Common Tool for Intelligent Scheduling / Critical Chain Project Management for US Navy & Contractor Shipyards

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Enhancements to Traditional Project Management

- Project Management
- Intelligent Scheduling
- Critical Chain
Benefits

Current Benefits

Greater throughput with same resources

Execution driven by global priorities
US Navy Shipyards & Contractors Utilize Many Scheduling / Project Management Tools

Primavera P6
Artemis
PS8 (by Sciforma)
Open Plan (by Deltek)
Microsoft Project
PSS
Databases / Non-traditional PM tools: e.g. SQL Server
Navy & Contractor Tools

**Project Management:**
- Primavera P6
- Artemis
- PSS
- Open Plan
- MS Project
- PS8
- Aurora

**Intelligent Scheduling:**
- Open Plan
- Aurora

**Critical Chain:**
- PS8
- Aurora
Aurora Functionality

- Project Management
- Critical Chain
- Intelligent Scheduling

Aurora

Stottler Henke
Smarter Software Solutions
Interfaces: Aurora can interface with all others.
Build in current tool: Benefit from Intelligent Scheduling &/or Critical Chain

Aurora: Intelligent Scheduling & Critical Chain

- PS8
- Open Plan
- Artemis
- MS Project
- Primavera P6
- PSS
PSS Case Study (1)

• PSS – Solution used by US Navy
  – Single project only
• Developed Aurora import capability
• Successfully scheduled sample PSS provided by the Navy
  – Informed that PSS project models have not been successfully scheduled in other tools
PSS Case Study (2)

- Multi-project: Aurora successfully performs multi-project scheduling from multiple PSS models
  - Over 70,000 total tasks
  - Capability not currently available to the Navy
Projects Completed by

• Synchronized effort of multiple resources

• Goal of *Intelligent Scheduling*: optimize the synchronization of resources and other constraints to minimize the duration of the project
Intelligent Scheduling: Expert Knowledge & Experience Needed

• Mathematics is not enough (Problem is NP-Complete, takes exponential time for optimal solution)
• Encoding expert knowledge & experience in software can make this knowledge available to others
  – Found domain specific heuristics many times beneficial in other domains.

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Aurora Summary

World’s most intelligent scheduling engine and standard project management features

- Multiple-pass intelligent resource-constrained scheduling
- Mixed-mode scheduling providing both forward and backward scheduling, available on a task-by-task basis
- Schedule Rationale – Aurora includes the rationale for each task on why it was schedule where it was schedule
- Designed for customization
- Designed for integration
Aurora Customers (1)

**The Boeing Company**

The Boeing Company uses Aurora to prioritize production of the Boeing 787 Dreamliner™. Aurora’s dynamic assembly schedule adapts to real-time production variations, so Boeing can produce aircraft as efficiently as possible.

**Aurora-ProPlan**

Aurora-ProPlan is a component of the Intelligent based Manufacturing (IBM) initiative at Pfizer. It adds capabilities necessary to perform pharmaceutical production optimally.

**NASA: Kennedy Space Center**

Aurora schedules the use of floor space and other resources at the Space Station Processing Facility, the world’s largest low-particle clean room.

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**Air Force Satellite Scheduling**

The Aurora intelligent scheduling framework has been applied to Air Force Satellite Control Network (AFSCN) scheduling to create an automatic scheduling and deconfliction capability called MIDAS. [Read the MIDAS Story](#)

**MASS General Hospital**

Aurora is used by the Massachusetts General Hospital to schedule its medical residency program. Aurora reduces the time and effort needed to generate schedules, and provides better support for the hospital’s complex staffing needs.

**Bombardier Learjet**

Aurora helps Bombardier Learjet schedule their airplane assembly operations more quickly, so they can handle production rate changes and component delivery delays more effectively.
Aurora Customers (2)

**Automobile Industry**
A major automobile manufacturer selected Aurora to optimize its vehicles for destructive and non-destructive crash testing.

**Mitsubishi Heavy Industries**
Mitsubishi Heavy Industries (MHI) is using Aurora to accelerate its production of Boeing 787 Composite Wing Boxes.

**United Space Alliance**
United Space Alliance included Aurora in the design of Temporis, a scheduling system targeted for use by NASA crew members on board next generation spacecraft during deep space missions.

**Korean Aerospace Industries**
Aurora helps Korean Aerospace Industries (KAI) to schedule production of composite parts for Boeing’s Dreamliner.

**Navy: Submarine Support**
The US Navy has selected Aurora-CCPM™ software to schedule submarine maintenance operations at the Naval Submarine Support Facility (NSSF).

**Clipper Windpower**
Clipper Windpower selected Aurora to schedule the manufacturing of its Liberty series wind turbine, the largest wind turbine made in the United States.
Value Proposition: Aurora

The EXACT same project can be completed significantly faster by using the intelligent scheduling engine in Aurora, versus ANY other software available.

- That is, once the resource-loaded project model is developed, using Aurora will determine a shorter initial schedule, and then by using Aurora during the execution of the project Aurora will make more efficient decisions based on the reality on the ground so the execution results in a shorter project duration versus any other software available.
Why order matters?

The example below involves jobs using two resources, purple and white.

Schedule 1: B before C

Schedule 1: C before B
Aurora-CCPM Summary

Enterprise-Level Critical Chain Project Management Software

Multi Project

Provide GLOBAL view of entire project – prioritize execution to maximize overall project benefit
Potential Workflow with P6: Flowchart for Critical Chain

- **Build in Primavera P6**
- **Schedule in Aurora**
  - Transfer to Aurora via XER
  - Transfer results to Primavera P6
- **PMs use updated Primavera P6 model for EVM, etc.**
- **PMs use updated Aurora model for Task Priorities via Critical Chain**
- **Enter status updates**
Aurora Unique
Capabilities & Benefits (1)

Large project support
- Supports 100,000+ tasks per project

Integrates with Enterprise Software
- Oracle, SAP, proprietary systems

Multiple-pass intelligent resource-constrained scheduling
- Generates shorter project duration & shorter remaining project durations during execution

Mixed-mode scheduling providing both ASAP & ALAP scheduling, available on a task-by-task basis.
- All other critical chain software *only* provides ALAP scheduling
Aurora Unique
Capabilities & Benefits (2)

Primavera P6 Integration
• Only Critical Chain software that is designed to work with Primavera P6

Support beyond Finish-to-Start Constraints
• Only software that understands and can perform Critical Chain with S-S, F-F, etc., also supports Leads and Lags.

Schedule Rationale
• Aurora includes the rationale for each task on why it was schedule where it was scheduled

Designed for Customization
• Can be extended to work with enterprise specific needs
Aurora Unique Capabilities & Benefits (3)

Supports More Types of Constraints

• Resource constraints
• Resource Sets – job can be performed by 2 different specialists or (1 generalist and 1 specialist) or 2 generalists.
• 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
Aurora Unique Capabilities & Benefits (4)

Supports More Types of Constraints

- Skills / Certifications in addition to Occupations
  - E.g., Mechanic (occupation) with 4 additional skills or certifications
- Constraints based on status/state
  - E.g., no hot work when other conditions in effect
- Shift based constraints
  - Task needs to be completed during single shift
  - Do not start task unless x% of time left in shift
Explanation of Why each Task was Scheduled
Where it was
Schedule Results: Explanation

<table>
<thead>
<tr>
<th>scheduled order</th>
<th>explanation</th>
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<tbody>
<tr>
<td>The end date was affected by the maximum flow time of 7300.00 days, which set it to 12/27/2033 00:00.</td>
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<tr>
<td>The start date was affected by Hypergol Servicing for Booster Aft Skirt(s), which set it to 01/03/2014 00:00.</td>
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<tr>
<td>The end date was affected by Establish Hazardous Control Area for Ordnance Ops, which set it to 12/25/2033 10:49.</td>
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<td>The start date was affected by Hypergol Servicing for Booster Aft Skirt(s), which set it to 01/04/2014 22:00.</td>
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<td>The start date was affected by ForwardSchedule, restricted by availability of Hazardous Pad-1; waiting for Pre-Ordnance Operations for Orion Pyro Safe and Test Panels, which set it to 01/05/2014.</td>
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<tr>
<td>The end date was affected by ForwardSchedule, based on duration and start time, which set it to 01/05/2014 15:00.</td>
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</table>
Resource Contention: Visual

Viewing resource contentions in Aurora

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

<table>
<thead>
<tr>
<th>Task #</th>
<th>Resources Needed</th>
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<tbody>
<tr>
<td>2</td>
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<td>3</td>
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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.
Resource Contention: Task 6

The Single Element Display in Aurora helps the user visualize the relationships between tasks:

- Blue-grey lines denote a resource-constrained work flow
- Red lines denote temporally-constrained work flow

Referring to the three diagrams to the right:

- Task 6 can start any time after Task 2 is completed (red line in Single Element Display), but must wait for Task 5 to release resources (blue-grey line).
- Tasks 3 and 8 must wait for 6 to release resources before they can start, as shown in the Gantt Chart View
- Task 7 starts after Task 6 completes (red line in Single Element Display)
Constraints Add Complexity

- Technical constraints (E.g., F-S, F-F, S-F, lags)
- Resource constraints
  - Labor constraints
  - 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 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
More Complexity:
Shipbuilding & Ship Maintenance

- Ingress & egress: limited
- Skills / Certifications in addition to Occupations
  - E.g., Mechanic (occupation) with 4 additional skills or certifications
- Constraints based on status/state
  - E.g., no hot work when other conditions in effect
- Shift based constraints
  - Task needs to be completed during single shift
  - Do not start task unless x% of time left in shift
Aurora is used at Naval Submarine Support Facility (NSSF) at the Naval Submarine Base New London

Interfaces with Microsoft SQL Server
NSSF: Submarine Maintenance

- Each dock is different
- Different work rules if another submarine on other side of pier
- Each crane is different & there is a waterborne crane
- Multiple occupations with skills/certifications
  - Task may require occupations with skills/certs
    - Skill/certs combination needed per task may be by worker or by task
Concurrent & Non-Concurrent

- Complex operations requires concept of concurrent & non-concurrent tasks
- Adds another layer of complexity
Turnaround Project Network 2,500+ Tasks
Results: 2,500+ Turnaround

- Primavera P6 65 days
  - Performed by 3rd party
- Aurora 57 days
- Primavera P6 14% longer than Aurora
- Critical Path is 46 days
  - P6 is 19 days longer than CP
  - Aurora is 11 days longer than CP
  - So % diff over CP is > 73%
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
Set Resource Pool to 5

- Only one type of resource to make the problem ‘simple’
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
Simple Enough, Right?

• Another view of the solution
But there is a better solution ... P6 Model: Resource Leveled = 8 days
Simple?

- Critical Path = $1 + 1 + 5 = 7$
- 1 resource
- 5 total units
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?
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
Long-Term Refinery-Related Upgrade

MS Project 2007 = 1,627 days
Primavera P6 = 1,528 days
Intelligent scheduling (Aurora) = 1,240 days
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
  - Performed by Deltek
- Aurora: 102.5 days
Take Aways

• Scheduling engine is critical
• Paying up to 100% penalty due to the scheduling engine
• Changing to an improved scheduling engine may be the greatest potential improvement available to your project
  – Just press a different button
• Provide an unfair competitive advantage
Aurora: Intelligent Scheduling / Critical Chain Project Management
The world’s most advanced scheduling software?

Well, you decide. Boeing uses Aurora™ to build their new 787 Dreamliner. Aurora has a proven track record of reducing schedules by up to 33%. This could translate into millions of dollars worth of additional productivity within your organization. Aurora works with most popular project management tools including Primavera™ and Microsoft Project.

With Aurora, is the sky the limit?

Well, no actually. Aurora has been used to send missions to outer space. NASA uses Aurora to solve some of their most challenging scheduling problems. Aurora is currently in use for the Space Shuttle, Space Station, and several more NASA projects. Aurora has also been chosen by the United Space Alliance for the next generation Crew Exploration Vehicle.

Submit your schedule to Aurora@StottlerHenke.com
We’ll analyze it and send you the results FREE!

Web: www.stottlerhenke.com Tel: (650) 931-2715
Critical Chain – Example 3

As scheduled:

Critical chain:
Why can’t you search for the best order?

- Ordering options scale as N!
Two tasks that can occur in either order (one at a time)

results in two options
Three tasks that can occur in any order (one at a time)

results in six options

[Diagram showing three tasks with arrows connecting them, resulting in six options]
Four tasks that can occur in any order (one at a time)

results in twenty-four options
Why Intelligent Scheduling?

Resource-loaded scheduling is difficult

- Whole field of Operations Research

Not leveraged in the Project Management domains that Primavera serves

Usually demand is generated from knowledgeable users

Not promoted by solution providers
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 why it was placed (where it is placed).
Scheduling is Fast

- 300 tasks ~ 3-6 seconds
- 2,000 tasks ~ 11 seconds
- 3,000 tasks ~ 15-20 seconds
- 4,000 tasks ~ 43 seconds
- 10,000 tasks ~ 125 seconds

- High degree of variation - it depends a lot on the shape of the problem
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: Planning & Execution

- Results in a better **initial** schedule
- **Execution**: Schedule is more flexible and better able to accommodate change.
  - If scheduler is inefficient, every delay will be magnified because re-allocation of resources will be deficient
  - 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.
Critical Resources

• Initial schedule usually has different critical resources via different schedulers

• Execution mode updates will also usually have different critical resources
  – Picking less than optimal resources if resource increases are used to make up slippage.

• Better to find more efficient schedule with intelligent scheduling, then increase critical resources if necessary.
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/execution of schedule