OBSOLETING 60 YEARS OF SCHEDULING CALCULUS

Introducing The Graphical Path Method aka GPM

GUI PONCE DE LEON, PHD, PE, PMP, LEED AP
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CONFERENCE

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Human history teaches us. . .that economic growth springs from better recipes, not just from more cooking.

(Paul Romer, 2008)

Romer, Paul M. “Economic Growth.” In *The Concise Encyclopedia of Economics*, edited by David Henderson. Library of Economics and Liberty. Article published August 2008. http://www.econlib.org/library/Enc/EconomicGrowth.html#

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Gui Ponce de Leon

Founder/CEO of PMA Consultants, LLC aka PMA, a global pure project management firm with a 44-year track record

Professional experience includes executive and senior roles as investor's developer, program manager, construction manager, project controls engineer, planner/scheduler, and forensic scheduler

A project management inventor, who holds 4 U.S. patents on his groundbreaking graphical path method aka GPM

Primary author of the *Forensic Scheduling Body of Knowledge Part I* and more than 35 academic papers

An AACE member since 1975 (# 00802)

Universidad Nacional de Ingeniería, Promo IC-65

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ABSTRACT

In May 2003, O'Brien, et al. could not see the logic in many CPM schedules. In the intervening years, a number of scheduling experts, including this author, have posited that the critical path method (CPM) is past its prime. However, seemingly, nothing much has changed as mainstream scheduling practice continues to be hindered by overly detailed, flawed schedules that stakeholders cannot decipher—much less collaborate on—in the face of the Internet social revolution that cries out for more engaging, transparent, and "stakeholder-centric" processes. In this keynote, Dr. Gui presents to professionals in Peru the graphical path method introduced in 2008 in response to O'Brien's plea for a return to scheduling fundamentals.

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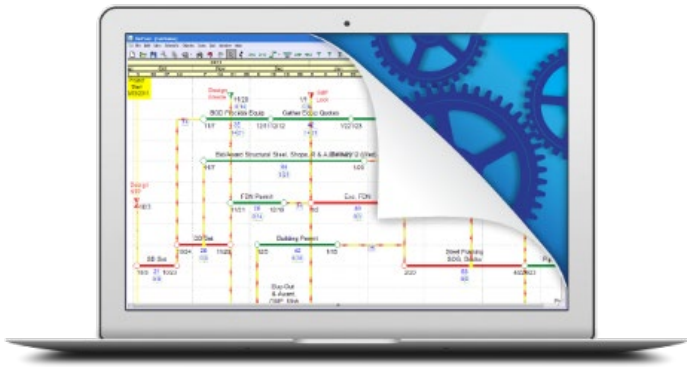
GRAPHICAL PATH METHOD

The graphical path method (GPM) is similar to the critical path method (CPM) but embodies a simpler scheme of thought in ways CPM can't

Using NetPoint®, the software embodiment of GPM, this presentation introduces GPM and contrasts analogous GPM & CPM principles



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CPM

The method in a nutshell

Networking method that, following any input for any activity, logic tie, or milestone, requires a forward pass and a backward pass for the *entire network* as a preceding step to obtain an output of the schedule

Date constraints are required to schedule activities on *planned dates*

Neither total floats nor the as-built critical path can be calculated left of the data date

METAPHOR

Written Communication:

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GPM

The method in a nutshell

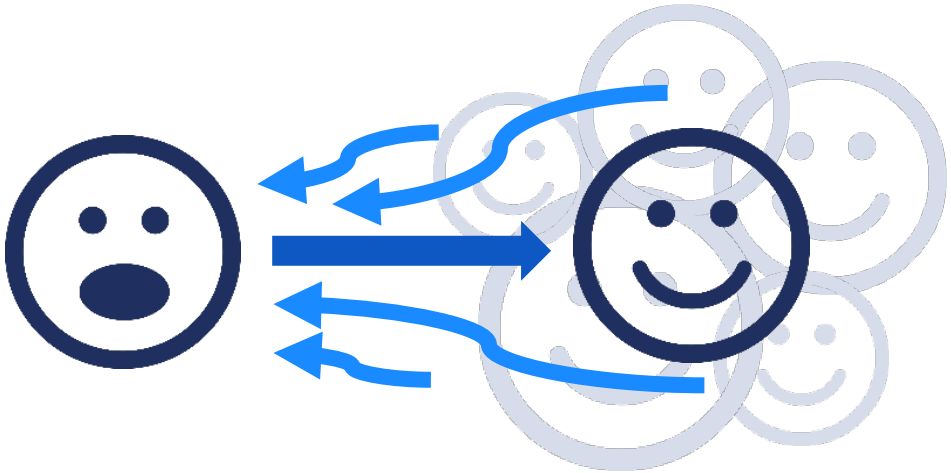
Graphical & visualization method that, **without** a forward or backward pass, kinetically refreshes the schedule *where impacted* as the user adds/deletes/revises/repositions activities, logic ties, and milestones

Activities on planned dates may float back (in GPM lexicon, have drift)

Total floats and the as-built critical path are algorithmically calculated left of the data date

METAPHOR

Verbal Communication:



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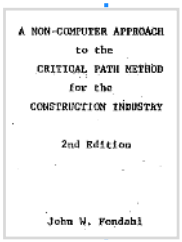
SELECTED EVENTS FROM CPM'S FIRST 20 YEARS

1955 1960 1965 1970 1975

1957–On October 26, Kelley and Walker meet with DuPont's chief engineer and obtain authorization to use their critical path method on an actual project

1959–Kelley and Walker announce their CPM work at the Eastern Joint Computer Conference in Boston


A NON-COMPUTER APPROACH
to the
CRITICAL PATH METHOD
for the
CONSTRUCTION INDUSTRY
2nd Edition
John W. Fondahl

1961–Kelley publishes a paper presenting the mathematical basis of CPM

1961–Stanford University Professor Fondahl's work on activity-on-node CPM is released

1962-1972–Fondahl's text in 1962 followed by Moder & Phillips' text in 1964 starts a decade rich in CPM texts

1963–IBM credits the H.B. Zachry Company with the development of the precedence form of CPM

1964-1974–In this decade, practitioners extend CPM to schedule-related claims analysis, culminating with Wickwire's 1974 article, *The Use of Critical Path Method Techniques in Contract Claims*

1965–1st edition of Jim O'Brien's *CPM in Construction Management*

1965–INTERNET, the predecessor to the IPMA, is founded

1967–Wiest proposes a heuristic model for scheduling with limited resources

1968–Krishnamoorthy's report on mathematical developments in critical path analysis cites 125 academic treatises

1969–PMI is founded in Philadelphia, PA

1972–3rd International Congress on the Application of Project Planning by Network Techniques is held in Sweden

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SELECTED EVENTS FROM CPM'S NEXT 30 YEARS

1975 1980 1985 1990 1995 2000 2005

1975-1990–Mainframe, CPM-based systems dominate the scheduling landscape (Project/2, MSCS, PMS, PCS et al.)

1976–O'Brien authors his *Construction Delay* text on analysis of delay using CPM

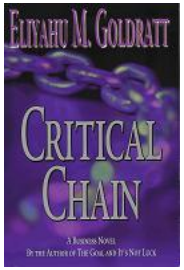
1976–The Associated General Contractors in the U.S. publishes the 2nd edition of *The Use of CPM in Construction*

1984–Primavera holds its 1st user conference

1991–P3 is selected over Project/2 as the scheduling software for the CA/T project aka Big Dig in Boston

1994–Primavera stops supporting the original CPM arrow diagramming method

1997–Critical chain is introduced in Goldratt's book, *Critical Chain*



2003–*ENR* Article "Critics Can't Find the Logic in Many of Today's CPM Schedules"

2006–Plotnick's RDCPM, a variant of CPM, is introduced in the 6th edition of *CPM in Construction Management*

2007–Theme of the PMICOS 4th conference in Vancouver: "CPM Turns 50: *A Birthday Celebration*"

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THE CPM STATE OF AFFAIRS IN 2003

1. CPM had become schedule-centric, and “planning,” the casualty
2. Logic networks had been largely supplanted by logic Gantt charts
3. Schedulers had become obsessed with overly detailed schedules
4. Stakeholders had disengaged but scheduled their work just the same
5. A “dates rule, logic serves” ethos had turned planning upside down
6. Mathematically flawed schedules had become endemic due to overuse of date constraints and preferential lags

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THE CPM STATE OF AFFAIRS IN 2003 *(cont'd)*

7. Building a network on a computer *on the fly* had disabled pull planning, making CPM impractical for Lean Construction planners

8. With CPM non-functional left of the data date, there was no incentive to accurately record actual dates and conform actual logic

9. Resource leveling had fallen by the wayside, because black-box, automated resource leveling produces unrealistic results

10. Spreadsheets were becoming de rigueur tools for capital planning

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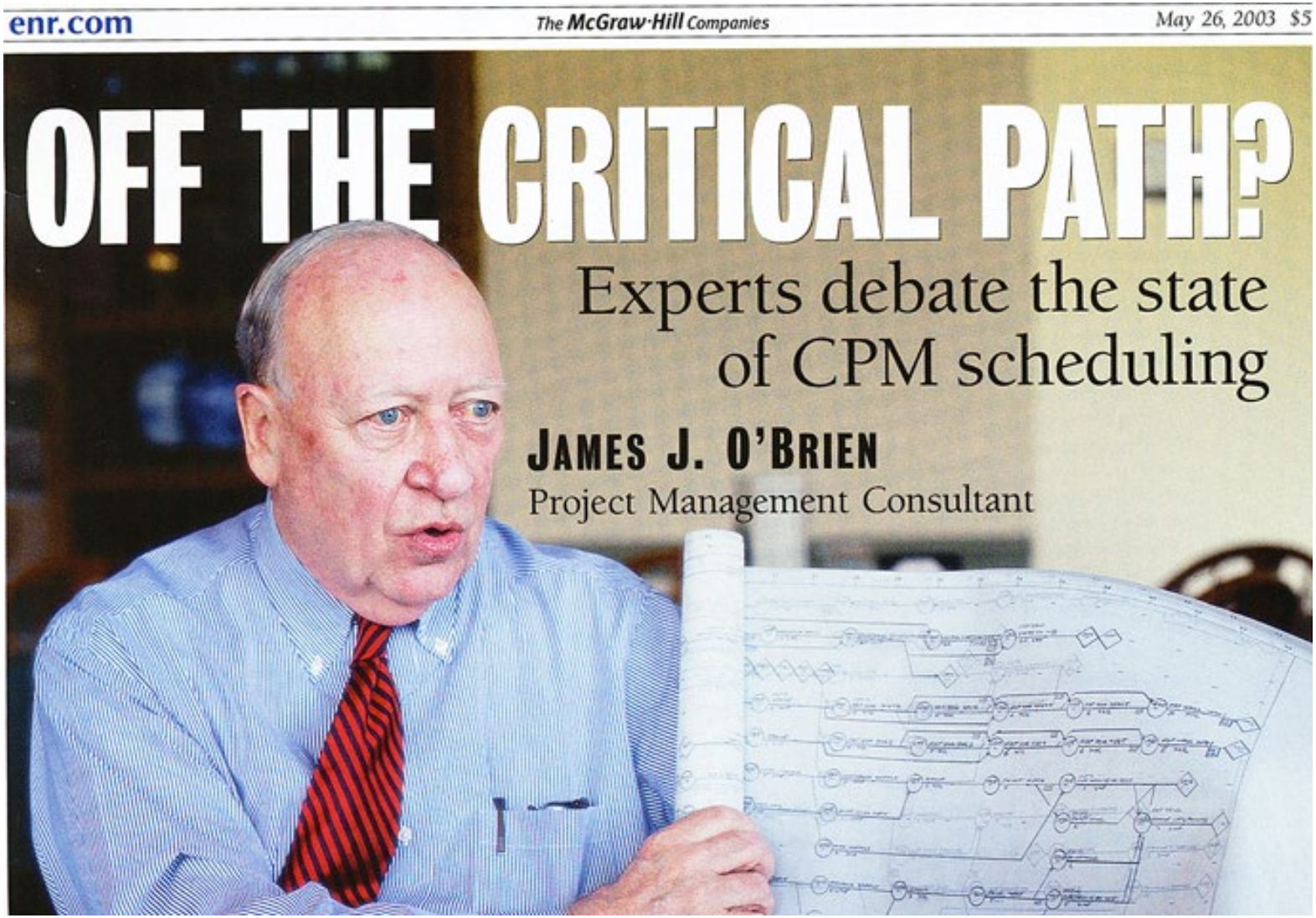
THE FORK IN THE CPM ROAD



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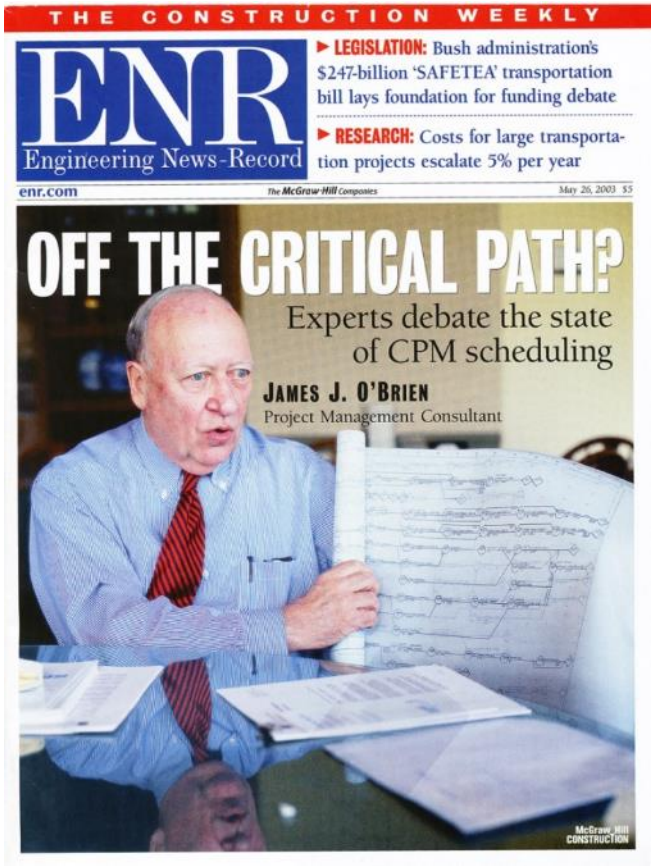
SNIPPETS OF HOW CPM WENT OFF THE RAILS

"What is described as a CPM schedule these days sometimes is not one at all"

"They say they see widespread abuses of powerful software to produce badly flawed or deliberately deceptive schedules that look good but lack mathematical coherence or common sense about how the industry works"


THE CONSTRUCTION WEEKLY

ENR Engineering News-Record

► LEGISLATION: Bush administration's $247-billion 'SAFETEA' transportation bill lays foundation for funding debate

► RESEARCH: Costs for large transportation projects escalate 5% per year

enr.com The McGraw-Hill Companies May 26, 2003 $5

OFF THE CRITICAL PATH?

Experts debate the state of CPM scheduling

JAMES J. O'BRIEN
Project Management Consultant

McGraw-Hill CONSTRUCTION

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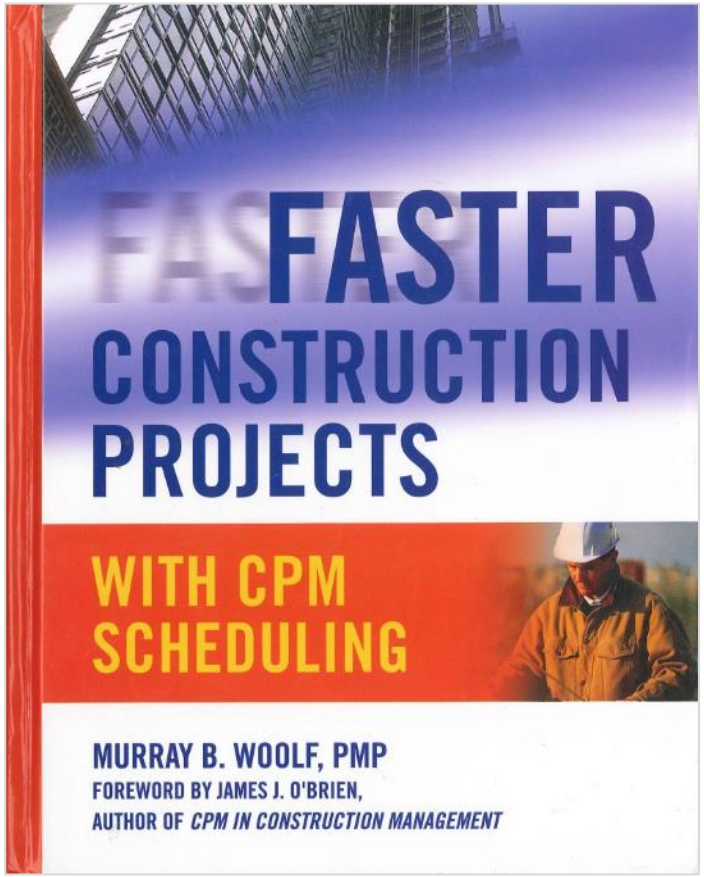
MORE ON HOW CPM WENT OFF THE RAILS

"we have collectively evolved the profession to where planning is no longer the essential first step in the scheduling process"

"Among the young guys, computers have made it easy to slap together something that looks right, but there is a thought process that must be involved, and it is hard to tell in many contemporary schedules if the thinking happened or not"



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TWO RECENT INSTANCES OF DISCONTENT WITH CPM

Eric Lamb, in "How to Fix a Broken Scheduling System"

"Schedules with an exhaustive level of detail in a CPM network try to predict day-to-day activities years in advance and are inherently flawed"

"For an industry striving to be more productive, the current state of scheduling practices is wasteful"

"Simply, we have created a monster"

Stu Ockman, in "Dearth of Scheduling Software Expertise Still Bedevils Many Legal Cases," alluding to a 2,900-activity schedule that had *928 constraints*, lamented that

"The multiple constraints made finding the critical path for the project's start and end dates impossible, not to mention the nearly 83 workdays of negative float they yielded. Lawsuits followed the project"

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GPM AS APPLIED IN PLANNING/SCHEDULING

The *engine* behind graphical & visualization apps that, without the CPM forward/backward pass, kinetically cause the schedule to refresh as stakeholders working on the display surface add/delete/revise/reposition activities, logic ties, and milestones

Visualization is enabled by a new time-scaled logic diagramming method (LDM) that combines the strengths of arrow & precedence diagrams

Activities may be on planned dates without resorting to date constraints or preferential lags

An activity on *GPM planned dates* can drift back (to the early start date) and may float forward (to the late finish date)

The kinetic interface is enabled by GPM self-healing and scheduling algorithms, which—as a planner is physically manipulating activities—restore the *impacted aspects* of the network to their correct mathematical state

Both forward *(push)* planning and backward *(pull)* planning are enabled

In every schedule update, total floats left of the data date are calculated, which allows algorithmic identification of the *then-existing* as-built critical path

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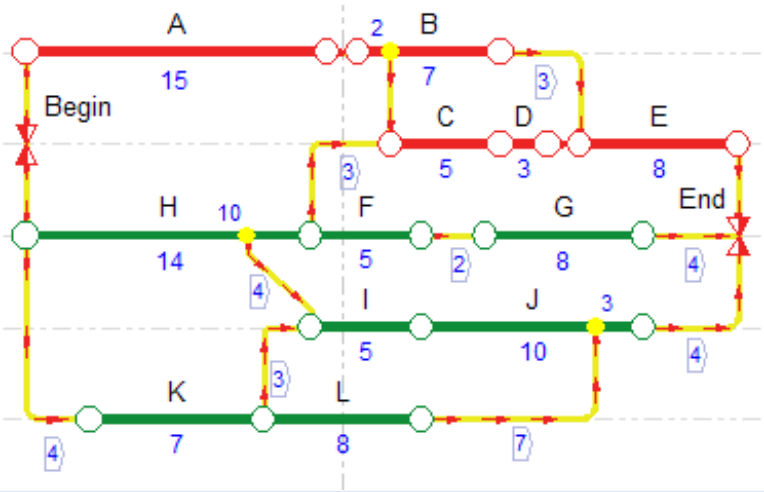
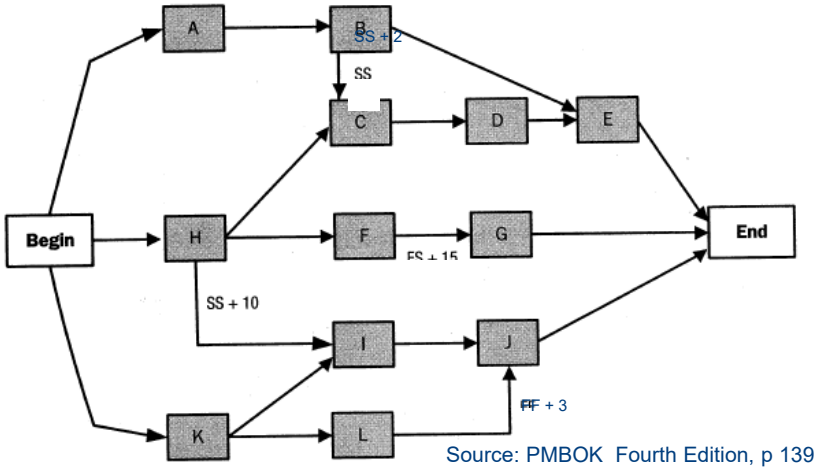
GPM RELIES ON A NEW *THIRD* NETWORK NOTATION

GPM



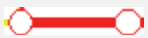
CPM



Source: PMBOK Fourth Edition, p 139

Logic Diagramming Method (LDM)
(rheonomic activity flow graph)

Precedence Diagramming Method (PDM)
(scleronomic activity flow graph)



Time-scaled, horizontal, noded bars convey activities

Polyline, orthogonal, or straight yellow lines embedding arrowheads convey links

Commonly, boxes convey activities

Commonly, polyline, orthogonal, or straight lines ending in arrowheads convey links

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THE GPM PLANNING/SCHEDULING ETHOS

1. Graphical, visual, and sufficiently simple schedules are a priority
2. Emphasis is on collaborative planning vs. schedule machinations
3. Stakeholder engagement trumps fictive precision
4. Collaboration improves where activity level of detail stimulates stakeholder participation
5. Time-scaled networks with PDM logic are superior to Gantt charts with logic ties

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THE GPM PLANNING/SCHEDULING ETHOS *(cont'd)*

6. The network may be built forward or backward or using both planning approaches

7. Stakeholders, not the network algorithm, drive activity dates

8. Stakeholder strategies in context drive resource leveling

9. Furthering a schedule is predominately carried out by physically manipulating activities and logic ties

10. Contemporaneous analysis of delay is greatly enhanced because GPM reveals the critical path left of the data date

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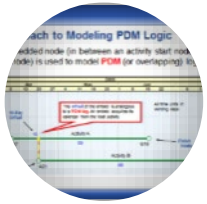
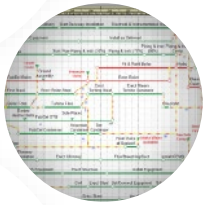
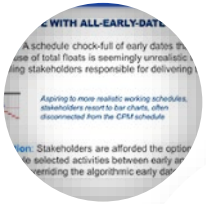
GPM TOPICS SELECTED FOR FURTHER DISCUSSION



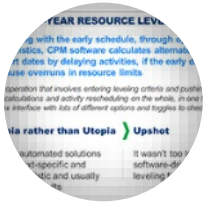
I. A novel approach to modeling PDM logic



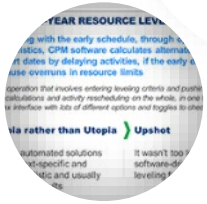
II. Sufficiently simple schedule presentations



III. Overcoming the all-early-dates predicament



IV. *Core* float precepts in GPM



V. CPM vs. GPM resource leveling

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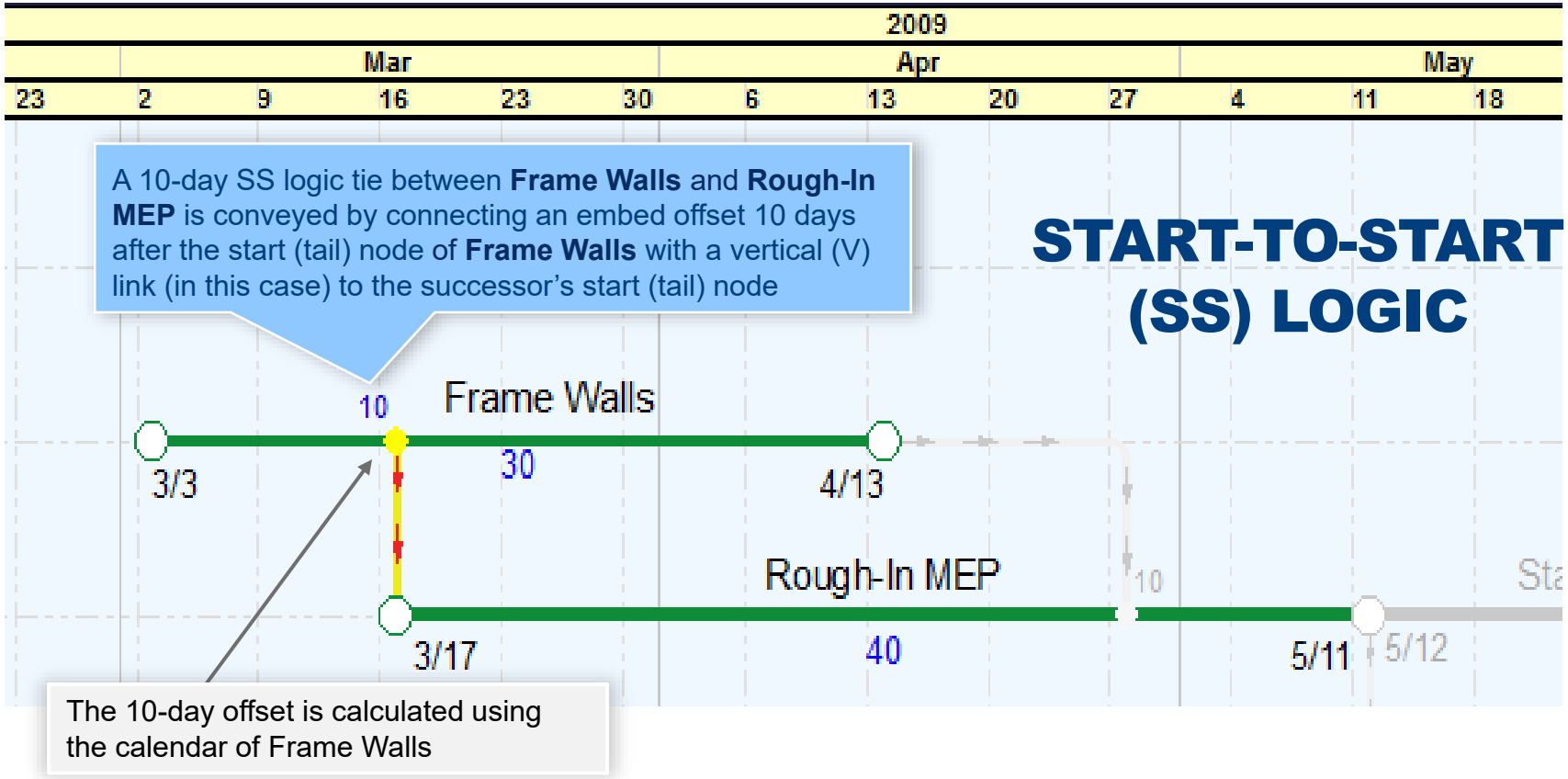
I. APPROACH TO MODELING PDM LOGIC

An embedded node (in between an activity start node and finish node) is used to model PDM (or overlapping) logic



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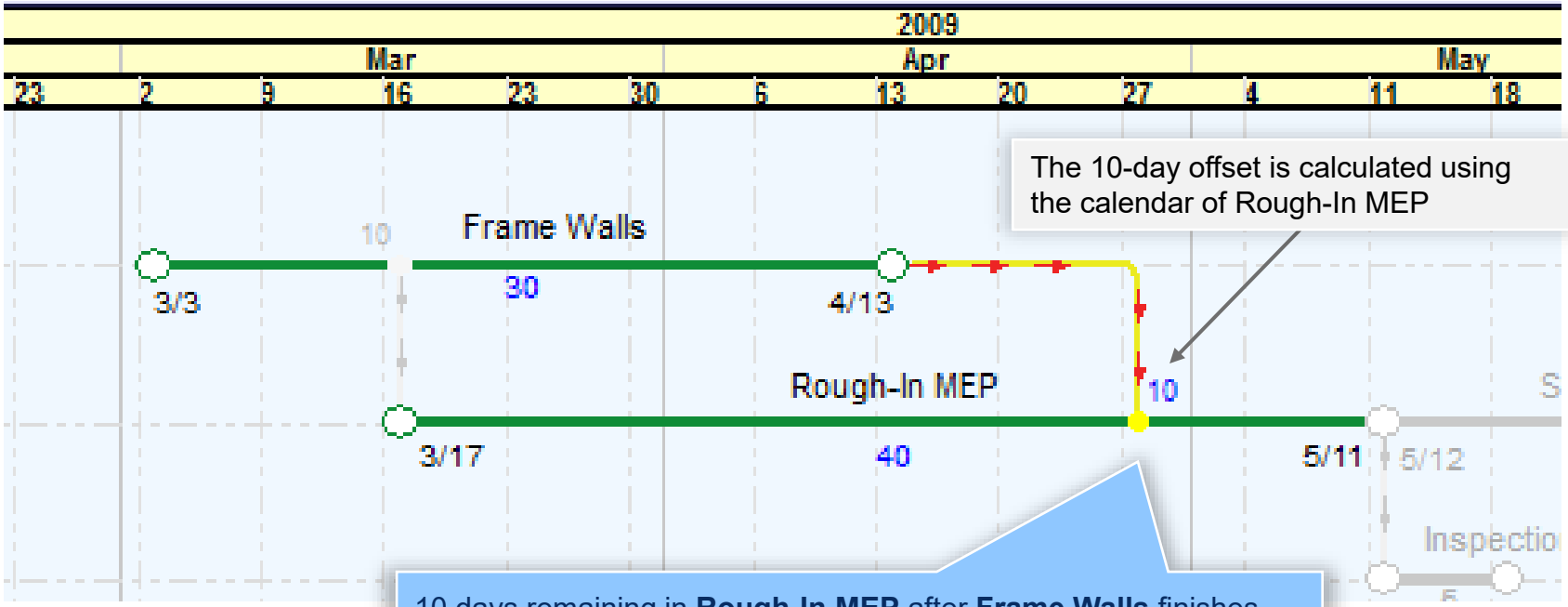
FINISH-TO-FINISH (FF) LOGIC



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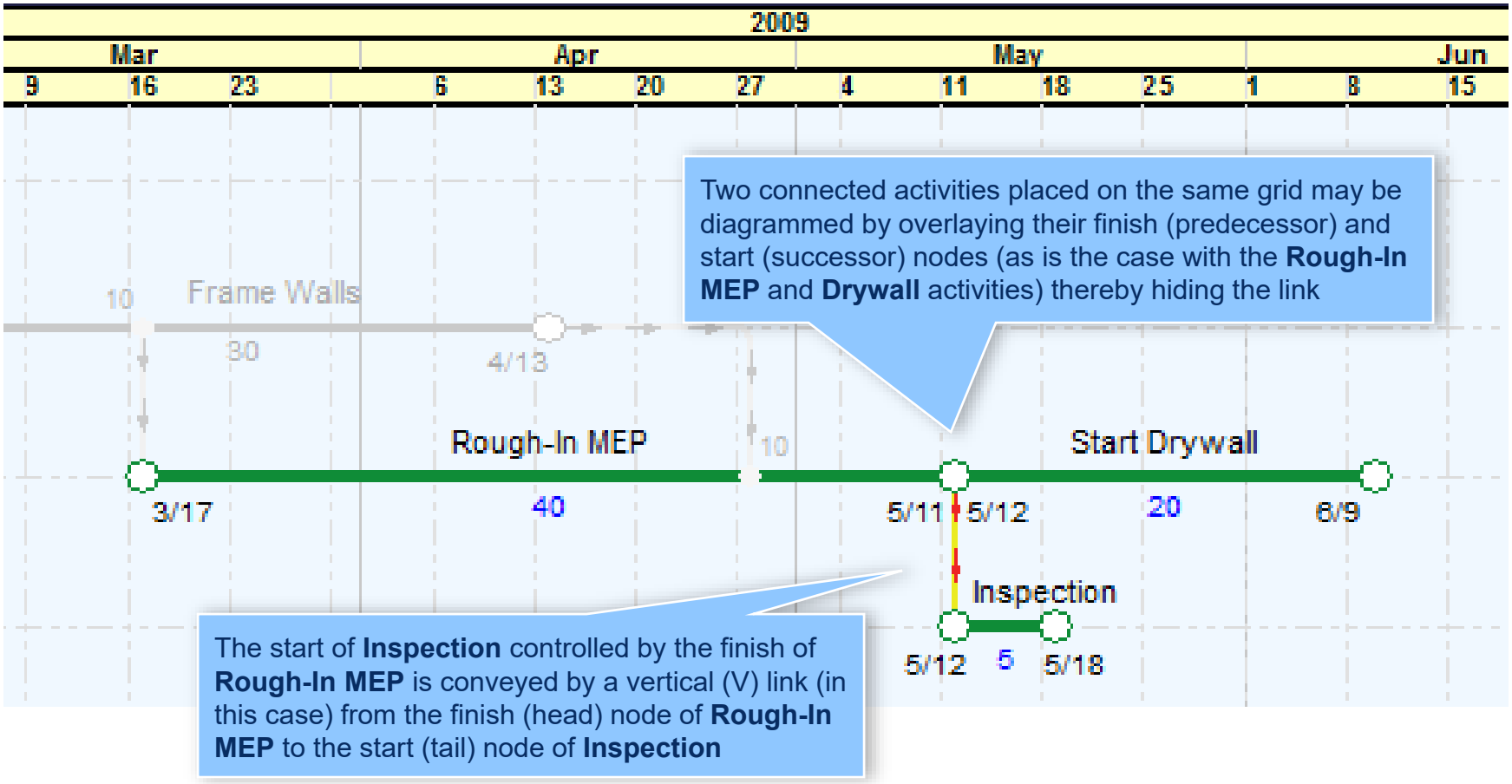
FINISH-TO-START (FS) LOGIC



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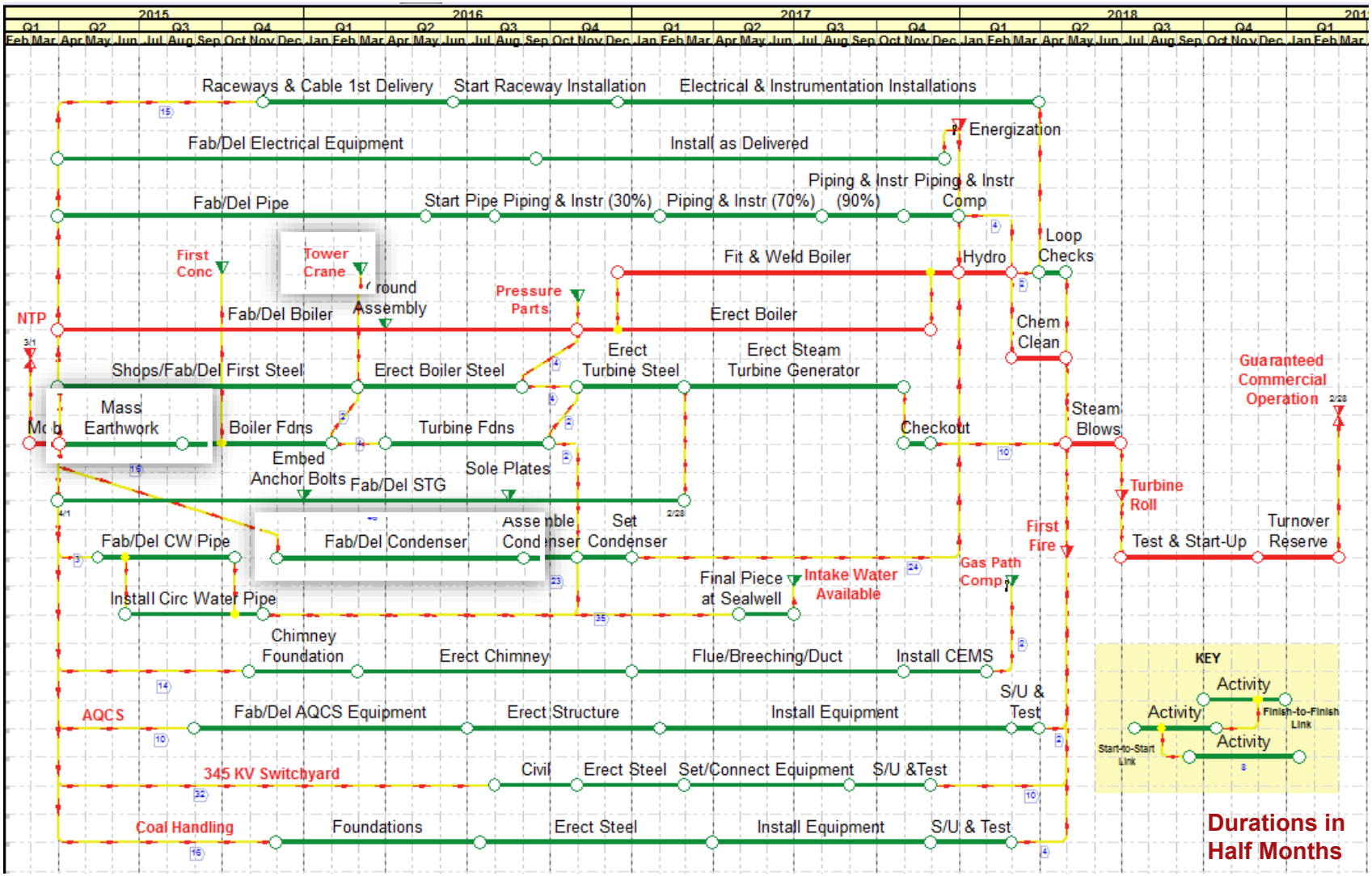
II. A SUFFICIENTLY SIMPLE SCHEDULE PRESENTATION



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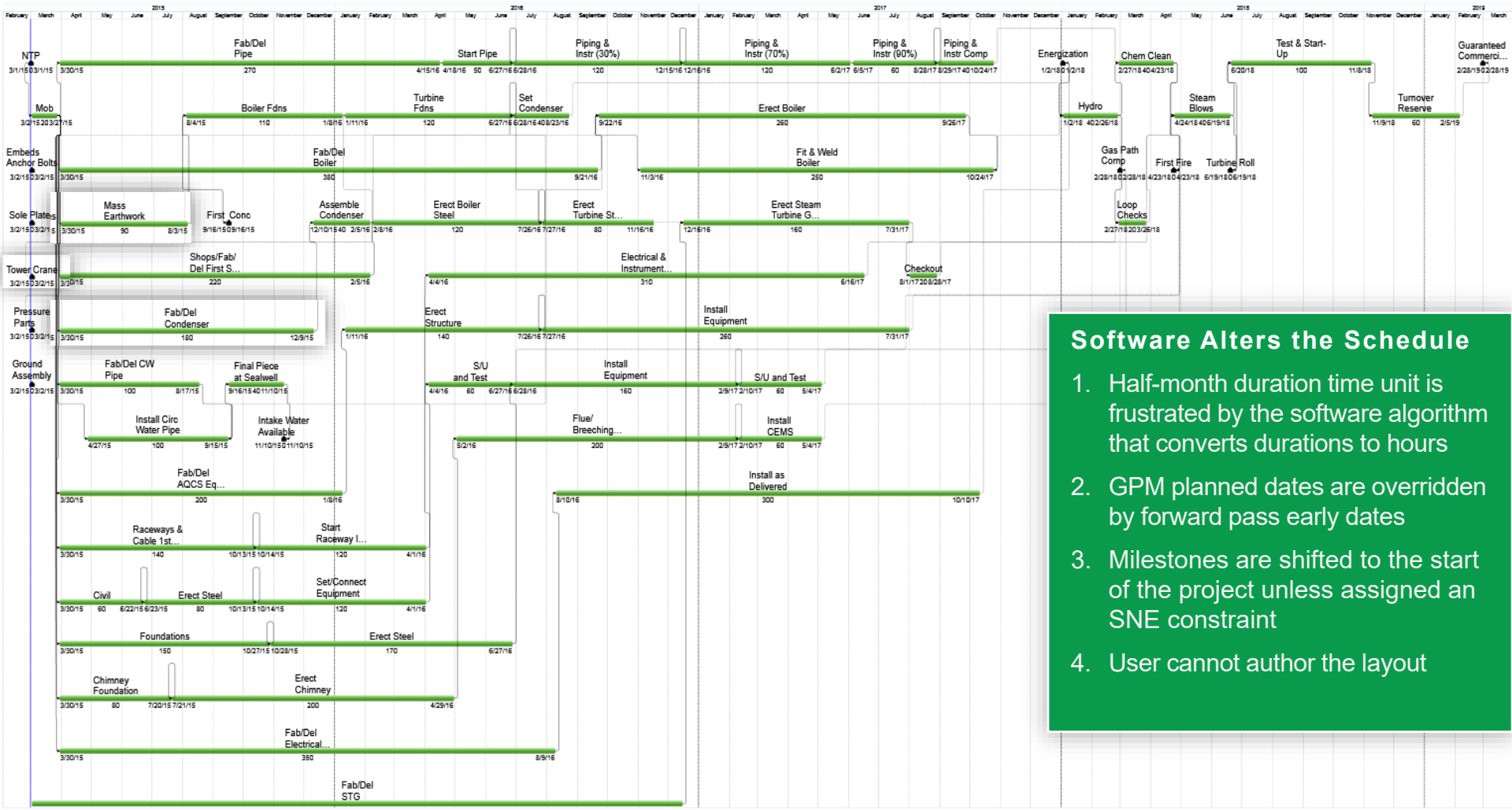
A SCHEDULE ONLY A TRAINED EYE CAN FOLLOW



Software Alters the Schedule

1. Half-month duration time unit is frustrated by the software algorithm that converts durations to hours
2. GPM planned dates are overridden by forward pass early dates
3. Milestones are shifted to the start of the project unless assigned an SNE constraint
4. User cannot author the layout

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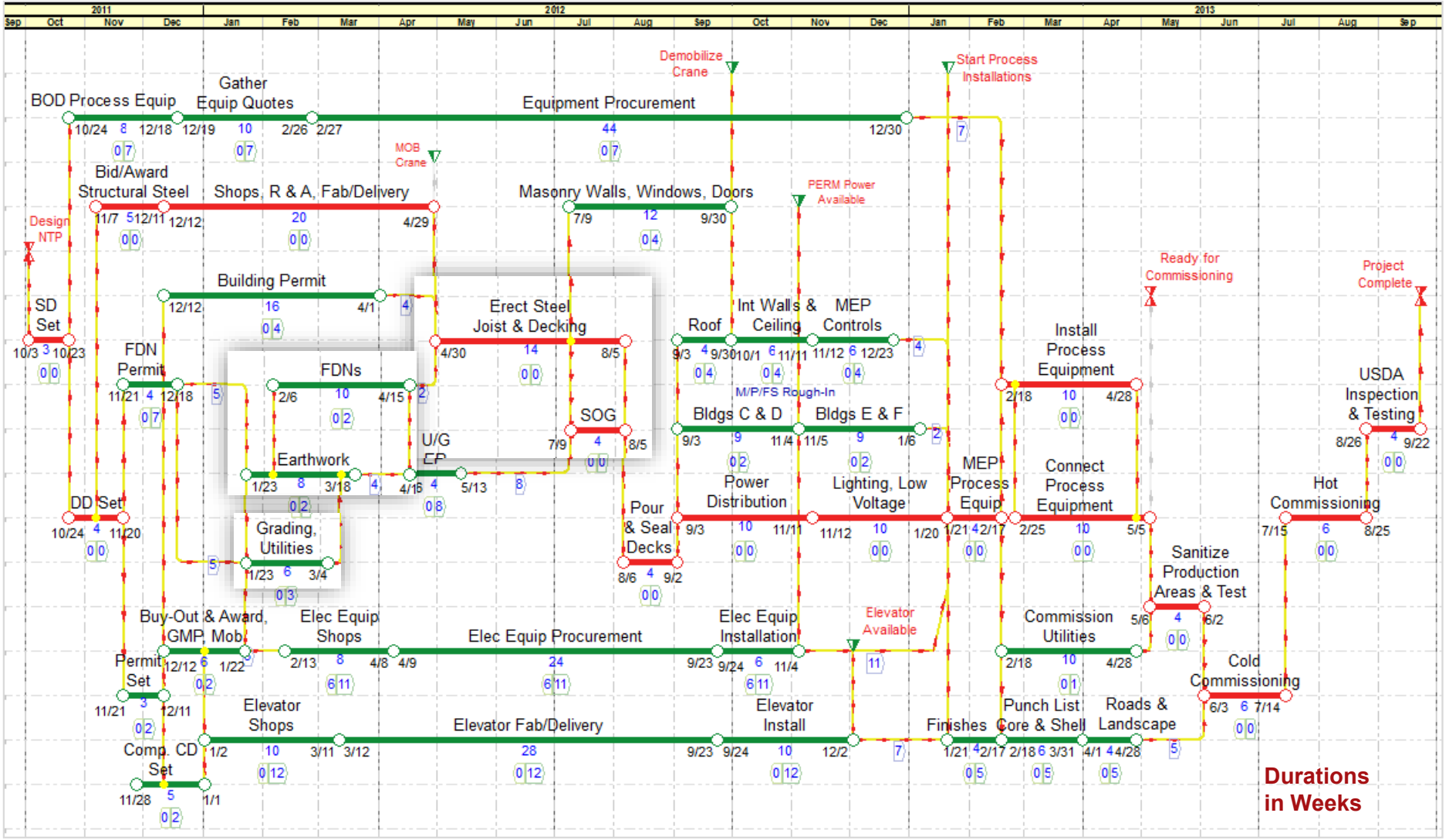
ANOTHER SUFFICIENTLY SIMPLE SCHEDULE DISPLAY



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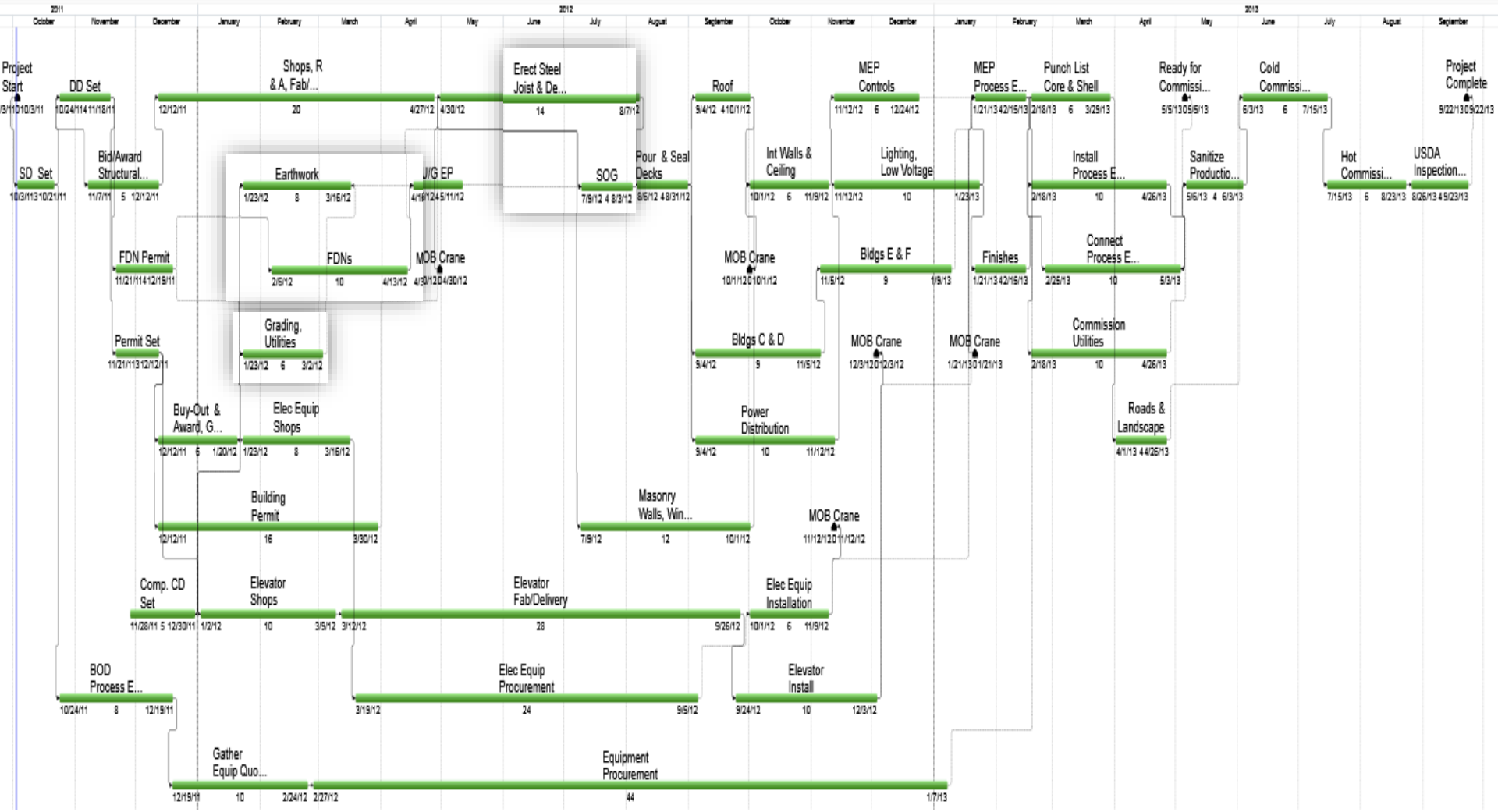
AN EQUIVALENT TIME-SCALED PRECEDENCE DIAGRAM



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III. OVERCOMING THE ALL-EARLY-DATES PREDICAMENT

Problem: A schedule chock-full of early dates that neglects making use of total floats is seemingly unrealistic to non-scheduling stakeholders responsible for delivering the project

Aspiring to more realistic working schedules, stakeholders resort to bar charts often disconnected from the CPM schedule

The GPM Solution: Stakeholders are afforded the option to manually schedule selected activities between early and late dates ***without overriding*** the algorithmic early dates

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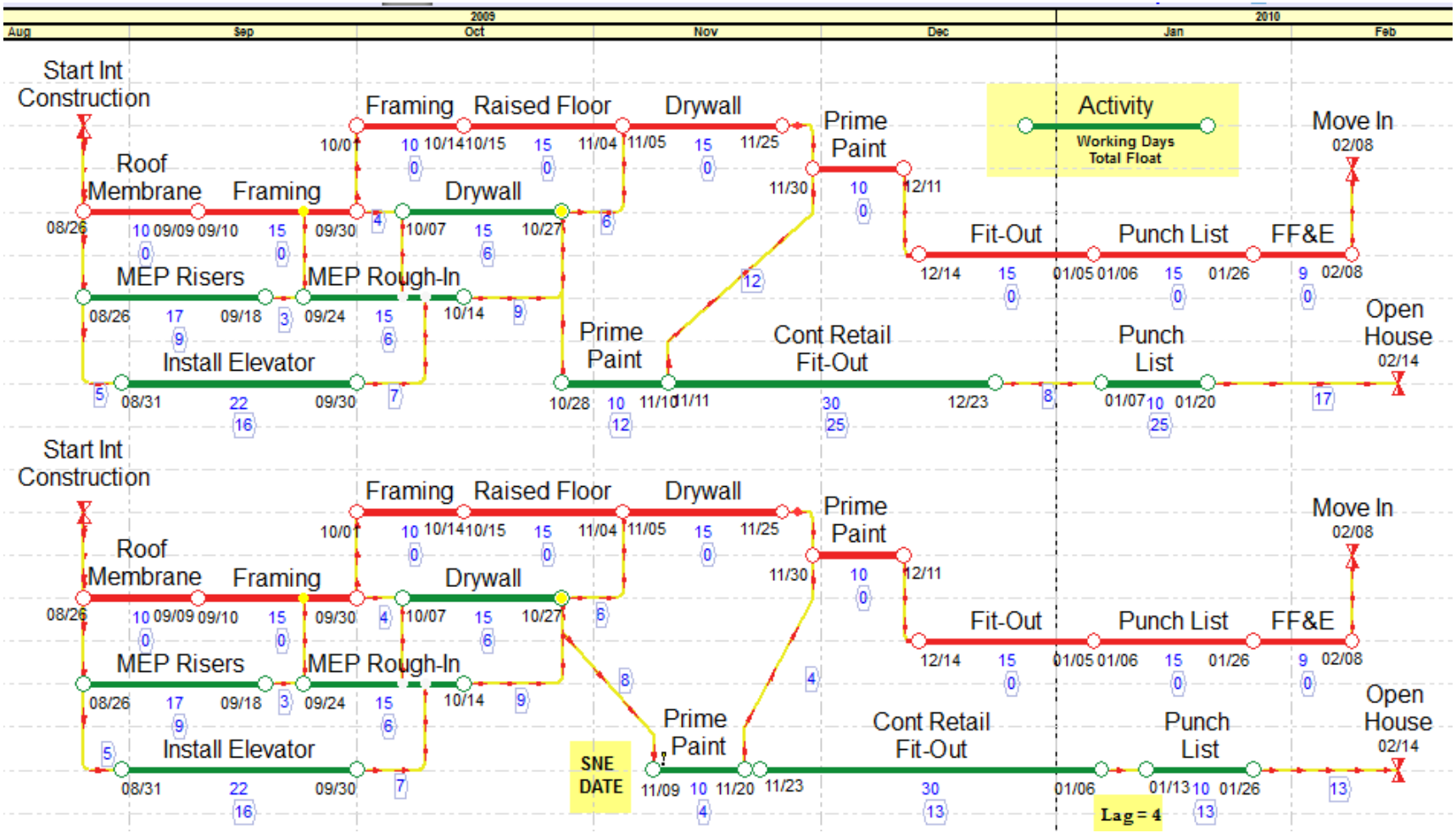
PLANNED DATES IN CPM

In CPM, to place an activity on a planned date—between early and late dates—a constraint or a preferential lag is imposed



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THE *GPM PLANNED* DATES PRECEPT IN SCHEDULING

Stakeholders may manually override activity early dates

Activities placed between early and late dates are on GPM planned dates; the GPM algorithm retains the algorithmic early dates

Because planned dates do not override early dates, GPM detects that an activity retains the ability to *drift back* as much as the early start date permits and to *float* forward as much as the late finish date permits

The combination of planned-dates/drift/float represents a paradigm shift from the CPM early-date bias, one-directional float protocol

DRIFT + **FLOAT** = **TOTAL FLOAT**

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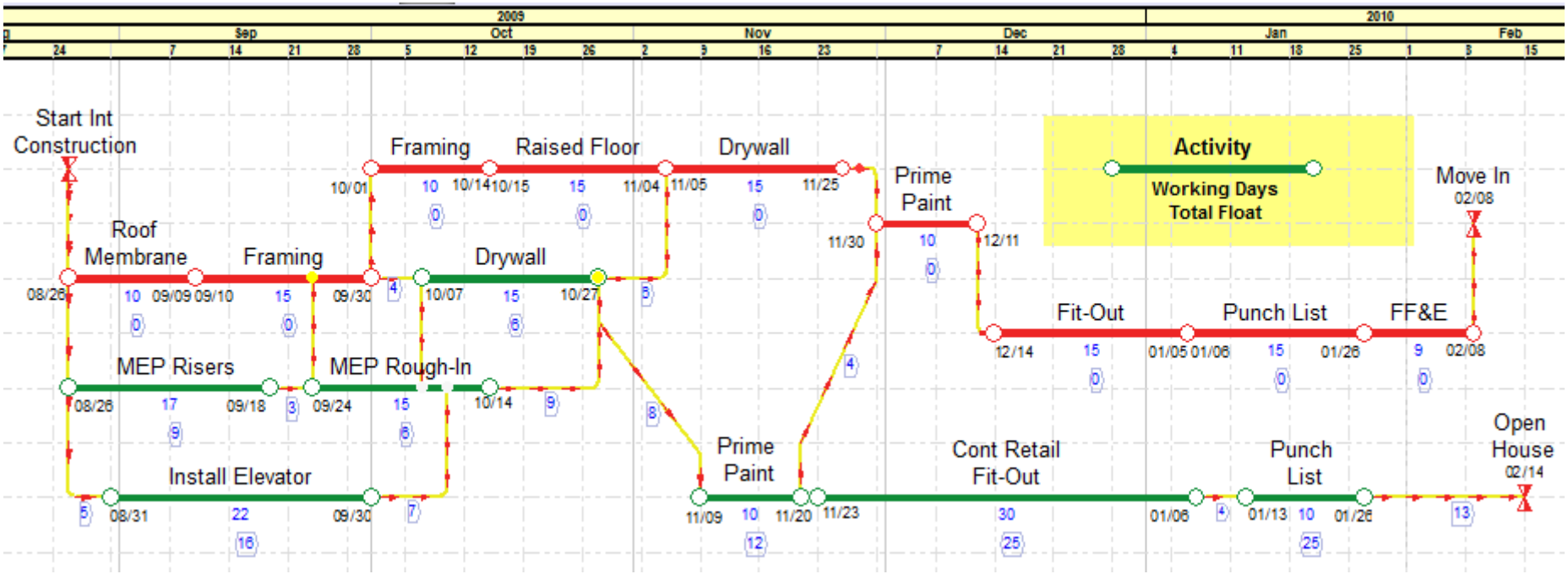
PLANNED DATES IN GPM

GPM was conceived so that scheduling an activity between the early start date and late start date is a natural proposition



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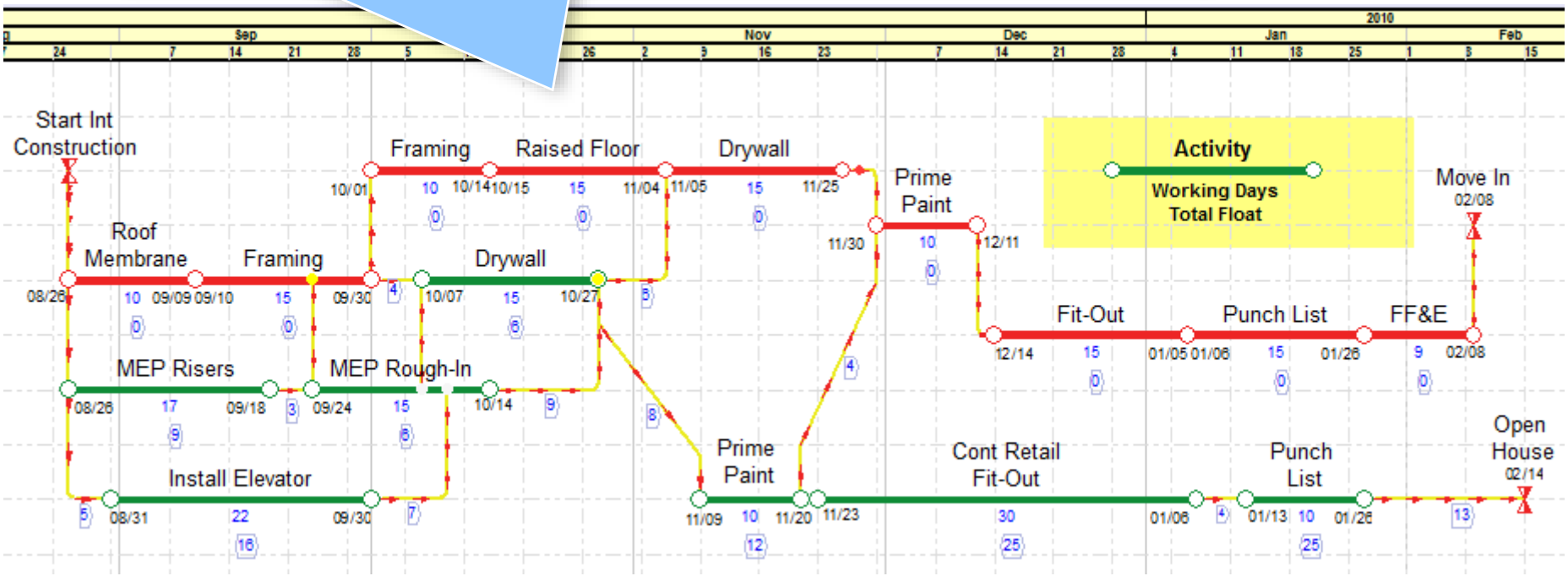
IV. *CORE* FLOAT PRECEPTS IN GPM

When an activity is on early dates, drift = 0 and float = total float; conversely, when on late dates, drift = total float and float = 0



As an activity is repositioned to later dates, drift increases, float decreases, and total float is a constant; if the activity is repositioned to earlier dates, drift decreases, float increases, and total float remains constant

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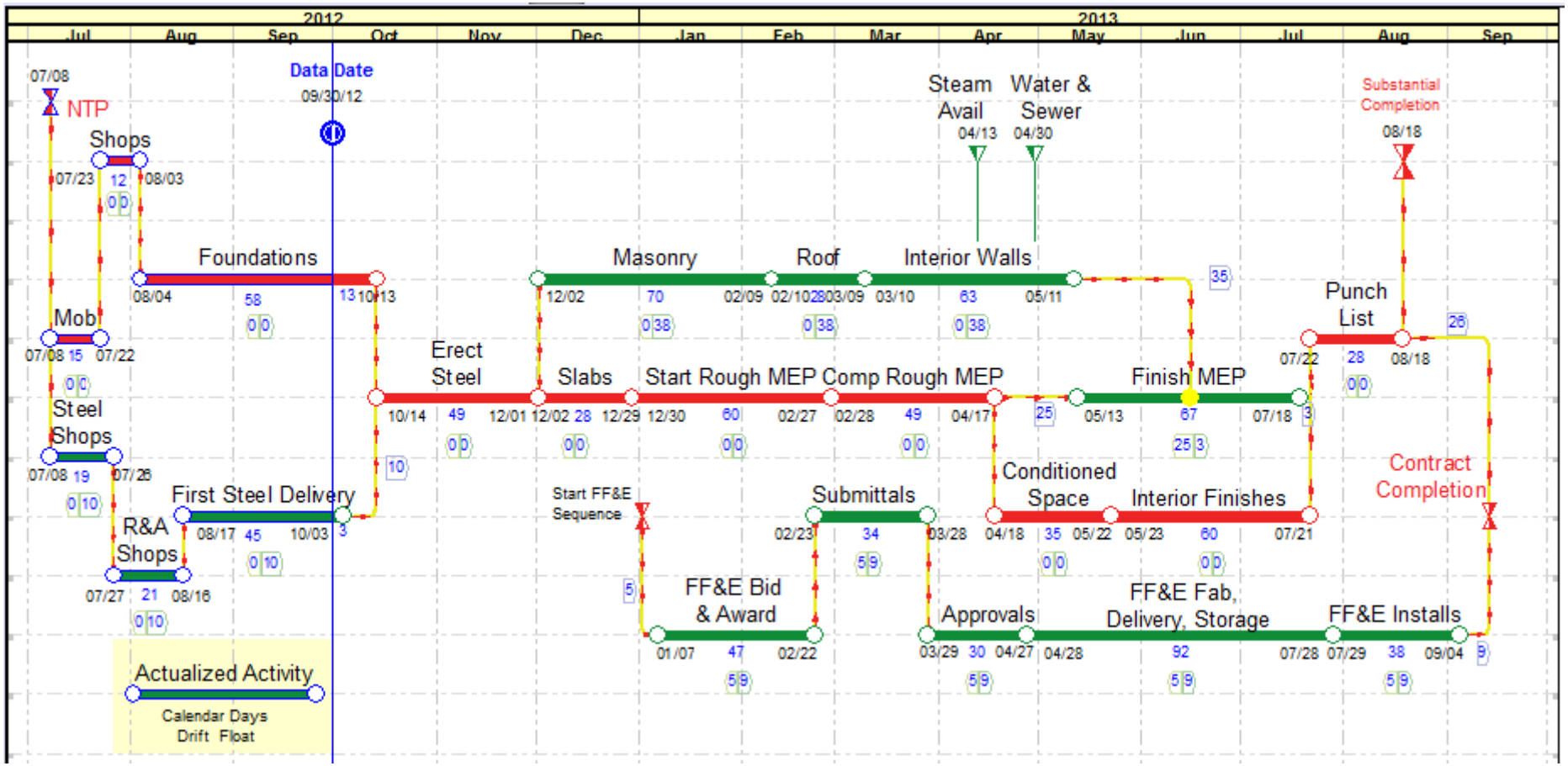
GAPS/DRIFTS/FLOATS/TOTAL FLOATS

Drift/float/total-float emanate from link gaps, which for a link yields days that the predecessor may be delayed and not impact the successor, and that the successor may gain schedule and not impact the predecessor



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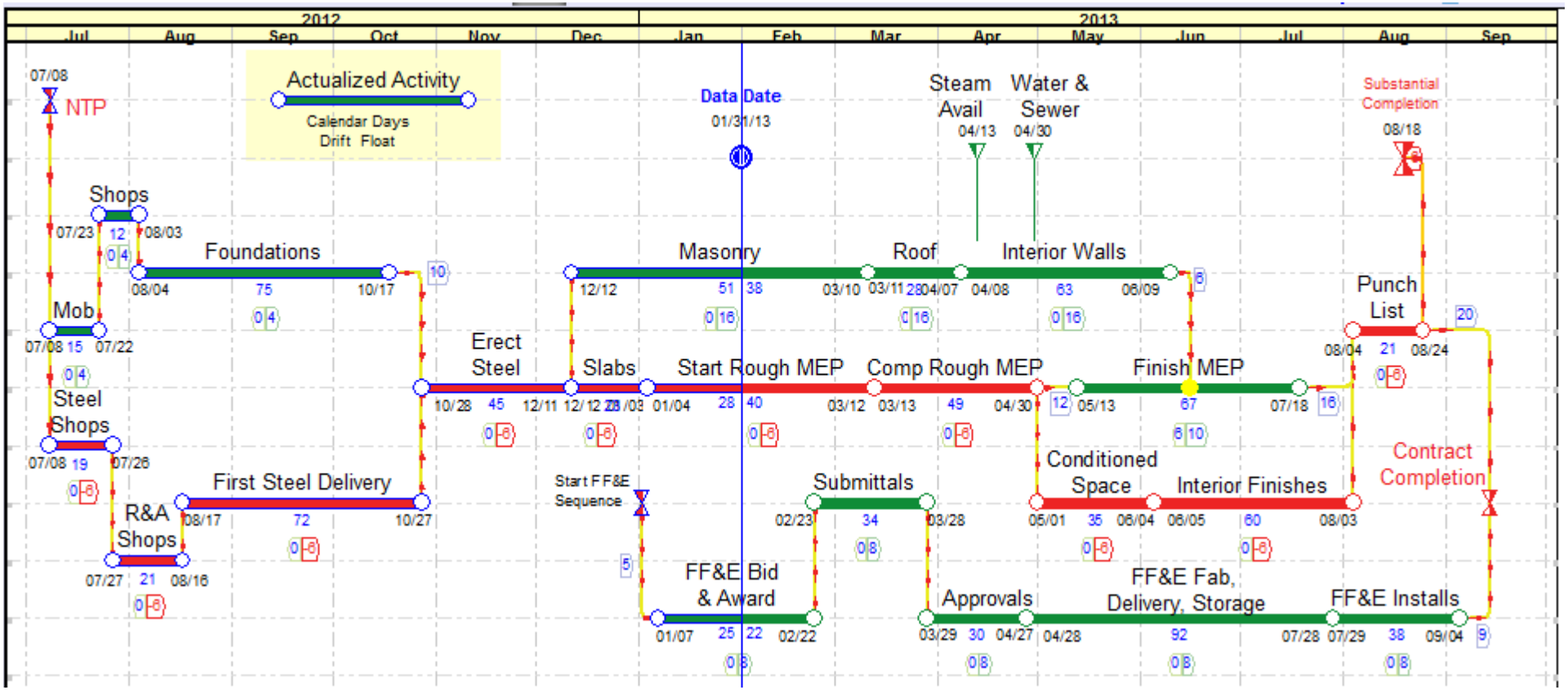
TOTAL FLOATS/FORENSIC TOTAL FLOATS

Total floats left of the data date aka forensic floats may change from update to update (as the data date advances) because they must necessarily reflect any changes in total floats right of the data date



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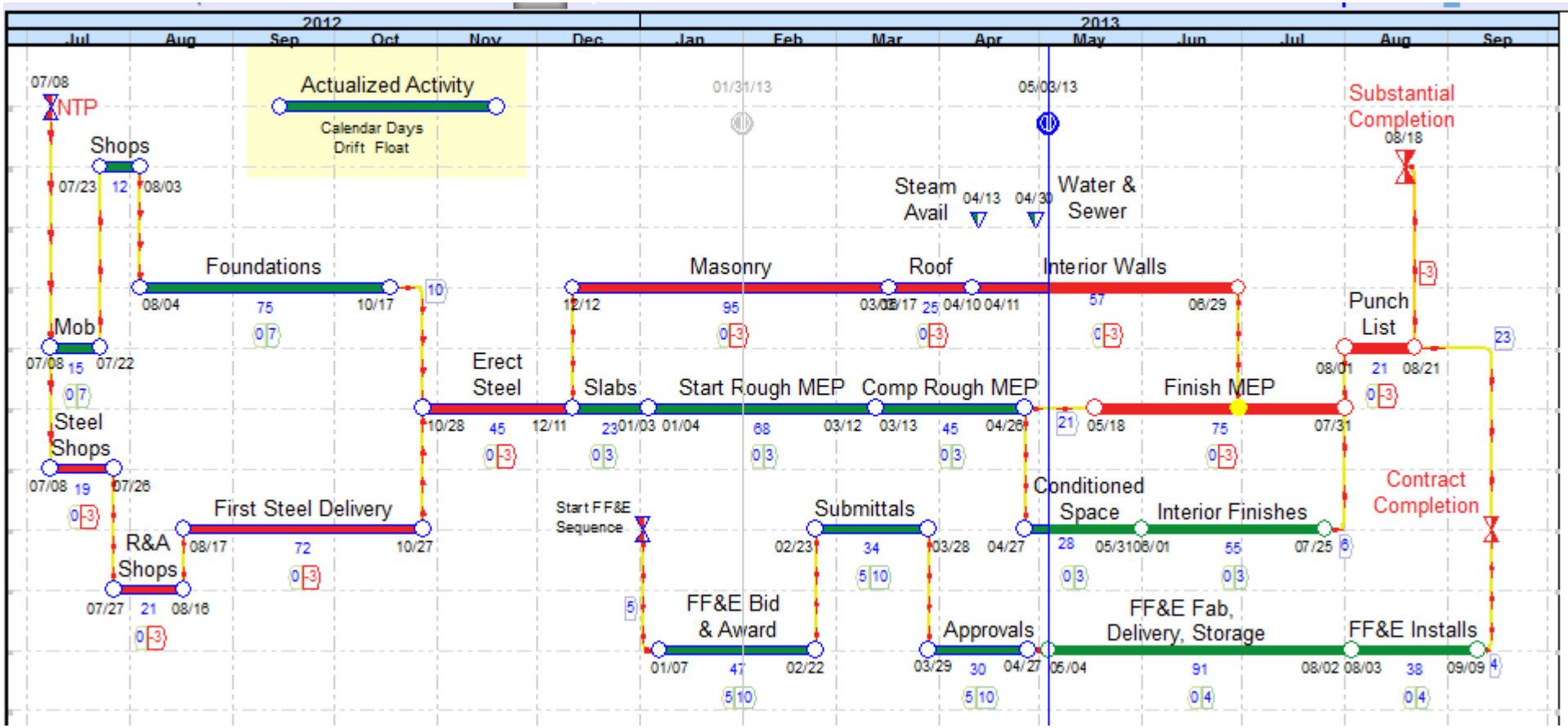
THEN-EXISTING AS-BUILT CRITICAL PATH

If the critical path right of the data date changes for any reason, the *then-existing* as-built critical path left of the data date accordingly will change so as to maintain critical path continuity through the network



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V. CPM vs. GPM RESOURCE LEVELING

Starting with the early schedule, CPM software calculates alternate activity start dates by delaying activities, if the early dates cause overruns in resource limits

A black-box operation that involves entering leveling criteria and pushing a button, followed by calculations and activity rescheduling on the whole, in one fell swoop

Very complex interface with lots of different options and toggles to check

Dystopia rather than Utopia

Black-box, automated solutions are not context-specific and produce unrealistic and usually very inefficient results

Upshot

It wasn't too long before software-driven resource leveling fell by the wayside

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THE CPM RESOURCE LEVELING PREDICAMENT

MURRAY WOOLF

Author of *Faster Construction Projects with CPM Scheduling*

"In general, I discourage the use of any button that, once pushed, takes the decision-making out of the minds of those who are charged with managing the project and instead delegates it to a softly hissing microchip"

"…If you give this power to the computer (software), no human will thereafter be able to (easily) identify or understand the total-float of activities because it obscures the various paths and, hence, one will not be able to exploit activities according to available total-float. Do you really want to surrender such power to the computer?"

› So, what's a stakeholder to do?

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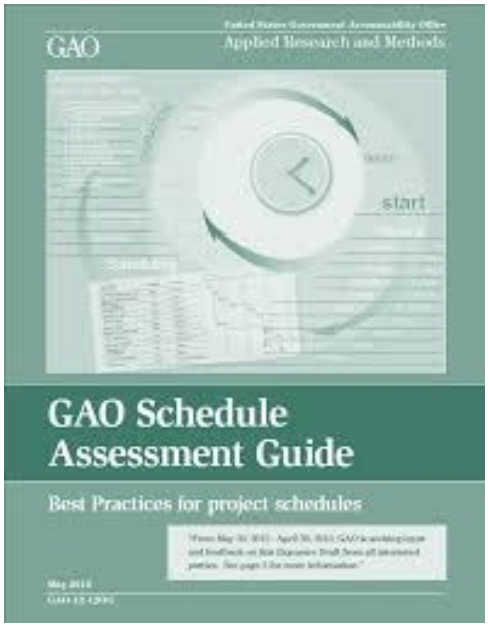
THE CPM RESOURCE LEVELING PREDICAMENT *(cont'd)*



Woolf's views are echoed in the *GAO Schedule Assessment Guide*:

"Automated leveling may produce inefficient output, such as delaying activities if resources are partially available and, thus, prevent activities from being partially accomplished while the project waits for the full complement of resources to become available"

The GAO Guide further posits that:

"Resource leveling can be performed automatically with scheduling software or *manually by management and planners* or both" *(italics by author)*

❯ So, what's a stakeholder to do?

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SYNERGIZING STAKEHOLDER/MACHINE INTERACTION

GPM resource-constrained scheduling is a *transparent, hybrid, stakeholder-driven/software-aided* process that amalgamates schedule context and stakeholders' judgment

To improve a resource histogram profile, stakeholders, utilizing float and drift, may in every possible way (manually or by conceding to the software), shift a selected activity, crash or extend the activity, split the activity, and/or push UNDO to return to any prior state

- ✓ *As an activity is manually or digitally manipulated, other preceding and/or succeeding activities that are impacted based on logic are simultaneously repositioned along the time scale*
- ✓ *The GPM algorithms also kinetically refresh the evolving resource histograms*

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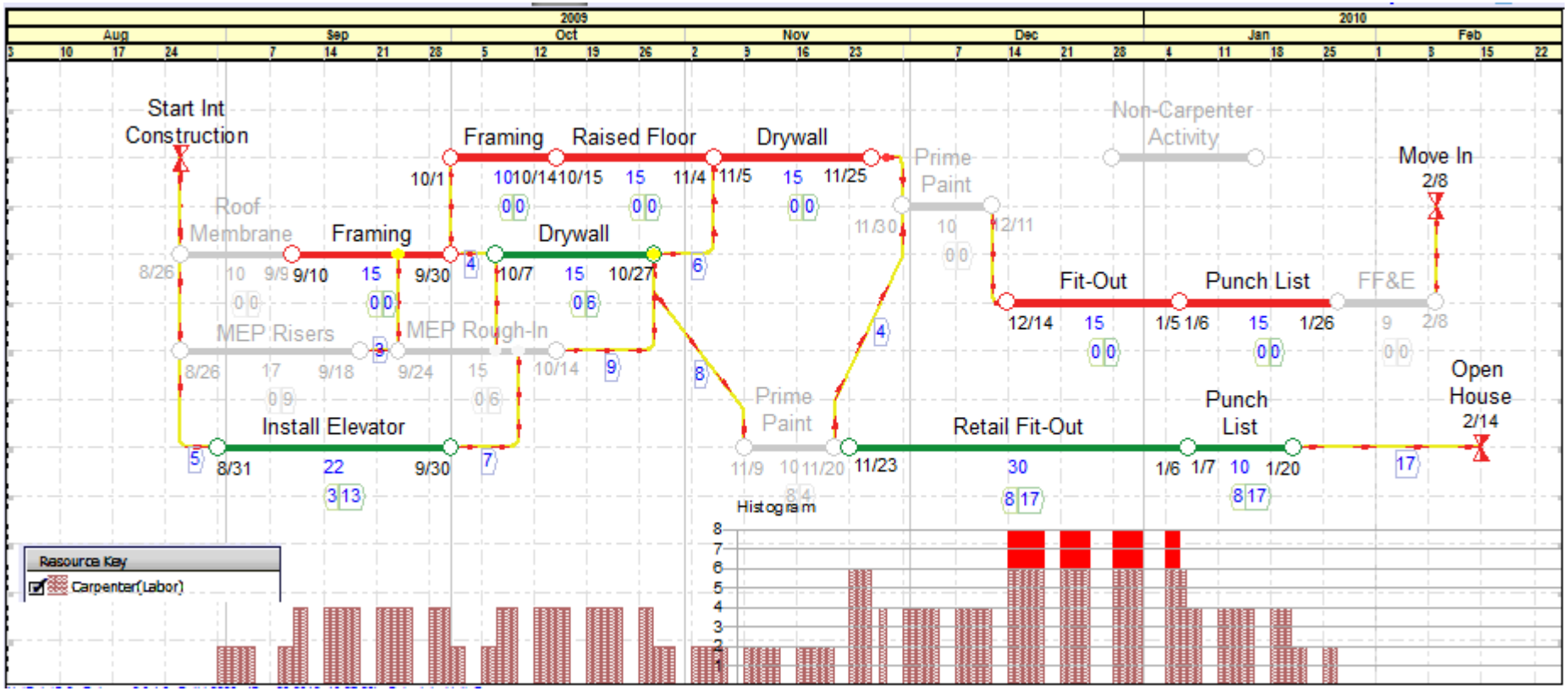
SIMPLE GPM RESOURCE ALLOCATION EXERCISE

The objective is to eliminate the carpenter limit (6 carpenters) overrun between Dec 14 & Jan 5; the selected activity is 'Retail Fit-Out' because it contributes to the overrun, is noncritical, and uses carpenters



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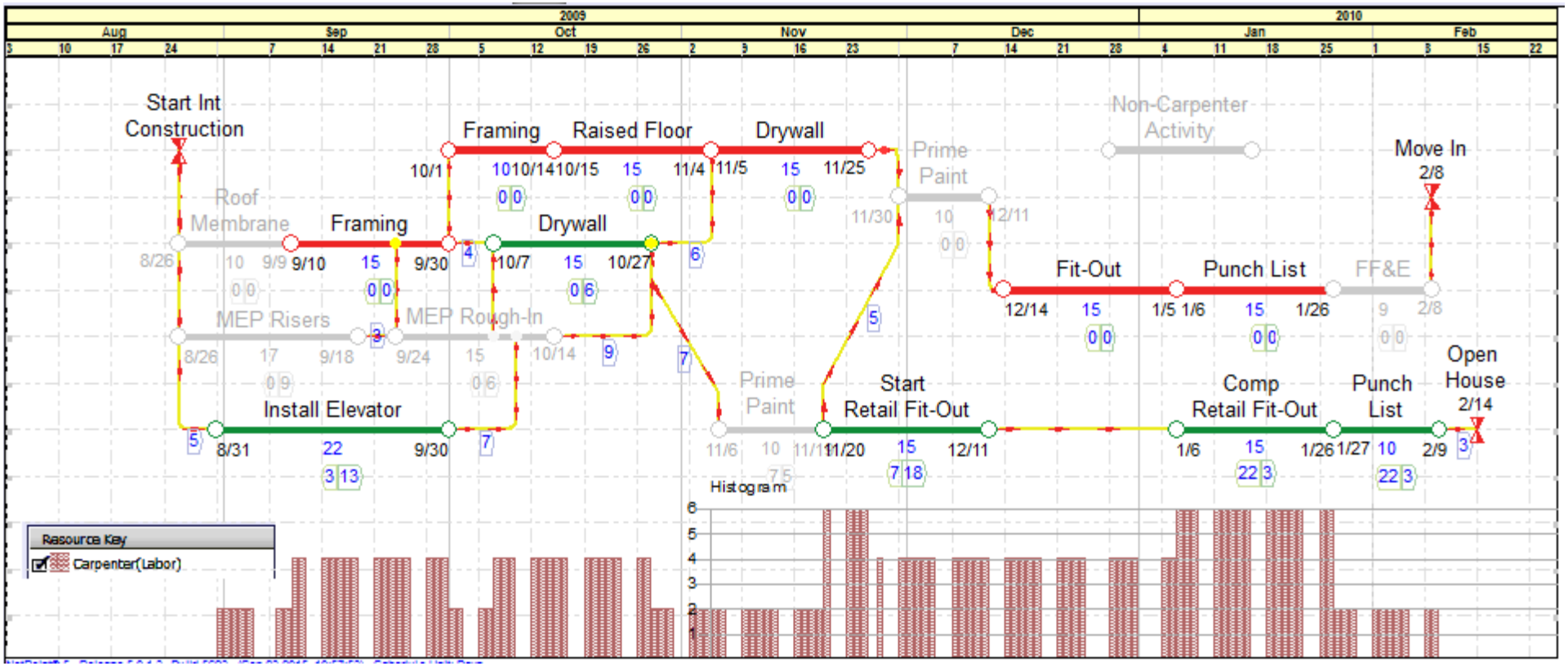
FIRST 3-STEP SEQUENCE IN LEVELING EXERCISE

Step 1: 'Retail Fit-Out' is split (on 14 Dec 09) into two 15-day activities
Step 2: 'Comp Retail Fit-Out' floats by 14 days (gap reduces to 3 days)
Step 3: 'Start Retail Fit-Out' drifts back 1 day (drift reduces to 7 days)



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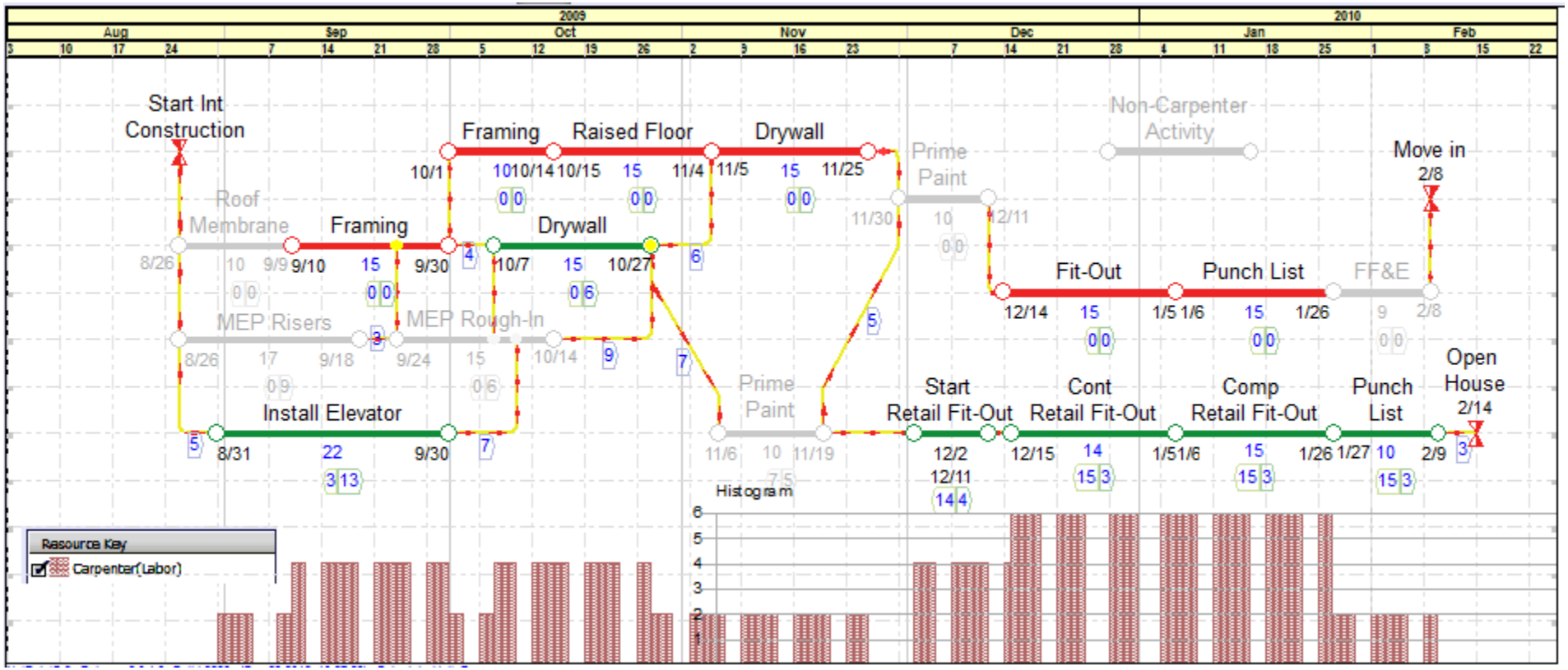
SECOND 3-STEP SEQUENCE IN LEVELING EXERCISE

Step 4: Extend 'Start Retail' to 30 days; crew reduces to 2 carpenters
Step 5: Split 'Start Retail' (on 14 Dec 09) into 16-day and 14-day activities
Step 6: Turn "Logic" off, crash 'Start Retail' to 8 days from its start node, crew doubles to 4 carpenters; drift 'Start' Retail' by 1 day and turn Logic back on



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THE P6 RESOURCE LEVELING PREDICAMENT

The small network used in the GPM leveling exercise was exported into Primavera P6 software and…

- If the completion date is constrained by both the 2/8/10 and 2/14/10 deadlines, P6 is unable to impact the resource histogram AT ALL
- If the completion date constraints are lifted, P6 simply shifts critical path activities far enough to meet the 6-carpenter limit, resulting in a 16-working-day delay to completion

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KEY EVENTS IN GPM'S FIRST FIVE YEARS

2003 2004 2005 2006 2007 2008 2009

2003–May 26 *ENR* article "Critics Can't Find the Logic in Many of Today's CPM Schedules"

2004–The seminal May 2003 *ENR* article spurs development within PMA of a computer graphics, event-driven planning and scheduling application rooted in float-preserving planned dates, total floats, and the critical path

2006–In October, PMA internal document discloses graphical method for simultaneously planning, scheduling and presenting activities, events, and their relationships in a hybrid arrow and precedence network format in a manner easily understandable to schedulers, other professionals, and even to laypersons

2007–PMA files first patent application for a new network-based planning/scheduling process, which came to be known as the graphical path method or GPM

2008–GPM ***self-healing*** algorithms enabling a kinetic planning/scheduling user interface are developed by Dr. Ponce de Leon

2008–Dr. Ponce de Leon introduces the basic GPM planning/scheduling scheme of thought and NetPoint Version 3 at the PMICOS 5th Annual Conference in Chicago

2008–Email conveying Jim O'Brien's favorable peer review of Dr. Gui's initial academic paper on GPM states: "To me, the loss of the logic diagram has been the unrecognized tragedy in the evolution of CPM scheduling and your GPM brings it back full circle."

2009–In the first quarter, a Top 20 U.S. contractor/construction manager in the *ENR Top* 400 Contractor's List licenses 12 copies of NetPoint®

2009–GPM forensic total float is introduced at the PMICOS 6th Annual Conference in Boston, MA

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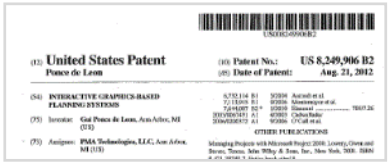
GPM TIMELINE–2010 THROUGH 2015

2010 2011 2012 2013 2014 2015

2010–The NetPoint Team designs and develops an entirely new user interface, NetPoint Version 4

2010–O'Brien & Plotnick's 7th ed. of *CPM in Construction Management* cites NetPoint as providing "superior graphics for managing a project"

2011–NetPoint Version 4 is introduced at the 1st NetPoint User Conference in Orlando, FL



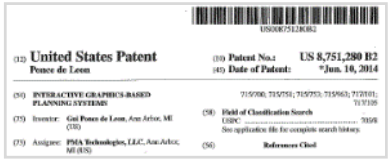
2012–First GPM patent is awarded by the USPTO in August

2013–GPM Risk and its software embodiment, NetRisk, are introduced at the NetPoint & GPM Conference

2014–AutoGRAPH, NetPoint's constraint-based network layout authoring method, is introduced at the 4th NetPoint & GPM Conference

2014–In April, a top 10 EPC contractor on the *ENR* Top 400 U.S. Contractors list orders its 36th license of NetPoint

2014–Fourth GPM patent is awarded by the USPTO in June



2015–NetPoint Version 5 and NetRisk cost risk assessment are unveiled at the 5th NetPoint & GPM Conference

2015–The NetPoint Team designs and develops additional risk assessment features, as well as ***Schedule IQ***, a new paradigm in schedule metrics

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TAKE-AWAYS

1. Graphical/visualization planning/scheduling methods that are inherently suitable for surface computing are more stakeholder-centric than CPM and other methods that batch input, separate from calculations, separate from printouts
2. GPM networks, due to their sufficiently simple visuals, are intuitive and more fluently processed by schedulers and non-scheduling stakeholders alike
3. GPM planned dates, which generate drift, not only preserve total float traceability, but also, at last, render resource leveling practical
4. GPM resource leveling allows stakeholders to remain engaged and to direct resource leveling to proceed manually or digitally, activity by activity
5. The kinetic nature of algorithmic GPM software provides a more cognitively responsive environment for both schedulers and non-schedulers alike
6. Collaborative pull planning on a graphic, computerized surface better synergizes network schedules at the project level and pull plans at the field level
7. In every update, GPM contemporaneously reveals the as-built critical path left of the data date, bringing transparency to retrospective delay analysis

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