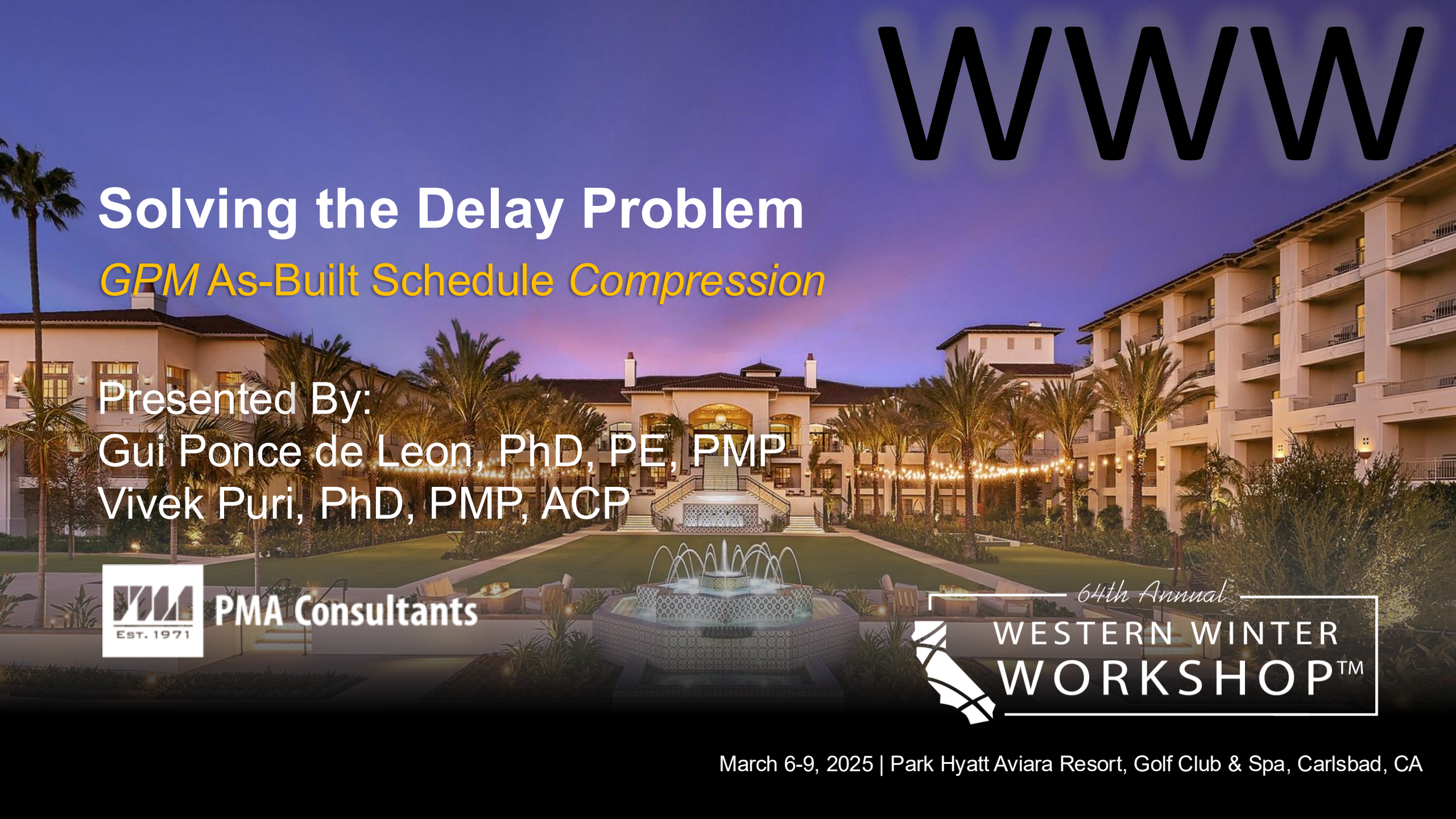


Solving the Delay Problem

GPM As-Built Schedule *Compression*

Presented By:
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PMA Consultants
Est. 1971

64th Annual
WESTERN WINTER WORKSHOP™

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Abstract

Instead of considering the fully progressed update the **natural** as-built schedule, forensic schedulers have for decades resorted to ***manually*** creating a simplified as-built schedule and to use as-planned vs. as-built methods or as-built schedule collapsing *heuristics* to measure delay impact. In the early 2000s, time impact methods that use CPM software to *reprocess archived* schedules showing *what was supposed to happen* gained ground over collapsed as-built methods. By *algorithmically* crashing delays from a fully progressed update, as-built schedule compression epitomizes a forward leap in forensic schedule analysis that is consistent with original CPM schedule compression.

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I. Problem Statement

When first introduced, CPM schedules were ***prospective*** models, devoid of actuals; calculations were based solely on logic and activity durations (Kelley & Walker 1959)

IBM CPM software changed this by keeping the project start date, introducing the concept of the progress cut-off date aka *data date* along with *actual dates*, and not applying the forward pass/backward pass algorithm left of the data date (IBM 1966)



Circa 1966 TO DATE!!!

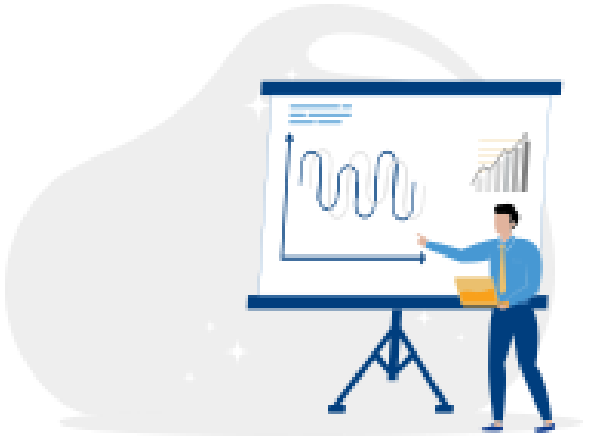
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CPM Software Fully Progressed Update *Dilemma*

Quoting from RP 29R-03, left of the data date, without total floats, finding the as-built critical path is a showstopper (¶ 1.5.B.2):

- "Note that the critical path and float can be computed by commonly available commercial CPM software only for the portion of the schedule forward (future) of the data date."



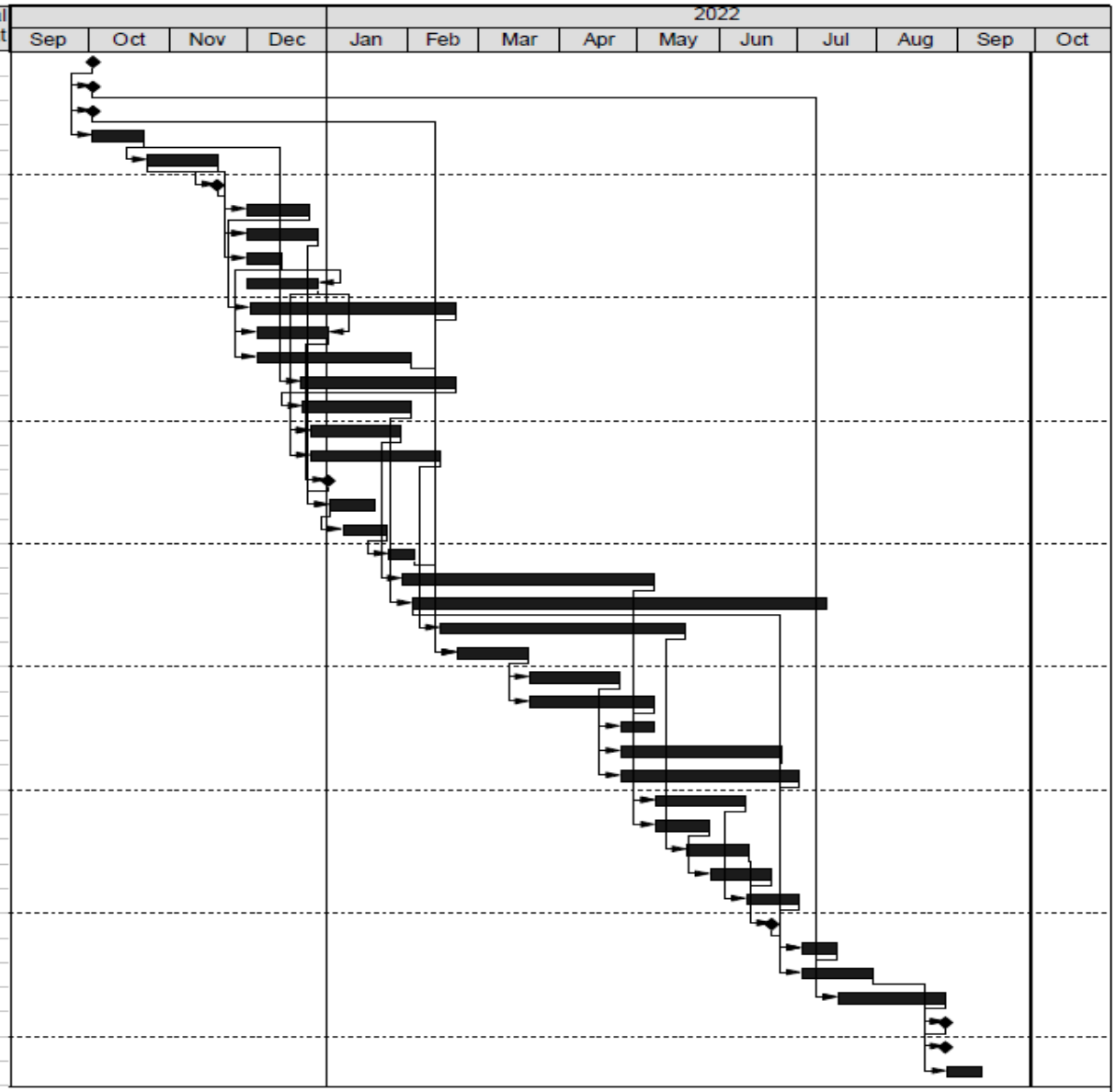
Noted delay analysts' perspective:

- There is no ready-made CPM software function that calculates the as-built critical path (Winter 2004, Avalon et al. 2019)

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Act. ID	Activity Name	Dur.	Start	Finish	Total Float
2	Design NTP	0	03-Oct-21 A		
6	Start Process Installation	0	03-Oct-21 A		
7	MOB Crane	0	03-Oct-21 A		
8	SD Set	21	03-Oct-21 A	23-Oct-21 A	
9	DD Set	28	24-Oct-21 A	20-Nov-21 A	
5	Design Freeze	0		20-Nov-21 A	
11	Bid/Award Steel	25	01-Dec-21 A	25-Dec-21 A	
13	FDN Permit	28	01-Dec-21 A	28-Dec-21 A	
14	Permit Set	14	01-Dec-21 A	14-Dec-21 A	
22	Comp. CD Set	28	01-Dec-21 A	28-Dec-21 A	
12	Shops, R&A, Delivery	80	02-Dec-21 A	19-Feb-22 A	
17	Buy-Out & Award, GMP, Mob	28	05-Dec-21 A	01-Jan-22 A	
18	Building Permit	60	05-Dec-21 A	02-Feb-22 A	
10	BOD Process Equip	60	22-Dec-21 A	19-Feb-22 A	
15	Gather Equip Quotes	42	23-Dec-21 A	02-Feb-22 A	
23	Elevator Shops	35	26-Dec-21 A	29-Jan-22 A	
32	Elec Equipment Shops	50	26-Dec-21 A	13-Feb-22 A	
3	GMax Lock	0		01-Jan-22 A	
19	Earthwork	18	02-Jan-22 A	19-Jan-22 A	
40	FDNs	18	07-Jan-22 A	24-Jan-22 A	
41	UGEP	10	25-Jan-22 A	03-Feb-22 A	
24	Elevator Fab/Delivery	98	30-Jan-22 A	07-May-22 A	
16	Equipment Procurement	160	03-Feb-22 A	12-Jul-22 A	
33	Elec Equipment Fab/Delivery	95	14-Feb-22 A	19-May-22 A	
20	Steel, Joists, Decking	28	20-Feb-22 A	19-Mar-22 A	
21	SOG, Pour & Seal Decks	35	20-Mar-22 A	23-Apr-22 A	
26	Walls, Windows, Doors	49	20-Mar-22 A	07-May-22 A	
27	Roof	14	24-Apr-22 A	07-May-22 A	
29	Piping/HVAC/FS Rough-In	63	24-Apr-22 A	25-Jun-22 A	
30	Power/Lighting/Low Voltage	70	24-Apr-22 A	02-Jul-22 A	
25	Elevator Install	35	08-May-22 A	11-Jun-22 A	
28	Int Walls & Ceiling	21	08-May-22 A	28-May-22 A	
34	Elec Equip Installation	24	20-May-22 A	12-Jun-22 A	
31	MEP Controls	24	29-May-22 A	21-Jun-22 A	
37	Finishes	21	12-Jun-22 A	02-Jul-22 A	
4	Perm Power Available	0		21-Jun-22 A	
35	MEP Process Equip	14	03-Jul-22 A	16-Jul-22 A	
38	Punchlist Core & Shell	28	03-Jul-22 A	30-Jul-22 A	
36	Install/Connect Process Equip	42	17-Jul-22 A	27-Aug-22 A	
1	Ready for Commissioning	0		27-Aug-22 A	
53	Process Equipment Complete	0		27-Aug-22 A	
52	Startup/Commissioning	14	28-Aug-22 A	10-Sep-22 A	



Actual Work
Remaining Work
Critical Remaining Work
Milestone

Fully Progressed Update

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Upshot of the Fully Progressed Update Dilemma



CPM software limitations left of data date have acted as a deterrent to using the *fully progressed update* as the **inherent** as-built schedule even after RP 29R-03 discussed the concept (¶ 2.2.A)

Delay analysts instead measure delay by:

- building, from scratch, highly simplified as-built schedules using actual dates/logic in the contemporaneous updates and/or the project record and using *observational* as-planned vs. as-built methods or as-built schedule collapsing *heuristics* (O'Brien 1976, 1984), *or*
- impacting the as-planned schedule

Circa 1966 TO DATE!!!

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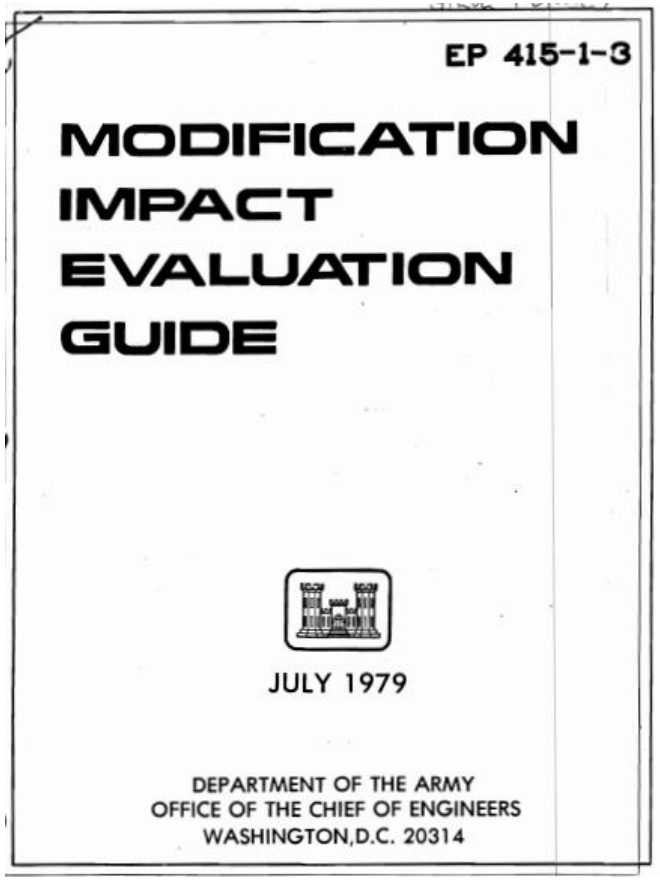


The Rise of Retrospective Time Impact Analysis

In 1979, the Corps of Engineers begun requiring ***prospective*** use of the contractor's CPM schedule to forecast the presence and extent of impact of a contract modification (USACE 1979)

- **Theory**: Well-prepared and current project CPM schedules can be used *prospectively* to ***predict*** the impact of delay events on completion

In time, analysts applied time impact analysis *retrospectively*, a hypothetical that *predicts* delay impact after the actual impact has occurred, i.e., it predicts yesterdays' weather (Sanders 2024)


EP 415-1-3

MODIFICATION IMPACT EVALUATION GUIDE

JULY 1979

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON,D.C. 20314

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II. Solving the Delay Problem *Post-Completion*

Theory: The fully progressed update can and should be used to extract, with reasonable certainty, the actual impact of delays on project completion

Circa 2024



Methods that use updates seek to *predict* impact of delays that already occurred (Agrawal et al. 2024, Sanders 2024) and must be based on the following:

1. The parties in interest, for the sake of resolution, mutually agree to a *hypothetical* analysis
2. When completed, negative-float paths and the finish date match those in the fully progressed update
3. The analysis explains why the delay protocol/s followed reasonably apply/ies to the facts of the case

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Contemporaneous vs. Post-Completion Analysis

Theory: It is unreasonable *to equate* a delay to a CPM schedule *early finish date* to a delay on the date completion of the project may be achieved

Circa 2024



1. A schedule predicts but one of many probable finish dates; without a simulation, it is not a reliable predictor of when the project will be completed or of which activities are likely to control completion
2. ***Drop in*** completion date *P-value* is a more valid measure of impact on completion than delay to the update finish date (Ponce de Leon and Puri 2014)
3. CPM schedules may be used *prospectively* to *hypothesize* delay impact for the sake of resolution

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III. Graphical Path Method (GPM) Synopsis

Several papers introducing GPM were presented at PMI and AACEi conferences from 2008-2011

Circa 2010



1. CPM and GPM scheduling algorithms yield the same early and late dates, total floats, and critical paths (Ponce de Leon 2008, Mather et al. 2011)
2. Total float: Whereas CPM uses early and late dates, GPM uses link gaps (Ponce de Leon 2008)
   - ➢ Gap on a link equals the extent a predecessor may be delayed and not delay the successor
3. The GPM scheduling algorithm is not limited by CPM software limitations (Ponce de Leon 2010)

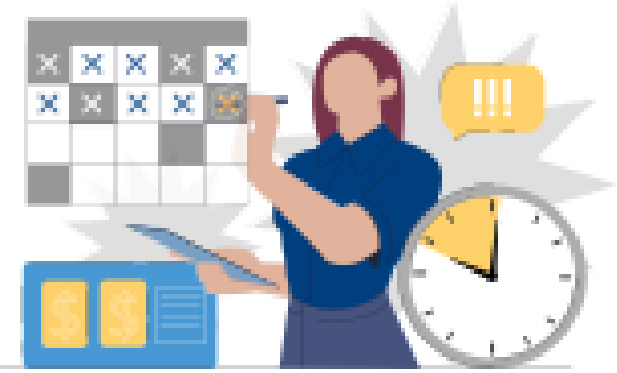
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The Power of GPM *Forensic* Algorithms

The GPM scheduling algorithms calculate for ***completed activities*** (Ponce de Leon 2010):

- *early dates*, which reveals pre-used total float,
- *late dates*, which reveals unused total float, and
- as-built total floats and as-built critical path/s



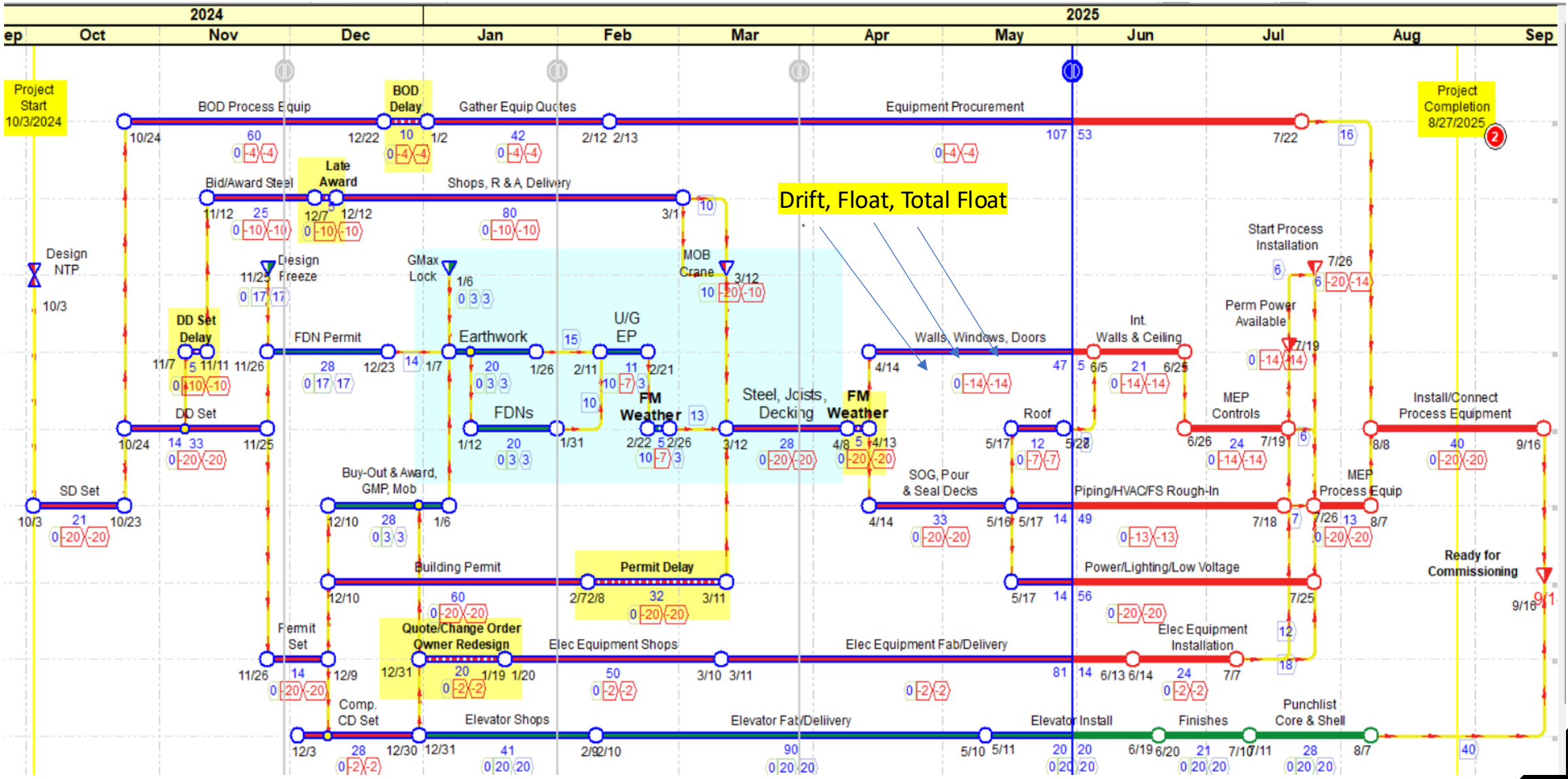
GPM allows activities to be started between early and late dates—called ***planned dates***

- Left of the data date, actual dates are planned dates

GPM simplifies delay analysis and algorithmically explains delay features better than CPM, yet it is deliberately ignored (Hertwig and Engel 2016)

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Gaps and Total Floats *Both Sides* of the Data Date



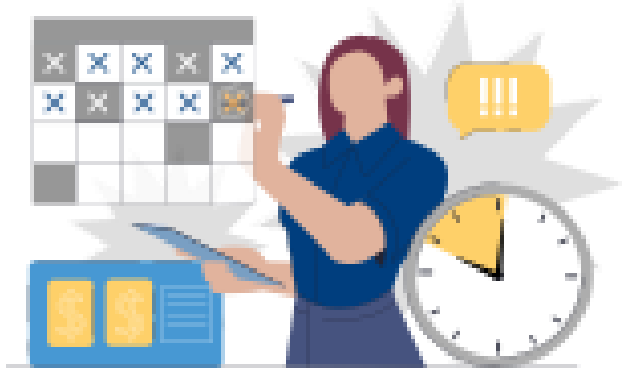
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IV. Flaws in Methods That Use *But-For* Heuristics

Quoting from RP 29R-03 (¶ 3.9.K.4.b)

- "Stepped extraction: The delays are extracted individually or in groups, and the impact is determined after each iterative extraction"

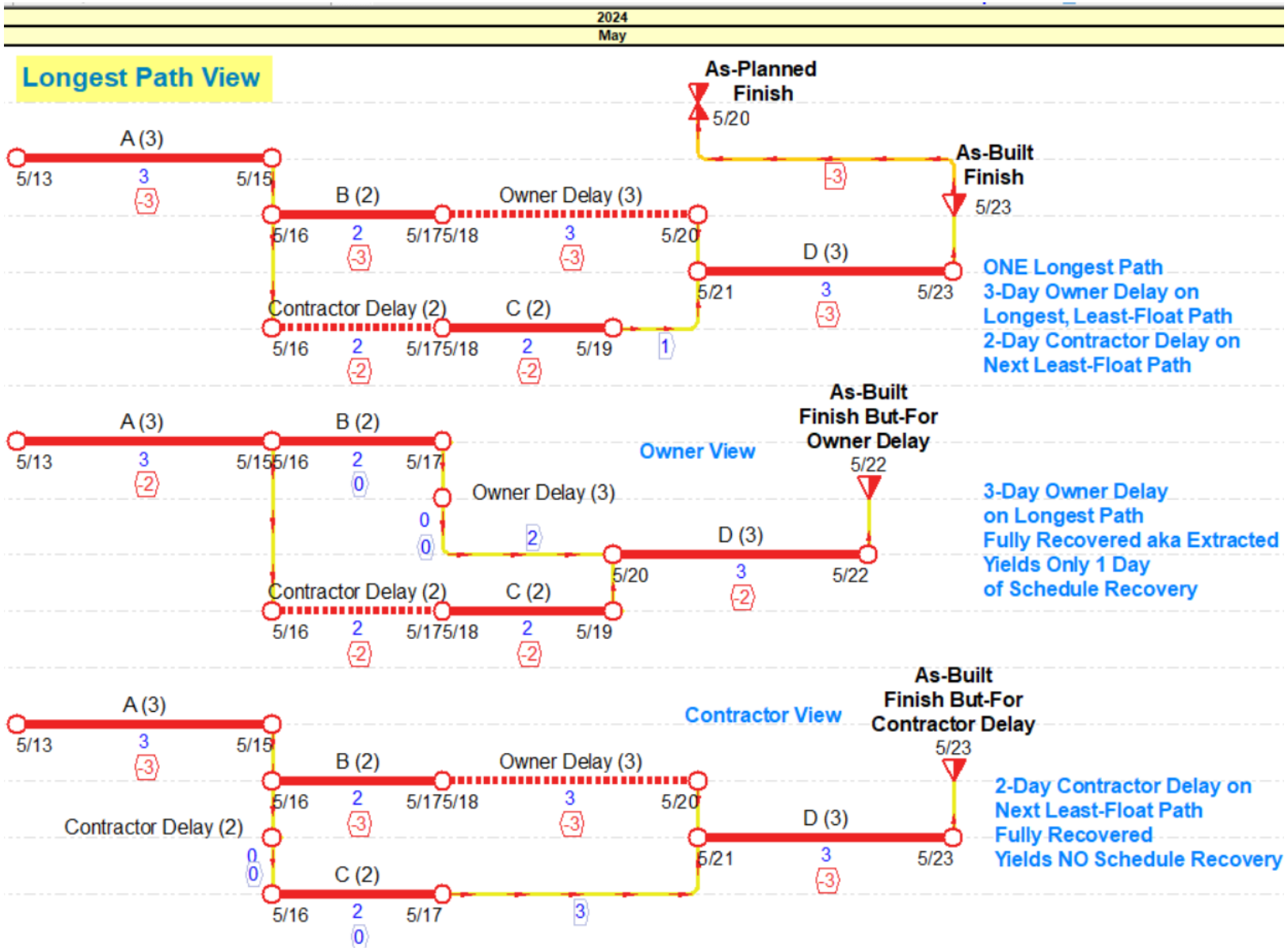


Stepped extraction flaws (Mbabazi et al. 2005)

- First flaw: extracting a delay even if such removal doesn't collapse the as-built schedule
- Second flaw: extracting delays in groups, ignoring concurrency, leads to inconsistent, non-algorithmic owner and contractor results

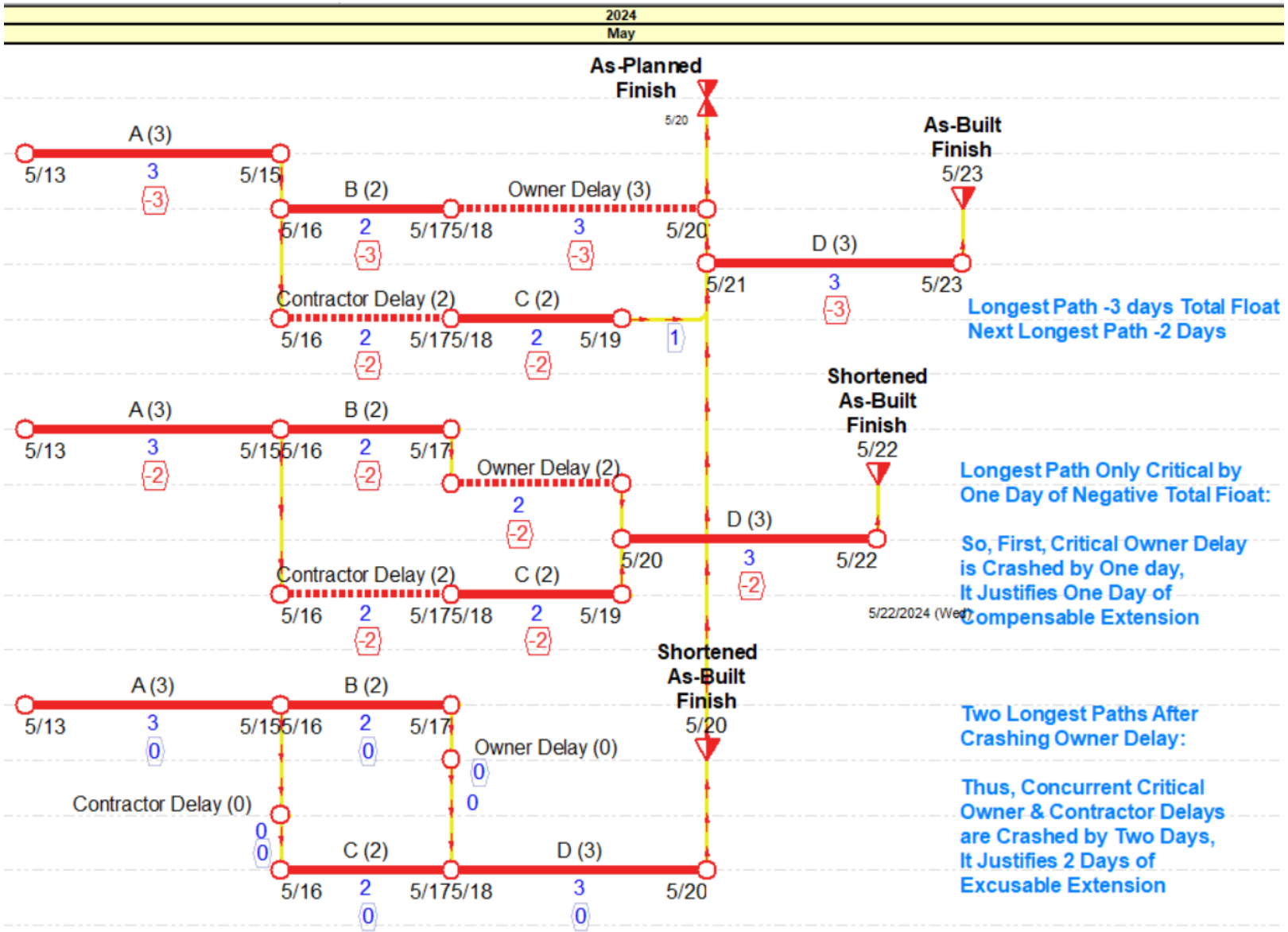
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The *Longest Path* Non-Algorithmic View



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The Algorithmic *Schedule Compression* View



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V. CPM vs. GPM Schedule Compression

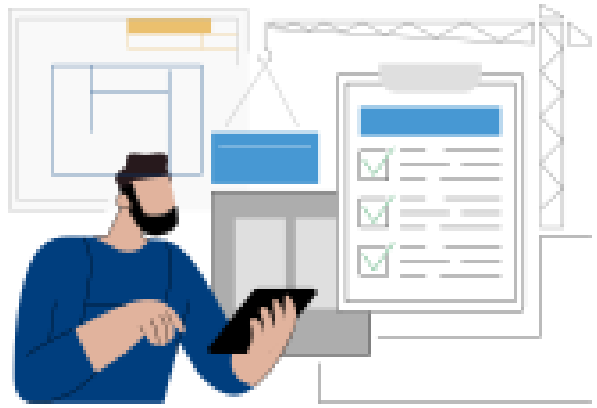
The CPM *prospective* schedule compression algorithm *crashes activities* provided shortening the schedule day per day with activity crashing

- The objective function minimizes increases in project cost by trading off activity direct costs and general conditions costs

The GPM *retrospective* as-built schedule compression algorithm *crashes delays* provided reversing as-built schedule prolongation

- The objective function exhausts compensable and excusable as-built schedule prolongation reversal per day of delay crashing

Circa 1959



Circa 2024

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Step 1—Out-of-Sequence (OOS) Logic

As-planned schedule: early dates and late dates result from *as-planned* logic ties

As-built schedule: *as-built* logic ties result from as-built dates of the linked activities

- An OOS as-built logic tie contradicts the tenets of its as-planned logic tie counterpart

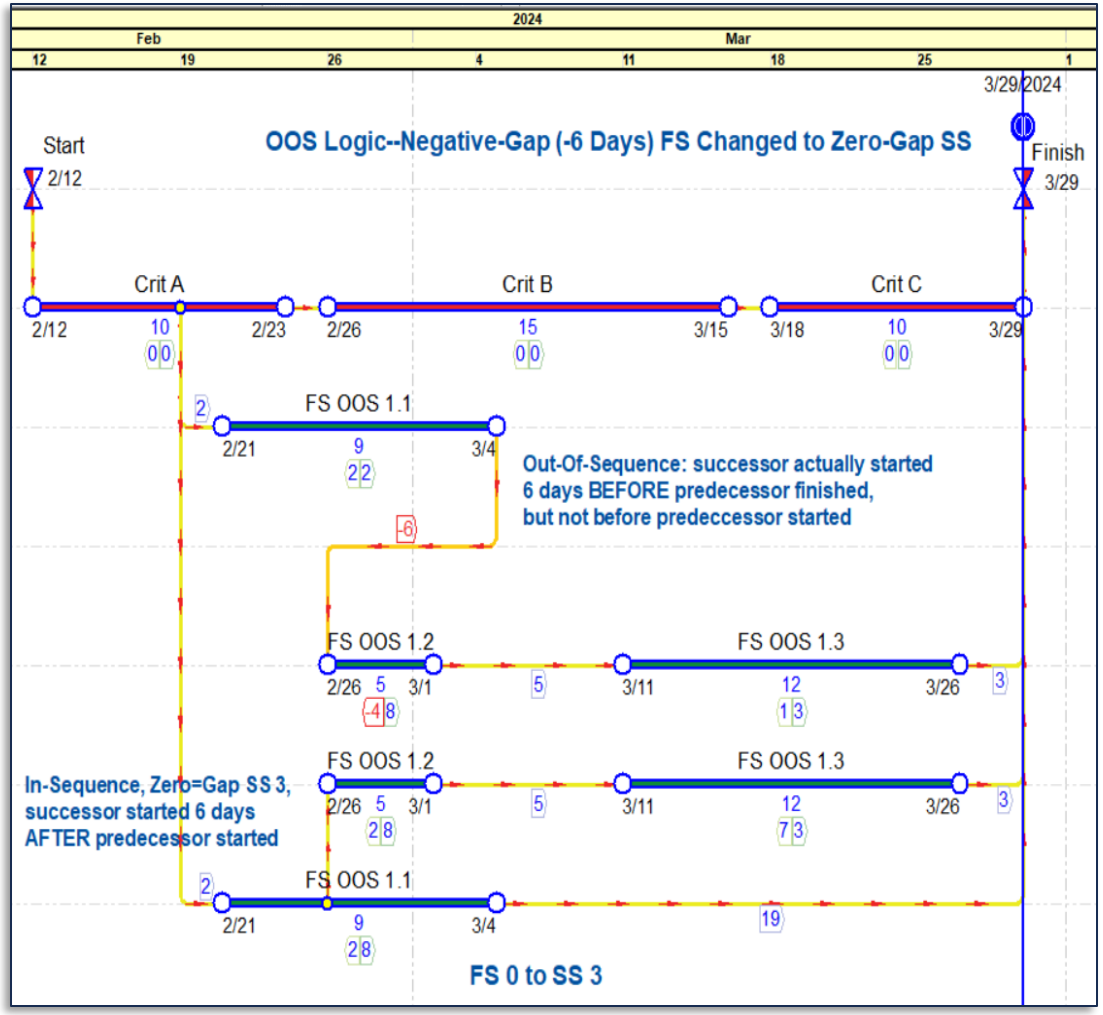
When using CPM software to de-status and recalculate a fully progressed update, as-planned logic ties supersede as-built logic ties

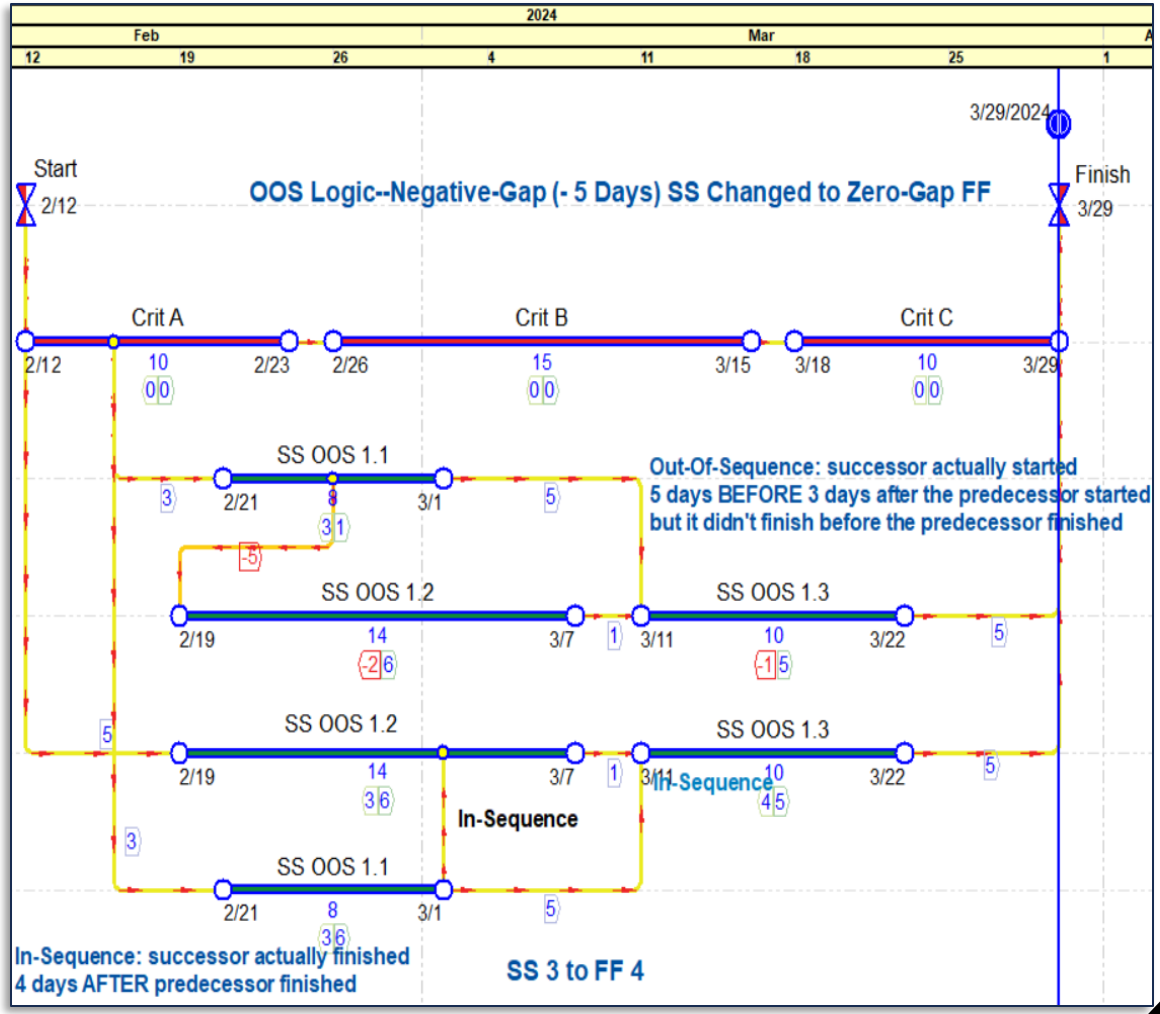
- This forces different early/late dates and total floats than the *algorithmic* early/late dates and total floats in the fully progressed update



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Converting OOS Logic into *As-Built* Logic





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Step 2—*Algorithmic* Fully Progressed Update

Open in GPM software a fully progressed update, right click on the Data Date icon, and select “Reset to the Project Start Date”

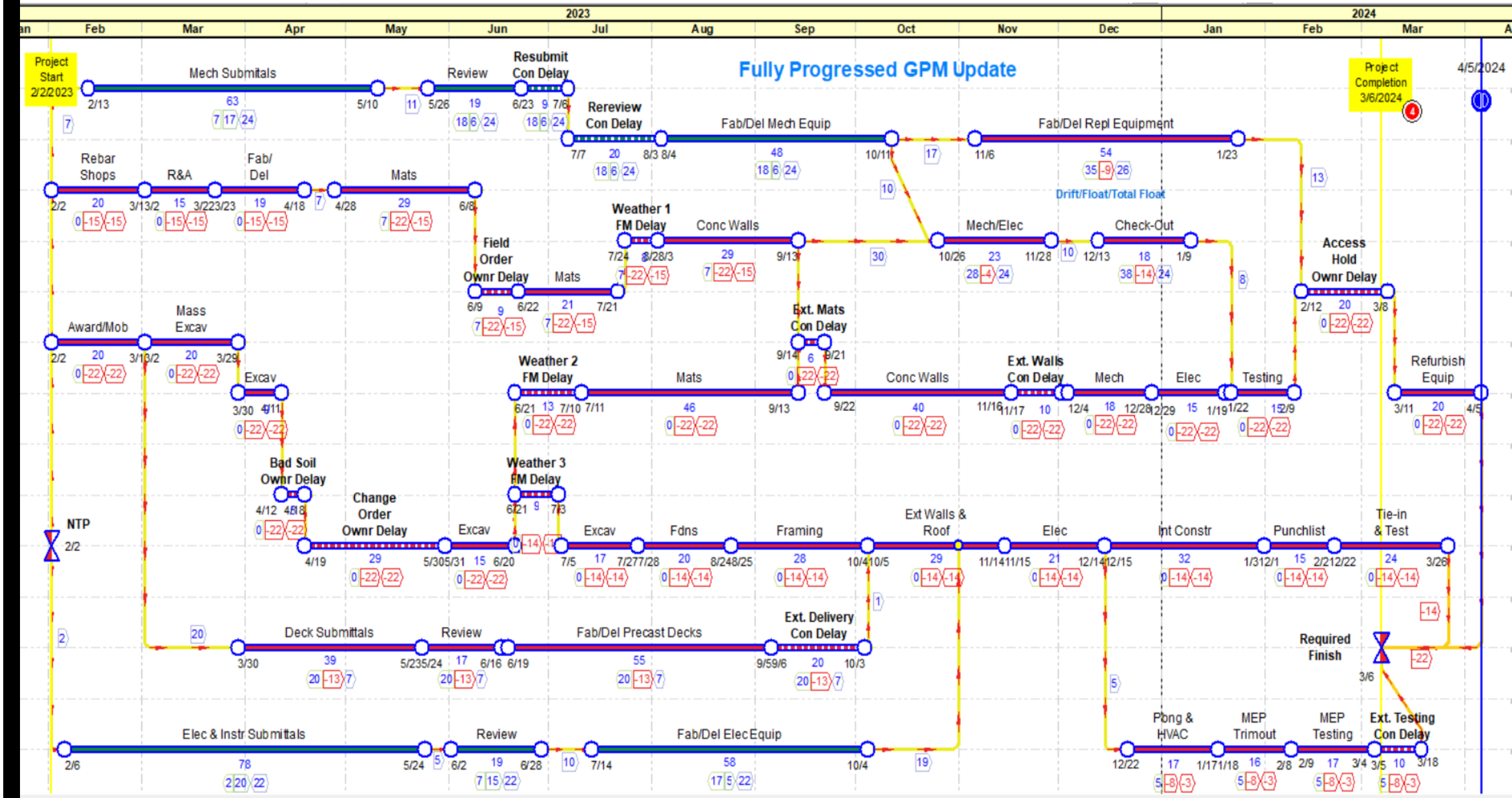
- Actual start dates at once become planned start dates and the schedule reverts to an algorithmic mode (Ponce de Leon and Puri 2024); and
- label activities as ***contractor*** activity or ***owner*** activity and, if not already so labeled, label delays in the schedule as owner delay, force majeure delay, or contractor delay

Delays ***modeled*** in the fully progressed update with activities and logic are ***overt*** delays



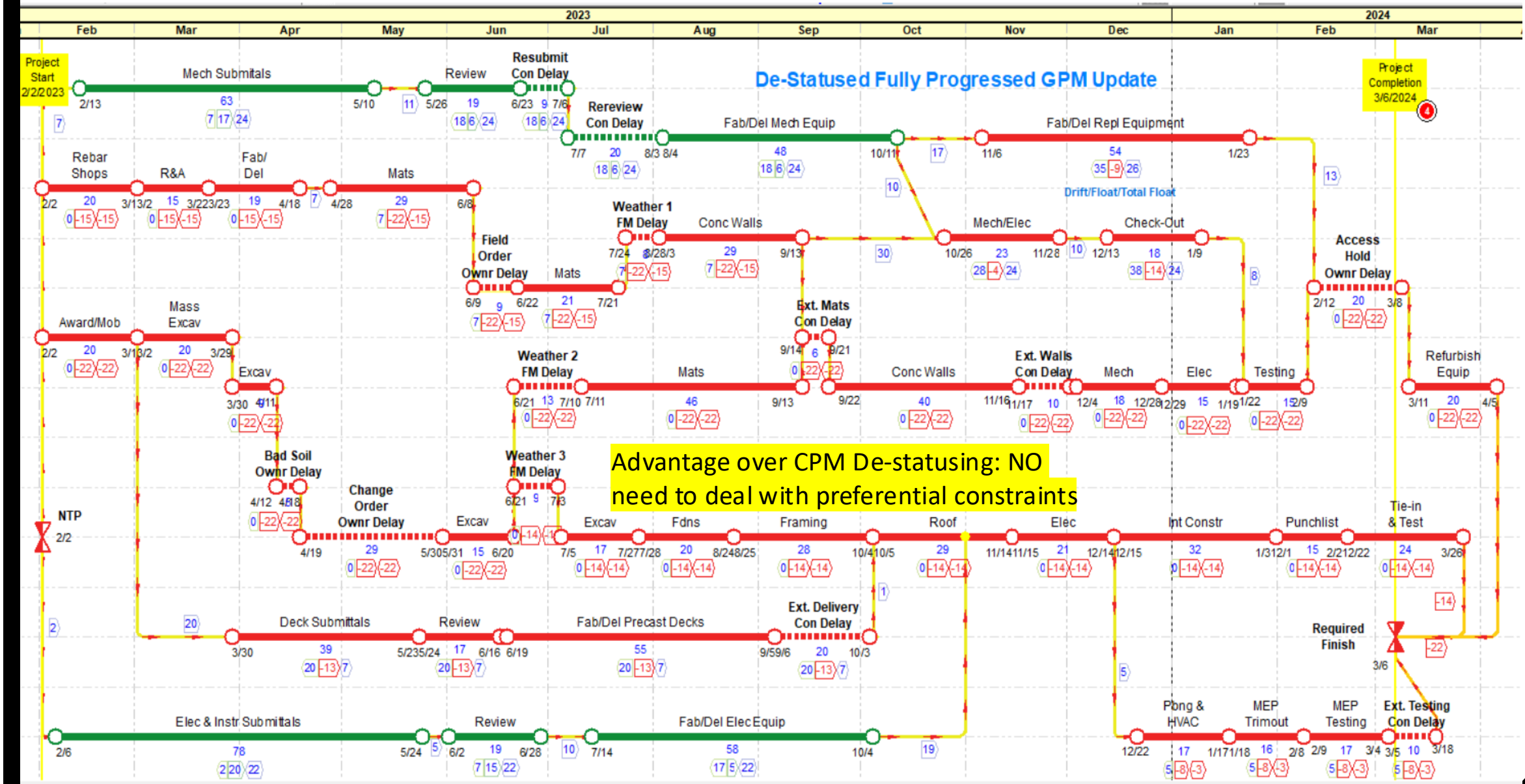
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Step 3—As-Built Drifts Become *Drift Activities*

GPM forensic algorithms replace any positive-gap link that generates as-built drift for the successor with a *contractor drift* activity if preceding a contractor activity and an *owner drift* activity if preceding an owner activity

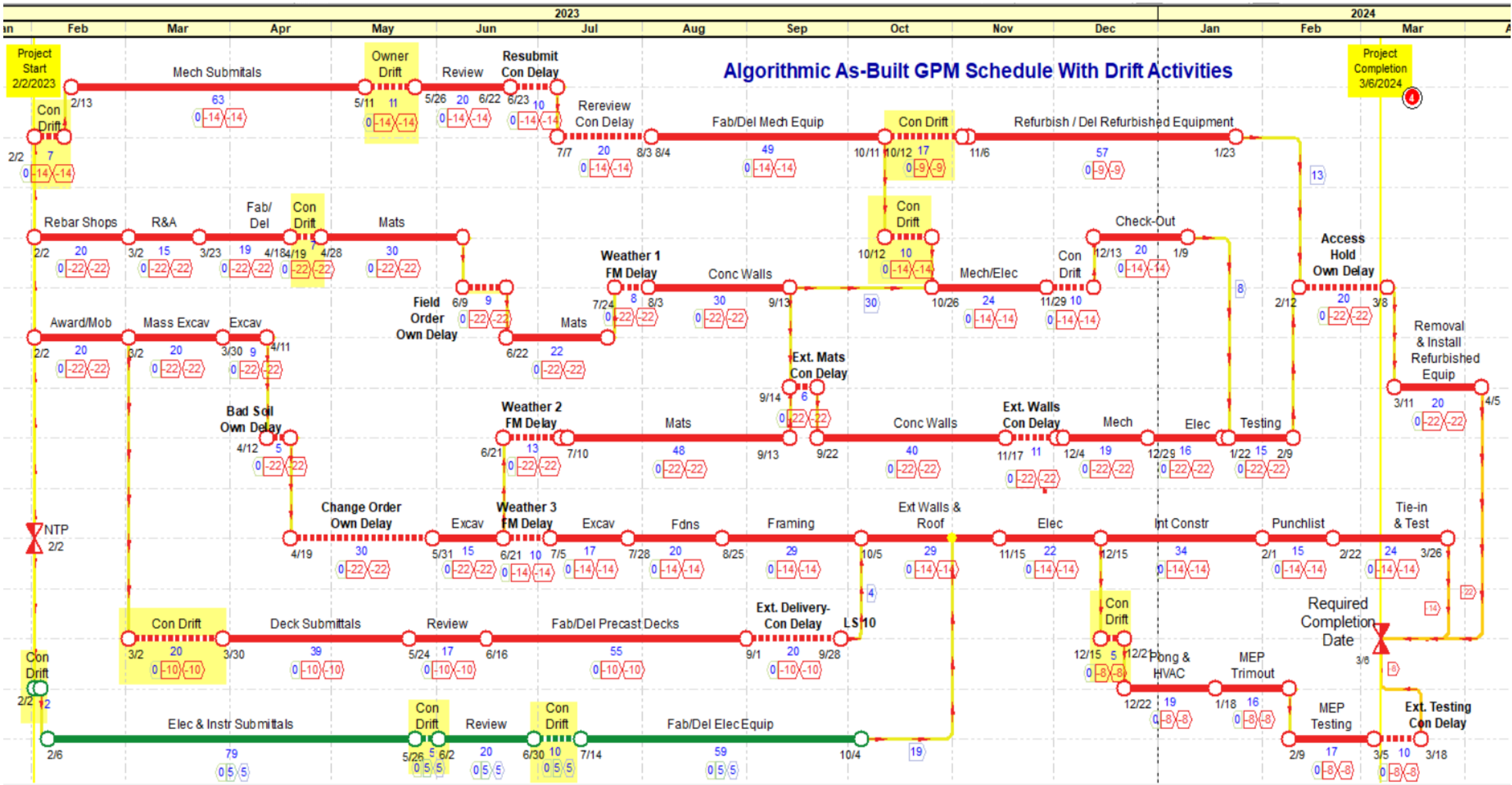


- This step is a prerequisite to identifying ***covert*** delays arising from pre-consumed total float

A ***negative-TF*** drift activity becomes a delay, should it be on a path with overt delays and other drift activities with sum duration equal ***to less than*** the subject drift activity TF overrun

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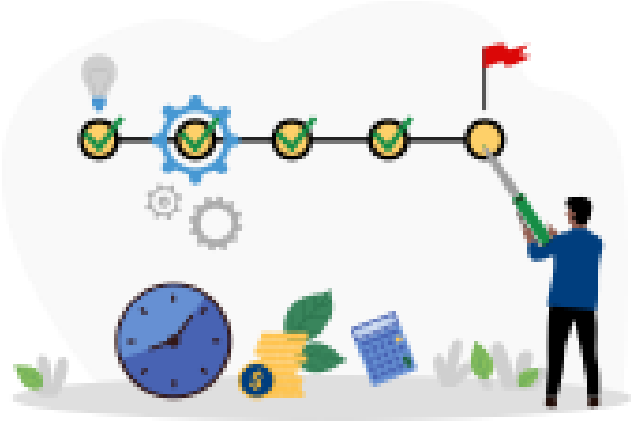




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Step 4—*Zero-Total-Float* Longest Path

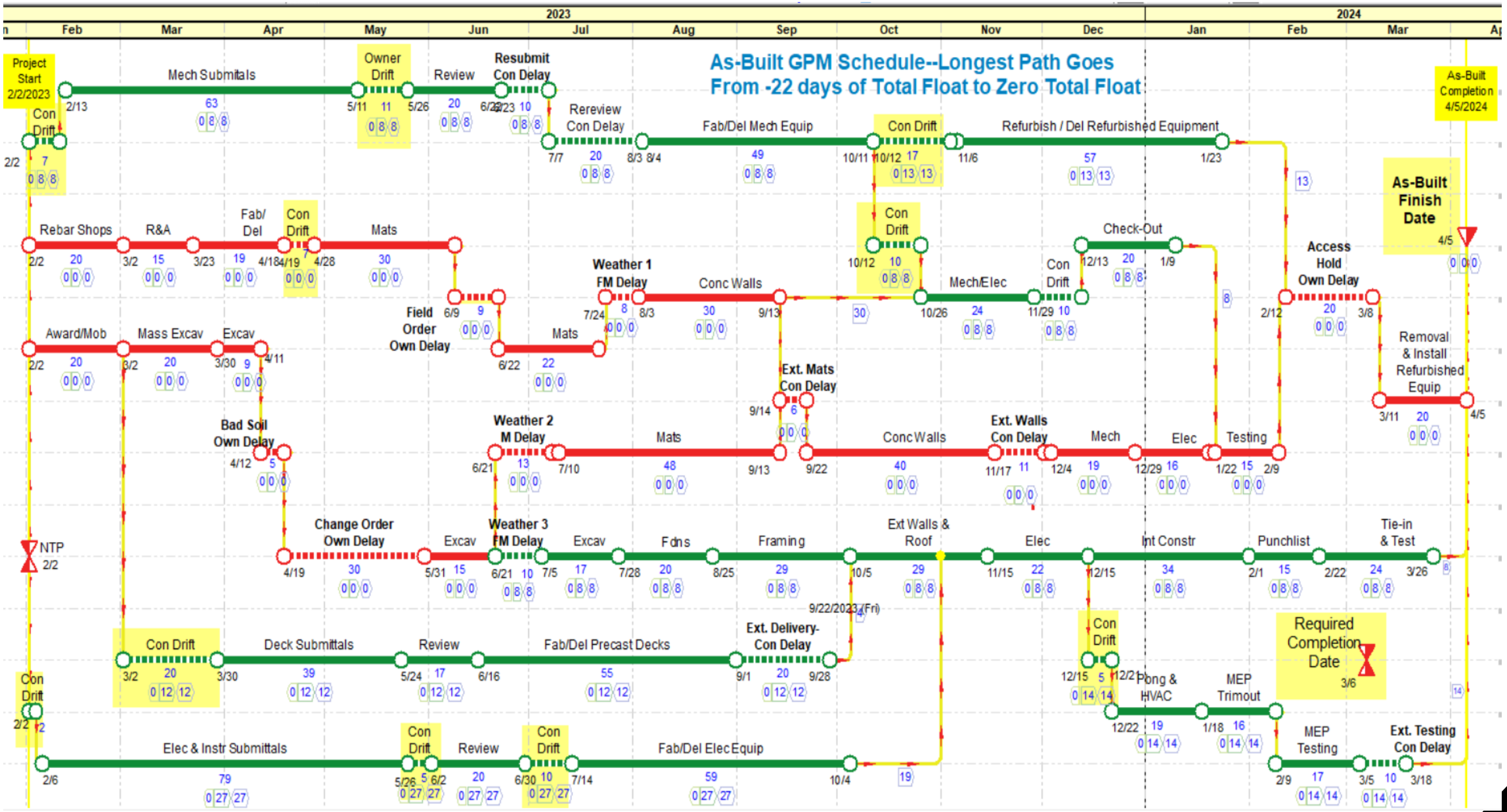
In the fully progressed update, to change the longest path from the most negative total float to zero, and base criticality on zero total floats:



- links connecting activities to a finish benchmark marking the project completion date are deleted;
- an as-built finish date milestone is added and activities linked to the finish benchmark are linked to the as-built finish date milestone; and
- the project completion object is made *calculated mode* so it tracks the as-built finish milestone during and at the end of each crashing cycle

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Step 5—*In-Series* Delays vs. *In-Parallel* Delays

In-series delays are delays that are linked by a link or through a path

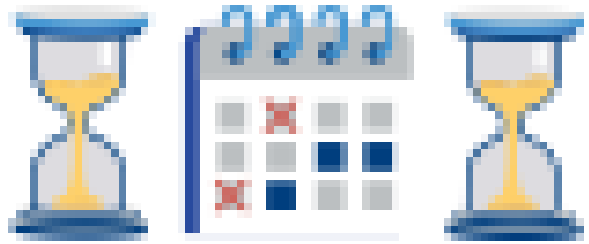
- Crashing a delay will cause a day-per-day earlier start for a downstream *in-series* delay

Two delays not *in series* are *in parallel*

- Crashing a delay will not impact start dates of any *in-parallel* delay

A recursive *logic matrix* algorithm establishes any two delays as *in series* or *in parallel*

- The logic matrix is reduced to a delay-only matrix that codes *in-series* vs. *in-parallel* delays



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Step 6—Crashing Algorithm

Exhausts compensable and excusable as-built schedule compression by crashing zero-TF, *aka* ***eligible*** **delays**, based on the following priority:

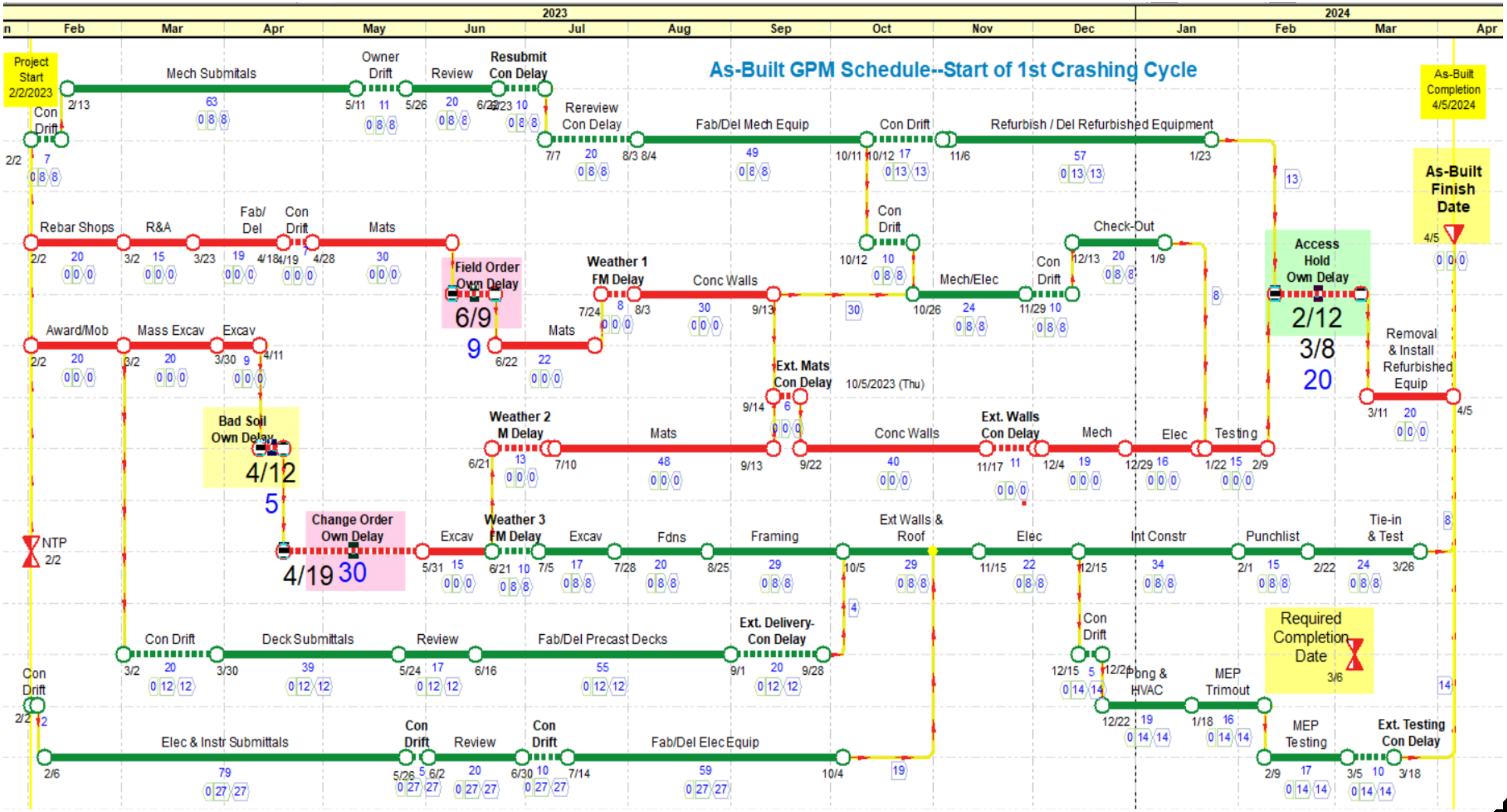
- **Compensable** compression: crashing an *eligible* owner delay or concurrent eligible owner delays/s
- **Excusable** compression: crashing and *eligible* force majeure delay, concurrent *eligible* force majeure delay/s, or concurrent *eligible* owner delay, and/or force majeure delay, and/or contractor delay

Besides not crashing *in-series* delays in the same cycle, **rules control**: 1) delay/s crashed for competing crashing; 2) crashing limit; and 3) when crashing ends



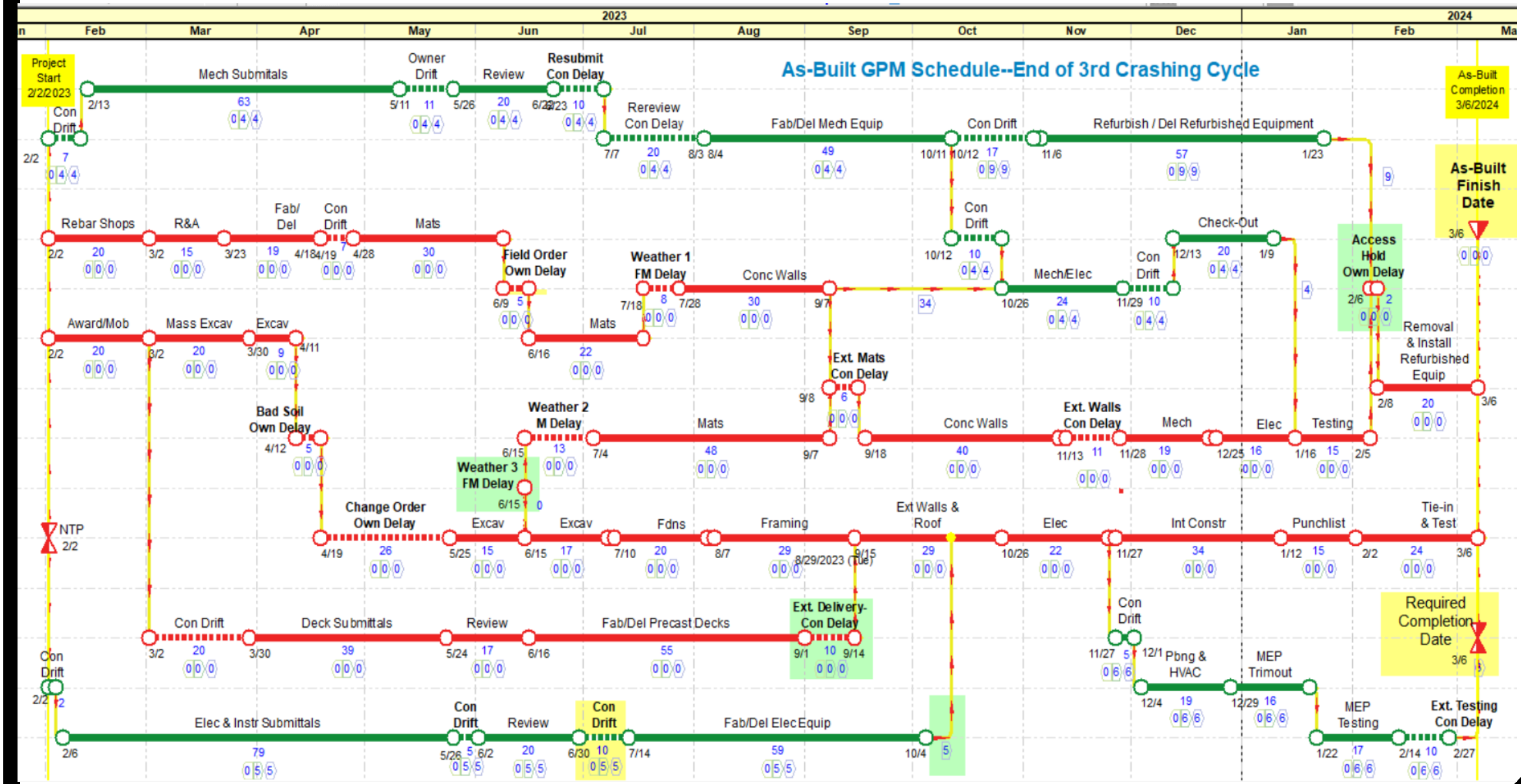
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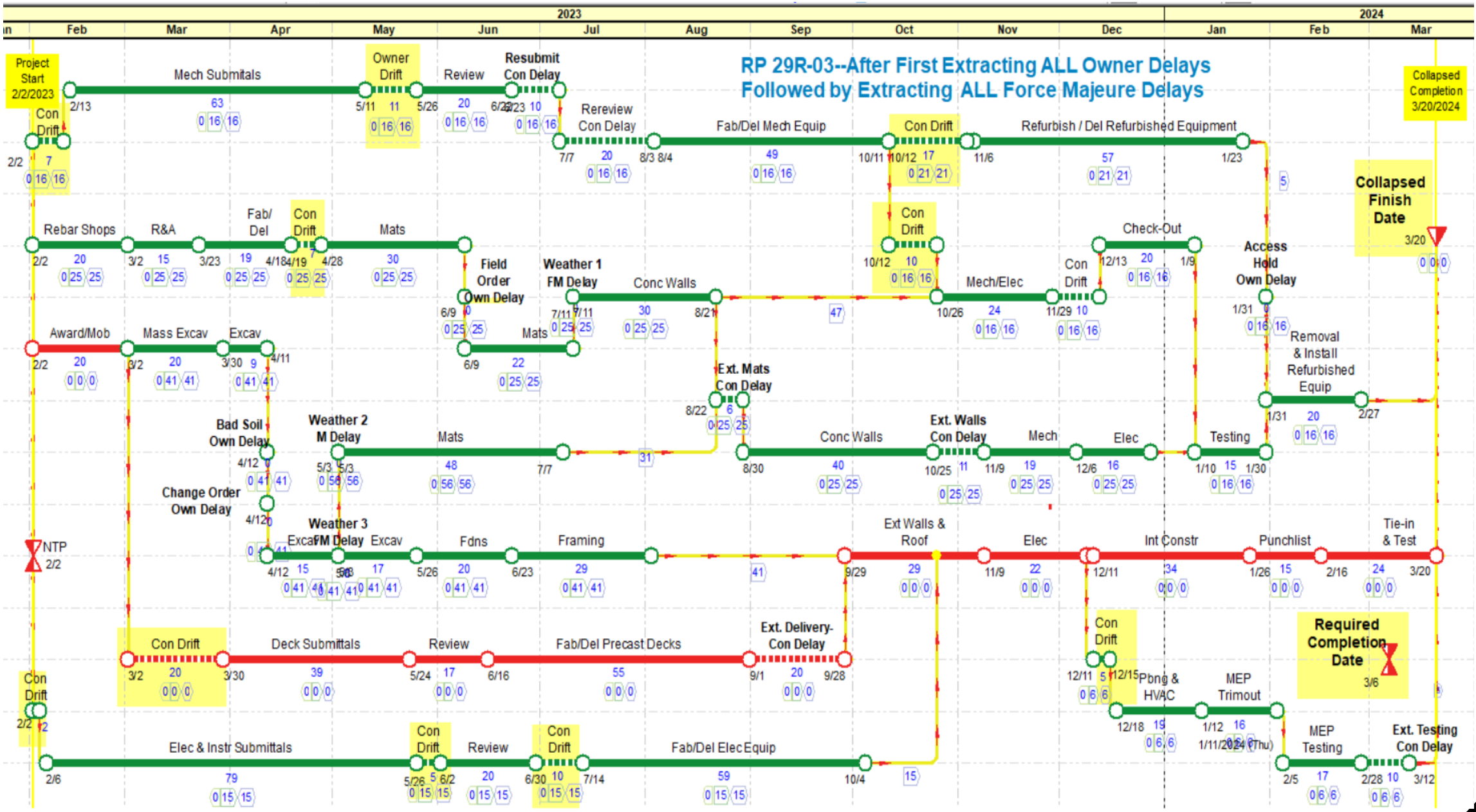
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	GPM As-Built Schedule Compression Method Case Study				Completion
As-Built Schedule	**Compensable Crashing**	**Reversal W/C Days**	**Excusable Crashing**	**Reversal W/C Days**	**04/05/2024**
First Cycle	Access Hold—8 days	8/10			03/26/2024
Second Cycle	Field Order & Change Order—4 days	4/6			03/20/2024
Third Cycle			Access Hold, Weather 3, and Ext,. Delivery—10 days	10/14	**03/06/2024**
As-Built Schedule Compressed to the Required Completion Date		**12/16**		**10/14**	

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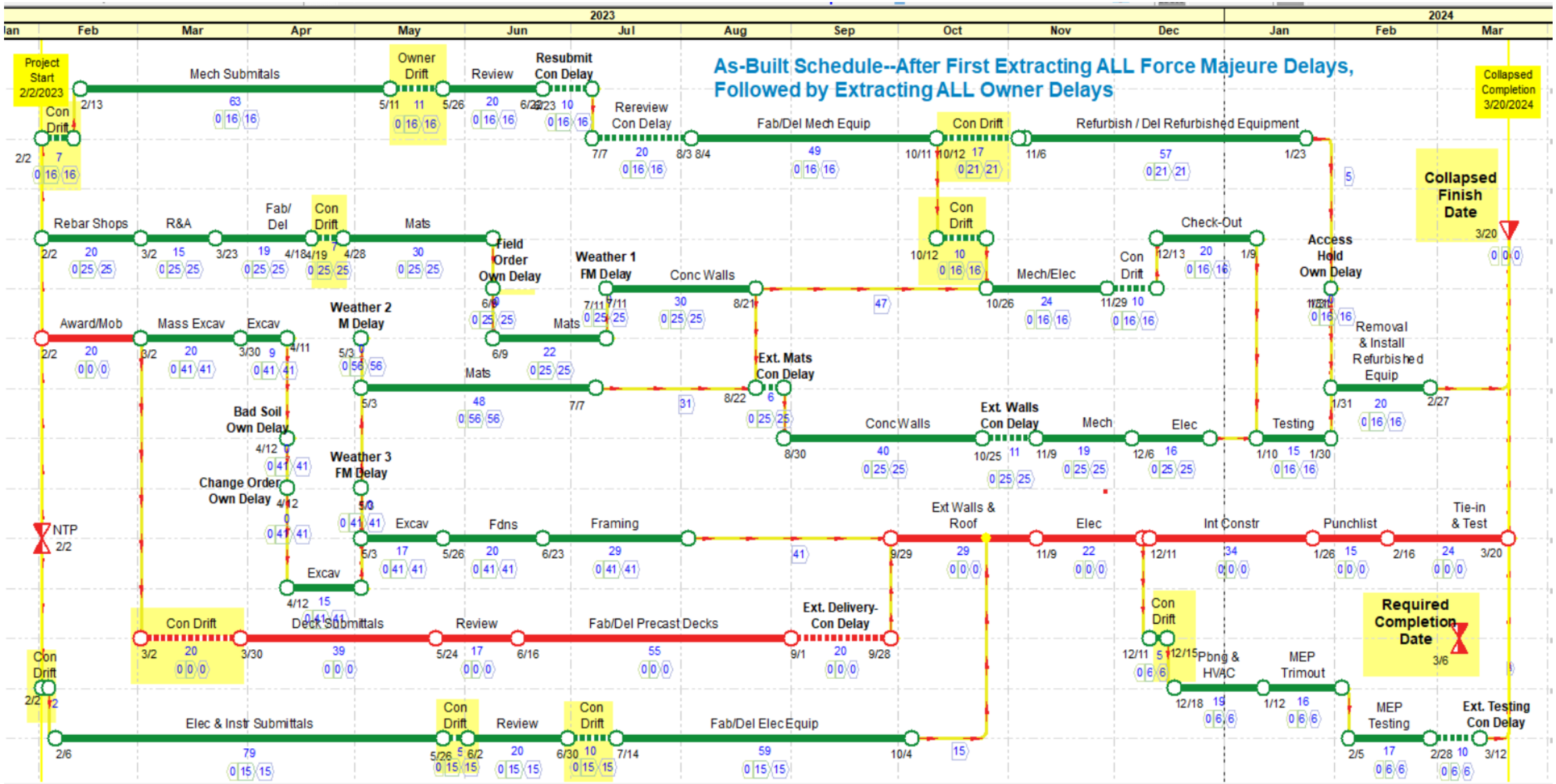
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RP 29R—All Owner, Then All Force Majeure

Fully Progressed Update		Reversal		Reversal	04/05/2024	
	Compensable Crashing	C/Days	Excusable Crashing	C/Days	Finish Date	Inexcusable Prolongation
First Stepped Extraction	Access Hold—20 days	16			03/20/2024	
	Field Order—9 days					
	Change Order—30 days					
	Bad Soil—5 days					
Second Stepped Extraction			FM Rain 1–8 days	0	03/20/2024	
			FM Rain 2–13 days			
			FM Rain 3–10 days			
Collapsed Schedule		16		0		14

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RP 29R—All Force Majeure, Then All Owner

Fully Progressed Update		Reversal		Reversal	04/05/2024	
	Excusable Crashing	E/Days	Compensable Crashing	C/Days	Finish Date	Inexcusable Prolongation
First Stepped Extraction	FM Rain 1—8 days	10			03/26/2024	
	FM Rain 2—10 days					
	FM Rain 3—10 days					
			Access Hold—20 days			
Second Stepped Extraction					03/20/2024	
			Change Order—30 days	6		
			Field Order—5 days			
			Bad Soil—5 days			
Collapsed Schedule		10		6		14

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As-Built Compression vs. RP 29R Collapsing

	Total Payment to Contractor	Compensable Shortening		Excusable Shortening		Inexcusable Shortening	
		Cal Days	$ to Contractor	Cal Days	$ to Contractor	Cal Days	$ to Contractor
To monetize the three outcomes, assume liquidated damages $15,000/day and general conditions $20,000/day							
GPM As-Built Compression	**$320,000**	16	$320,000	14		0	
Collapse Owner & Then Force Majeure	**$110,000**	16	$320,000	0		14	-$210,000
Collapse Force Majeure & Then Owner	**-$90,000**	6	$120,000	10	$-0-	14	-$210,00

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Takeaways



A CPM schedule shows one of many probable outcomes. Without a simulation, ***it is not a reliable predictor*** of when the project will be completed or of which activities are likely to control completion.

It is *not logical* for analysts to use updates to contemporaneously analyze delay impacts only to set aside the fully progressed update simply because it is rendered non-algorithmic by CPM software.

The two algorithmically correct options to quantify delay impact are: 1) a *contemporaneous* statistical analysis that *calculates probable impact* from the drop in completion date P-value, or 2) a *post-completion* analysis that *extracts* impact from the fully progressed update using GPM as-built schedule compression.

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Thank You!

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