help Screen Options

CREATING A RE-BASELINED PROJECT SCHEDULE

The steps to create a re-baselined Project file are listed here and in the tutorial sections above:

1) Select "File > Save" to save the project file to confirm that the original file is preserved.

2) Select "Save As" and save the project file to a different name to hold the re-baselined project schedule.

3) Select the "Retain" option in the "Save As" dialog for the purposes of creating a re-baselined project schedule.

4) Following steps in the tutorial section for details on how to finish setup the re-baselined schedule in the new Project file.

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Chrono Project Wizards

One of the largest barriers in the past to using Monte Carlo simulations for project estimation was the complexity of creating well-formed schedules. Typically, project experts with either experience or specialized training with Monte Carlo simulations were required to get reliable results. If mistakes are created while preparing the pre-simulation project data, then the output of the simulation can not be trusted to guide project decisions. The set of Chrono™ project wizards greatly help mitigate this problem by walking the user through a path that will commonly result in a well-formed schedule. As always, the project manager will need to confirm that the results are reasonable and with experience notice any anomalies that the set of Chrono™ wizards might not catch. The set of Chrono project wizards are listed in the table below.

Chrono Project Wizards

	Wizard Name	Wizard Functions	Activation Method
1	**Blank Project Wizard**	Sets up a New Project with essential start and end bounds. Pre-establishes Project Settings which enable a Valid Project set-up.	User Selection via "New" File Options.
2	**Chrono Wizard**	For setting up new projects: Sets Hard and Soft Constraints conducive to SRA (Schedule Risk Analysis) and EVM (Earned Value Management). Incrementally helps Users set up and change Predecessor/Successor Task Relationships. Enables establishment of valid Interdependencies between Tasks. Incrementally helps Users to establish and change 3-point duration estimates per Task. Provides drop-down menus for Task Opportunity and Risk Descriptions. For fixing validation issues: is launched automatically and incrementally goes to tasks with Issues (e.g., Predecessor/Successor Task Relationships, Task Durations and 3-point estimates). This Wizard is driven by Default settings.	Activated by the Chrono Tab Button. This wizard is automatically triggered when the Validation Wizard finds an Issue to resolve.

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Chrono Project Wizards

	Wizard Name	Wizard Functions	Activation Method
3	**Validation Wizard**	Checks the entire Project structure to ensure that construction criteria for appropriate SRA (Schedule Risk Analysis) and EVM (Earned Value Management) is supported. Provides help and options for fixing issues identified by automatically launching the Chrono Wizard to help fix IMS issues.	Activated by the Chrono Tab Button. This wizard is automatically triggered when identifies need for Simulation updates (due to changes) and Chrono Tab Button.
4	**TriCoBi™ Simulation Wizard**	Collect and sends all the IMS data to the Cloud for SRA and Earned Schedule computations and graphic output generation. Automatically invokes the Validation Wizard if changes have been made. Formats the Simulation Data for multiple Gantt chart views in local MS Project file which are accessed by Chrono tab buttons.	Activated by the Chrono Tab Button or whenever a RED Flag in the Chrono Tab is selected. This wizard is automatically triggered when Baselines are established, and when Project Progress Updates are Previewed and Published.
5	**Gantt Chart View Wizard**	Creates the database for multiple (i.e., 4 or 5) IMS Gantt charts (at different 'S' Curve %Confidence values) and sends to local MS Project file. Enables the different Gantt charts to be displayed in the local MS Project file when the Chrono Tab selection is made.	This wizard is automatically triggered when viewing the selected IMS Gantt charts and their column data. Enables viewing with either Baseline for comparison purposes.

Chrono Project Wizards

	Wizard Name	Wizard Functions	Activation Method
6	**Set Project Baseline Wizard**	Automatically established IMS (Integrated Master Schedule) Baselines (both a "Nominal" task duration baseline for the traditional Critical Path and a Business task duration baseline established for the Team Commitment). Sets up the ES (Earned Schedule) Baseline data for use in generating ES metrics automatically. Provides a warning to user to ensure Sponsor approval is obtained first. Enables Selection of either Baseline in the Gantt Chart Views - the default for Nominal and Business Gantts are the Nominal and Business Baselines. Automatically disables "Defaults" from being changed after the Baseline is set - this prevents inappropriate changes.	Chrono Tab Buttons -- one for setting the baselines, and the other for selecting the baseline in Gantt Views.
7	**Project Progress Update Wizard**	Walks the user through Project progress updating that enables automatic generation of new SRA and Earned Schedule outputs. User sets the Update date, are sequenced through updates of Tasks that were open during that time up to the update date, automatically changes 3-points for remaining durations, allows checking of data, previewing of update results, and officially publishing the update when ready to do so. Ensures that the correct process is followed to make updating easy.	Chrono Tab Buttons, which are only available after the project plan has been "Baselined."

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Chrono Project Wizards

	Wizard Name	Wizard Functions	Activation Method
8	**Metrics Wizard**	Evaluates IMS relative to the Department of Defense's DCMA 14-point Metrics, established in 2005 to ensure that IMS designs can effectively support Earned Value Management calculations. This set of criteria is also valid for SRA Modeling and Simulation and Earned Schedule calculations.	Activated by the Chrono Tab Button.
9	**SRA Output Wizard**	A cloud-based system that takes current inputs and converts those into Graphic Outputs for SRA, ES and other data as deemed necessary (i.e., SRA Tornado chart, Merge Bias charts, Trend charts, etc.). Includes controls for knowing when Baselines are established and Updates are processed -- and provides trend data by keeping track of past inputs. The Distribution chart enables the user to go to any project Task within the network and view the: Input Distribution, Task Distribution, and Output Distribution – whereby the Output Distribution is the combination of Input and Task Distributions.	This wizard is automatically triggered when the TriCoBi™ Simulation is run, and user chooses to view the Probability data.
10	**Earned Schedule Output Wizard**	Takes Baseline and Update input data and establishes a data set that is used to process integrated trend charts with Earned Schedule ear performance indices and independent schedule estimations. Passes the above data to the SRA Output Wizard for viewing.	This wizard is automatically triggered as a result of selecting the "Set Project Baselines" and when Publishing (via Step 4) the "Project Progress Updates."
11	**Merge Bias Wizard**	This Wizard both quantifies the Merge Bias (i.e., extra schedule impact contributed to the SRA output as a result of the merging of overlapping parallel Tasks within the IMS network) and enables an innovative Gantt chart view that displays it graphically.	Chart is automatically triggered when the TriCoBi simulation is run. Gantt chart view is activated by the Chrono Tab Button.

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