A large industrial facility, likely an aerospace manufacturing plant, with several large rocket engines on display. Workers in hard hats are visible in the background. A Boeing logo is visible on the wall. The text is overlaid on the image.

# NEED FOR & BENEFITS OF ADDITIONAL REAL-WORLD PROJECT MODELING CAPABILITIES PART 2

IEEE Aerospace Conference 2025

Rob Richards, PhD  
Stottler Henke Associates, Inc.

Stottler  Henke



Many of Needs learned from NASA

Other Sources of Lessons from Boeing, LANL,  
GDEB, Bombardier, Axiom Space, ...

Aurora Software incorporates all of these lessons and  
is licensed to all of NASA

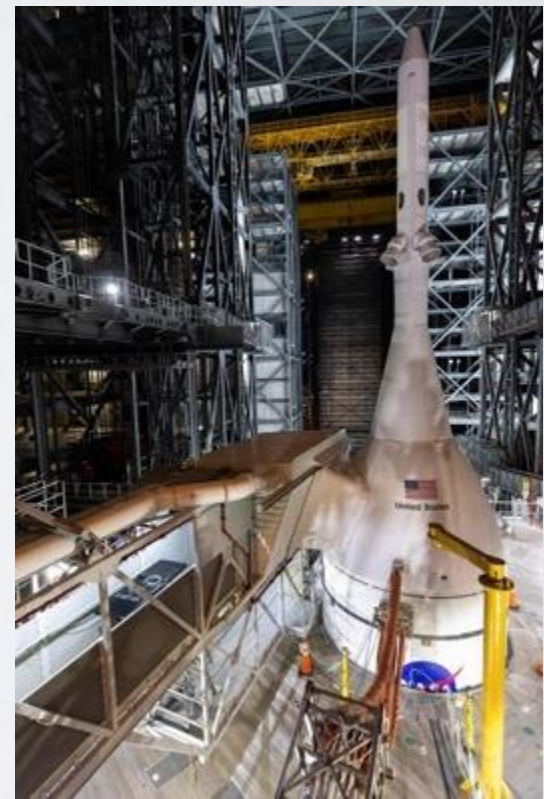
NASA has designated Aurora a Small Business Innovation Research  
Success Story

NASA created a Hallmark of Success video about Aurora

NASA has featured Aurora in multiple articles

# LESSONS & RESULTS

- Project models require more real-world constraints
  - Significant productivity lost due to inferior model details
- Learn from the human schedulers
- Model to level of detail required
- Reveal & explain the schedule
- Easy & fast to perform scenarios / what-ifs
- Results: Reduced project duration & greater transparency



# PROJECT MODEL NEEDS TO BE REALISTIC

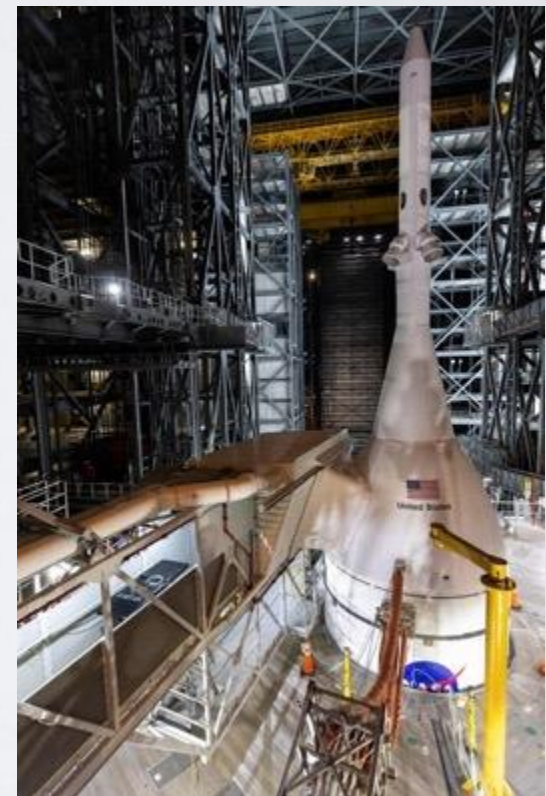
- Inability to model many real-world situations causes model to update inaccurately during execution

# EXECUTION EXCELLENCE

1. Model to the level of detail needed
2. Generated Global Priorities based on model & current situation
3. Humans make final decisions on what to work based on global priorities & other real-world factors, then update model with status

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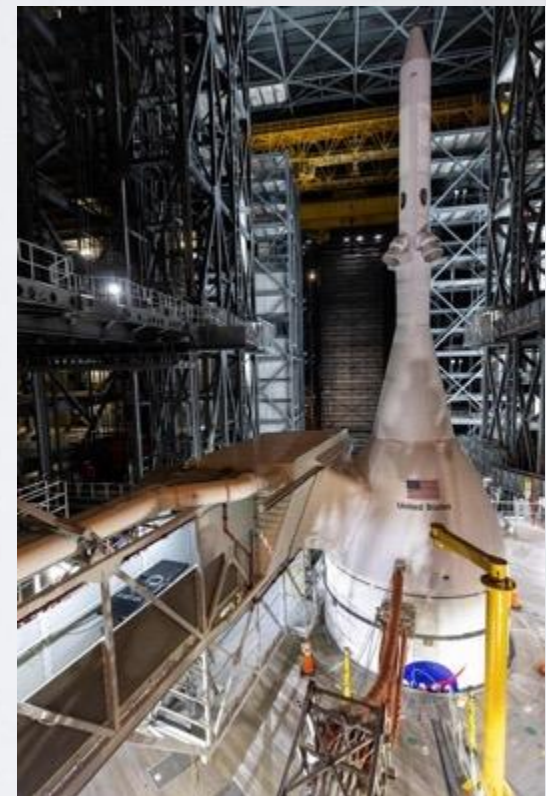


# LEARN FROM HUMAN SCHEDULERS

- Different scheduling applications generally require some different modeling capabilities, but many overlap
  - Human experts help drive the best decision per what non-standard modeling capabilities are most apropos
- When decisions / tradeoffs need to be made, use the expertise of expert schedulers
  - So that the scheduling system reacts as a human expert wants it to
  - E.g., when to work overtime, when to outsource

# LESSONS & RESULTS

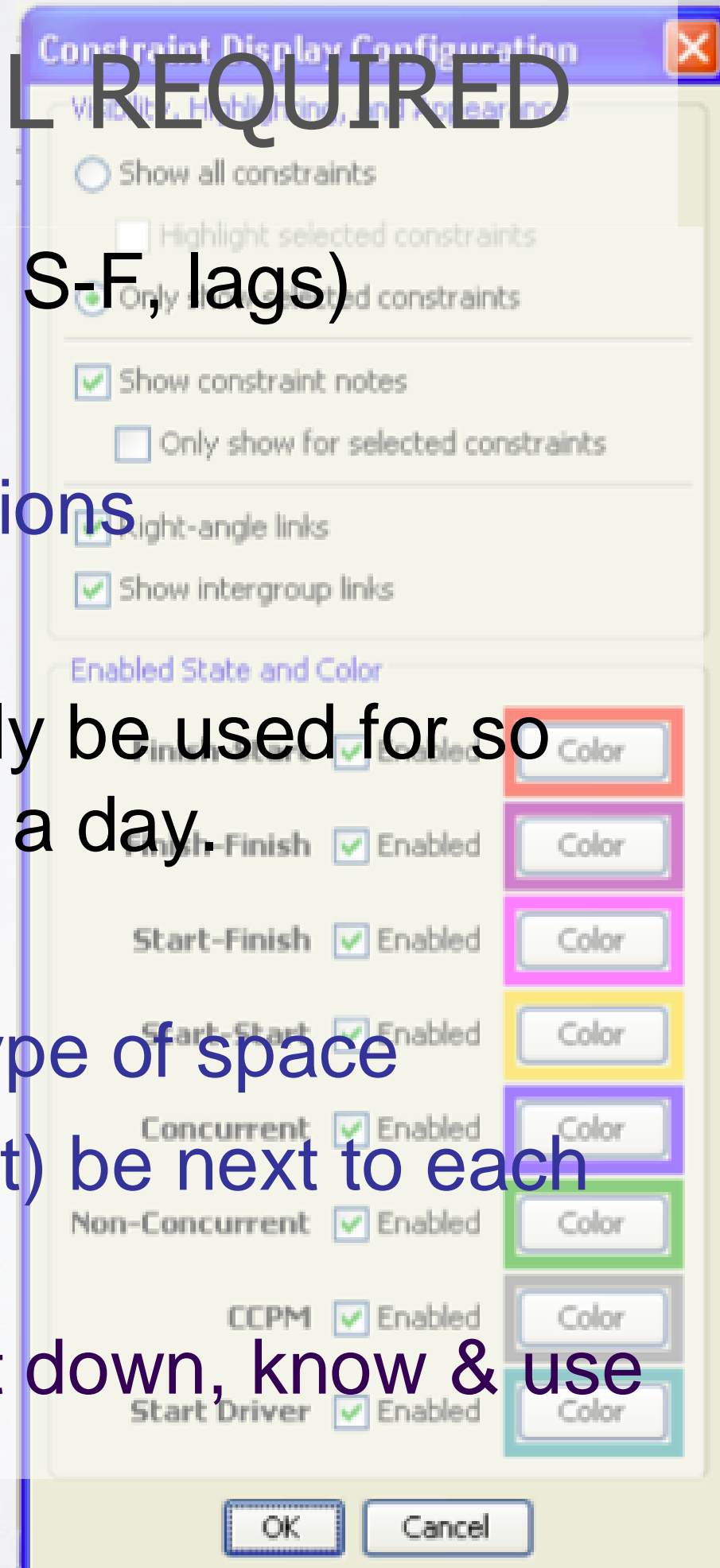
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# MODEL TO LEVEL OF DETAIL REQUIRED

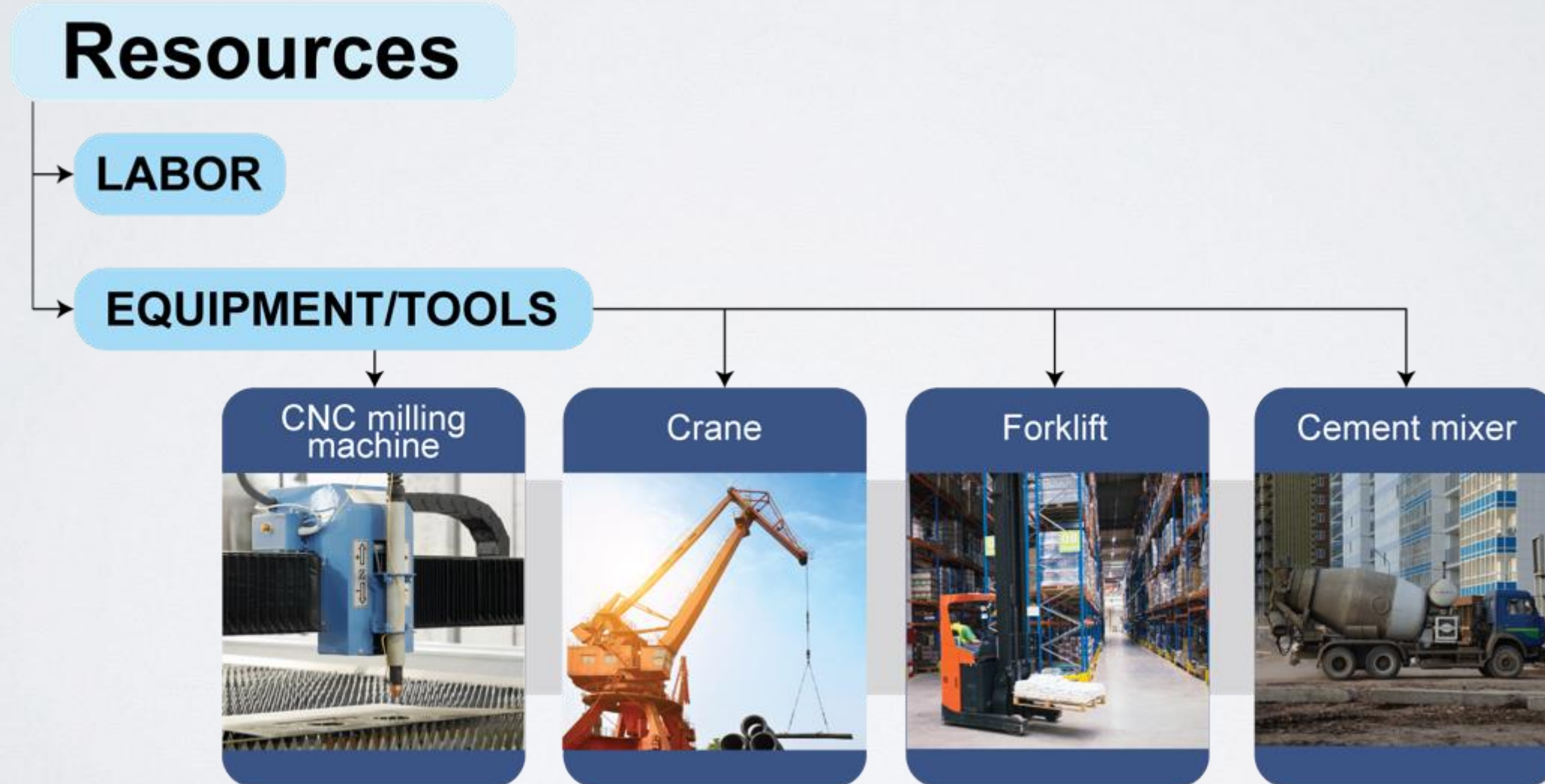
- Technical constraints (E.g., F-S, F-F, S-F, lags)
- Resources
  - Labor: Occupation, skills, certifications
  - Equipment, Tools (e.g., cranes)
- Usage constraints – e.g., tool can only be used for so many hours continuously &/or during a day.
- Spatial / physical space – e.g.,
  - job requires a certain location or type of space
  - two elements should (or should not) be next to each other
- Equipment substitutions – equipment down, know & use substitutes



# HIERARCHY OF RESOURCES



# EQUIPMENT RESOURCES



# EQUIPMENT SUBSTITUTIONS

- Equipment down, know & use substitutes

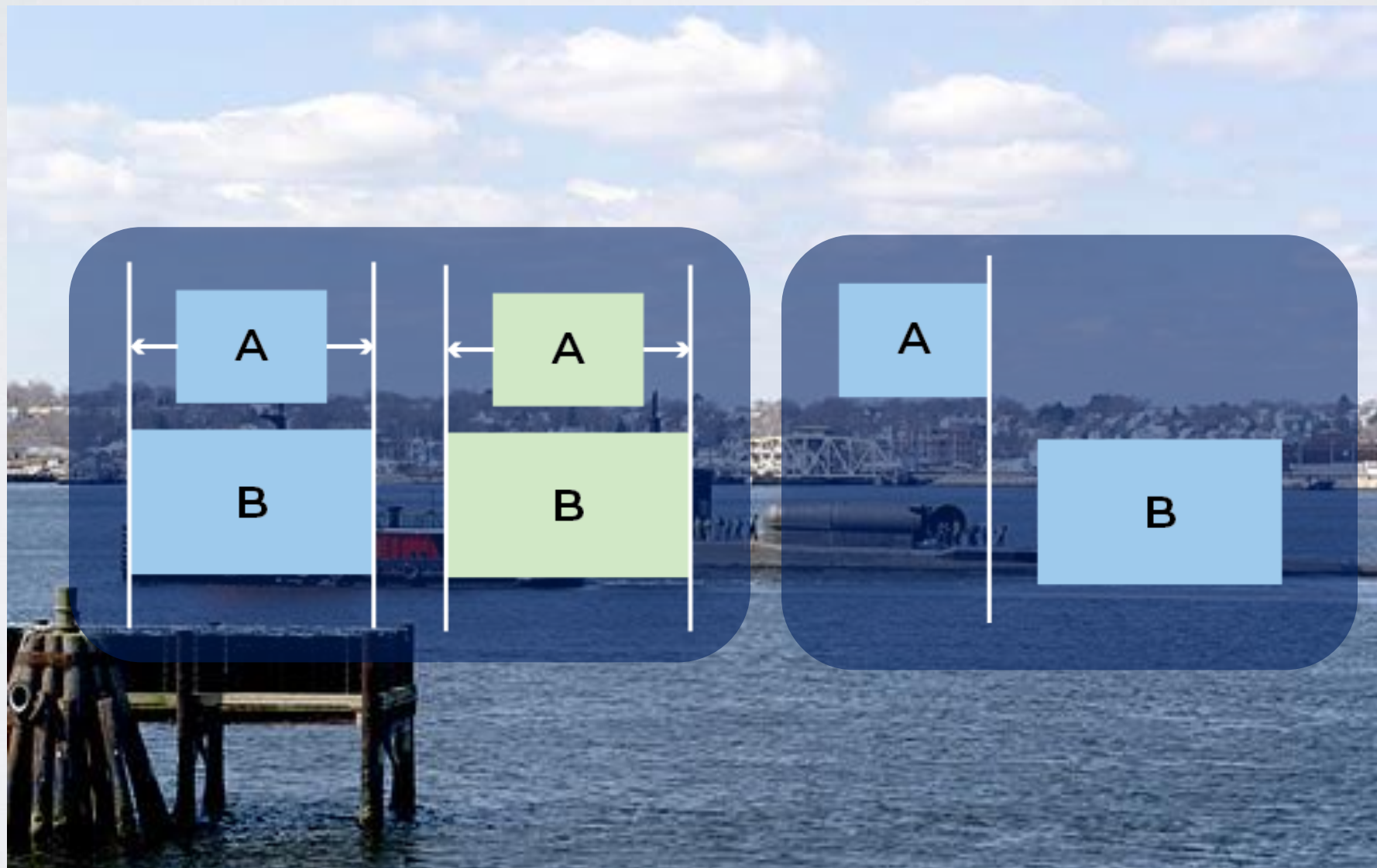


# EQUIPMENT: USAGE CONSTRAINTS

- E.g., tool can only be used for so many hours continuously &/or during a day.



# CONCURRENT & NON-CONCURRENT

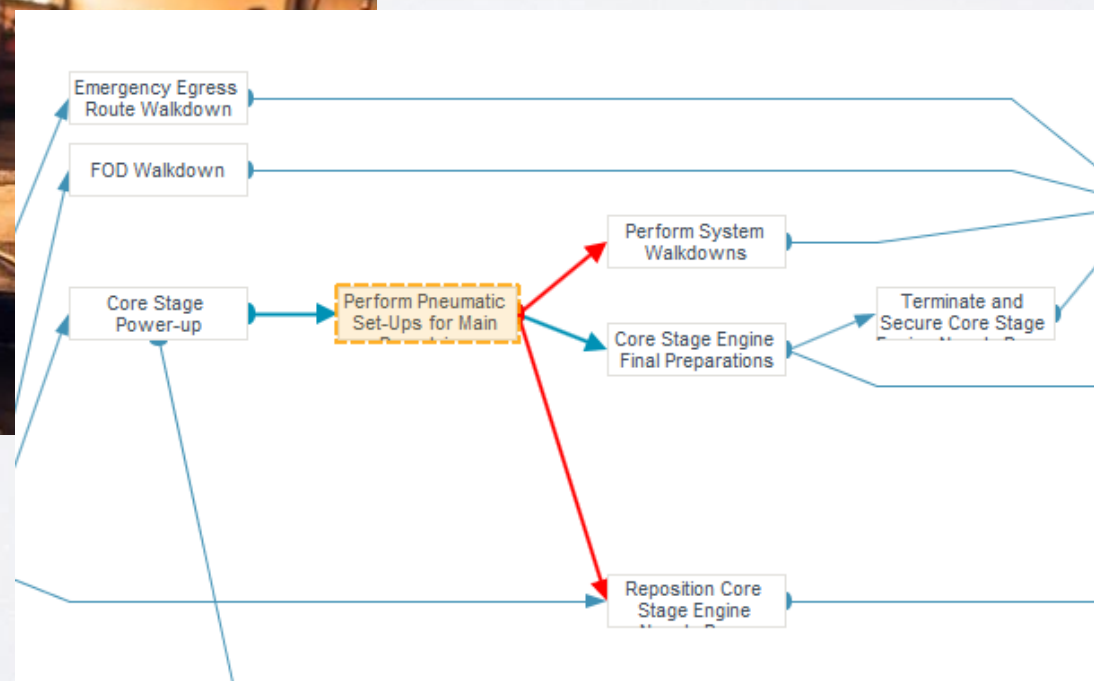


# SPATIAL / PHYSICAL SPACE CONSTRAINTS

- For example:

Job requires a certain location or type of space

Two elements should (or should not) be next to each other  
Concurrent or non-concurrent constraint



# ERGONOMIC CONSTRAINTS – INDIVIDUAL LIMITATIONS ON WORK CONDITIONS

- E.g., only work so long:  
continuously requiring kneeling, and/or  
so much kneeling during a shift





# SHIFT-BASED CONSTRAINTS

- This is a set of properties that allows the user to control how jobs interact with shift breaks
- Only start a job if it can finish during the same shift
- Job can only be performed during the day shift
- Job can take multiple shifts, but requires same resource constraints

# ALTERNATIVE RESOURCE COMBINATIONS

- a task may require a Plumber and a Mechanic; however, there may also be Cross-trained person that can perform Plumber and Mechanic operations. So, the resource requirements for a task could be  
(Plumb & Mech) OR (Cross-trained).
- For cases where the same number of people are always needed, the resource requirement could be  
((Plumb & Mech) OR (Cross-trained & Mech) OR (Plumb & Cross-trained) OR (2 Cross-trained)).
- Aurora's intelligent scheduling assigns the Cross-trained individuals to maximize throughput

# SUCCESSOR START WITHIN LIMITED TIME FRAME

Normal

Finish <= Start

Offset: 0

Max Offset:

offset calendar  Select

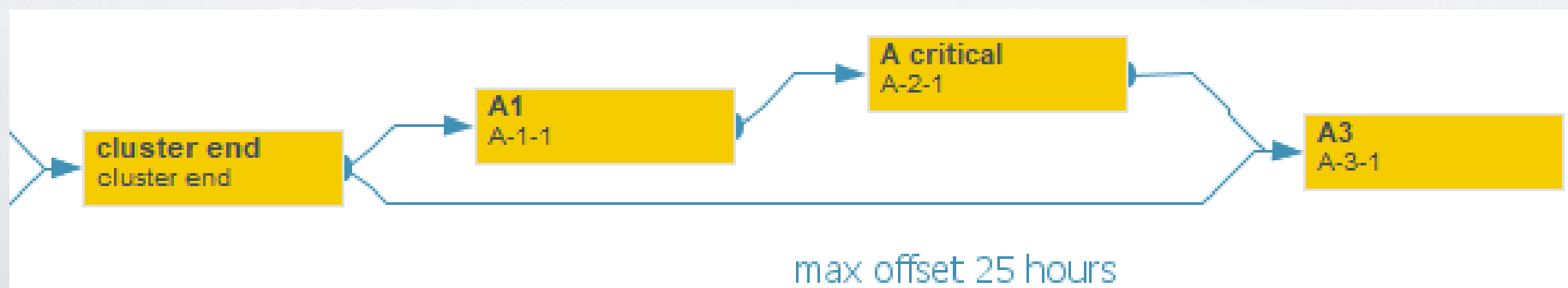
Core Properties

Note:

Bridging Constraint:

Active:

Close



# ENHANCED CONSTRAINT DIALOG

**Edit Constraint**

31498041  
↓  
31499486

Normal

Not Compatible

Finish <= Start

Offset (Hours): 0

Max Offset (Hours):

offset calendar  Select

Core Properties

Constraint Category:

Justification:

Note:

Bridging Constraint:

Active:

Constraint Type: precedence

History

last updated by: none supplied  
last updated on: 09/30/2024 13:42  
last reviewed by: unknown  
last reviewed on: before July 2021  
attention counter: 0

Mark Constraint as Reviewed

Close

# INTEGRATION WITH DIGITAL TWIN

- Aurora is incorporated in the Siemens Integrated Project Planning & Execution (IPP&E) Xcelerator product.
- Links schedule tasks with digital



# MONTE CARLO RISK SIMULATION

Monte Carlo Simulation Options

Each iteration will dynamically calculate a random duration for each job, based on its distribution, then schedule.  
In combination, these runs will give a sense of the likely project outcomes.

How many iterations would you like to run?

Each iteration will write out the schedule results for analysis.  
If you select 'Compile Results' then the results will be written to one long file.  
Otherwise, each iteration's results will be written to an individual file.

Compile Schedule Results

If desired, adjust the resource configurations for use in the Monte Carlo run.  
Note that this will edit the underlying resources.

Resource Configurations

Configuration Navigation Control

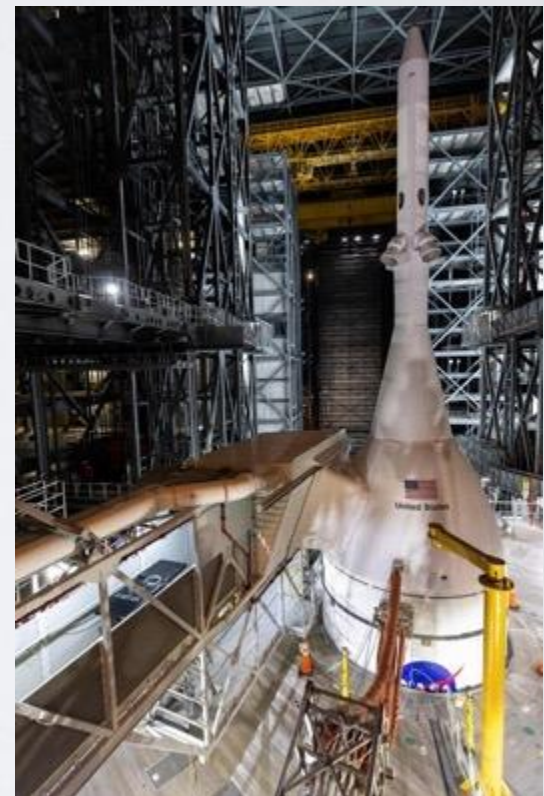
name	resource type	tracking resource	quantity	capacity plan
Boilermaker [BM]	Other	false	10	01/01/2018-12/30/2049: 10.0, 10.0
Carpenter [CA]	Other	false	5	01/01/2018-12/30/2049: 5.0, 5.0
Electrician [EL]	Other	false	20	01/01/2018-12/30/2049: 20.0, 20.0
Laborer [LB]	Other	false	15	01/01/2018-12/30/2049: 15.0, 15.0
Machine Mate + Machine Shop [OSM+ISM]	Other	false	5	01/01/2018-12/30/2049: 5.0, 5.0
Crane Operator [CO]	Other	false	2	01/01/2018-12/30/2049: 2.0, 2.0
Pipefitters [PF]	Other	false	7	01/01/2018-12/30/2049: 7.0, 7.0
Riggers [RG]	Other	false	1	01/01/2018-12/30/2049: 1.0, 1.0
Specialty Finishes [SS]	Other	false	10	01/01/2018-12/30/2049: 10.0, 10.0
Toolroom, Transportation, Warehouse [WH]	Other	false	1	01/01/2018-12/30/2049: 1.0, 1.0
Drydock Rigger / Painters [PA]	Other	false	10	01/01/2018-12/30/2049: 10.0, 10.0
Quality Assurance [QA]	Other	false	15	01/01/2018-12/30/2049: 15.0, 15.0
Safety [SA]	Other	false	1	01/01/2018-12/30/2049: 1.0, 1.0

30 rows in table

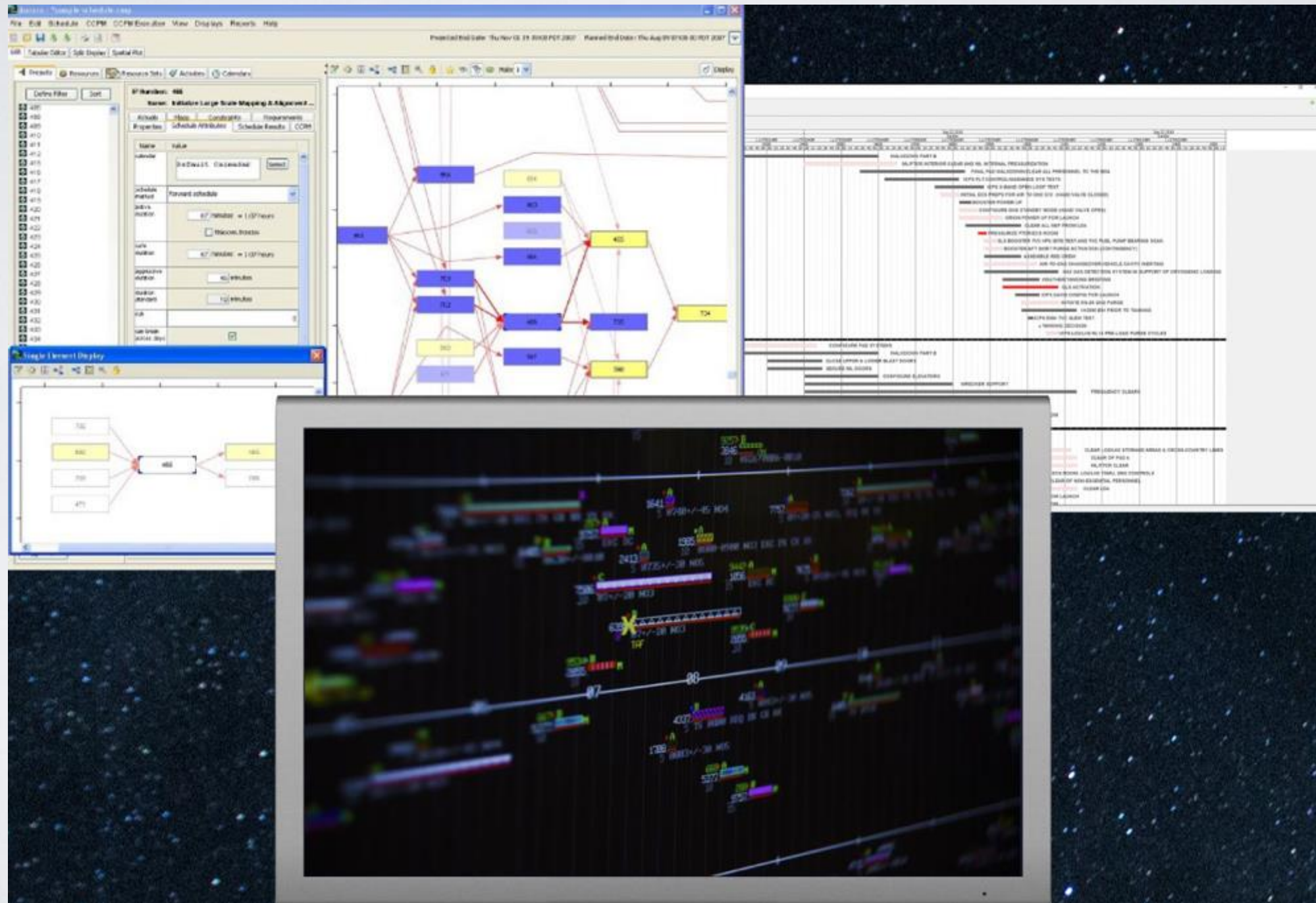
OK Cancel

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# REVEAL AND EXPLAIN THE SCHEDULE





# PROJECT NETWORK

File Edit Schedule Utilities CCPM CCPM Execution View Displays PERT Chart Reports Help

New Open Save Print Preview Schedule

Projected End Date: 04/02/2016 17:00 Planned End Date: 04/15/2011 15:24

Edit Gantt Chart PERT Chart Gantt Chart Histogram Plot Tabular Editor

Projects Resources Resource Sets Activities Calendars

Instances Filter Sort Exp: CCPM-EWS-005 <no job>

- Site work Outfall Tunnels
- Site work Intake Pump Station
- Coloso substation expansion (
- Site work Coloso to West Tunn
- Construction camp 1 Construct
- Piping - small bore - above gr
- Cable tray, conduit, raceway R
- Wire and cable Reverse Osmo
- Instrumentation Reverse Osmo
- Electrical equipment Reverse O
- Mechanical equipment Reverse
- Structural steel Reverse Osmo
- Architectural Reverse Osmosis
- Piping - large bore - above gr
- Piping - small bore - above gr
- Cable tray, conduit, raceway R
- Wire and cable Reverse Osmo
- Instrumentation Reverse Osmo
- Electrical equipment Reverse C
- Concesión Marítima NDP
- Modificación Concesión Marítin
- Obras Portuarias
- Interconexión sobre 23>kV
- Construcción de Obra Hidrául
- Construcción de Obra Hidrául
- Solicitud de Atravesio con Nora
- Solicitud de Atravesio con Blan
- Solicitud de Atravesio con Gas
- Solicitud de Atravesio con LAT

Project: CCPM-EWS-005  
Job:  
CSMP Summary:  
Task Name: Electrical equipment Reverse Os...

Property Search:

Properties Details

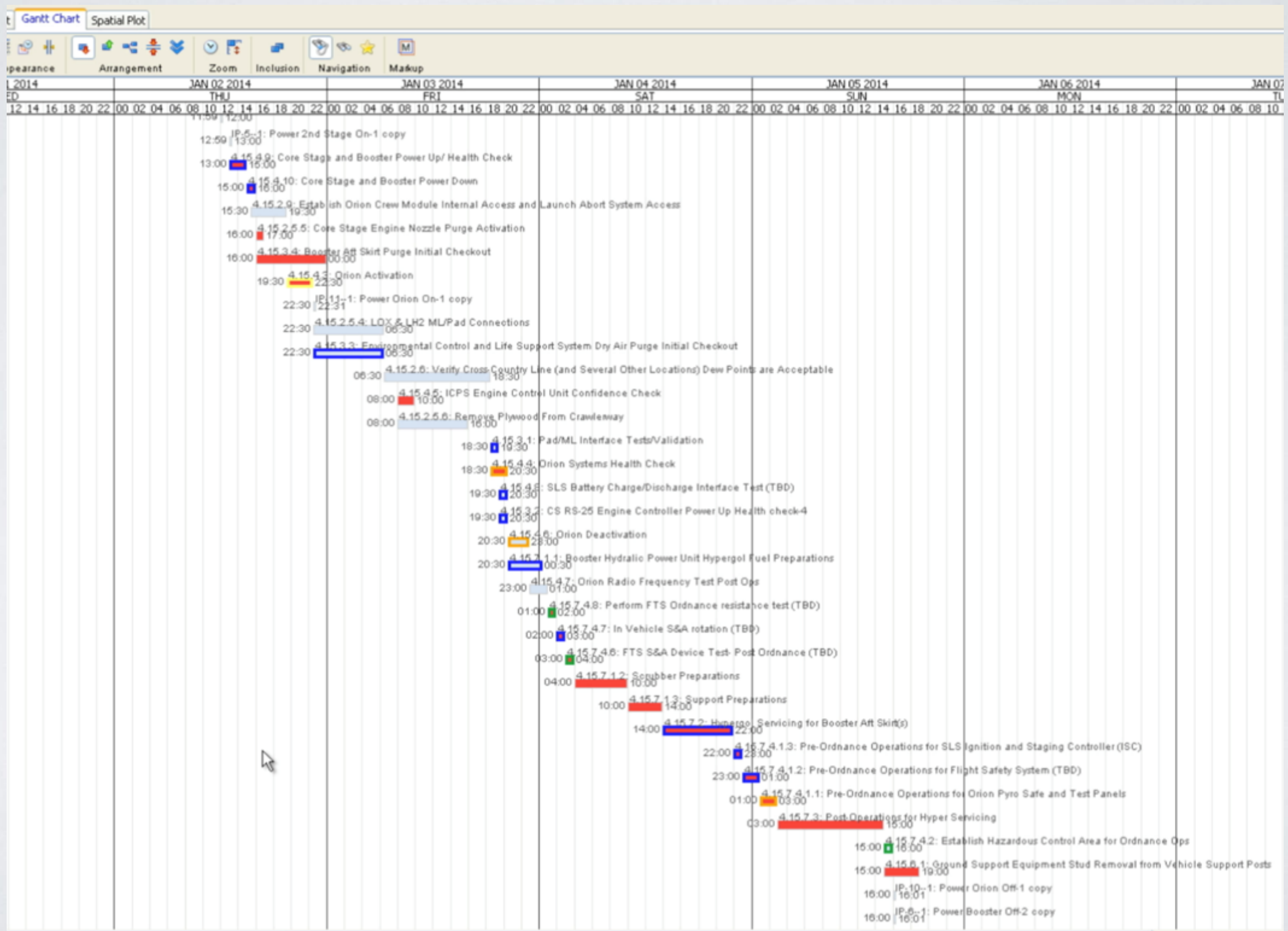
activity code: uipment Reverse Osmosis Fa  
task name: uipment Reverse Osmosis Fa  
job:  
CSMP Summary:  
project: CCPM-EWS- Select  
external id: 11  
description:  
work assignment:  
job type: In Sequence  
position:  
user attributes:  
name value  
ProjectUID 180040

Add Remove

Configuration Appearance Arrangement Zoom Inclusion Navigation Markup

Flow Halo: 0 Display

# GANTT CHART COLOR-CODED PER USER DESIRED CRITERIA



# RESOURCE CONTENTION: VISUAL

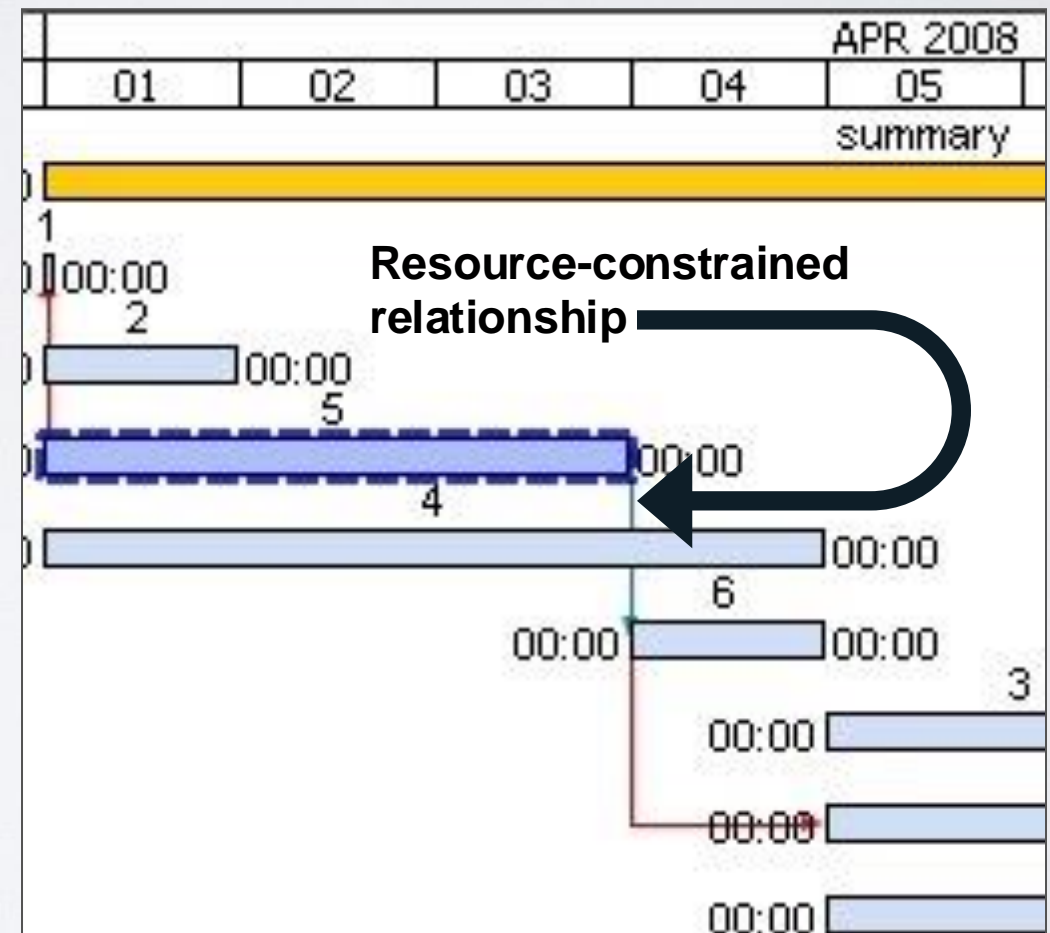
- Viewing resource contentions

In this sample schedule, each task has a resource requirement attached as follows

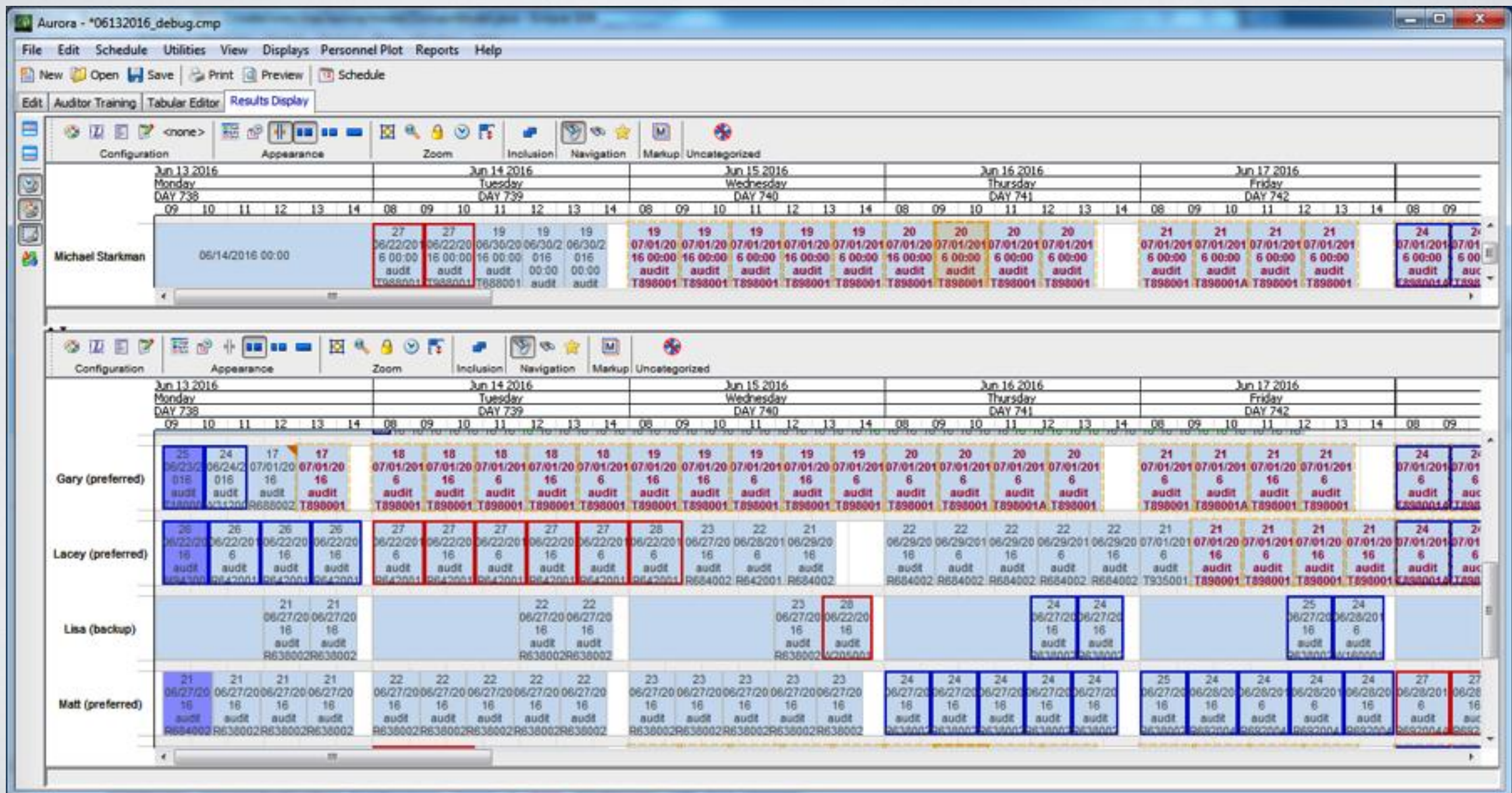
Task #	Resources Needed
2	1
3	2
4	2
5	2

Note that there is a total amount of only 5 resources. Tasks 2, 4, and 5 are started at the same time (5 resources used). Task 2 completes, but there are not enough resources left to start Task 6, so Task 6 must wait until Task 5 is complete.

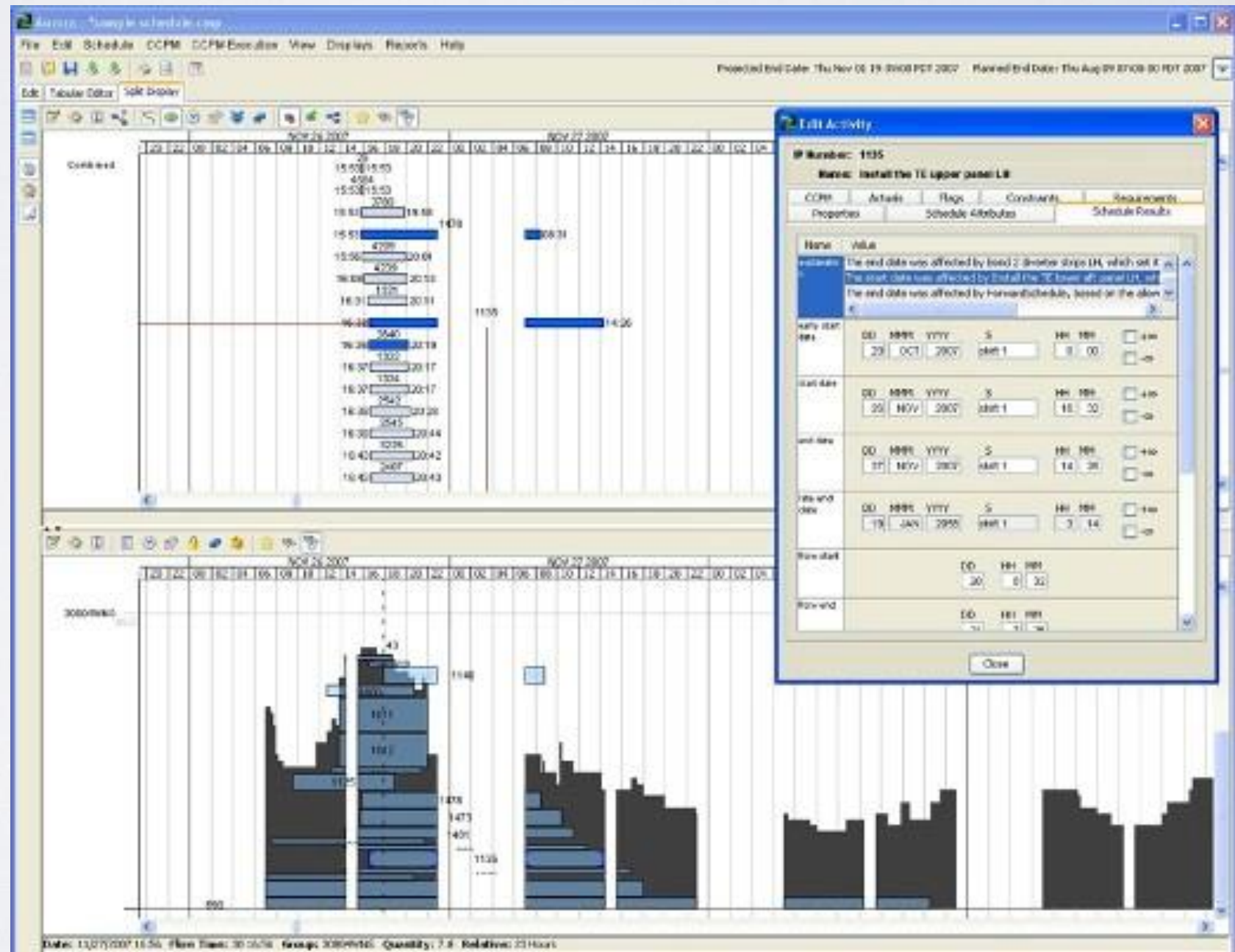
Aurora shows you this resource-constrained relationship with a blue-grey line between the two Tasks.



# TEAM ASSIGNMENT DISPLAY



# SPLIT VIEW SHOWING GANTT CHART SAME TIME SLICE AS HISTOGRAM, SHOWING ACTIVITIES CONSTITUTING RESOURCE NEED FOR ONE TIME INSTANCE



# NETWORK DIAGRAM W/ MINI-MAP DISPLAY & SINGLE ELEMENT VIEW

Aurora - \*GLP\_Goldratt\_Brazil\_in Aurora 2013-11-18.cmp

File Edit Schedule Utilities CCPM CCPM Execution View Displays PERT Chart Reports Help

Planned End Date: Mon Feb 04 09:00:00 PST 2013

**Projects** Resources Resource Sets Activities Calendars

Instances Filter Sort E

- Comentários RM Petrobras - Sistemas
- Requisição de materiais - Detetores d
- Modelagem 3D
- Modelagem de Instrumentação
- Folha de Dados
- Comentários FD Petrobras - Termôme
- Folha de Dados - Válvulas PSV'S (top
- Folha de dados - Termômetro
- Folha de dados - Transmissor de Pre:
- Comentários FD Petrobras - Válvulas I
- Folha de dados - Chave de Nível tipo
- Comentários FD Petrobras - Sistema c
- Comentários FD Petrobras - Sistema C
- Requisição de materiais - Transmisso
- Comentários FD Petrobras - Transmis
- Folha de dados - Válvulas Bloqueio EI
- Comentários FD Petrobras - Válvulas I
- Folha de dados - Válvulas Esfera Atua
- Comentários FD Petrobras - Válvulas I
- Folha de dados - Detetores de Gás (H
- Comentários FD Petrobras - Detetores
- Folha de dados - Detetores de Gás (H
- Comentários FD Petrobras - Detetores
- Verificação do Desenho do Fornecedo
- Verificação de DF e Certificação - Det
- Verificação de DF e Certificação - Cha
- Verificação de DF e Certificação - Sist
- Verificação de DF e Certificação - Ter

**Project: GLP\_Primavera\_XER**

Job:  
CSMP Summary:  
Task Name: Verificação de DF e Certificação - ...

Property Search:

**Properties** Details

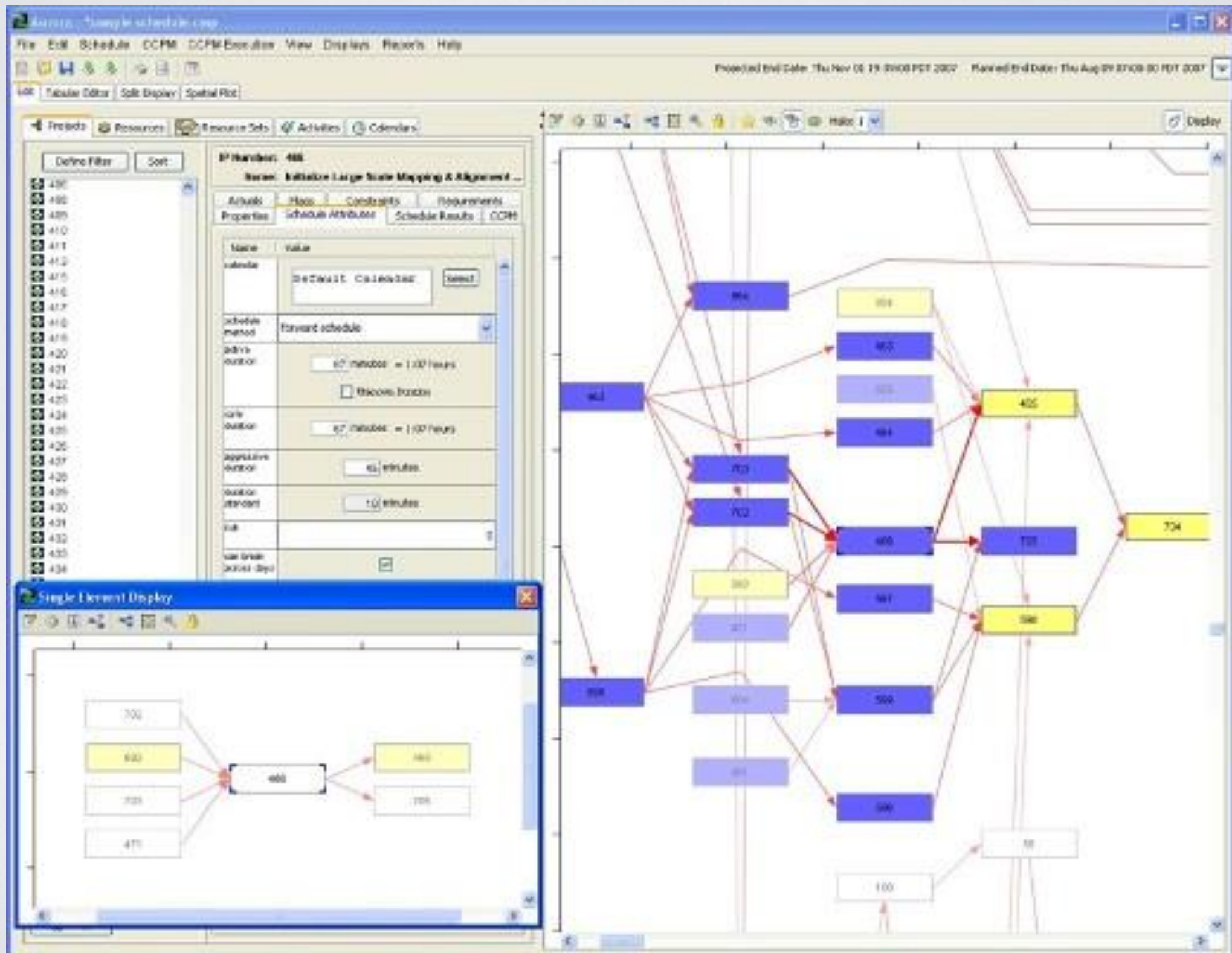
IP Number: e Certificação - Termômetro  
task name: e Certificação - Termômetro  
job:  
CSMP Summary:  
project: GLP\_Primavera\_XER  
external id: 2148  
description:  
work ass:  
job:  
pos:  
use att:

**Single Element Display**

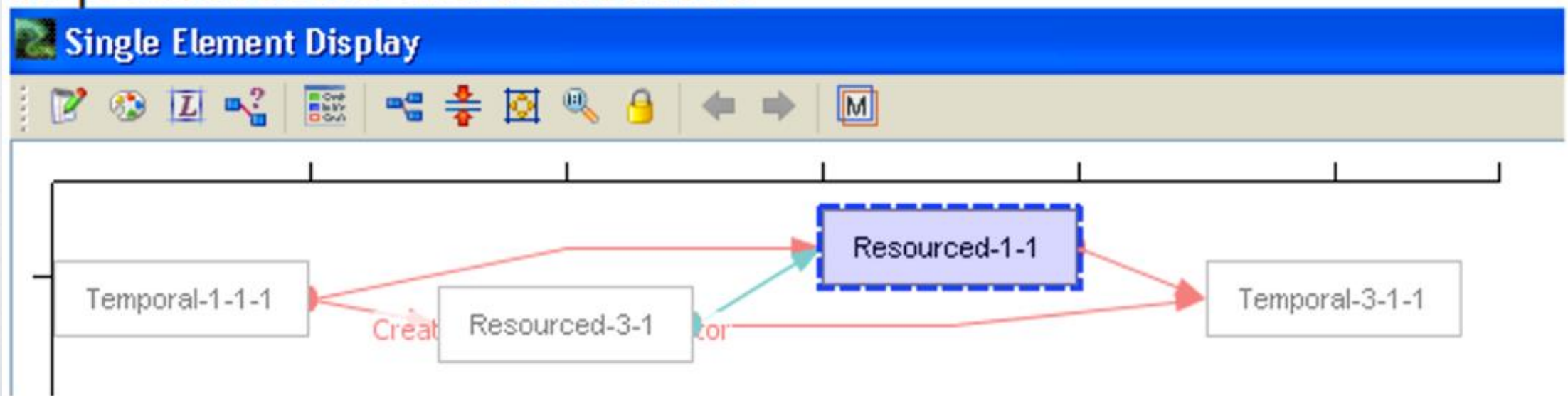
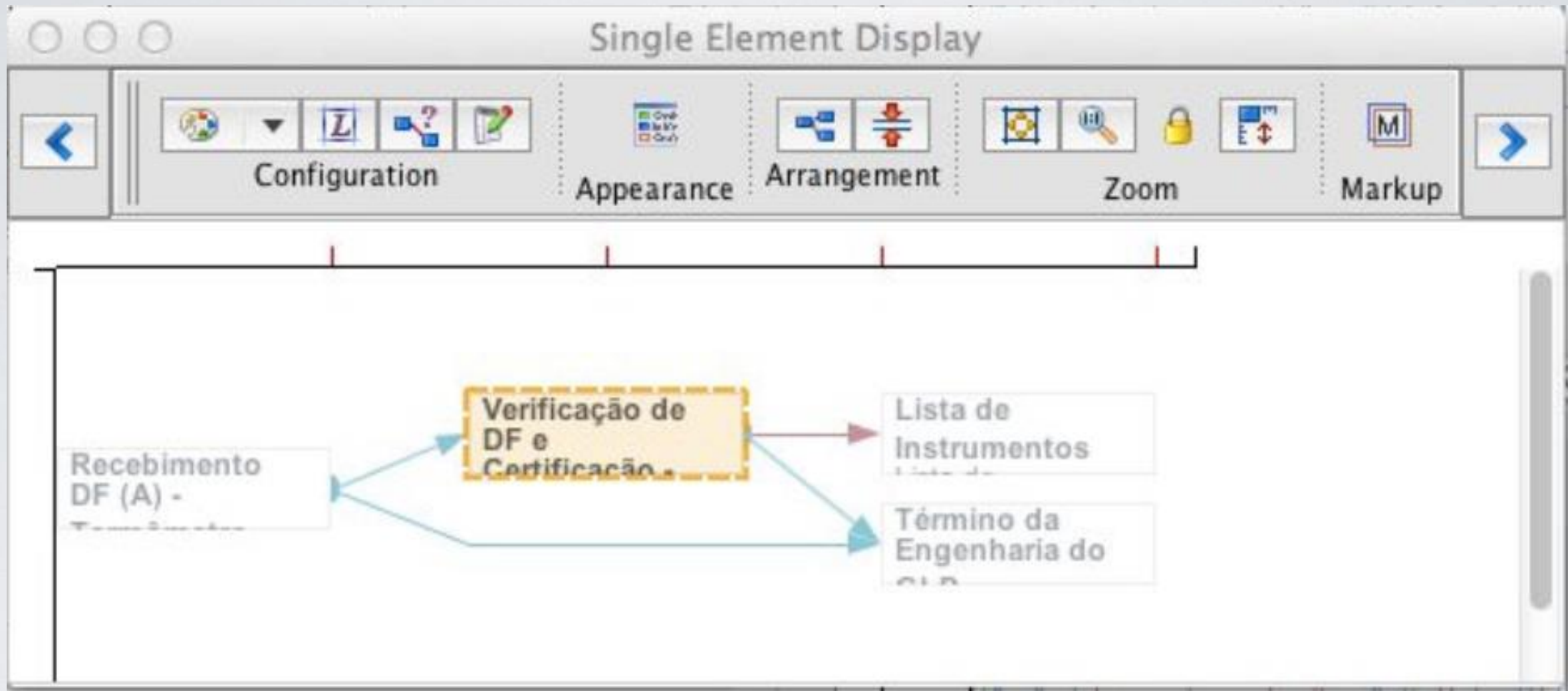
Recebimento DF (A) -> Verificação de DF e Certificação -> Lista de Instrumentos  
Verificação de DF e Certificação -> Término da Engenharia do

The screenshot displays the Aurora software interface. The main window shows a network diagram with a grid background. A mini-map is visible in the top right corner. A 'Single Element Display' window is open, showing a detailed view of a task named 'Verificação de DF e Certificação'. The diagram includes various nodes and connections, such as 'PATEC Emissão', 'Compra - Termômetro', and 'Recebimento DF (A)'. The interface includes a menu bar, a toolbar, and a sidebar with project navigation options.

# NETWORK DIAGRAM SHOWING SINGLE-ELEMENT VIEW OPTION

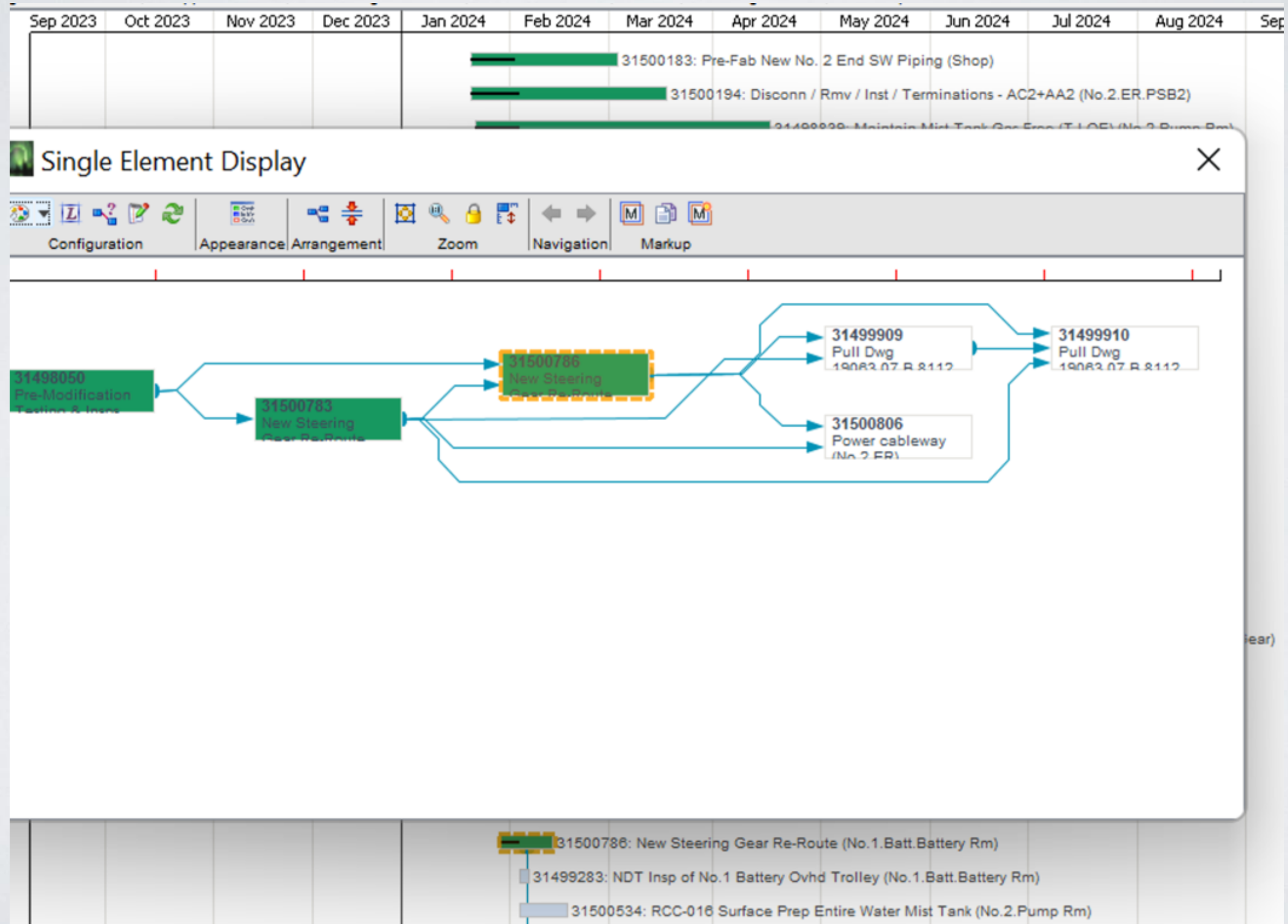


# SINGLE ELEMENT DISPLAY





# SINGLE ELEMENT DISPLAY FROM GANTT CHART



# BURNDOWN CHART

Burndown by Day (start date)



# EXPLAIN THE SCHEDULE

Name: Post-Operations for Hyper Servicing	
Property Search: <input type="text"/>	
Properties   Details   Geometry   Duration Info   Schedule Attributes   <b>Schedule Results</b>   CCPM   Analysis   Actuals   Integrations   Flags   Constraints   Requirements	
scheduled order	
42	
explanation	<p>The end date was affected by the maximum flow time of 7300.00 days, which set it to 12/27/2033 00:00</p> <p>The start date was affected by <a href="#">Hypergol Servicing for Booster Aft Skirt(s)</a>, which set it to 01/03/2014 00:00</p> <p>The end date was affected by <a href="#">Establish Hazardous Control Area for Ordnance Ops</a>, which set it to 12/25/2033 10:49</p> <p>The start date was affected by <a href="#">Hypergol Servicing for Booster Aft Skirt(s)</a>, which set it to 01/04/2014 22:00</p> <p>The start date was affected by ForwardSchedule, restricted by availability of <a href="#">Hazardous Pad-1</a>; waiting for <a href="#">Pre-Ordnance Operations for Orion Pyro Safe and Test Panels</a>, which set it to 01/05/2014</p> <p>The end date was affected by ForwardSchedule, based on duration and start time, which set it to 01/05/2014 15:00</p>

The start date was affected by the flow start time, which set it to 12/01/2017 00:00

The end date was affected by the maximum flow time of 7300.00 days, which set it to 11/26/2037 00:00

The start date was affected by [null--66](#), which set it to 12/27/2017 11:00

The end date was affected by [null--108](#), which set it to 10/29/2037 12:00

The start date was affected by [null--66](#), which set it to 01/06/2018 11:00

The start date was affected by ForwardSchedule, restricted by availability of [LWUA](#); waiting for [null--72](#), which set it to 01/16/2018 11:00

The end date was affected by ForwardSchedule, based on duration and start time, which set it to 01/17/2018 17:00

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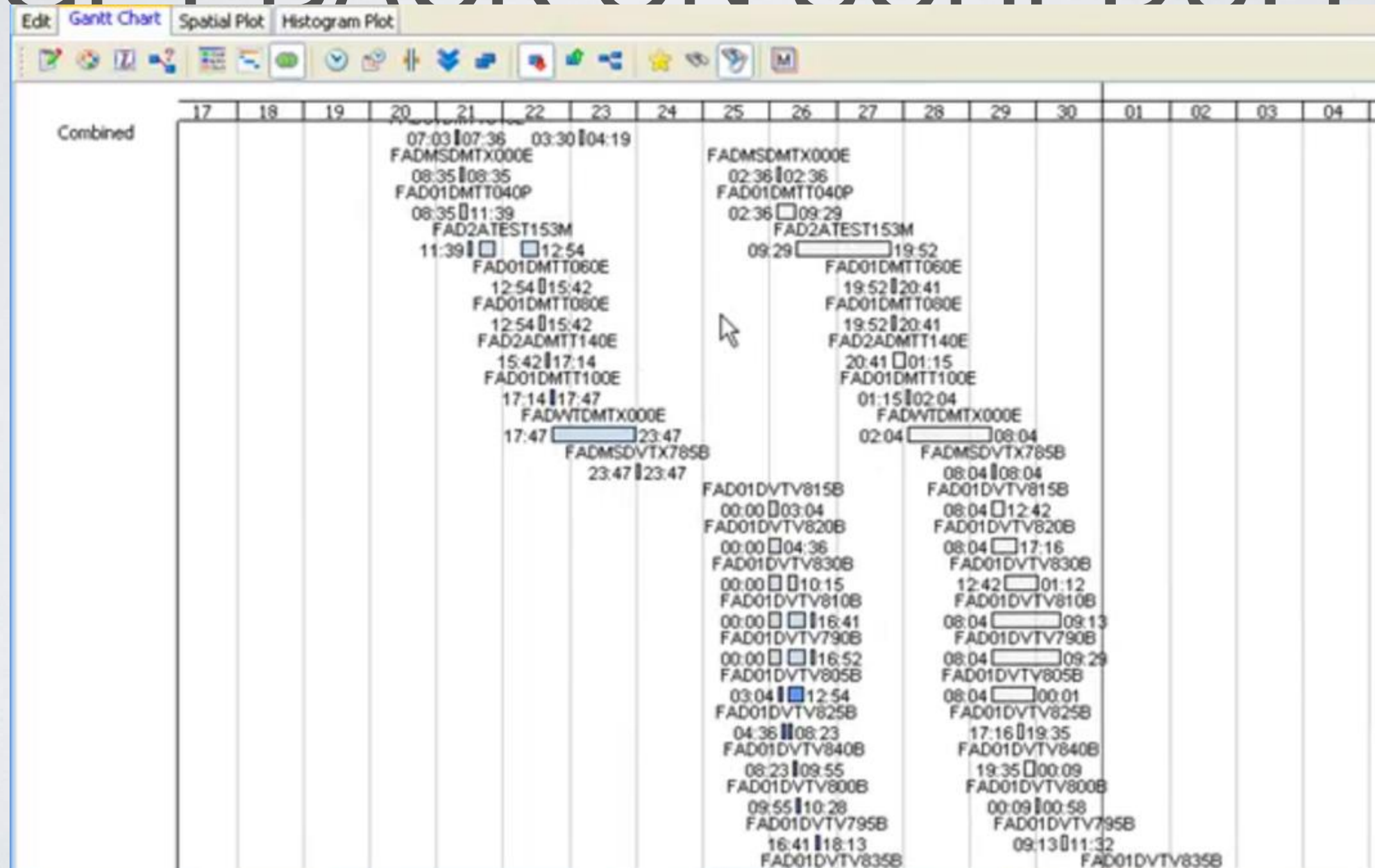


# EASY & FAST TO PERFORM SCENARIOS / WHAT-IFS

- Wall clock minimization to run a scenario critical so human schedulers will actually run them
- Provide ways to graphically compare results



# WHAT-IF: WORK WEEKEND TO GET BACK ON SCHEDULE



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# BENEFITS OF SOPHISTICATED UNDERLYING SCHEDULER

- Results in a more realistic 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 why it was placed (where it is placed).





# SIGNIFICANT PRODUCTIVITY LOST DUE TO NON-REALISTIC PROJECT MODELING

- If current tool can not model the project model correctly, it can not execute efficiently.

# AURORA LICENSED TO NASA, LANL, BOEING

## AURORA-VIEWER FREE FOR ALL

- <https://aurorascheduling.com/aurora-viewer/>
  - Primavera P6 XER file viewer (free)

# QUESTIONS?

IEEE Aerospace Conference  
2025

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Stottler  Henke

