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Enhancing Resource-Leveling via Intelligent Scheduling:

Turnaround & Aerospace Applications Demonstrating 25%+ Flow-Time Reductions

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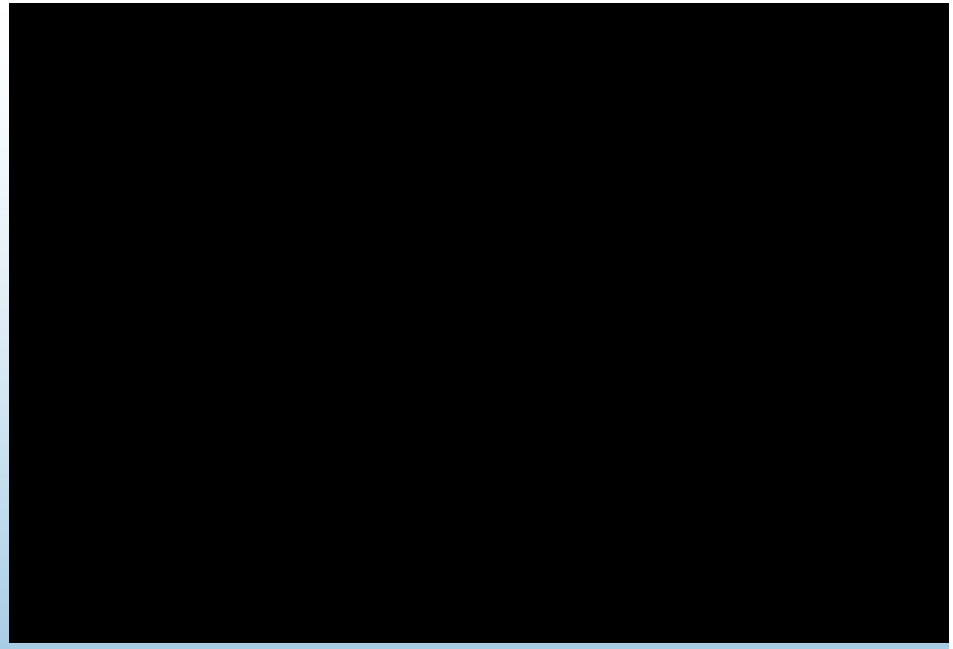
Background & Perspective

Stottler Henke

- Artificial Intelligence Research & Development
  - Software company
- Video: Project Management Experience



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Resources & Critical Path (Resource Loaded)

- Large organizations developing and building complex systems rely on schedules and project management.
- Many CPPM projects are resource constrained (in reality, even if not modeled that way)
- Resource constraints (e.g., labor, space, equipment) greatly complicates the scheduling problem.
  - Hence a '*reason*' to ignore

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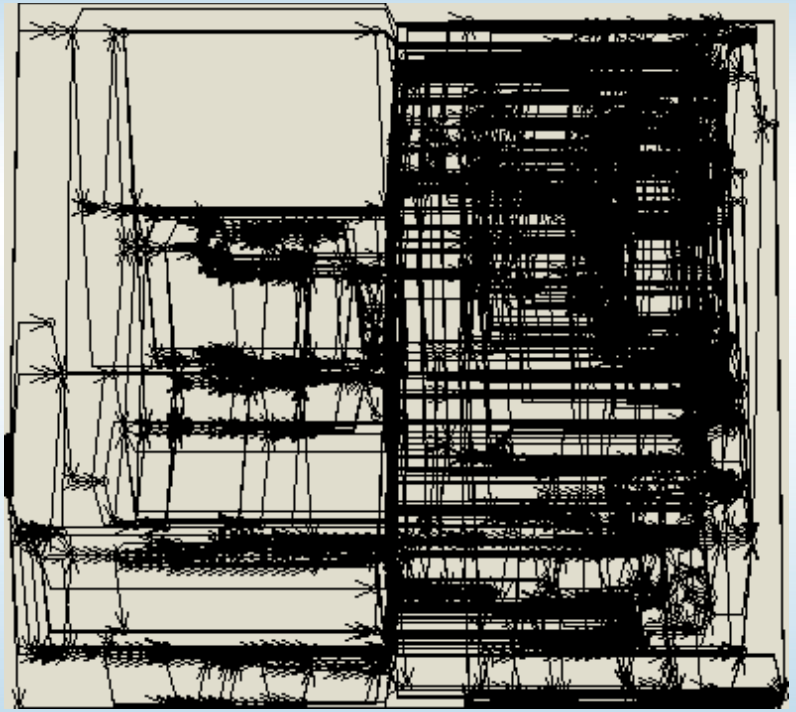
Where in the PM Space?



- Project Management
  - …
  - Critical Path (Resource Constrained)
    - …
    - **Scheduling / Level Resources ← ←**
    - …
  - …

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Scheduling Background / Comparisons

- Resource-Constrained Scheduling is NP-Complete, takes exponential time for optimal solution
  - I.e., it is a hard problem
  - Approximate methods are needed
- Most automatic scheduling systems use simple one-pass algorithms
- Standard constraint-based approaches are far less computationally efficient (Aurora takes advantage of structure of scheduling problems and heuristics)

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Why Important? / Motivation

- So much work is put into developing project plan before hitting the schedule / Level Resources … button Days, Weeks, Months
- What if your resulting schedule is **10% longer than it needs to be** because of the scheduling engine?
- **Would you care?**

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How about 25+% longer?

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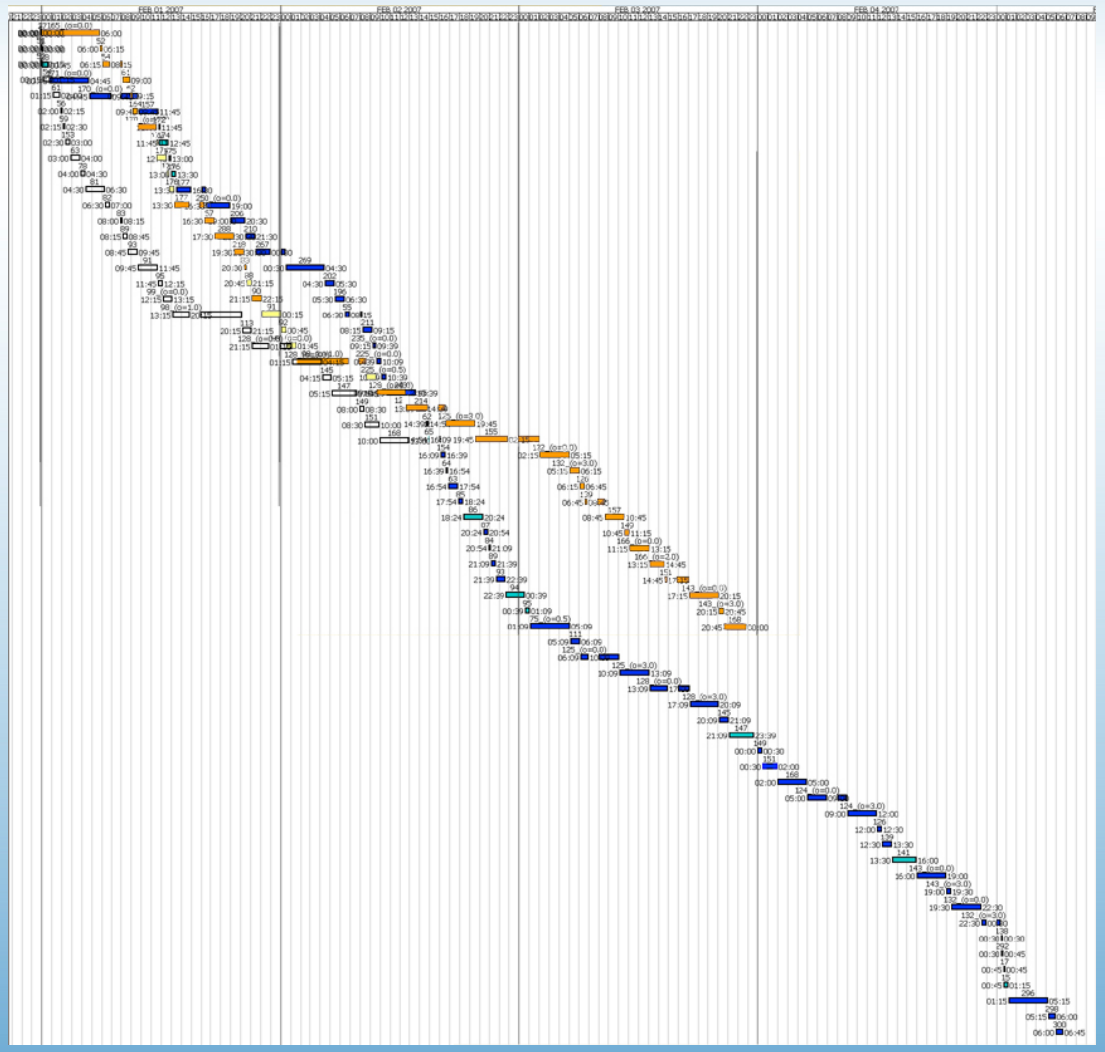
Motivation: Visual

- Following figure shows.
  - Critical Path
  - Resource Constrained Critical Path (theoretically correct)
- The **goal** is the **shortest** correct schedule

Scheduling Engine Comparison



Construction Examples
(Kastor & Sirakoulis, 2009)

Product	1st Example		2nd Example	
	Duration	Deviation from CPM (%)	Duration	Deviation from CPM (%)
Primavera P6	709	52.8	308	29.41
MS Project	744	60.34	314	31.93
Open Workbench	863	85.99	832	249.58

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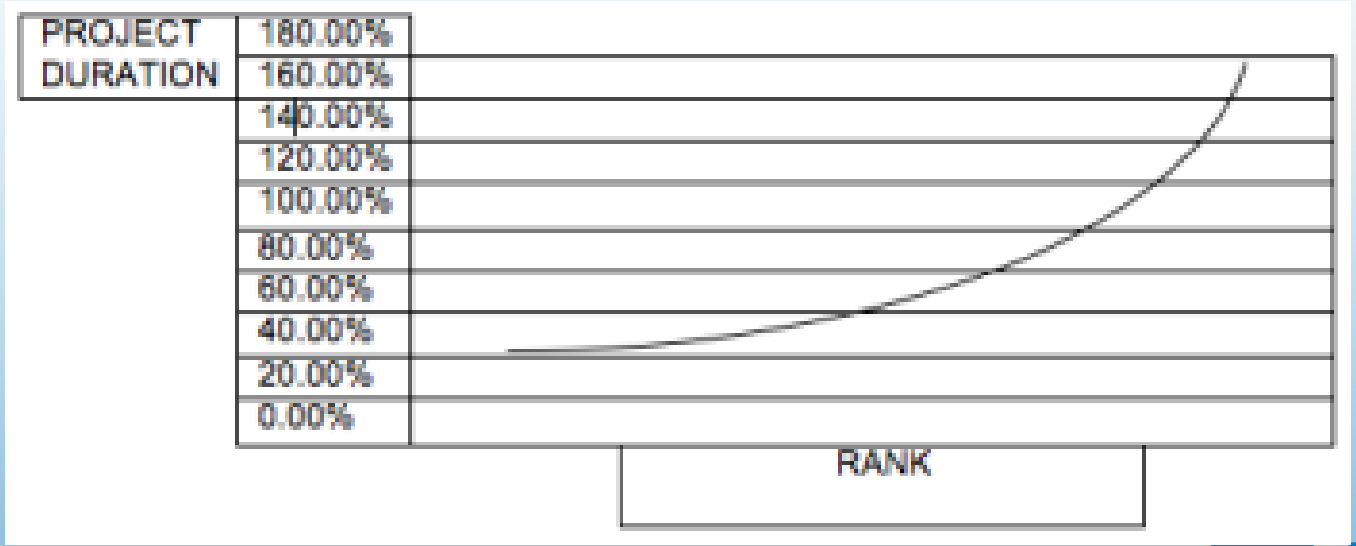
Different Resource-Leveling Techniques

- Deviation from Critical Path Duration



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Benefits of Sophisticated Underlying Scheduler

- Results in a better **initial** schedule
- **Execution**: Schedule is more flexible and better able to accommodate change.
  - Schedule is “self-aware” of what tasks can most easily be moved. I.e., tasks store information about what placed it where it is placed.
  - Quickly reschedule as if resources on late task are not available until after its estimated end time.

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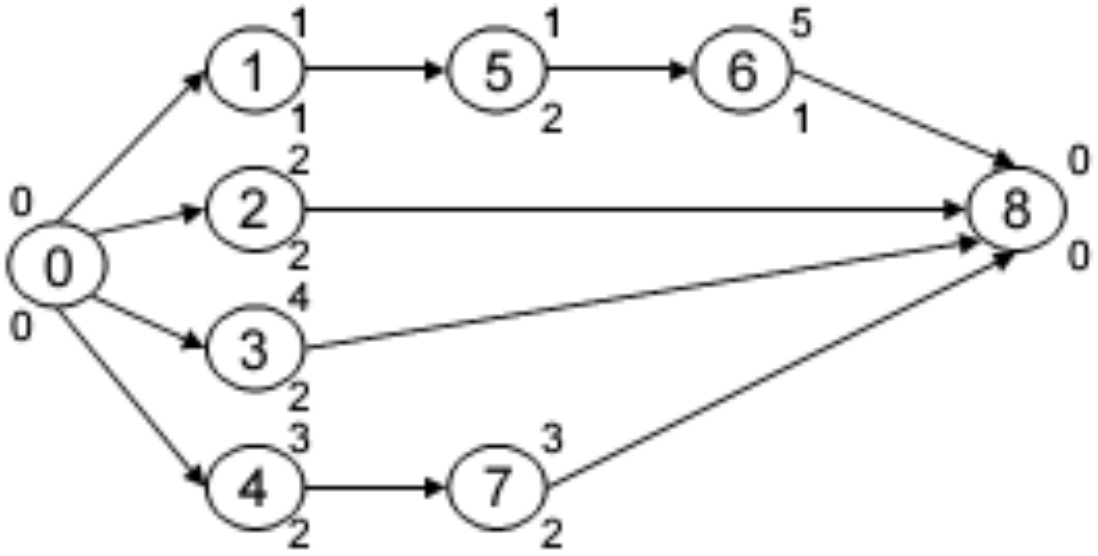
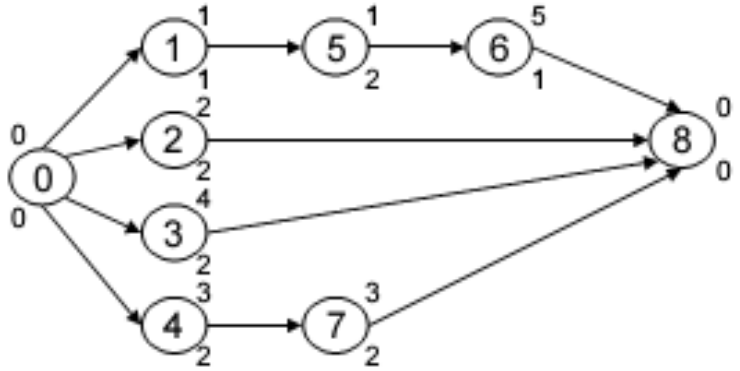
Maybe Only for 'Big' Problems?

- Let's look at a toy problem …
- 'Simple' problem with only 7 real tasks and 2 milestones.



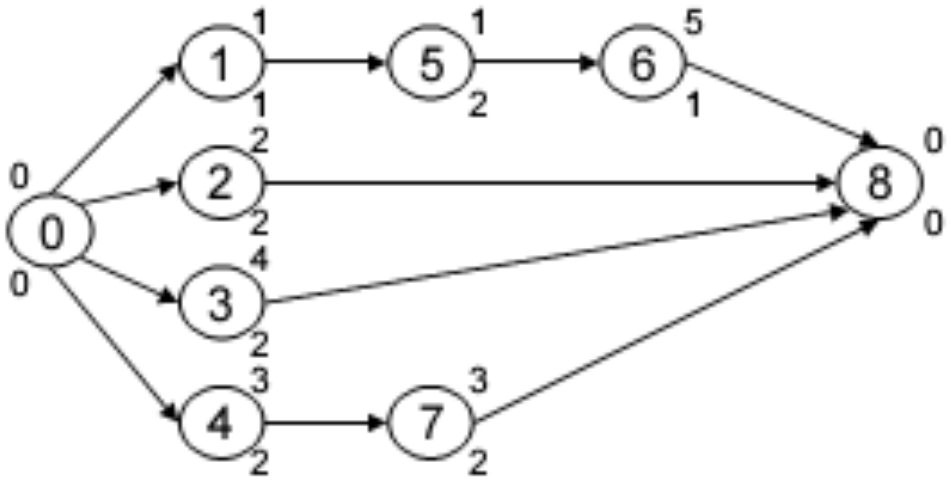
‘Simple’ Network details

- Number superscript of circle is duration in days
- Number subscript of circle is resources needed
- There is only 1 type of resource



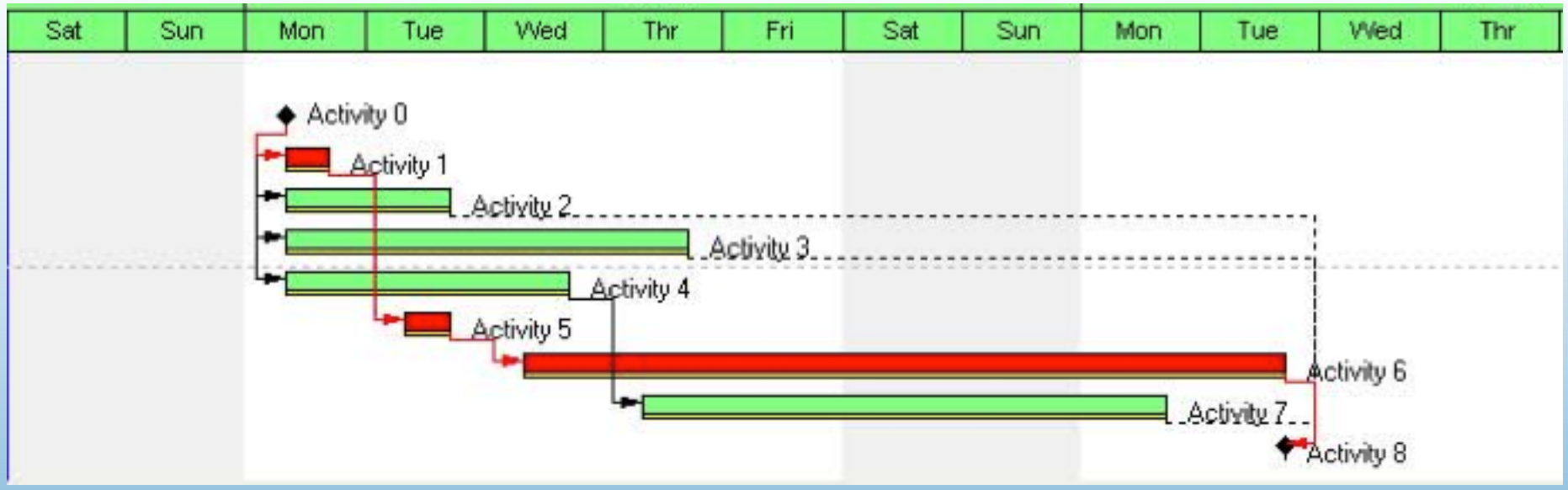
Critical Path of Network

- Solution when infinite resources available
  - Find longest path = 1 + 1 + 5 = 7
- So Critical Path is 7 days



Gantt Chart of Critical Path

- Note: Sat/Sun are not workdays



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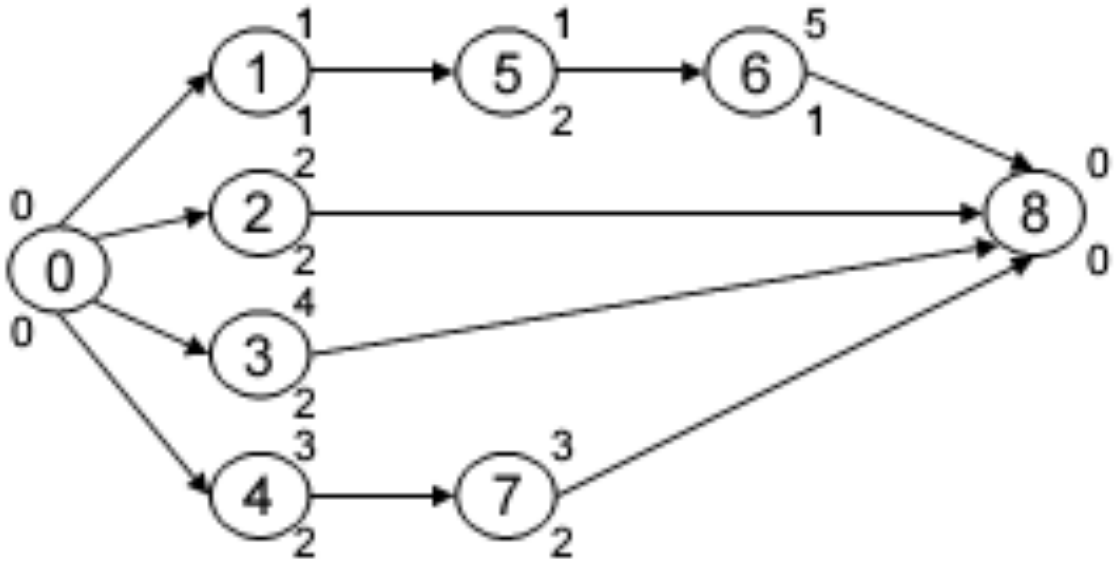
Set Resource Pool to 5

- Only one type of resource to make the problem ‘simple’



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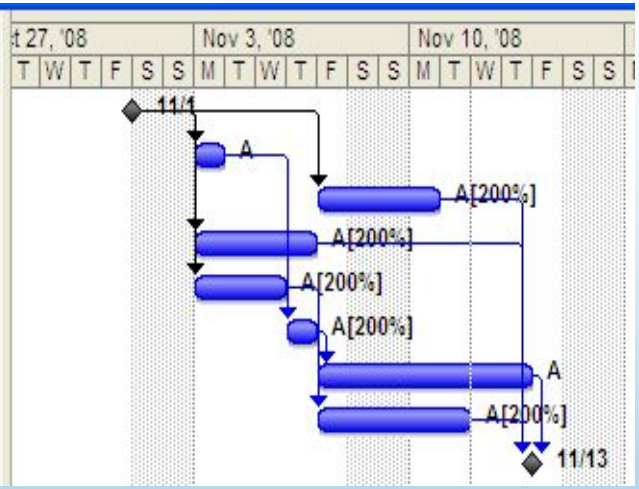
Gantt Chart Showing the Critical Path & Histogram

- Note: now some resources are overloaded
- Resource level to solve over allocation

Resource-Leveled in MS Project = 9 days

	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	T0	0 hrs	Sat 11/1/08 12:00 AM	Sat 11/1/08 12:00 AM		
2	T1	8 hrs	Mon 11/3/08 8:00 AM	Mon 11/3/08 5:00 PM	1	A
3	T2	16 hrs	Fri 11/7/08 8:00 AM	Mon 11/10/08 5:00 PM	1	A[200%]
4	T3	32 hrs	Mon 11/3/08 8:00 AM	Thu 11/6/08 5:00 PM	1	A[200%]
5	T4	24 hrs	Mon 11/3/08 8:00 AM	Wed 11/5/08 5:00 PM	1	A[200%]
6	T5	8 hrs	Thu 11/6/08 8:00 AM	Thu 11/6/08 5:00 PM	2	A[200%]
7	T6	40 hrs	Fri 11/7/08 8:00 AM	Thu 11/13/08 5:00 PM	6	A
8	T7	24 hrs	Fri 11/7/08 8:00 AM	Tue 11/11/08 5:00 PM	5	A[200%]
9	T8	0 hrs	Thu 11/13/08 5:00 PM	Thu 11/13/08 5:00 PM	7,8,3,4	



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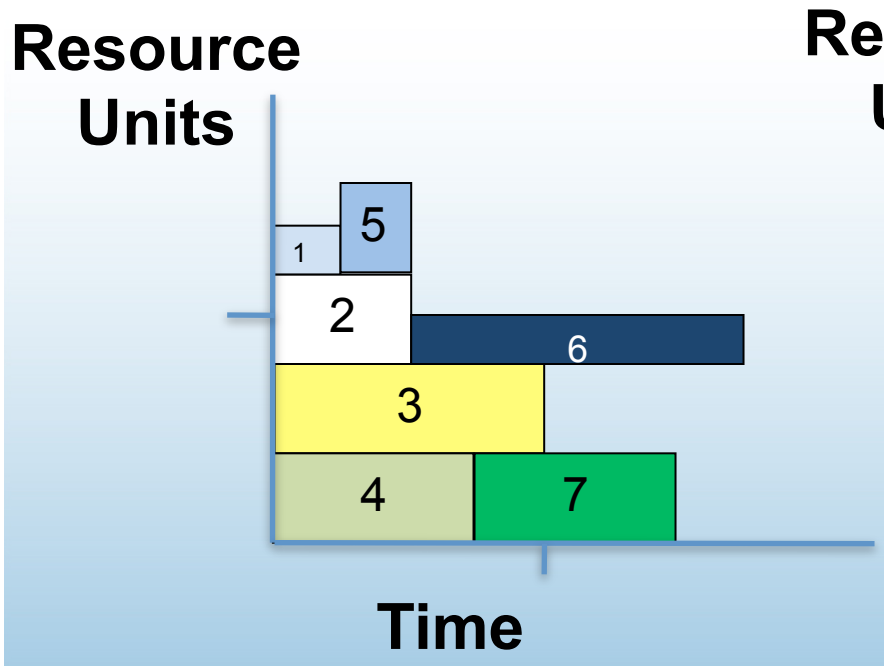
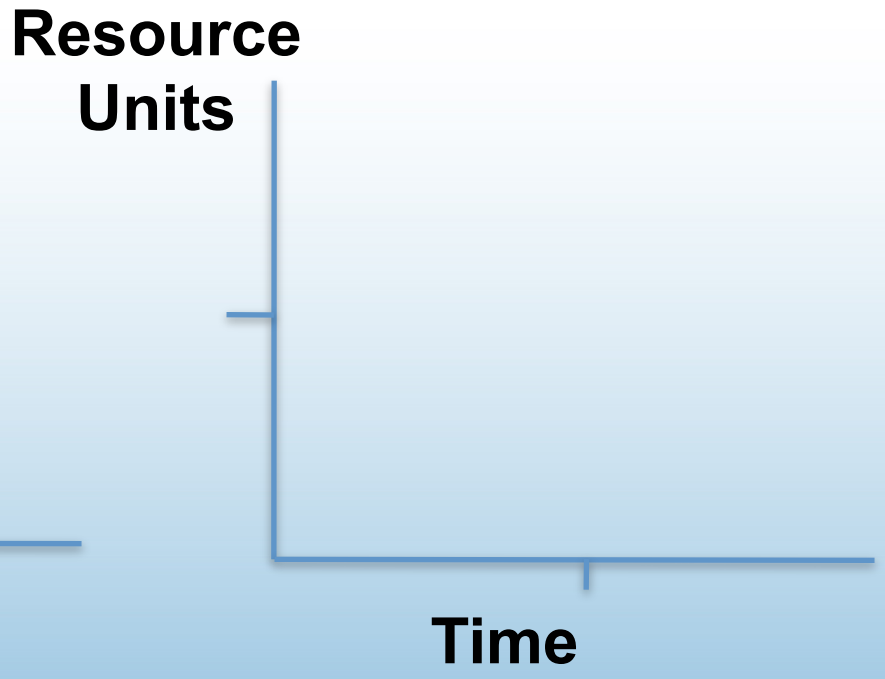
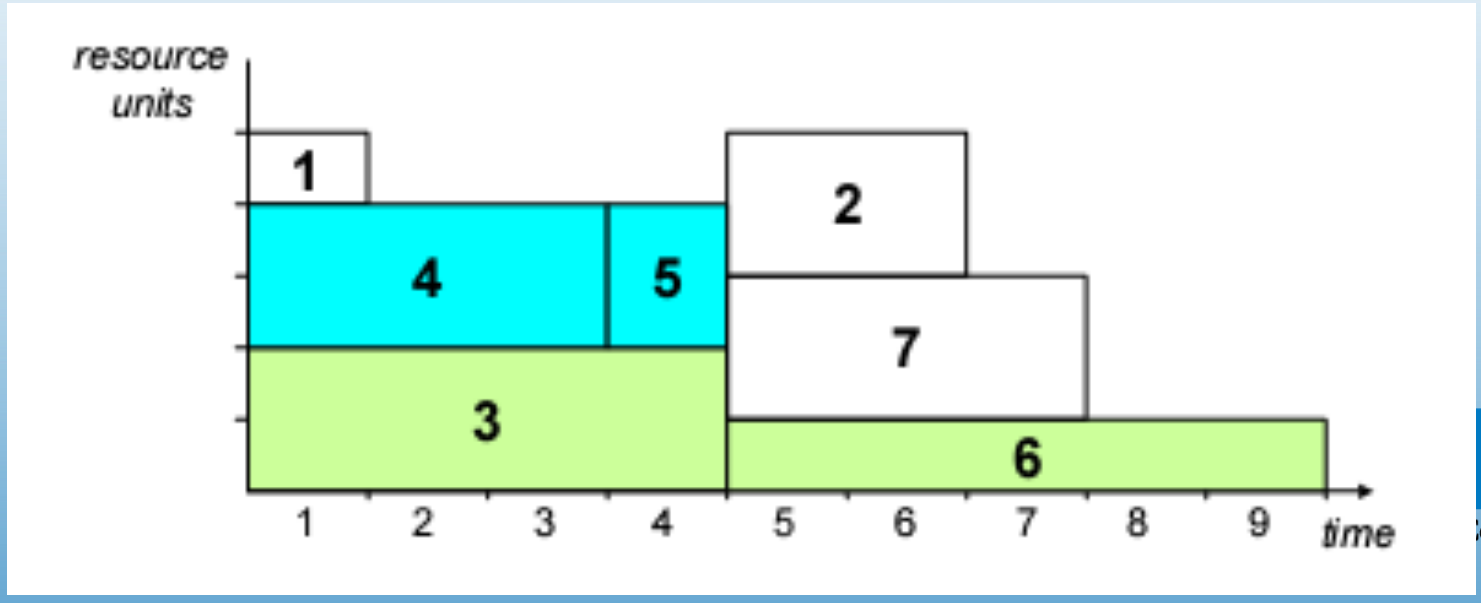

Resource Units
5
1
2
6
3
4
7
Time


Resource Units
Time

Simple Enough, Right?

- Another view of the solution



But there is a better solution … P6 Model: Resource Leveled = 8 days

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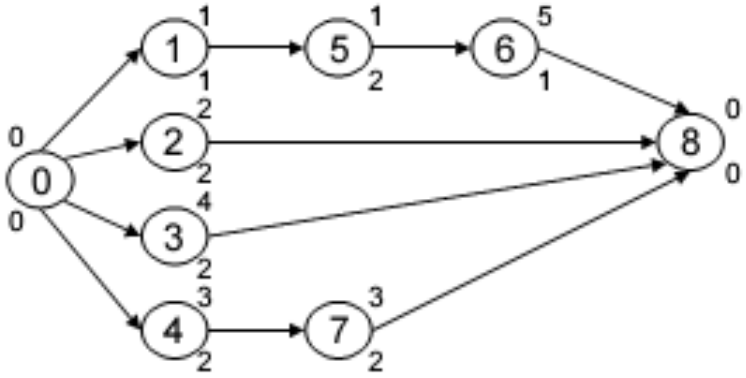
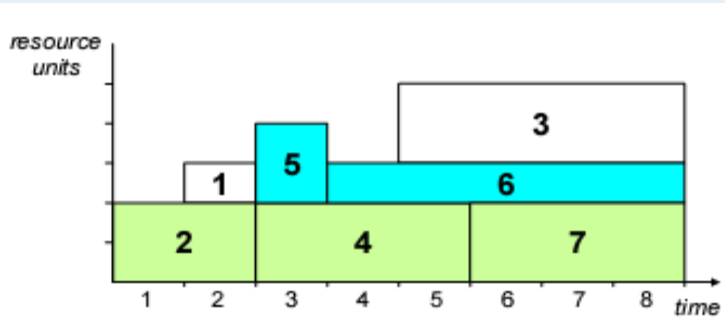
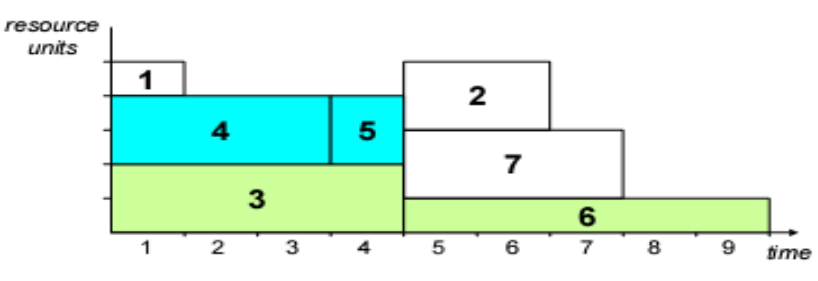
Simple?







Critical Path =

1 + 1 + 5 =7

1 resource

5 total units

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End of Story… Not quite

- There is an even better solution
- 7 days
- So this ‘simple’ problem could not even be solved well by the world’s ‘premier’ project management tools.
- Can you solve this ‘simple’ problem in 7 days?

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Constraints Add Complexity

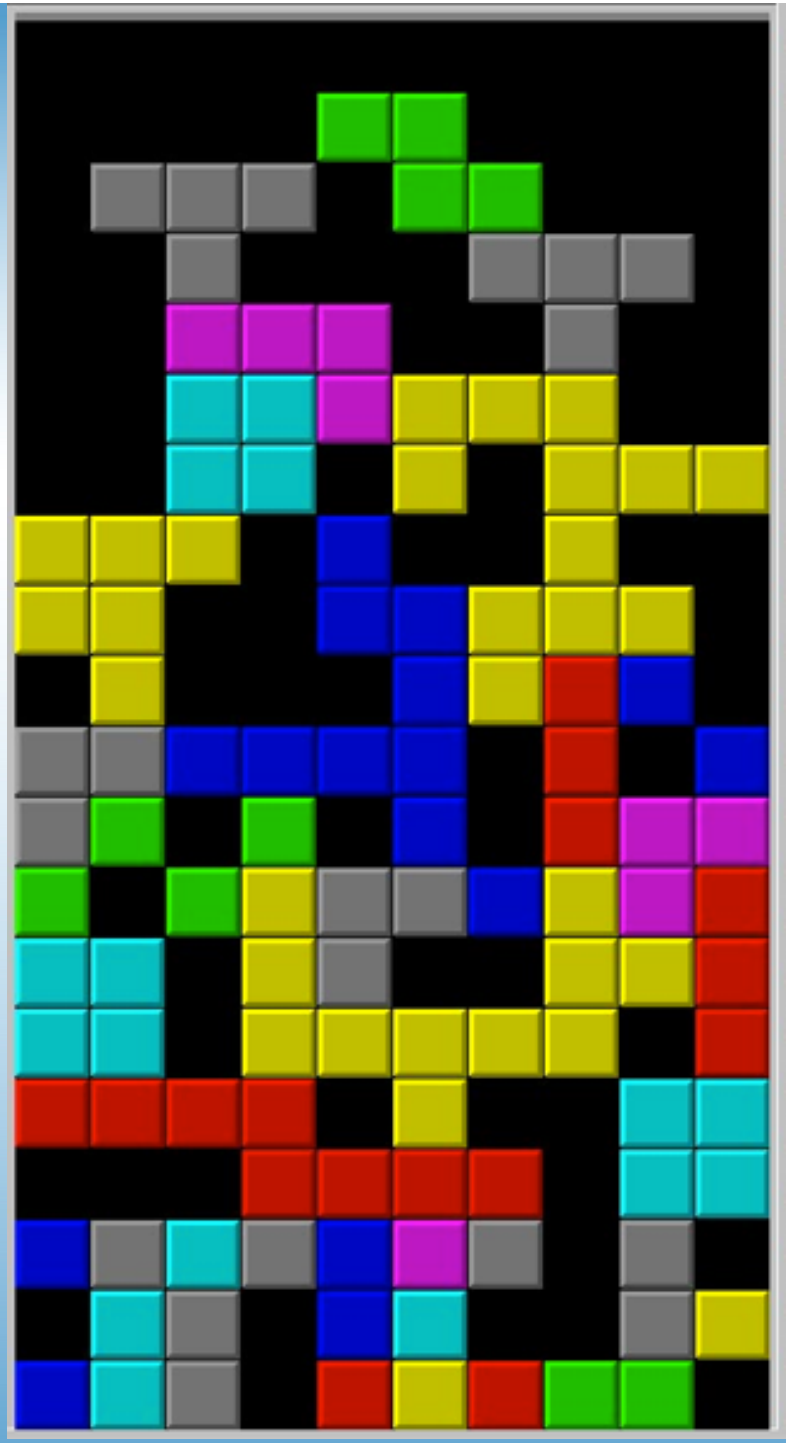
- Technical constraints (E.g., F-S, F-F, S-F, lags)
- Resource constraints
- Labor constraints
- Usage constraints – e.g., tool can only be used for so many hours continuously and/or during a day.
- Spatial constraints – e.g.,
  - job requires a certain location or type of space;
  - two elements should (or should not) be next to each other
- Ergonomic constraints – individual limitations on work conditions

Visualizing More Complex Situations

- No good methods shown to date
- Closest way is by similar problems
  - E.g., Tetris game, Tetris cube

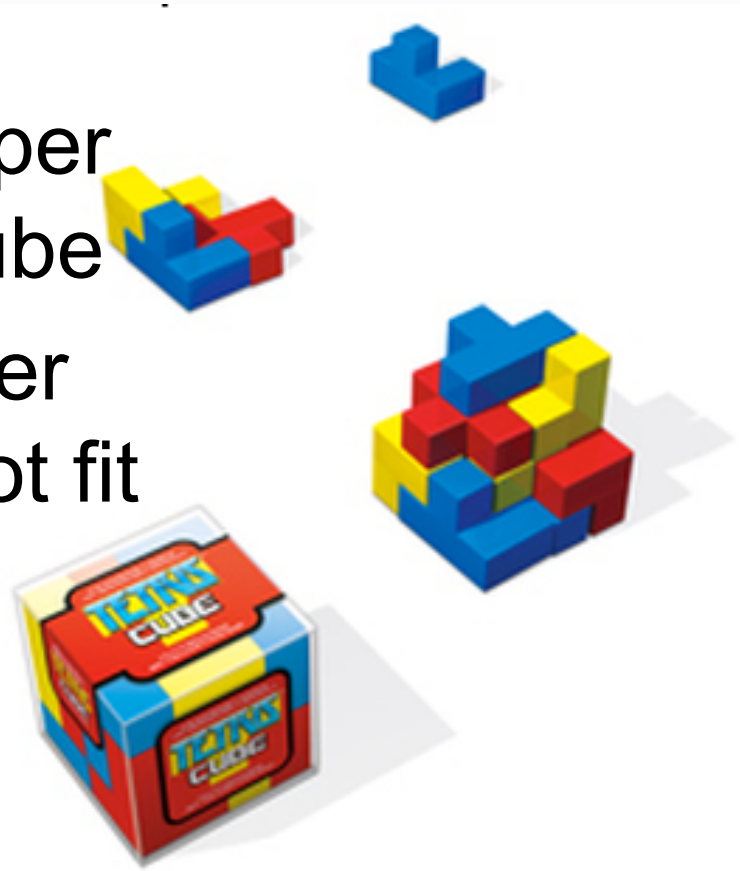
Tetris

- Shapes similar to resource profile of individual tasks
- Holes when playing Tetris represent resource allocation inefficiencies.
  - E.g., black regions in figure to the right
- Try www.FreeTretris.org for yourself.



Tetris Cube

- More realistic to scheduling multiple types of resources per task is the Tetris Cube
- If not pieced together properly then will not fit in box.
- Video



Refinery Turnaround Leveraging Intelligent Scheduling Technology

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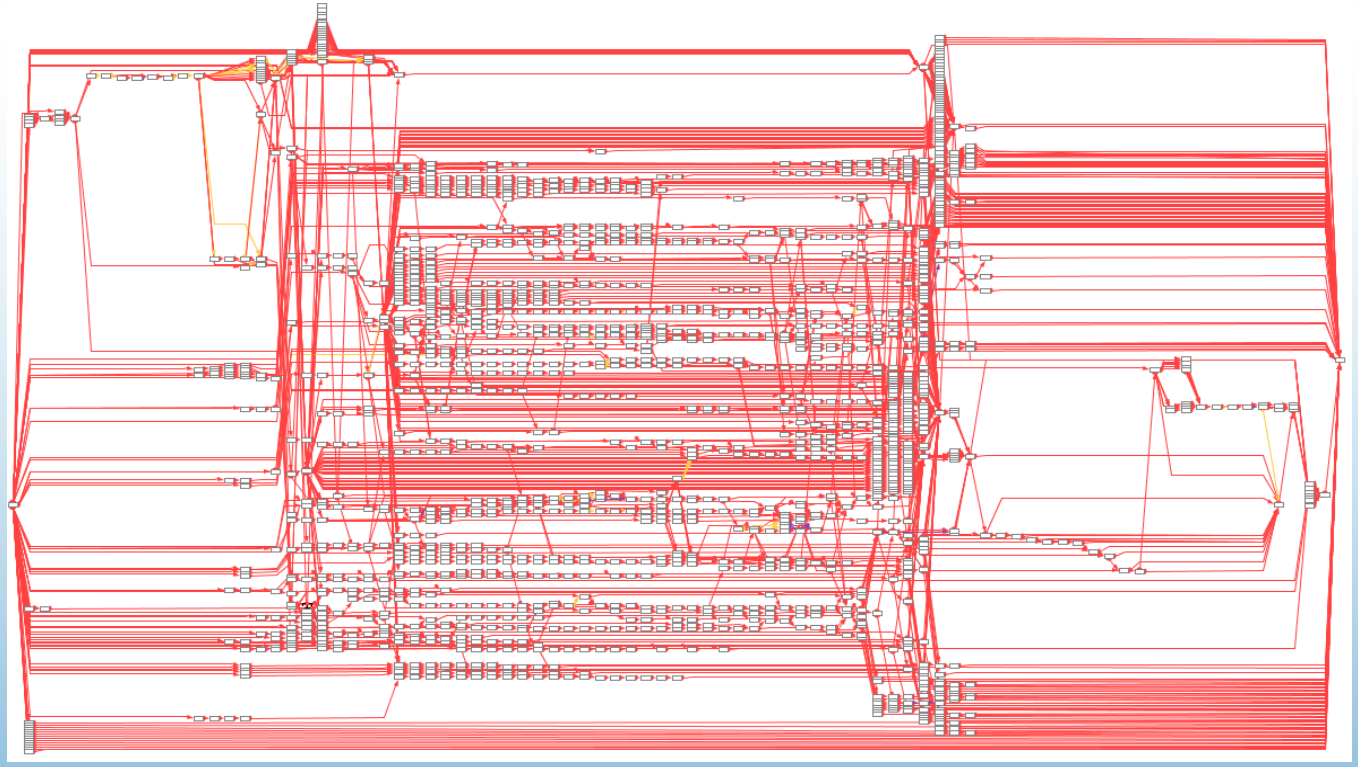
Turnaround Project Network 2,500+ Tasks



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Results: 2,500+ Turnaround

- Primavera P6**67.125**days
  - Performed by 3rd party
- Aurora**56.27**days
- Primavera P6 **19.3% longer** than Aurora
- Critical Path is 46 days
  - P6 is 21.125 days longer than CP
  - Aurora is 10.27 days longer than CP
  - So **% diff over CP is >100%**

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Long-Term Refinery-Related Upgrade

MS Project 2007	=	1,627 days
Primavera P6	=	1,528 days
Primavera P3	=	1,258 days
Intelligent scheduling (Aurora)	=	1,240 days

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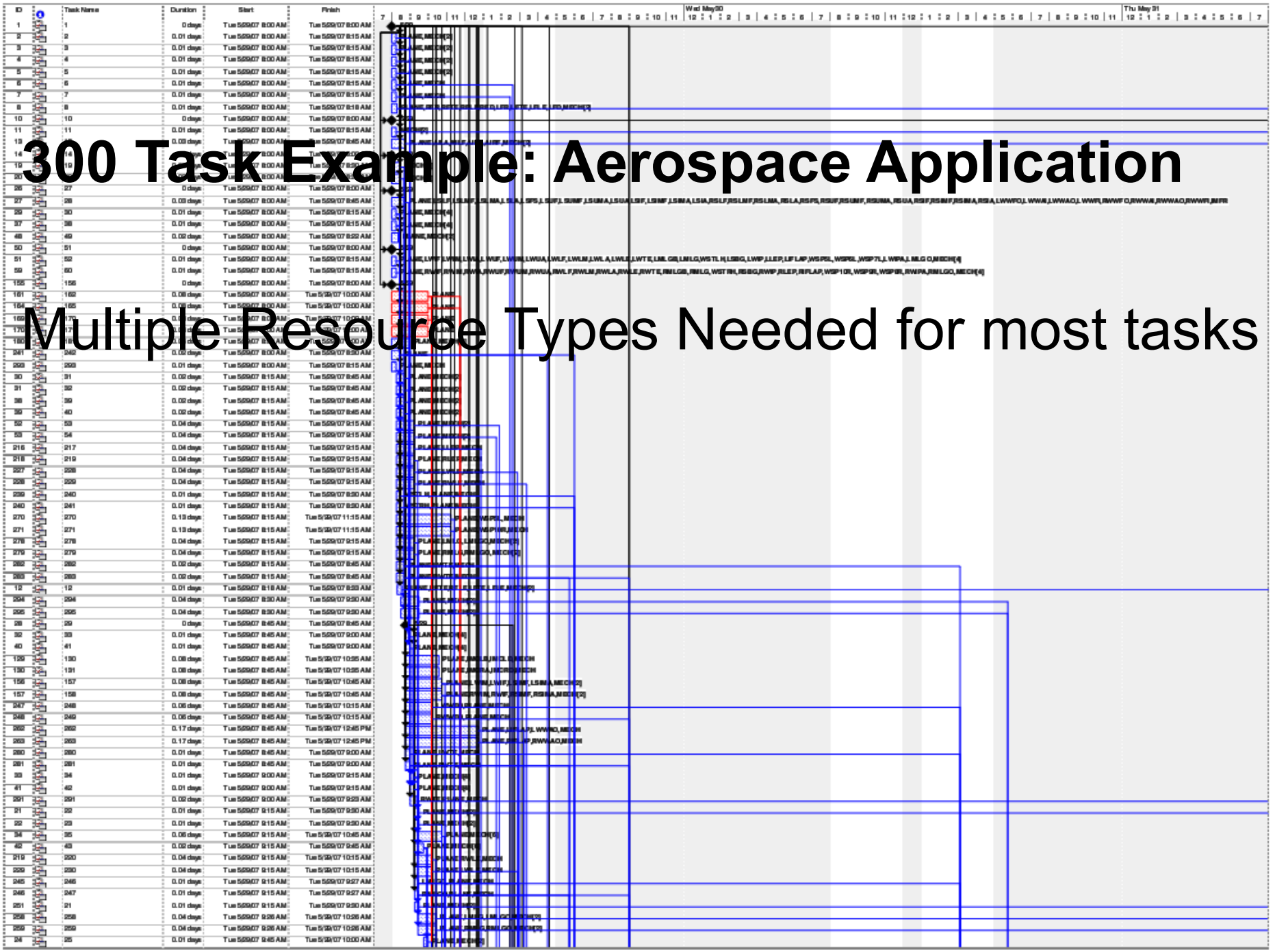
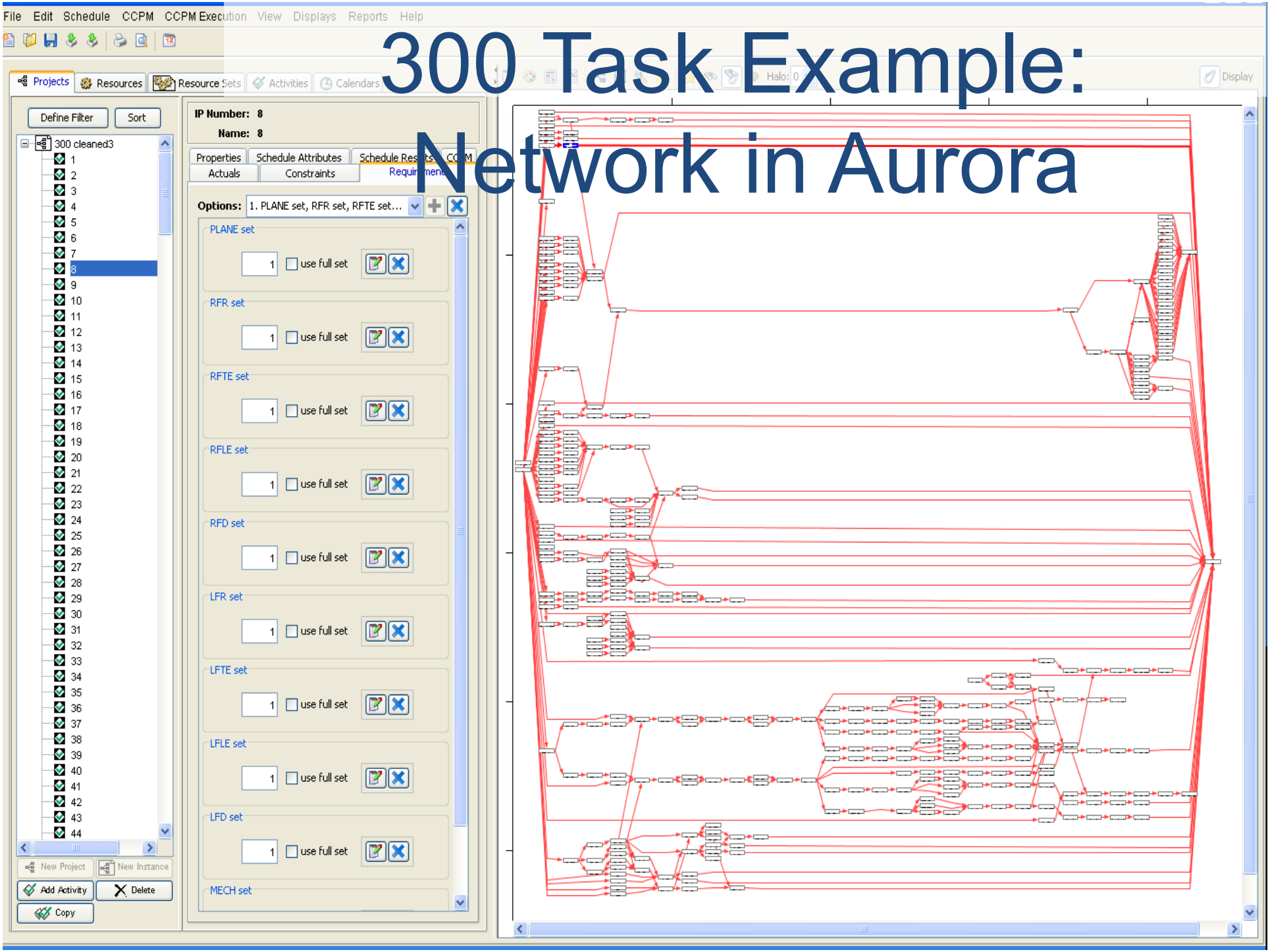
300 Task Example: Aerospace Application

Multiple Resource Types Needed for most tasks



300 Task Example: Network in Aurora



Results: 300 Task Example

- MS Project 2003 **145.6** days
- MS Project 2007 **145.6** days
- Primavera P6 **115** days
  - Performed by 3rd party
- Deltek Open Plan **110** days
- Aurora **102.5** days

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Results

- Multiple sources reveal the effect of the Scheduling Engine
- For larger projects (>1,000): Aurora has been able to find project durations **SIGNIFICANTLY** shorter than other software for the same data set.
- Much of the potential improvement offered by modeling resources is being squandered.
- Resource leveled schedules are sub-optimal

Planning & Execution

- Initial Schedule benefits
- Execution benefits even MORE
  - If scheduler is inefficient, every delay will be magnified because re-allocation of resources will be deficient

Benefits of Sophisticated Underlying Scheduler

- Results in a better **initial** schedule
- **Execution**: Schedule is more flexible and better able to accommodate change.
  - Schedule is “self-aware” of what tasks can most easily be moved. I.e., tasks store information about what placed it where it is placed.

Analogy: Chess

Chess mathematically is similar to resource loaded scheduling.

- Easy: Create basic rules to play
- Hard: Win against other intelligent players

Resource Leveling in most software is analogous to 'Easy' chess solution

Each move analogous to execution mode update, challenge continues throughout game/plan

Take Aways

- Scheduling engine is critical
- Paying up to 100% penalty due to the scheduling engine
- Changing to an improved scheduling engine is probably the greatest potential improvement available to your project
  - Just press a different button
- Use more than 1 scheduling engine

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Questions?

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Thank You For Attending!

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