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May 16, 2024 | **Online**

The *Algorithmic* As-Built Schedule

Vis-a-vis RP 29R-03, the SCL Protocol, & ASCE 67-17



Presented by:

Dr. Gui Ponce de Leon PE, PMP

Dr. Vivek Puri PMP



Meet the Presenter

Dr. Gui Ponce de Leon PE, PMP
CEO-Emeritus

Dr. Ponce de Leon is recognized as one of our nation's foremost planning and scheduling experts. His broad professional experience includes executive and senior roles as investor's developer, program manager, construction manager, and EPC contractor planner/scheduler. He continually pioneers innovations in project management and has written widely on the use of CPM as well as on schedule, delay, and acceleration analysis.

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Meet the Presenter

Dr. Vivek Puri PMP

Dr. Vivek Puri has significant experience planning and executing projects in both construction and information technology. Dr. Puri's recent work involves research and development relating to NetPoint, NetRisk, and Schedule MD. Three innovative tools were developed in-house by PMA. His doctoral work addressed simulation applications for construction planning.

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HEADS-UP

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

When a delay incorporated in an update falls on the critical path, equating delay in the early finish date to day-per-day delay in the completion of the project is ***doubling down*** on a flawed premise.

Unless quantifying delay impact on completion is grounded on a statistical analysis, the only reliable delay analysis option is to asses the ***as-built impact***, which is the rationale for this presentation.

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CURRENT ART

(CDR-3162) Identifying the As-Built Critical Path Using Recommended Practice 29R-03



Level: Advanced

Venue: 2019 AACE International Conference & Expo, June 16-19, 2019, New Orleans, LA, USA

Abstract: In retrospective forensic schedule analysis, the as-built critical path is one of the most important subjects. Yet, as suggested by one author's previous AACE presentation (Portland, 2002), "Catching the Elusive As-Built Critical Path," identification of the as-built critical path is not an easy task even for the most seasoned analyst. This paper examines whether the nine method implementation protocols (MIP) contained in AACE International Recommended Practice 29R 03, Forensic Schedule Analysis, (RP) are capable of identifying the as-built critical path (ABCP) and relates the authors' findings to the different methods discussed in the current 2011 revision of the RP regarding the identification of the ABCP.

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ADVANCING CURRENT ART

The authors wish to dispel the notion of the ***elusive*** as-built critical path and introduce the concept of the ***algorithmic*** as-built schedule. As demonstrated at the PMI Global Congress 2010, ***the fact is that*** the as-built critical path is alive and well left of the data date. With the primacy accorded to the as-built schedule, analysts may welcome the addition of the ***algorithmic*** as-built schedule alternative—sourced from the fully progressed update—in revisions of ASCE 67-17, RP 29R-03, and the SCL Protocol.

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ASCE 67-17, RP 29R-03, AND THE SCL PROTOCOL

- ASCE 67-17 provides 35 guidelines that focus on ***prospective*** analysis and offers **no** guidance pertaining to the as-built schedule
- RP 29R-03 hierarchical classification focuses on ***retrospective*** delay impact analysis techniques, modeled and observational
- In contrast, the SCL Delay and Disruption Protocol has a wider scope than RP 29R-03 and ASCE 67-17 as it covers both prospective and retrospective analysis methods



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PART I
PRIMACY ACCORDED TO THE AS-BUILT

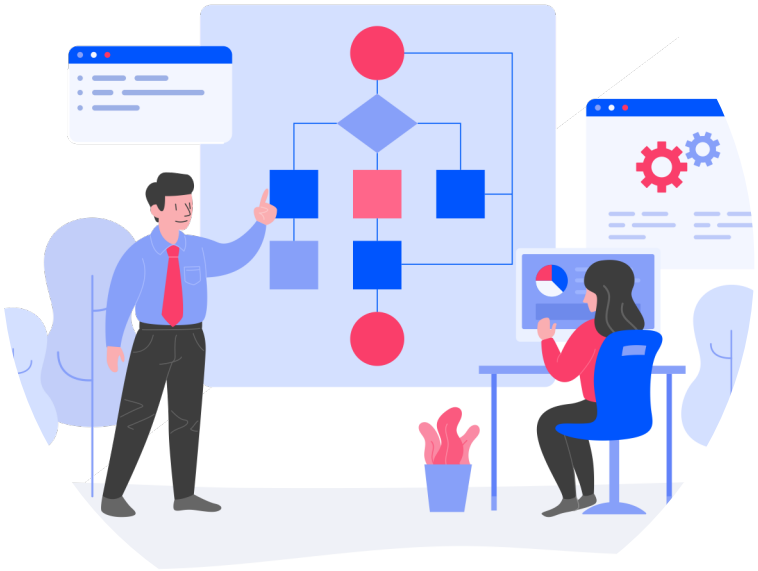
"At the end of the project, the choices of analysis methods are expanded with the full advantage of hindsight offered by the various forms of as-built documentation" (RP 29R-03 1.4.A2).

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RP 29R-03 AND SCL PROTOCOL PERSPECTIVES

- **RP 29R-03 1.4.A2** *"In addition, if as-built documentation is available, the best evidence rule demands that all factual investigations use the as-built as the primary source of analysis"*
- **SCL Protocol 11.4.(d)** *"Retrospective critical path assessments adopt the perspective evident at the end of the project (or window of time)"*



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EYEBALLING THE AS-BUILT THE CRITICAL PATH

Selected **RP 29R-03 4.3.C** views on the ***elusive*** as-built critical path (ABCP):

- *"It is **impossible to accurately** determine the as-built critical path by using only conventional float calculation on the past portion (left) of the data date."*
- *"The closest the analyst can come to determining the as-built critical path is to cumulatively collect from successive schedule updates the activities that reside on the critical path between the data date and the data date of the subsequent update."*



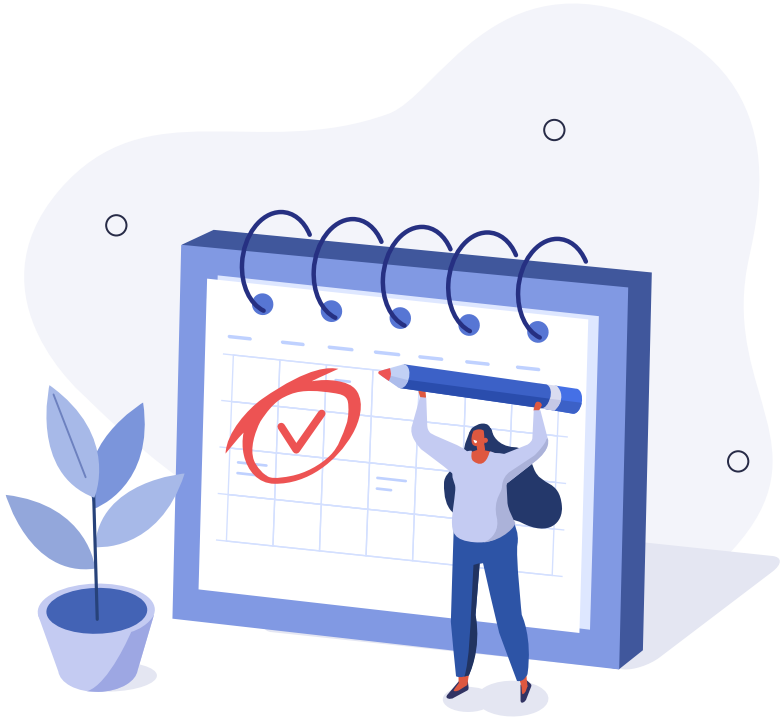
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SOME FORENSIC SCHEDULERS' PERSPECTIVES*

"There is no ready-made CPM software function that calculates the as-built critical path"

"The determination must be a composite process based on multiple sources of project data including the subjective opinion of the percipient witness"

"All sources used to identify controlling path should be tabulated and evaluated for reliability"

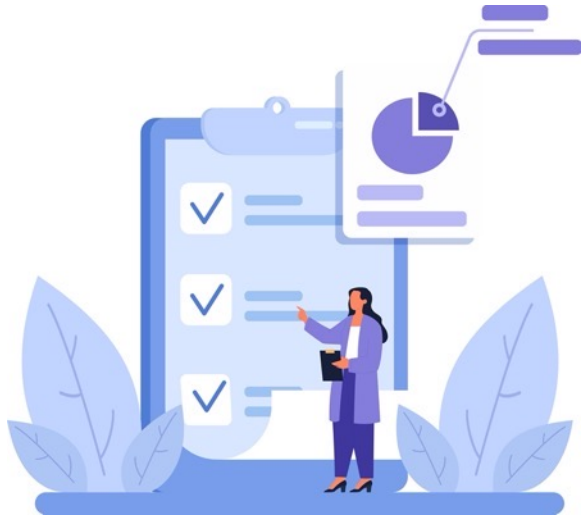


* Identifying the As-Built Critical Path Using Recommended Practice 29R-03

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THE AS-BUILT CRITICAL PATH *QUANDARY*

1. Sourcing the ***fully progressed update***—the ***genuine*** as-built scenario—for retrospective delay analysis is handicapped by CPM updates becoming non-algorithmic left of the data date
2. CPM software has misled schedulers into accepting as fact the notion that actual dates override early/late dates left of the data date
3. Post-completion, forensic scheduling continues to be held back by CPM software that casts the as-built in an unfavorable, non-algorithmic light vis-à-vis contemporaneous updates



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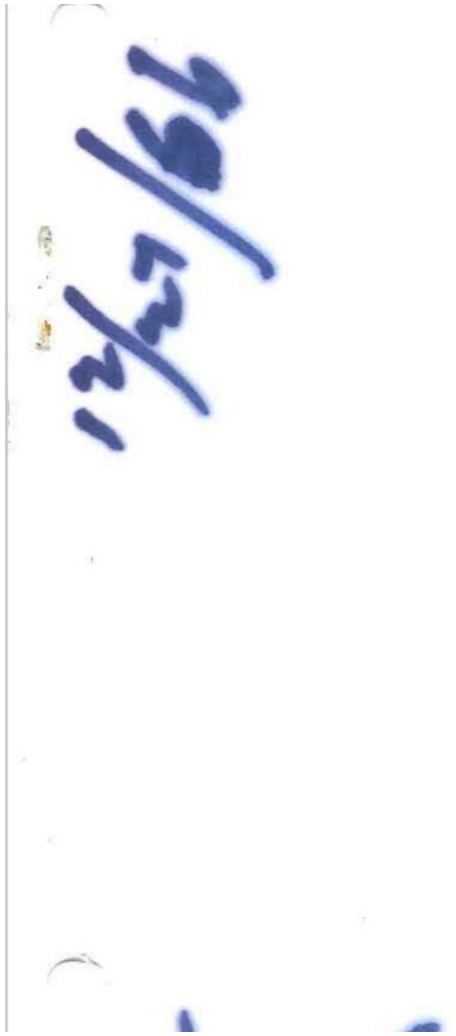
PART II
FINDING THE AS-BUILT CRITICAL PATH

"The ability to determine total floats and the critical path for the as-built portion of a schedule (left of the data date) is solved by the graphical path method (GPM)."

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THE DEMISE OF THE AS-BUILT CRITICAL PATH



Authors' Note—PCS created the concept of the "data date" and in-progress and completed activities, and elected to apply neither the forward pass nor the backward pass left of the data date

1440 Project Control System

(1440-MX-02X) User's Manual

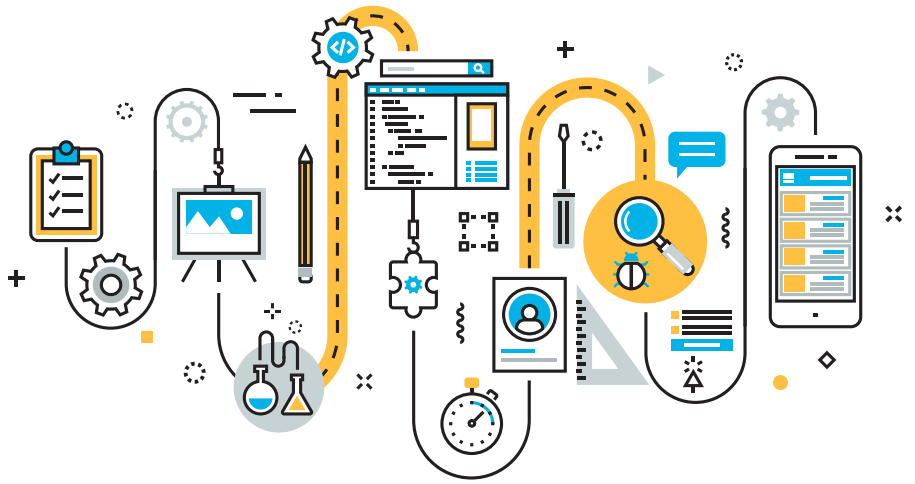
The 1440 Project Control System provides for the planning, scheduling, and control of construction projects through the use of the critical-path method. The system can accept data from networks planned in either the arrow-diagramming or precedence-diagramming methods. Sequence of processing and system outputs are controlled by a system control card. Output reports include status listings, bar charts, and management exception-type action reports.

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HOW THE AS-BUILT CRITICAL PATH WENT MISSING

All the way back to 1966, when IBM CPM software introduced the ***data date*** for completed activities, instead of calculating early dates and late dates, the software set them both equal to their actual dates

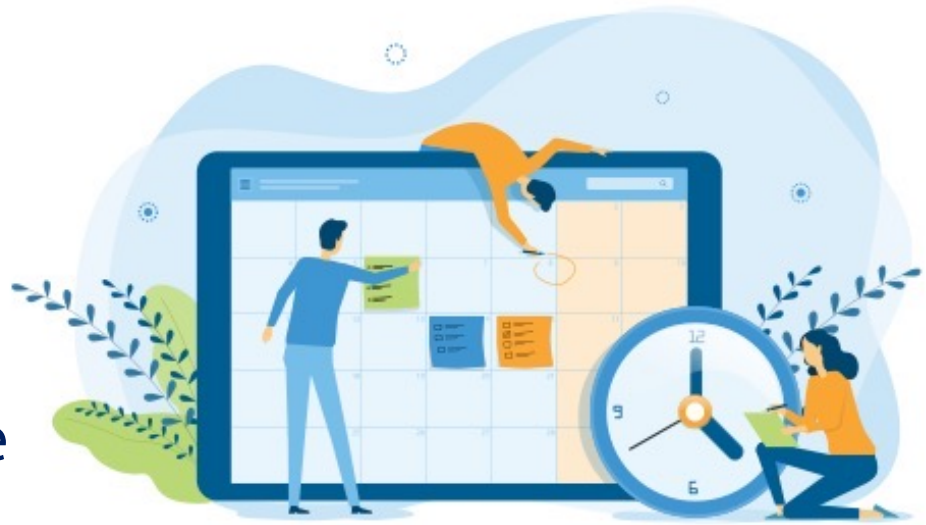
- In other words, when progress and actual dates were introduced, an alternate algorithm that calculates early and late dates based on actual durations and actual logic (i.e., solely on network topology) was not the protocol chosen



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AS-BUILT CRITICAL PATH *WORK AROUND*

RP 29R-03 4.3.C *"one method to show the as-built critical path is to create a collapsible as-built CPM schedule (Subsection 3.8.K.2) where the as-built schedule actual dates are converted into actual activity durations and actual driving lag durations."*



With activities in the analog (actual durations and logic) CPM schedule on early dates, they must be returned to actual dates with lags

- Pacing or floating predecessor activities may be more suitable than driving lags, mainly for activities with negative float

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AS-BUILT CRITICAL PATH MANUAL CALCULATION

On any CPM schedule, after having corrected out-of-sequence logic (i.e., logic conforms to as-planned logic rules), a scheduler could, **in theory**, manually carry on with the forward pass and backward pass left of the data date

P6 has long realized this as P6 does feature a protocol that yields *algorithmic late* finish dates but not early dates left of the data date

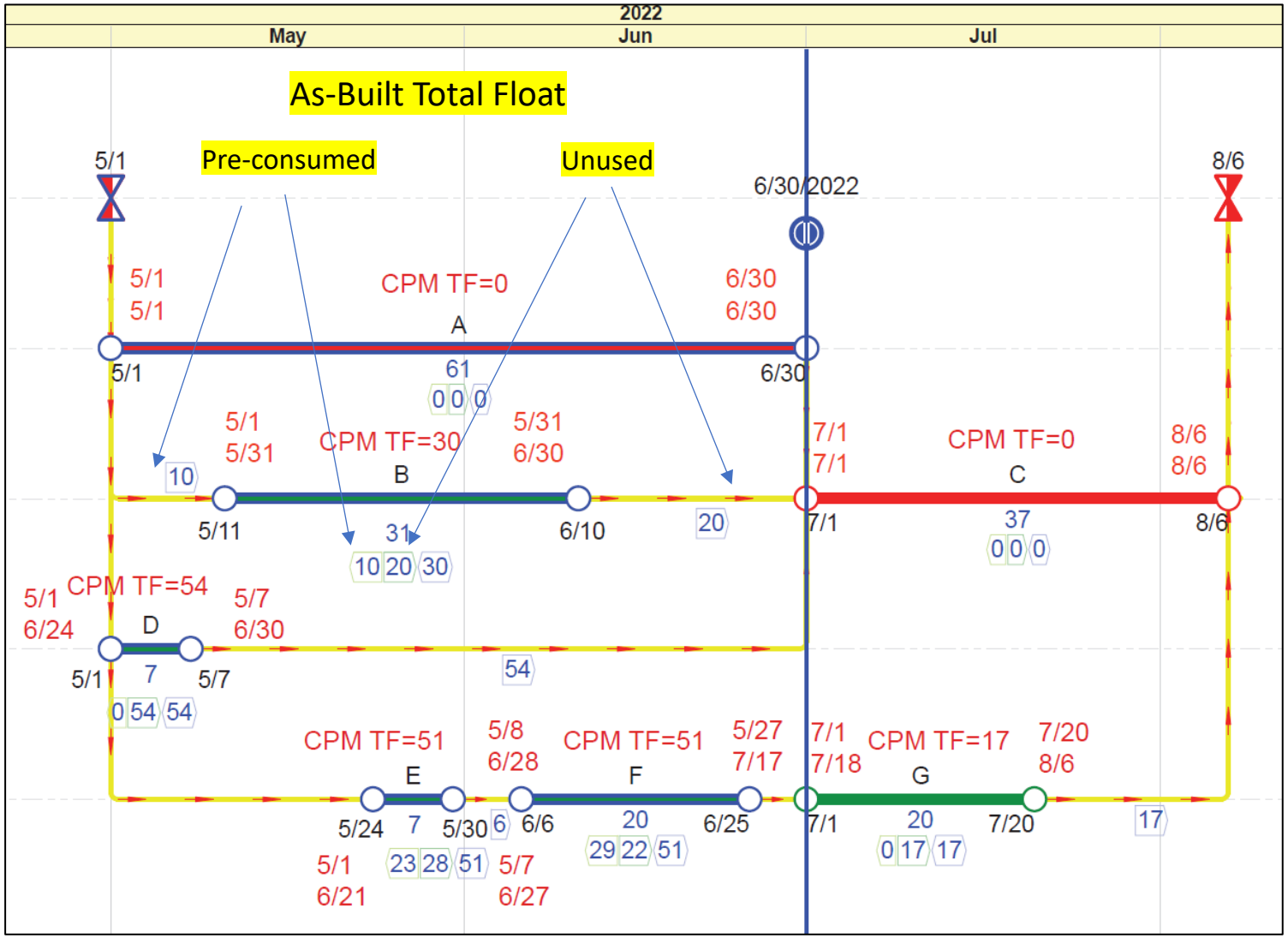
- That said, the P6 late finish dates protocol overstates late dates for completed activities with a successor that is also complete



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TOTAL FLOATS *LEFT* OF THE DATA DATE

Manual CPM forward pass and backward pass performed **both sides** of the data date, forward pass starting from the project start date 5/1/22, and backward pass pivoting back from the calculated schedule finish date 8/6/2022



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PART III
SOLVING THE CPM HANDICAP WITH GPM

GPM calculates not only as-built early dates, late dates, and total floats left of the data date, but also ***pre-consumed*** and ***unused*** total float, and the evolving as-built critical path.

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GPM AVOIDS THE CPM SOFTWARE HANDICAP



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Critical-Path Planning and Scheduling

JAMES E. KELLEY, JR.† AND MORGAN R. WALKER†

INTRODUCTION AND SUMMARY

AMONG the major problems facing technical management today are those involving the coordination of many diverse activities toward a common goal. In a large engineering project, for example, almost all the engineering and craft skills are involved as well as the functions represented by research, development, design, procurement, construction, vendors, fabricators and the customer. Management must devise plans which will tell with as much accuracy as possible how the efforts of the people representing these functions should be directed toward the project's completion. In order to devise such plans and implement them, management must be able to collect pertinent information to accomplish the following tasks:

(1) To form a basis for prediction and planning
(2) To evaluate alternative plans for accomplishing the objective
(3) To check progress against current plans and objectives, and
(4) To form a basis for obtaining the facts so that decisions can be made and the job can be done.

Many present project planning systems possess deficiencies resulting from techniques inadequate for dealing with complex projects. Generally, the several groups concerned with the work do their own detailed planning and scheduling — largely independent from one another. These separate efforts lead to lack of coordination. Further, it is traditional in project work that detailed schedules be developed from gross estimates of total requirements and achievements based on past experience. The main reason for this oversimplification stems from the inability of unaided human beings to cope with sheer complexity. In consequence, many undesirable effects may arise. Some important aspects of a project, which should be taken into account at the outset, may be ignored or unrecognized. As a result, much confusion may arise during the course of the project. When this happens, the management of the project is left to the coordinators and expediters. In such circumstances, management loses much of the control of a project and is never quite sure whether its objectives are being attained properly.

Recognizing the deficiencies in traditional project planning and scheduling procedures, the Integrated Engineering Control Group (I. E. C.) of E. I. duPont de Nemours & Co. proceeded to explore possible alternatives. It was felt that a high degree of coordination could be obtained if the planning and scheduling information of all project functions are combined into a single master plan — a plan that integrates all efforts toward a common objective. The plan should point directly to the difficult and significant activities — the problems of achieving the objective. For example, the plan should form the basis of a system for *management by exception*. That is, within the framework of the rules laid down, it should indicate the *exceptions*. Under such a system, management need act only when deviations from the plan occur.

The generation of such a coordinated master plan requires the consideration of much more detailed information at one time than heretofore contemplated in project work. In turn, a new approach to the whole problem of planning and scheduling large projects is required. In late 1956, I. E. C. initiated a survey of the prospects for applying electronic computers as an aid to coping with the complexities of managing engineering projects. The following were the questions of most pressing interest: To what extent can a computer-oriented system be used:

(1) To prepare a master schedule for a project?
(2) To revise schedules to meet changing conditions in the "most" economical way?
(3) To keep management and the operating departments advised of project progress and changes?

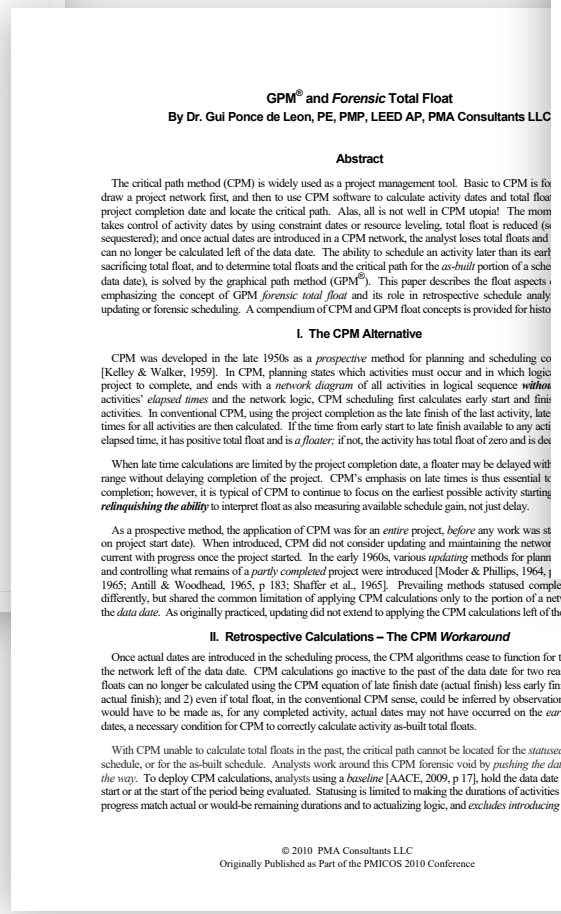
During the course of this survey outside help was solicited. As part of their customer service, Remington Rand UNIVAC assigned the first author to the job of providing some assistance. At the time the second author represented duPont in this effort. The result of our alliance is the subject of this essay.

We made a critical analysis of the traditional approach to planning and a study of the nature of engineering projects. It quickly became apparent that if a new approach were to be successful, some technique had to be used to describe the interrelationships among the many tasks that compose a project. Further, the technique would have to be very simple and rigorous in application, if humans were to cope with the complexity of a project.

One of the difficulties in the traditional approach is that planning and scheduling are carried on simultaneously. At one session, the planner and scheduler

† Mauchly Associates, Inc., Ambler, Pa.

From the collection of the Computer History Museum (www.computerhistory.org)



GPM® and *Forensic* Total Float

By Dr. Gui Ponce de Leon, PE, PMP, LEED AP, PMA Consultants LLC

Abstract

The critical path method (CPM) is widely used as a project management tool. Basic to CPM is fo
draw a project network first, and then to use CPM software to calculate activity dates and total floa
project completion date and locate the critical path. Alas, all is not well in CPM utopia! The mom
takes control of activity dates by using constraint dates or resource leveling, total float is reduced (s
sequestered); and once actual dates are introduced in a CPM network, the analyst loses total floats and
can no longer be calculated left of the data date. The ability to schedule an activity later than its earl
sacrificing total float, and to determine total floats and the critical path for the *as-built* portion of a sche
data date), is solved by the graphical path method (GPM®). This paper describes the float aspects
emphasizing the concept of GPM *forensic total float* and its role in retrospective schedule analy
updating or forensic scheduling. A compendium of CPM and GPM float concepts is provided for histo

I. The CPM Alternative

CPM was developed in the late 1950s as a *prospective* method for planning and scheduling co
[Kelley & Walker, 1959]. In CPM, planning states which activities must occur and in which logic
project to complete, and ends with a *network diagram* of all activities in logical sequence ***withou***
activities' *elapsed times* and the network logic, CPM scheduling first calculates early start and fini
activities. In conventional CPM, using the project completion as the late finish of the last activity, late
times for all activities are then calculated. If the time from early start to late finish available to any acti
elapsed time, it has positive total float and is *a floater;* if not, the activity has total float of zero and is de

When late time calculations are limited by the project completion date, a floater may be delayed with
range without delaying completion of the project. CPM's emphasis on late times is thus essential t
completion; however, it is typical of CPM to continue to focus on the earliest possible activity starting
relinquishing the ability to interpret float as also measuring available schedule gain, not just delay.

As a prospective method, the application of CPM was for an *entire* project, *before* any work was st
on project start date). When introduced, CPM did not consider updating and maintaining the networ
current with progress once the project started. In the early 1960s, various *updating* methods for plann
and controlling what remains of a *partly completed* project were introduced [Moder & Phillips, 1964,
1965; Antill & Woodhead, 1965, p 183; Shaffer et al., 1965]. Prevailing methods statused completed activities
differently, but shared the common limitation of applying CPM calculations only to the portion of a network right of
the *data date.* As originally practiced, updating did not extend to applying the CPM calculations left of the data date.

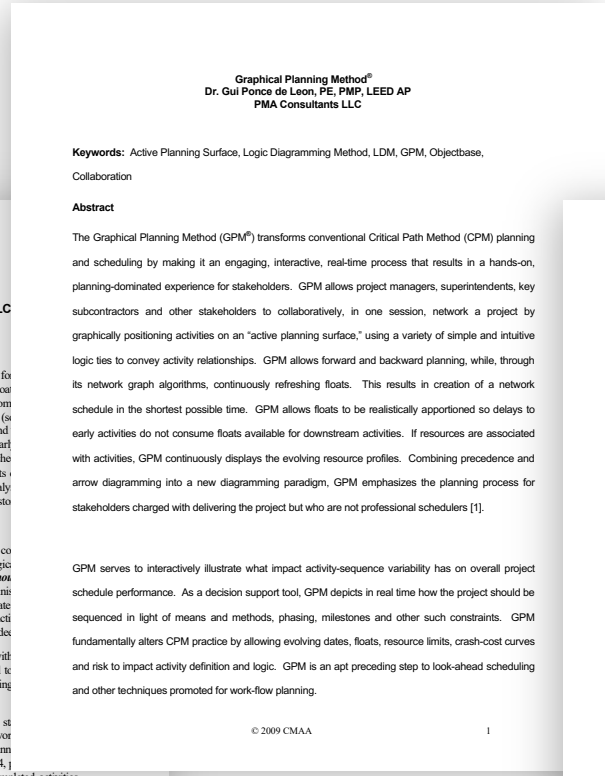
II. Retrospective Calculations – The CPM *Workaround*

Once actual dates are introduced in the scheduling process, the CPM algorithms cease to function for the portion of
the network left of the data date. CPM calculations go inactive to the past of the data date for two reasons: 1) total
floats can no longer be calculated using the CPM equation of late finish date (actual finish) less early finish date (also
actual finish); and 2) even if total float, in the conventional CPM sense, could be inferred by observation, corrections
would have to be made as, for any completed activity, actual dates may not have occurred on the *earliest possible*
dates, a necessary condition for CPM to correctly calculate activity as-built total floats.

With CPM unable to calculate total floats in the past, the critical path cannot be located for the *statused* portion of a
schedule, or for the as-built schedule. Analysts work around this CPM forensic void by *pushing the data date out of
the way.* To deploy CPM calculations, analysts using a *baseline* [AACE, 2009, p 17], hold the data date at the project
start or at the start of the period being evaluated. Statusing is limited to making the durations of activities experiencing
progress match actual or would-be remaining durations and to actualizing logic, and *excludes introducing* actual dates.

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Originally Published as Part of the PMICOS 2010 Conference



Graphical Planning Method®

Dr. Gui Ponce de Leon, PE, PMP, LEED AP
PMA Consultants LLC

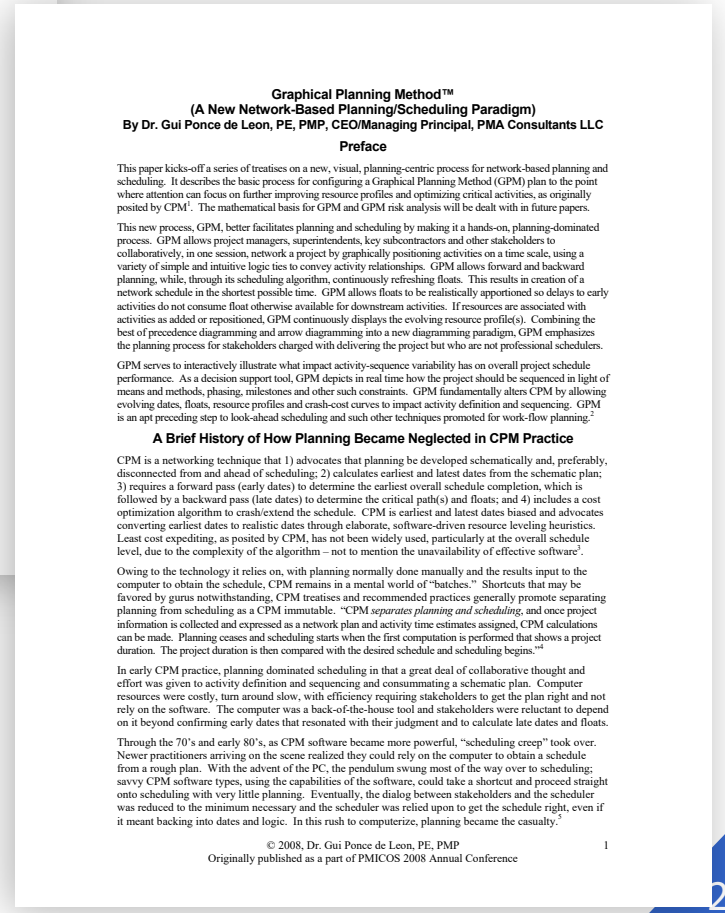
Keywords: Active Planning Surface, Logic Diagramming Method, LDM, GPM, Objectbase, Collaboration

Abstract

The Graphical Planning Method (GPM®) transforms conventional Critical Path Method (CPM) planning and scheduling by making it an engaging, interactive, real-time process that results in a hands-on, planning-dominated experience for stakeholders. GPM allows project managers, superintendents, key subcontractors and other stakeholders to collaboratively, in one session, network a project by graphically positioning activities on an "active planning surface," using a variety of simple and intuitive logic ties to convey activity relationships. GPM allows forward and backward planning, while, through its network graph algorithms, continuously refreshing floats. This results in creation of a network schedule in the shortest possible time. GPM allows floats to be realistically apportioned so delays to early activities do not consume floats available for downstream activities. If resources are associated with activities, GPM continuously displays the evolving resource profiles. Combining precedence and arrow diagramming into a new diagramming paradigm, GPM emphasizes the planning process for stakeholders charged with delivering the project but who are not professional schedulers [1].

GPM serves to interactively illustrate what impact activity-sequence variability has on overall project schedule performance. As a decision support tool, GPM depicts in real time how the project should be sequenced in light of means and methods, phasing, milestones and other such constraints. GPM fundamentally alters CPM practice by allowing evolving dates, floats, resource limits, crash-cost curves and risk to impact activity definition and logic. GPM is an apt preceding step to look-ahead scheduling and other techniques promoted for work-flow planning.

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Graphical Planning Method™
(A New Network-Based Planning/Scheduling Paradigm)

By Dr. Gui Ponce de Leon, PE, PMP, CEO/Managing Principal, PMA Consultants LLC

Preface

This paper kicks-off a series of treatises on a new, visual, planning-centric process for network-based planning and scheduling. It describes the basic process for configuring a Graphical Planning Method (GPM) plan to the point where attention can focus on further improving resource profiles and optimizing critical activities, as originally posited by CPM[1]. The mathematical basis for GPM and GPM risk analysis will be dealt with in future papers.

This new process, GPM, better facilitates planning and scheduling by making it a hands-on, planning-dominated process. GPM allows project managers, superintendents, key subcontractors and other stakeholders to collaboratively, in one session, network a project by graphically positioning activities on a time scale, using a variety of simple and intuitive logic ties to convey activity relationships. GPM allows forward and backward planning, while, through its scheduling algorithm, continuously refreshing floats. This results in creation of a network schedule in the shortest possible time. GPM allows floats to be realistically apportioned so delays to early activities do not consume float otherwise available for downstream activities. If resources are associated with activities as added or repositioned, GPM continuously displays the evolving resource profile(s). Combining the best of precedence diagramming and arrow diagramming into a new diagramming paradigm, GPM emphasizes the planning process for stakeholders charged with delivering the project but who are not professional schedulers.

GPM serves to interactively illustrate what impact activity-sequence variability has on overall project schedule performance. As a decision support tool, GPM depicts in real time how the project should be sequenced in light of means and methods, phasing, milestones and other such constraints. GPM fundamentally alters CPM by allowing evolving dates, floats, resource profiles and crash-cost curves to impact activity definition and sequencing. GPM is an apt preceding step to look-ahead scheduling and such other techniques promoted for work-flow planning.[2]

A Brief History of How Planning Became Neglected in CPM Practice

CPM is a networking technique that 1) advocates that planning be developed schematically and, preferably, disconnected from and ahead of scheduling; 2) calculates earliest and latest dates from the schematic plan; 3) requires a forward pass (early dates) to determine the earliest overall schedule completion, which is followed by a backward pass (late dates) to determine the critical path(s) and floats; and 4) includes a cost optimization algorithm to crash/extend the schedule. CPM is earliest and latest dates biased and advocates converting earliest dates to realistic dates through elaborate, software-driven resource leveling heuristics. Least cost expediting, as posited by CPM, has not been widely used, particularly at the overall schedule level, due to the complexity of the algorithm – not to mention the unavailability of effective software[3].

Owing to the technology it relies on, with planning normally done manually and the results input to the computer to obtain the schedule, CPM remains in a mental world of "batches." Shortcuts that may be favored by gurus notwithstanding, CPM treatises and recommended practices generally promote separating planning from scheduling as a CPM immutable. "CPM *separates planning and scheduling*, and once project information is collected and expressed as a network plan and activity time estimates assigned, CPM calculations can be made. Planning ceases and scheduling starts when the first computation is performed that shows a project duration. The project duration is then compared with the desired schedule and scheduling begins."[4]

In early CPM practice, planning dominated scheduling in that a great deal of collaborative thought and effort was given to activity definition and sequencing and consummating a schematic plan. Computer resources were costly, turn around slow, with efficiency requiring stakeholders to get the plan right and not rely on the software. The computer was a back-of-the-house tool and stakeholders were reluctant to depend on it beyond confirming early dates that resonated with their judgment and to calculate late dates and floats.

Through the 70's and early 80's, as CPM software became more powerful, "scheduling creep" took over. Newer practitioners arriving on the scene realized they could rely on the computer to obtain a schedule from a rough plan. With the advent of the PC, the pendulum swung most of the way over to scheduling; savvy CPM software types, using the capabilities of the software, could take a shortcut and proceed straight onto scheduling with very little planning. Eventually, the dialog between stakeholders and the scheduler was reduced to the minimum necessary and the scheduler was relied upon to get the schedule right, even if it meant backing into dates and logic. In this rush to computerize, planning became the casualty.[5]

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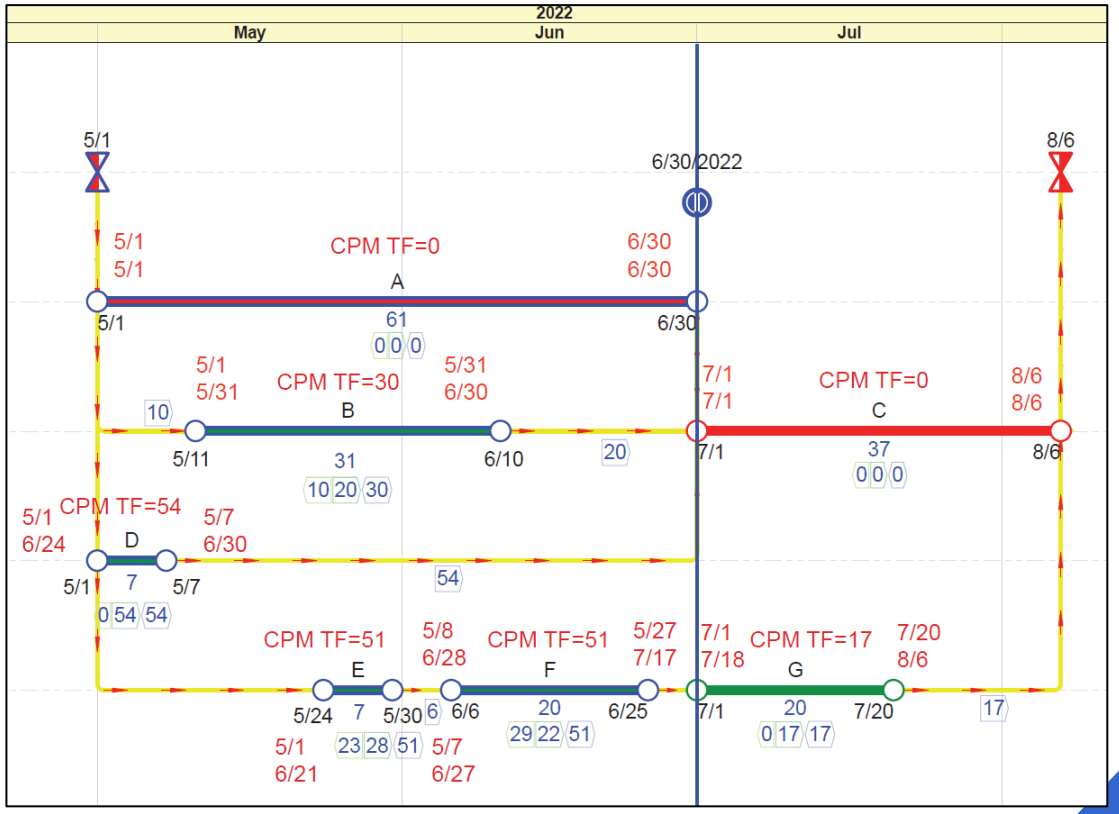
Originally published as a part of PMICOS 2008 Annual Conference

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GPM & CPM *TOTAL FLOATS* ARE IDENTICAL

If you process a CPM schedule in both CPM software and GPM software:

- The GPM algorithm and the CPM forward pass/backward pass algorithm yield **identical** early dates, late dates, total floats, free floats, and critical/near-critical paths
- If a GPM schedule uses planned dates and the CPM schedule counterpart imposes constraint dates instead, CPM overlooks preceding float, which reduces total float



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GPM PLANNED DATES AND DRIFT AND FLOAT

Planned dates **do not** replace the algorithmic early start dates

GPM planned start dates do preserve preceding total float aka GPM ***drift***

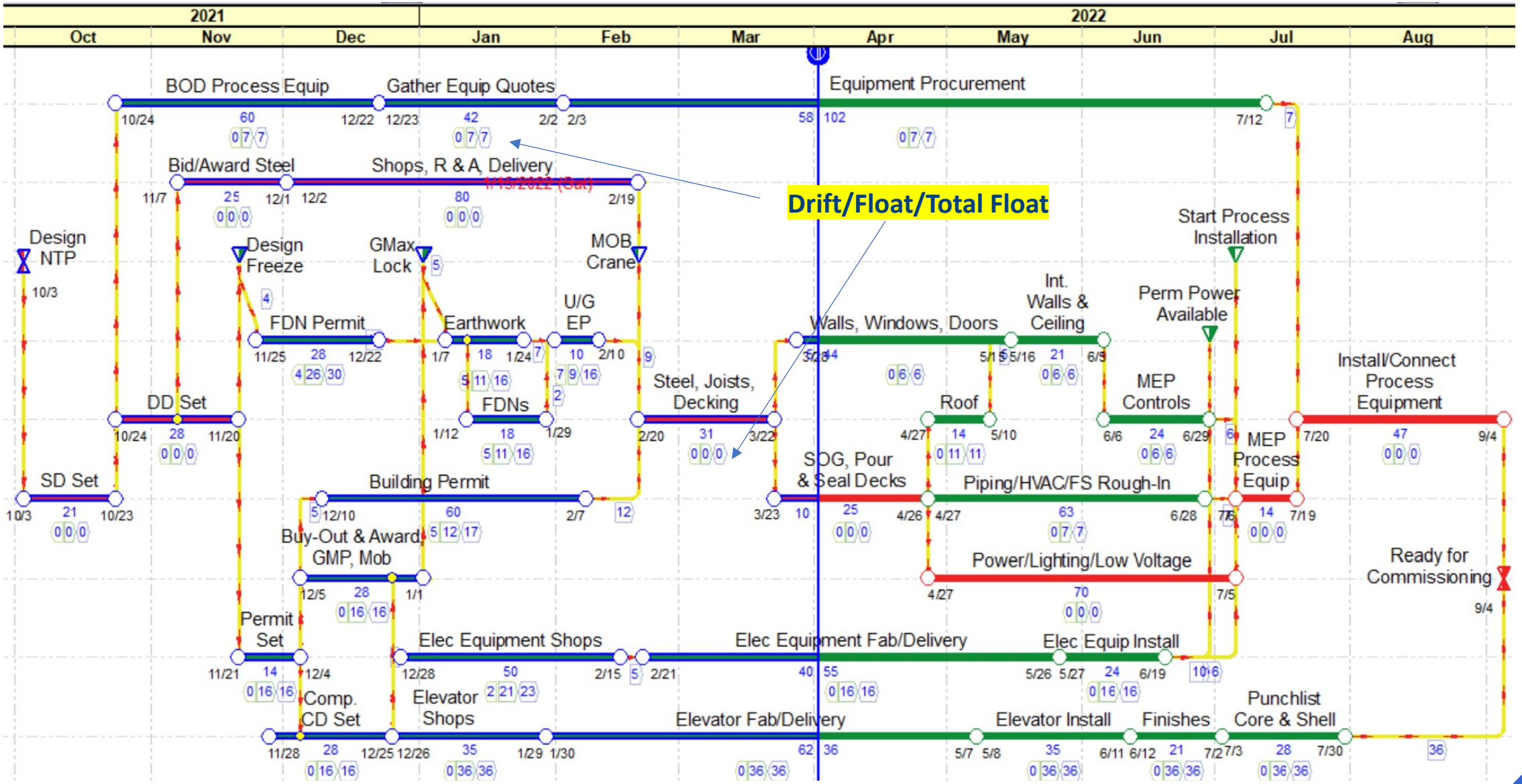
- Leeway from planned finish dates to late dates is GPM ***float***
- Drift (backward slide from planned to early start date) + float (forward slide from planned to late finish date) = total float

CPM **voluntary** not-earlier-than constraint dates choke total float; planned dates don't, thereby preserving total float continuity



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TOTAL FLOATS BOTH SIDES OF THE DATA DATE



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PART IV
THE *ALGORITHMIC* AS-BUILT SCHEDULE

The fully-progressed GPM update (data date on the as-built completion date) with recorded actual dates and ***algorithmic*** as-built drifts, floats, total floats, gaps, early start/finish dates, and late start/finish dates

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THE GPM DE-PROGRESSING PROTOCOL

GPM de-progressing KEY features:

- Right click on Data Date icon and select “Reset to Project Start
- No activity ***snapping*** to early dates
- Actual start dates become planned start dates
- Actual drifts (pre-consumed total floats) and actual floats (unused total floats) stay the same

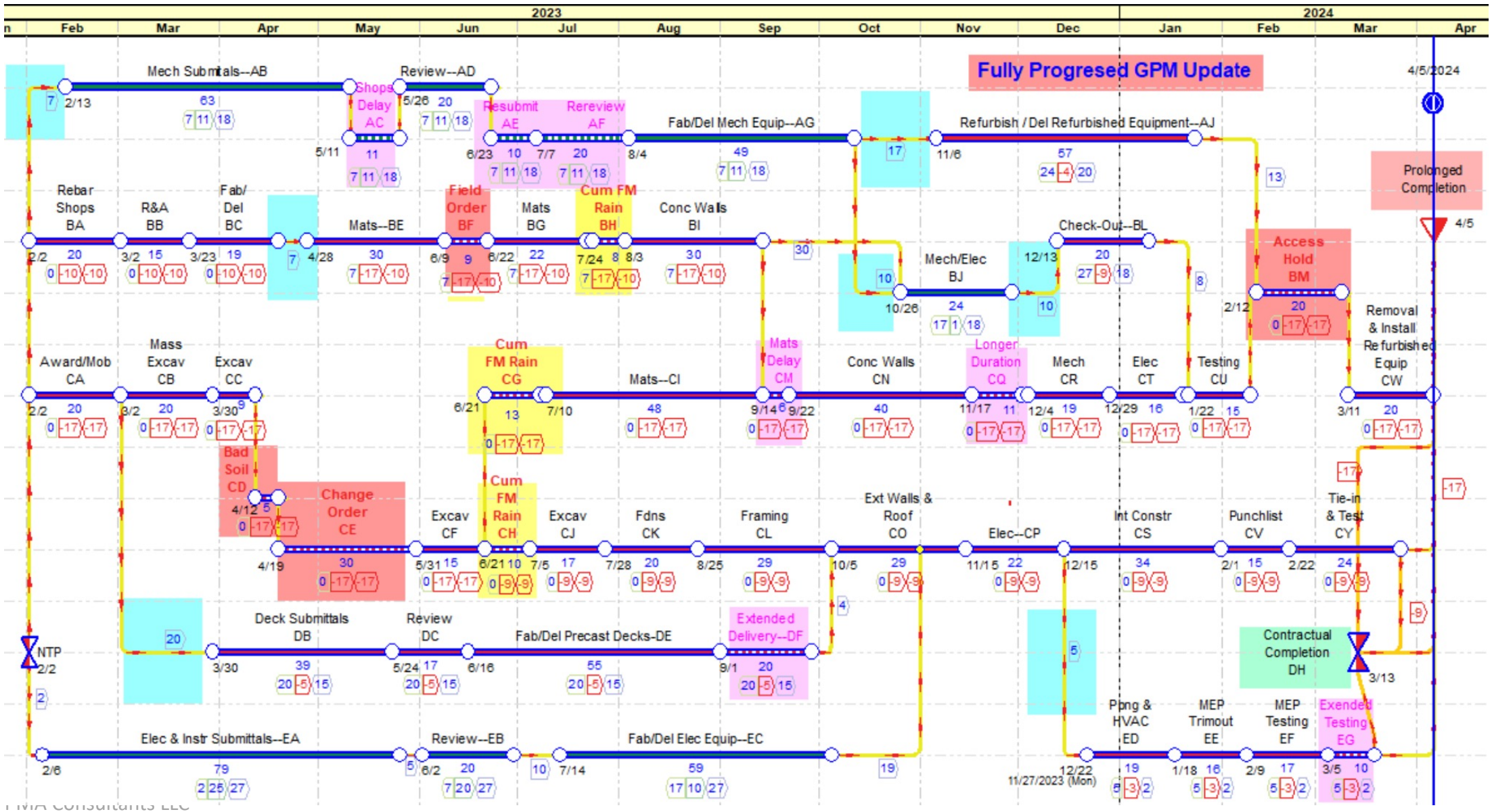
Manual intervention replaces positive-gap links into negative-float activities with ***Drift Delays***

- No need to add driving lag durations elsewhere



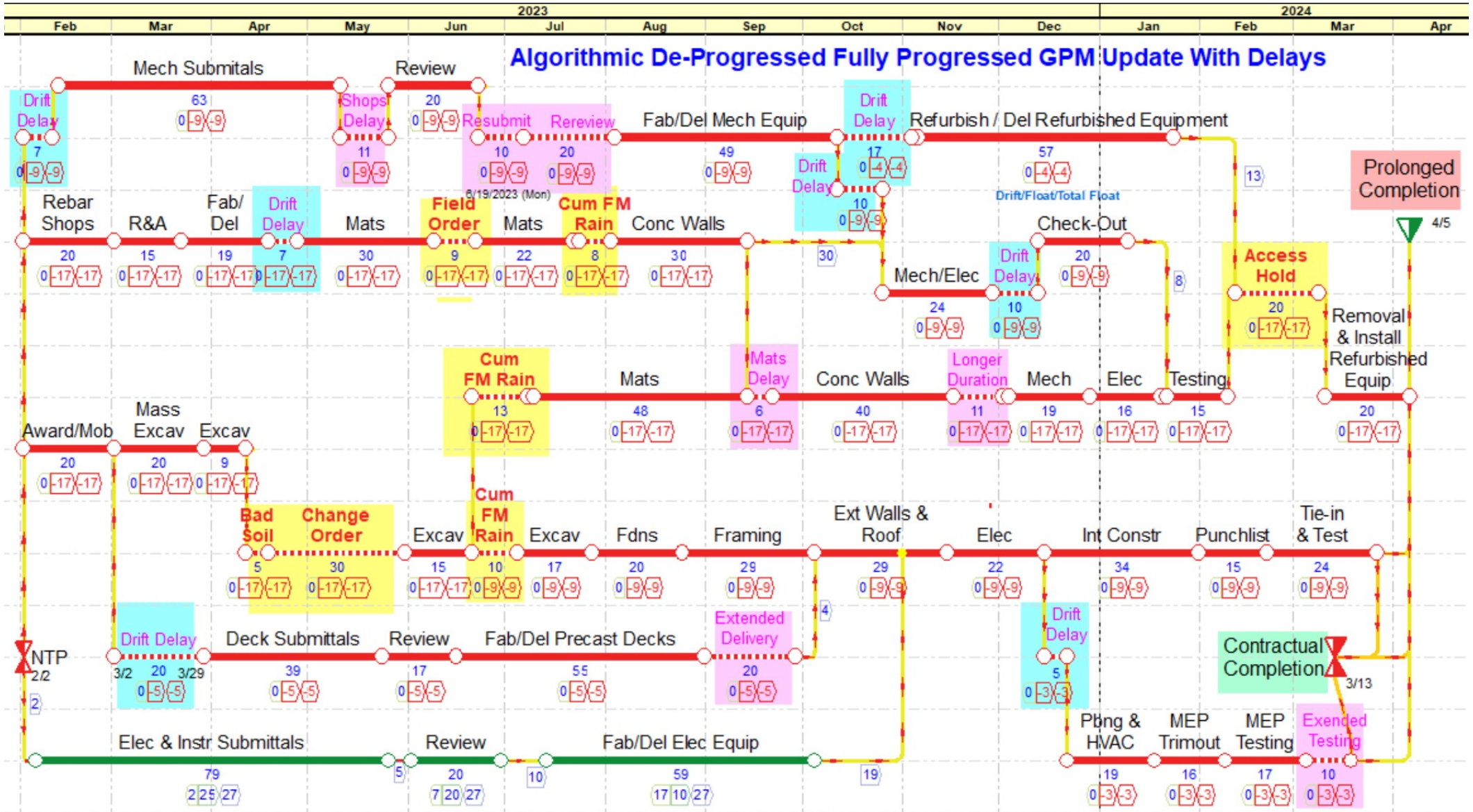
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IMPORT FULLY PROGRESSED CPM INTO NETPOINT



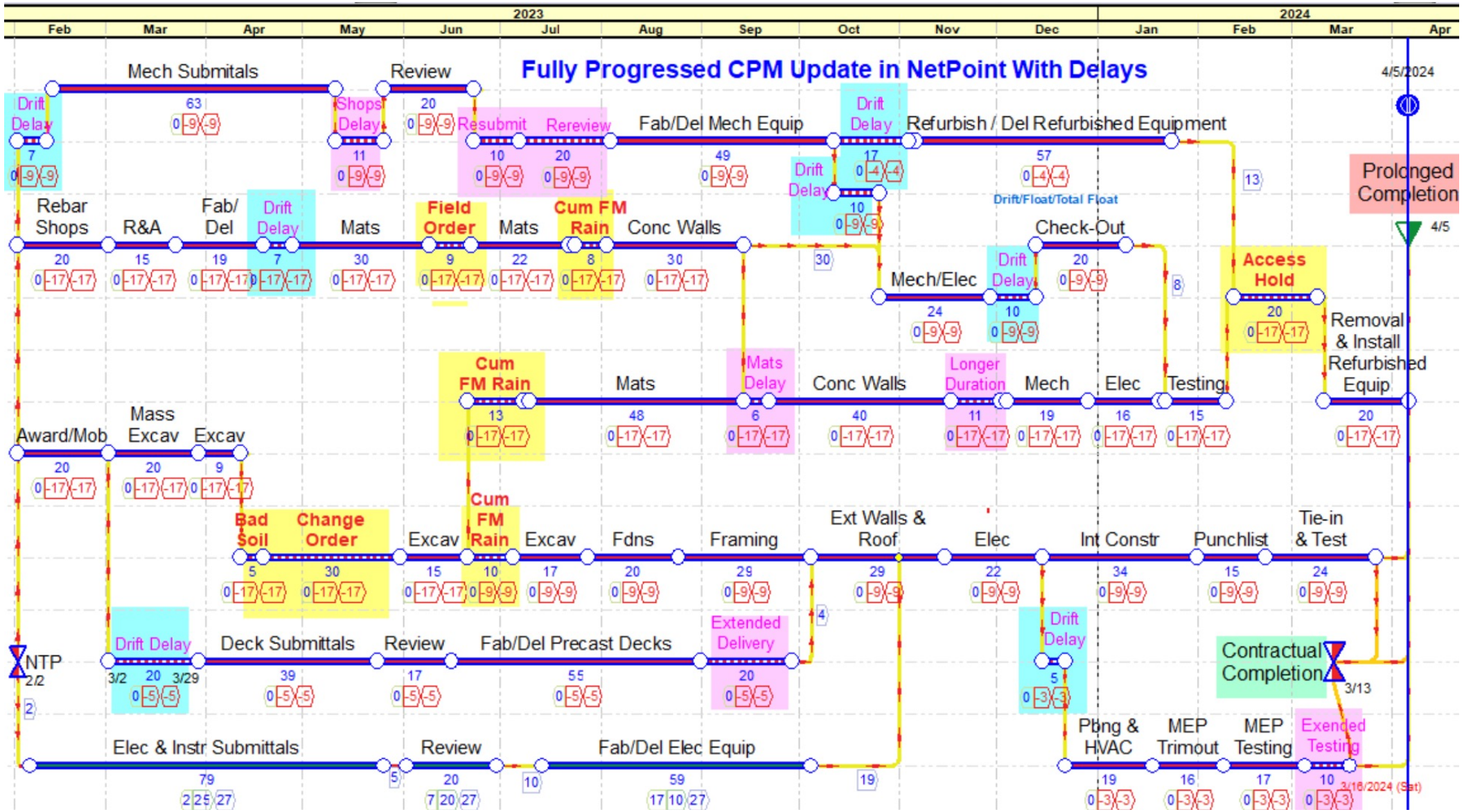
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RESET DATA DATE BACK TO PROJECT START DATE



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AS-BUILT GPM SCHEDULE WITH DRIFT DELAYS



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ALGORITHMIC GPM AS-BUILT SCHEDULE FEATURES

Algorithmic—activity data including early start, ***pre-consumed*** total float, actual start, actual duration, actual finish, *unused* total float, and late finish

- **No** driving lags needed to hold actual dates
- Actual start - early start = as-built drift
- As-built gaps into negative-float activities become drift delay by the drifting party

In the fully progressed update, delays inserted:

- May involve a fragnet connecting to impacted activities without altering their actual dates
- May replace pre-consumed total float
- May model part of actual duration that is delay



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PART V

ALGORITHMIC AS-BUILT DEMONSTRATIVE

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DELAYS AND NEGATIVE-TOTAL-FLOAT PATHS

The algorithmic as-built was generated by de-progressing the fully-progressed update

Unavoidable delays:

- 4 compensable delays
- 3 excusable weather delays
- 7 inexcusable delays

Negative-TF paths (**NO** common activities):

- Three -17 total-float paths
- Two -9 total-float paths
- One -5 total-float path, one -4 total-float path, and one -3 total-float path



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TAKE-AWAYS



The elusive as-built critical path is a construct originating from CPM software ***patently debunked*** by the GPM algorithm introduced in 2010 but ***overlooked*** nonetheless



Reversing schedule prolongation with the GPM crashing algorithm solves the challenge of late completion ***delay attribution***, delay by delay, with full consideration of ***concurrency***



Schedulers may wish to consider becoming proficient with GPM algorithms to be able to analyze their CPM schedules both sides of the data date using GPM software



ASCE 67-17, RP 29R-03, and the SCL Protocol may wish to consider adding guidance for sourcing the validated, fully-progressed GPM update as the algorithmic as-built schedule

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"Facts are stubborn things; and whatever may be our wishes, our inclinations, or the dictates of our passions, they cannot alter the state of facts and evidence."

– John Adams (Circa 1770)

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Thank You!

Any Questions?