LEVERAGING PHM IN CONJUNCTION WITH INTELLIGENT SCHEDULING TO IMPROVE MANUFACTURING RESILIENCE

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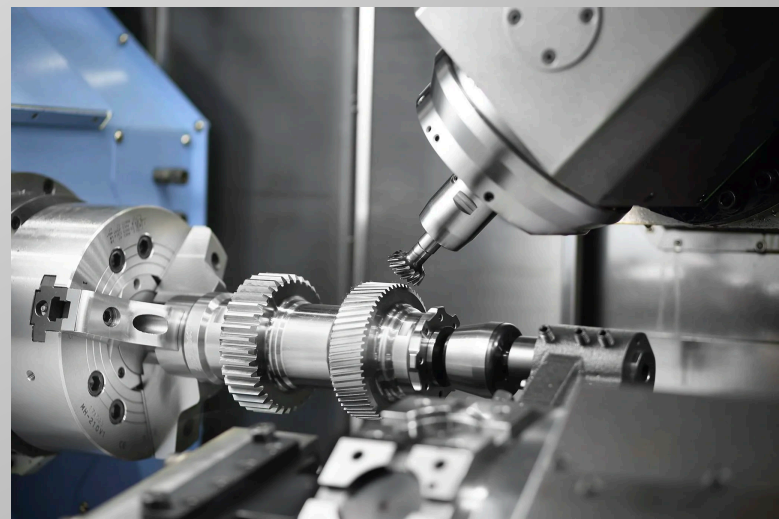
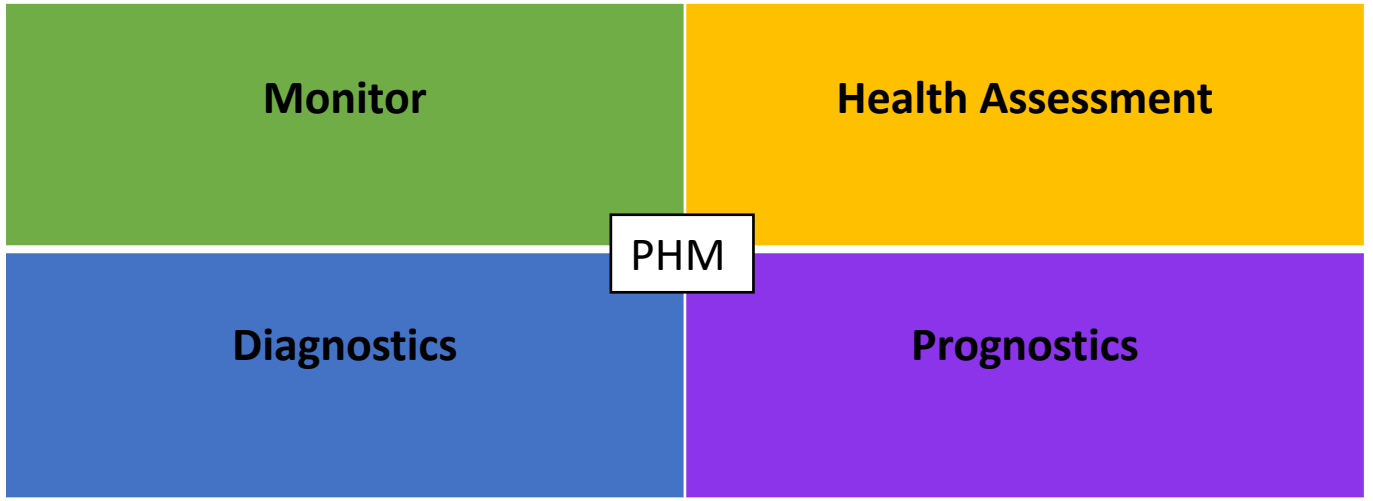


Prognostics & Health Management (PHM)

- Technology to enhance the effective reliability and availability of a product in its life cycle conditions by detection of current and approaching failures.
- Prognostics is the real-time enhancement of reliability and availability and the prediction of the remaining useful life of the product by assessing the extent of deviation or degradation of a product's monitored parameters from its expected normal operating conditions.
- Prognostics can yield an advance warning of impending failure in a system, thereby enabling more efficient and effective maintenance and corrective actions.



Scheduling

The process of assigning resources to tasks over time, with the goal of optimizing the result according to one or more objectives: Usually includes minimizing project duration maximizing throughput.

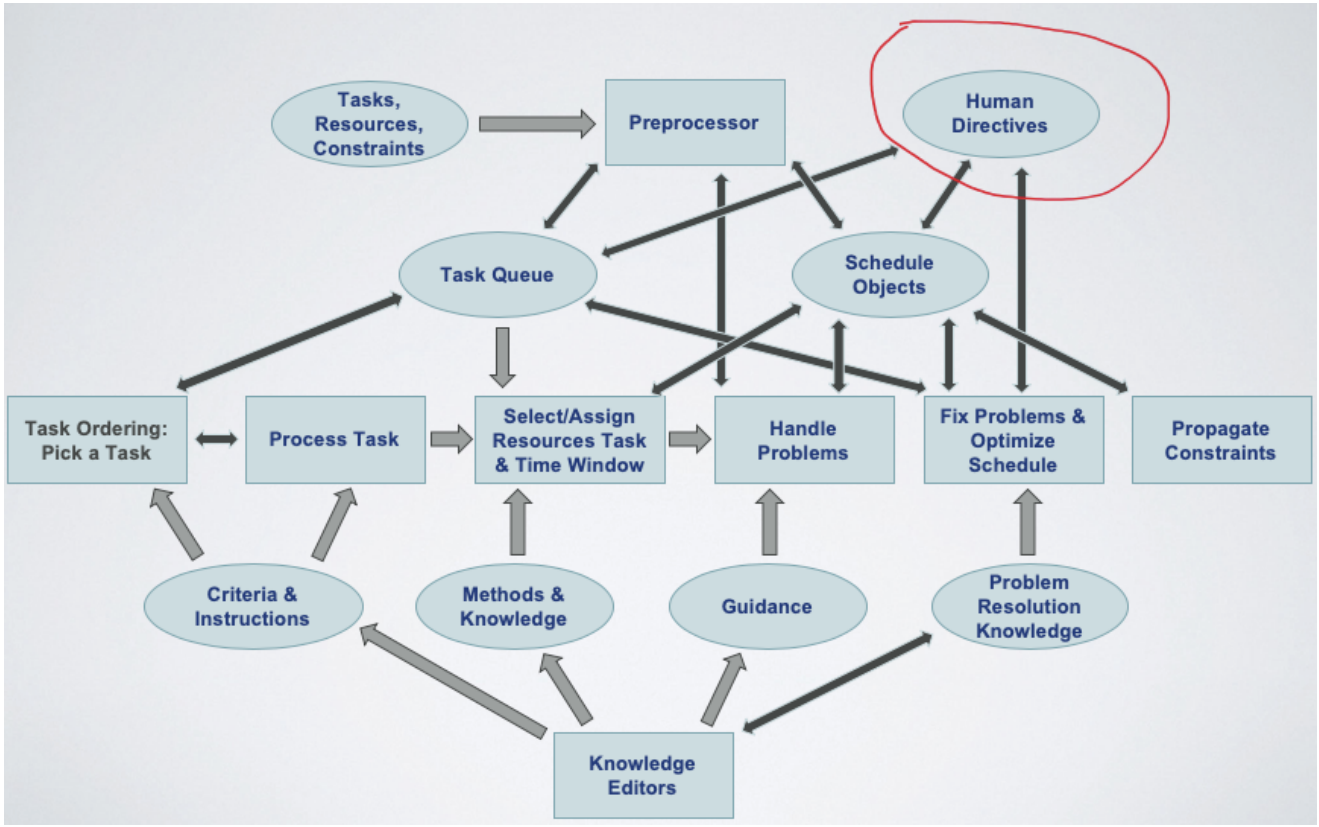
Temporal relationships: Tasks may have predecessors and successors relationships that must be respected; other temporal constraints include start no earlier than dates.

Resources: Each task can require that specific resources are required for the task to be scheduled. Examples of resources include people with specific skills, equipment, and physical space.

Calendars: Resources, both human and equipment have calendars associated with them. Resources can only be scheduled on tasks when their calendar shows the resource is available.

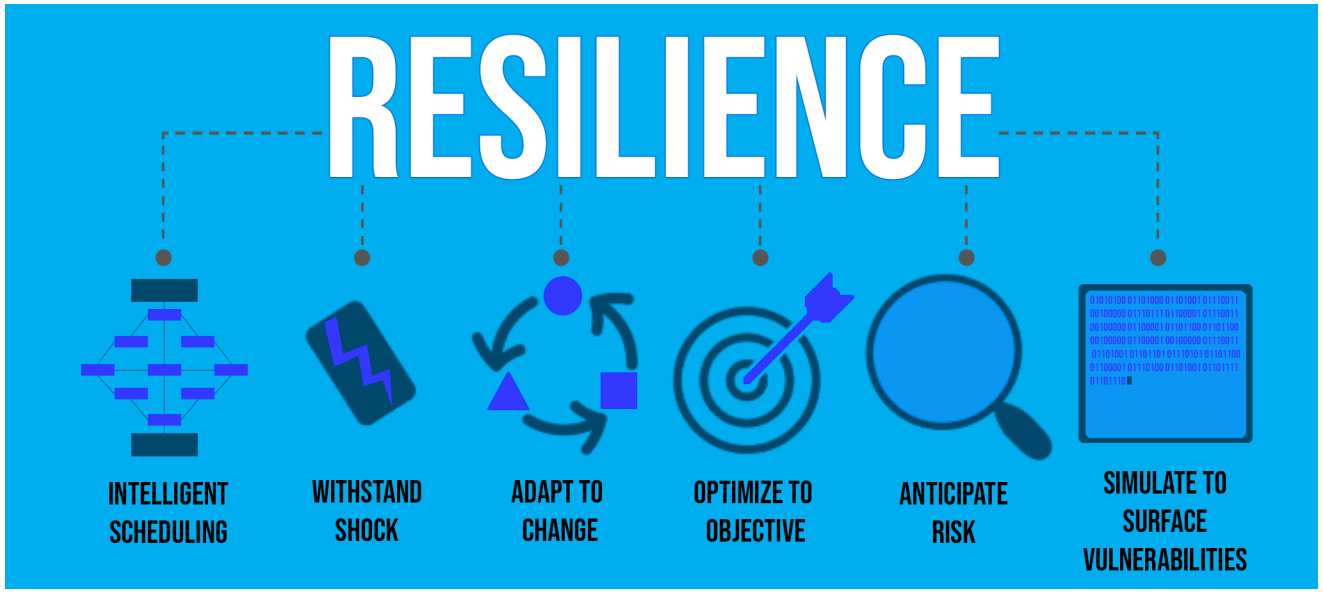
Intelligent Scheduler Architecture

- Stottler Henke Associates, Inc. uses the general heuristics gleaned from top experts, over a wide array of circumstances, to enhance our intelligent scheduling system.



Resilience

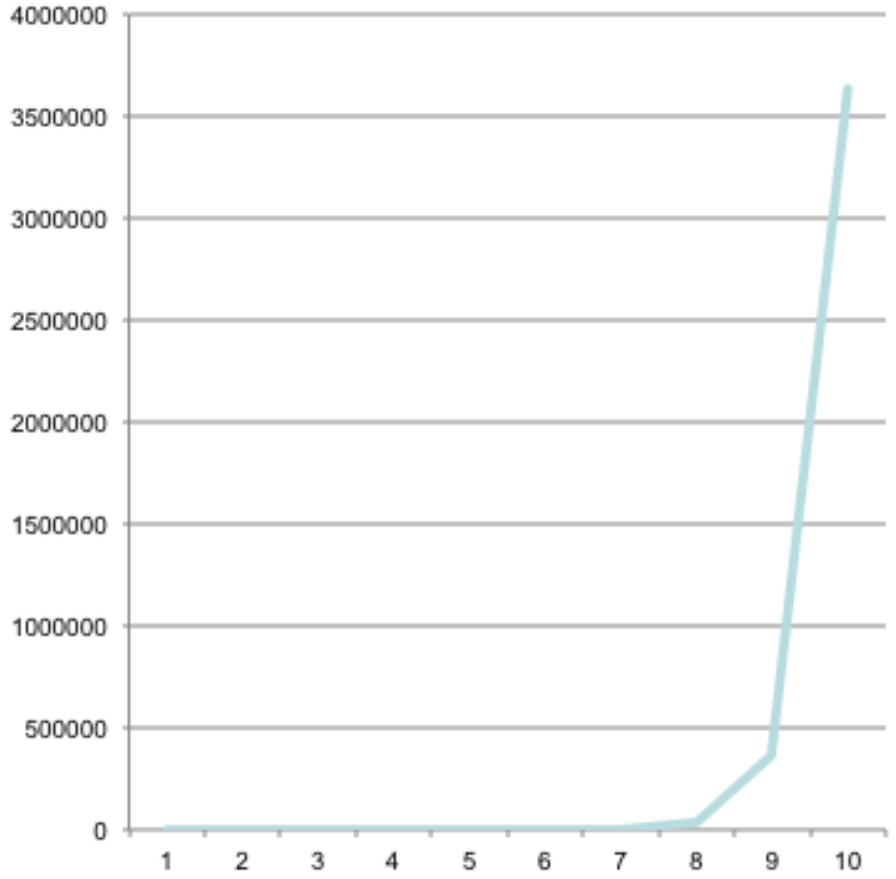
- The ability of a system to withstand potentially high-impact disruptions, and it is characterized by the capability of the system to mitigate or absorb the impact of disruptions, and quickly recover to normal conditions



Resource Scheduling: NP-Complete Problem

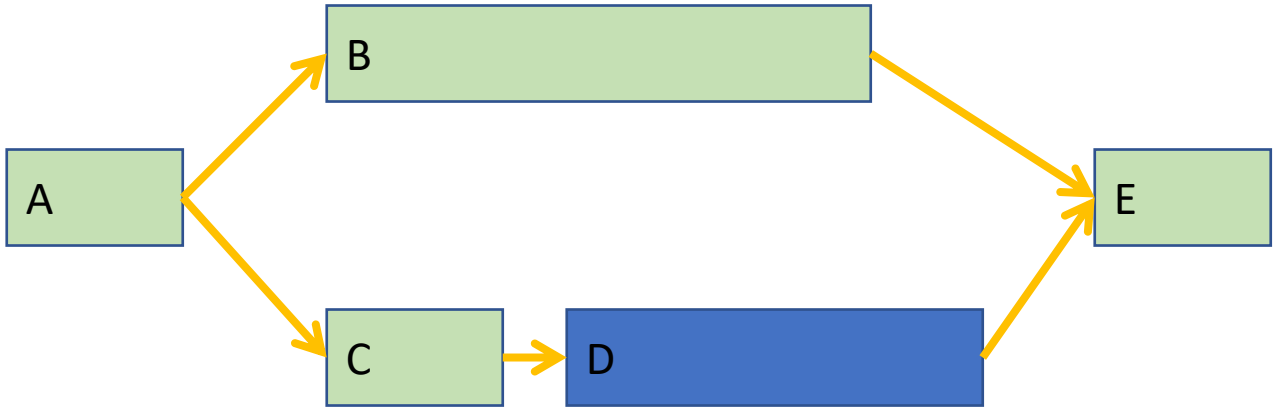
Ordering options scale as N!

1	1
2	2
3	6
4	24
5	120
6	720
7	5040
8	40320
9	362880
10	3628800

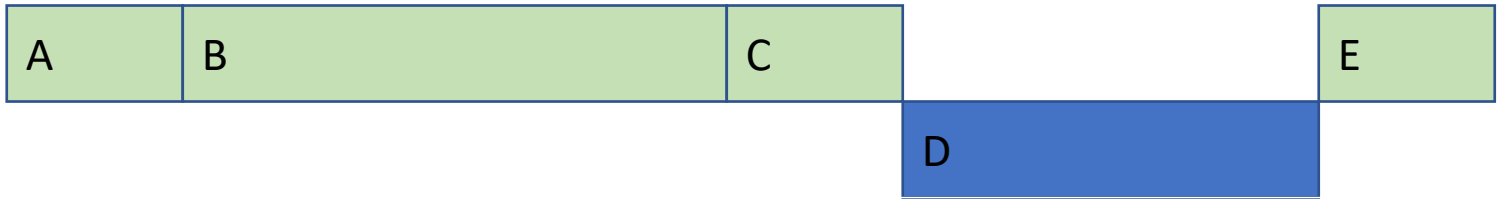


Why Order Matters?

The example below involves jobs using two resources, Different colors represent each resource



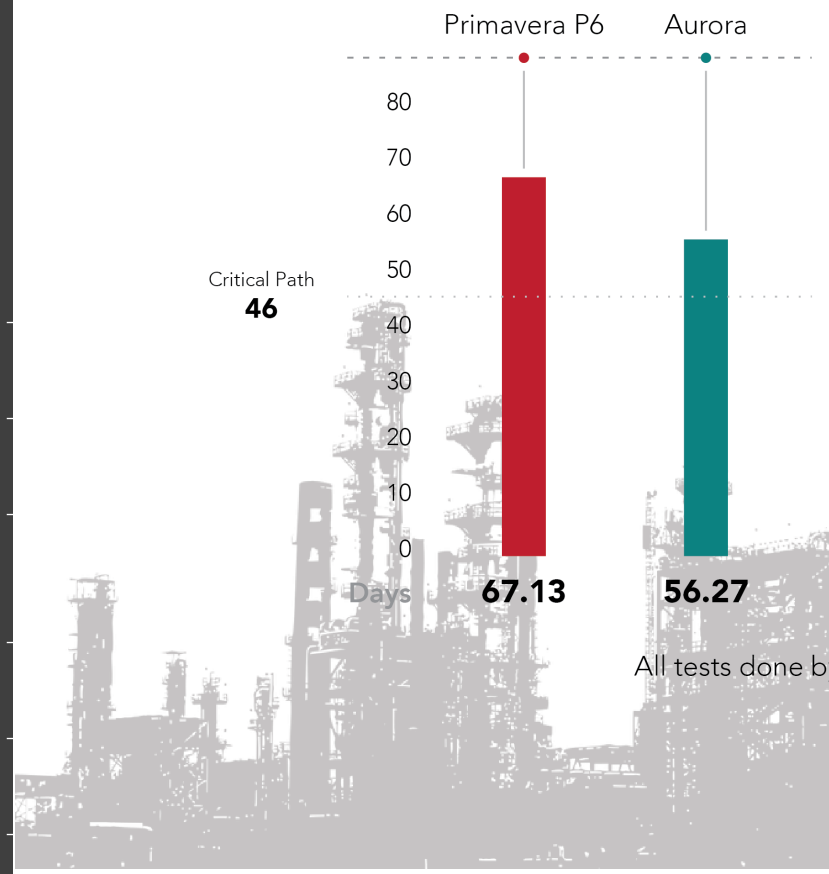
Schedule 1: B before C



Schedule 2: C before B

Intelligent Scheduling vs Resource-Leveling

REFINERY TURNAROUND
2500+ TASKS



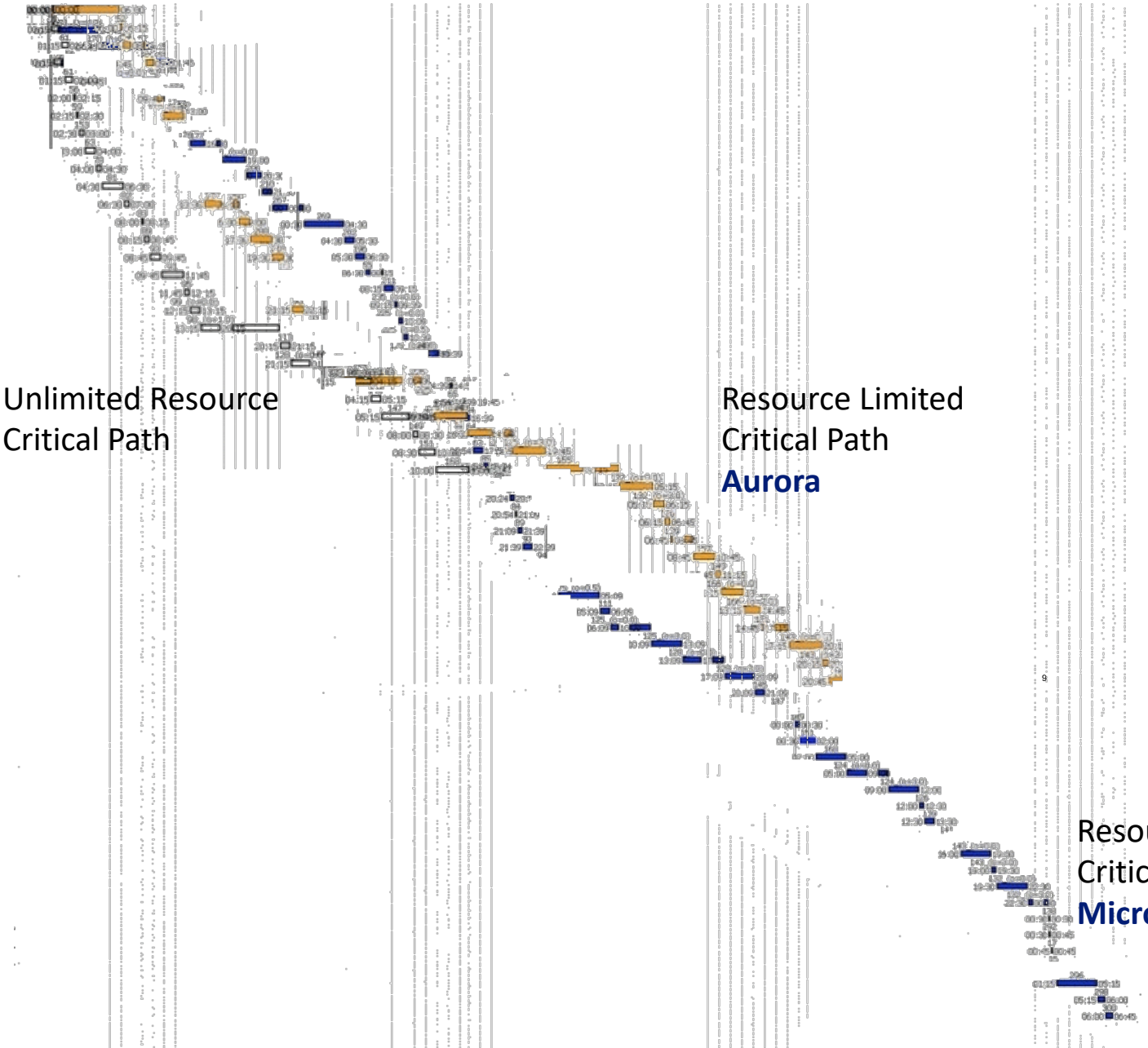
All tests done by third party

Aurora saves over

10

days versus Primavera P6

Scheduling Engine Comparison: Gantt Chart



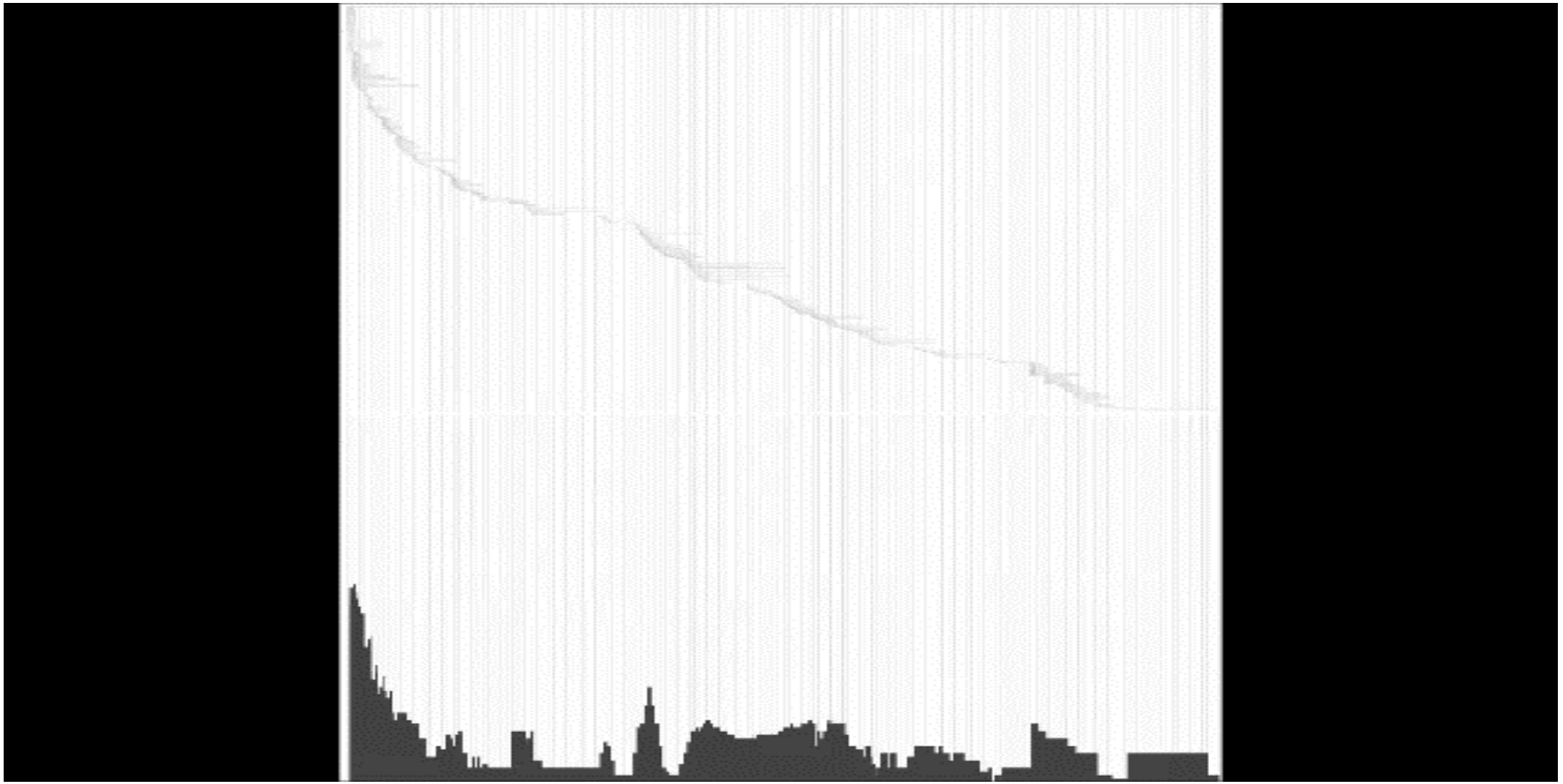
Unlimited Resource
Critical Path

Resource Limited
Critical Path
Aurora

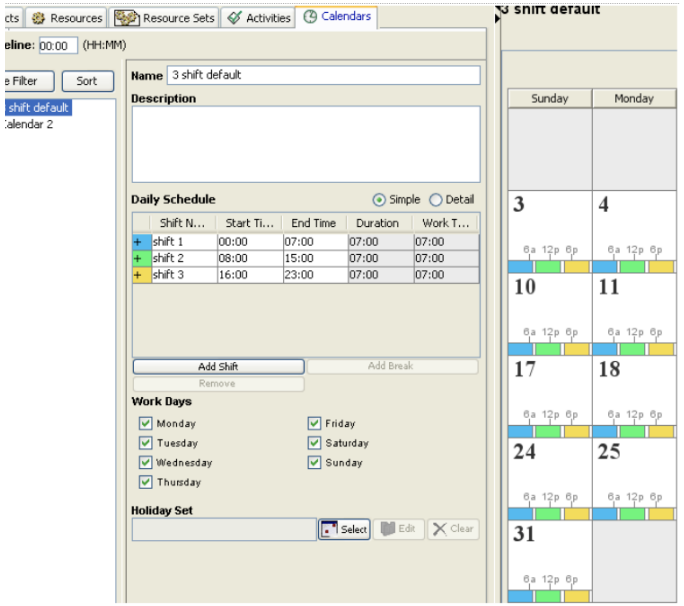
Resource Limited
Critical Path
Microsoft Project

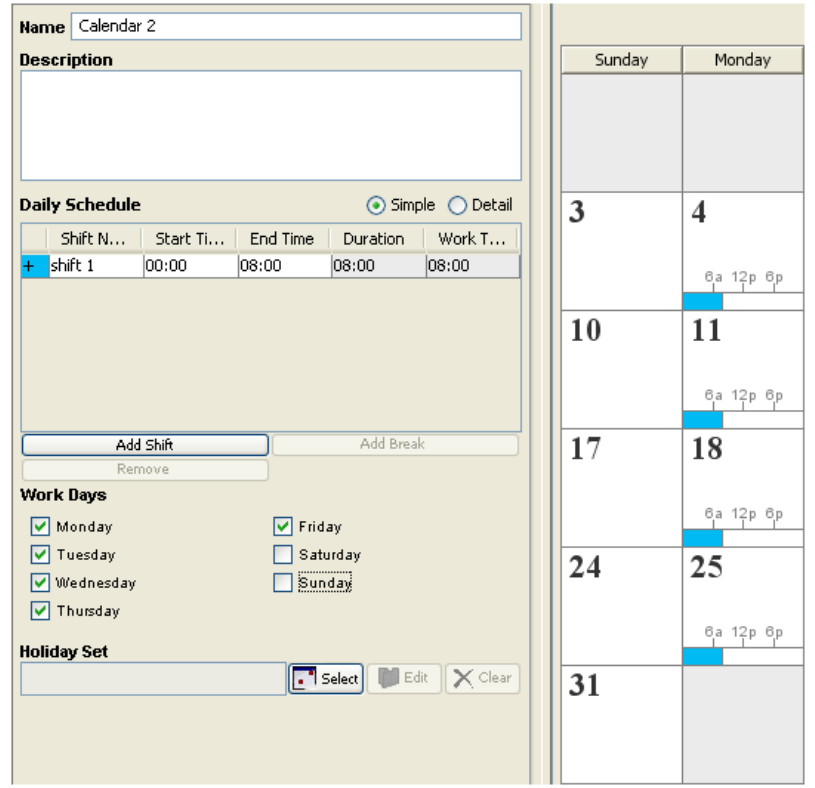
Stottler Henke
Smarter Software Solutions

MS Project results (START of animation)
VS. Aurora results (END)

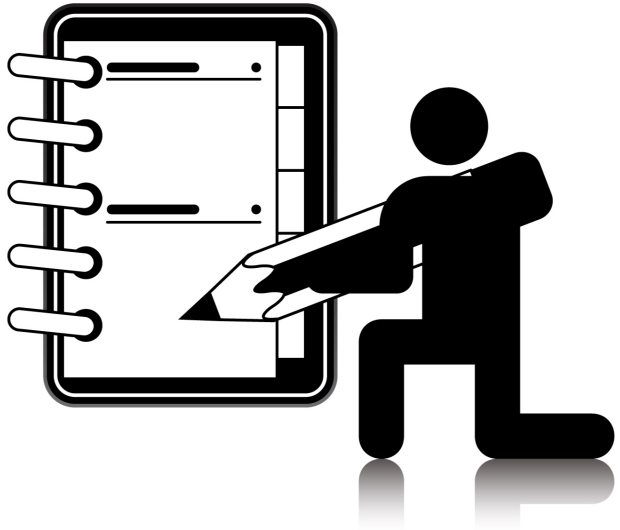


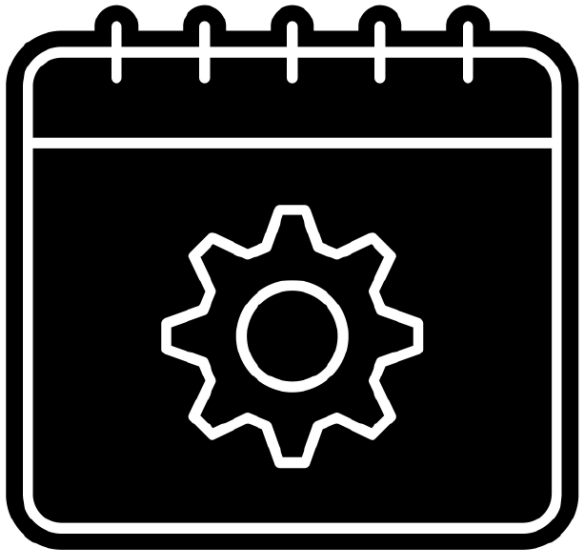
Equipment and all other Resources have Calendars





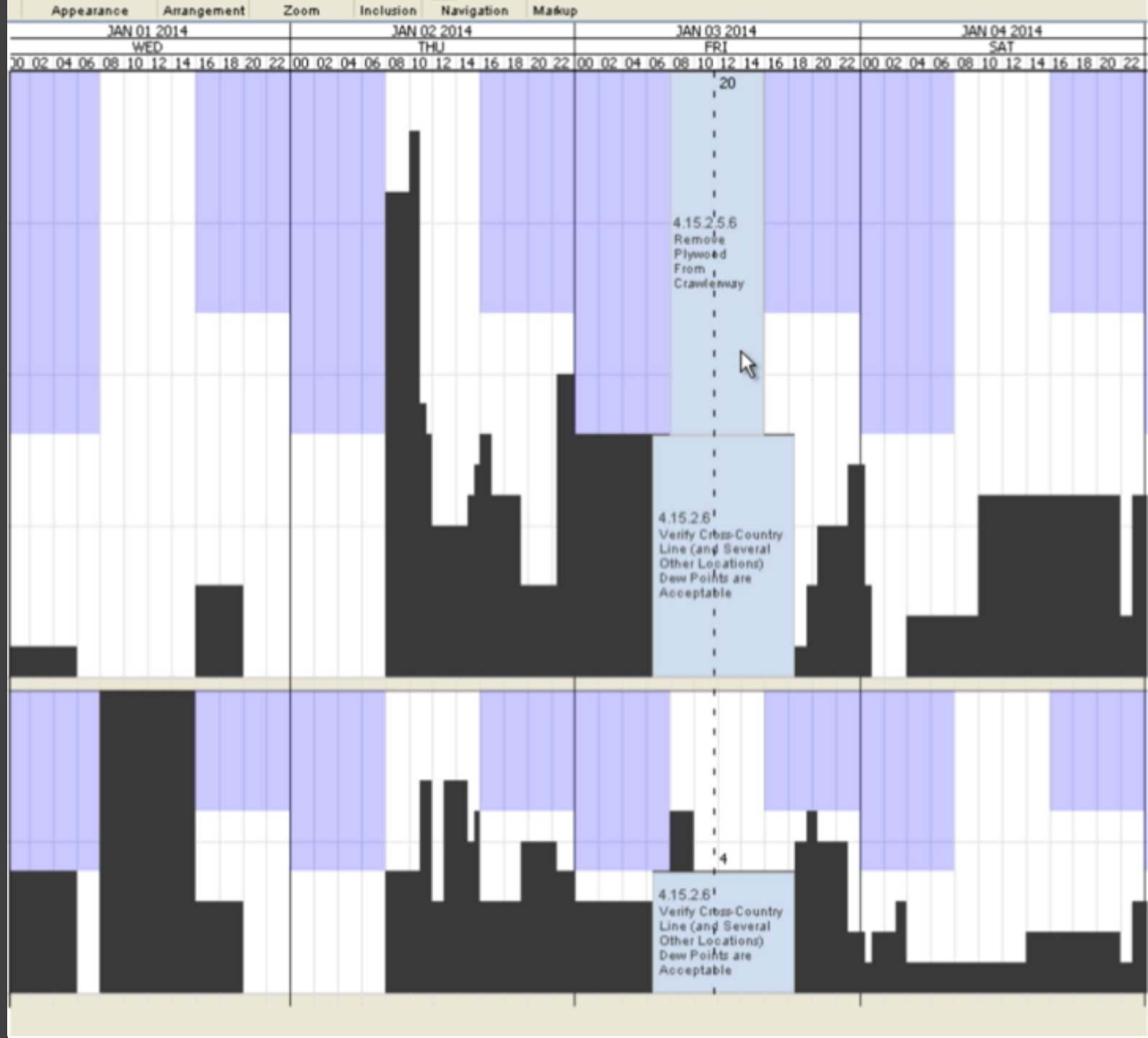
Intelligent Scheduling Adapts to Changes to Human & Machine Calendars





PHM Determines Timespan when Maintenance Must Occur

Histogram Analysis: Timeframes when Equipment was not Scheduled to be Used



Intelligence Scheduling Determines when best to Actually Schedule the Maintenance

Intelligent Scheduling Adapts to Changes to Human & Machine Calendars (2)

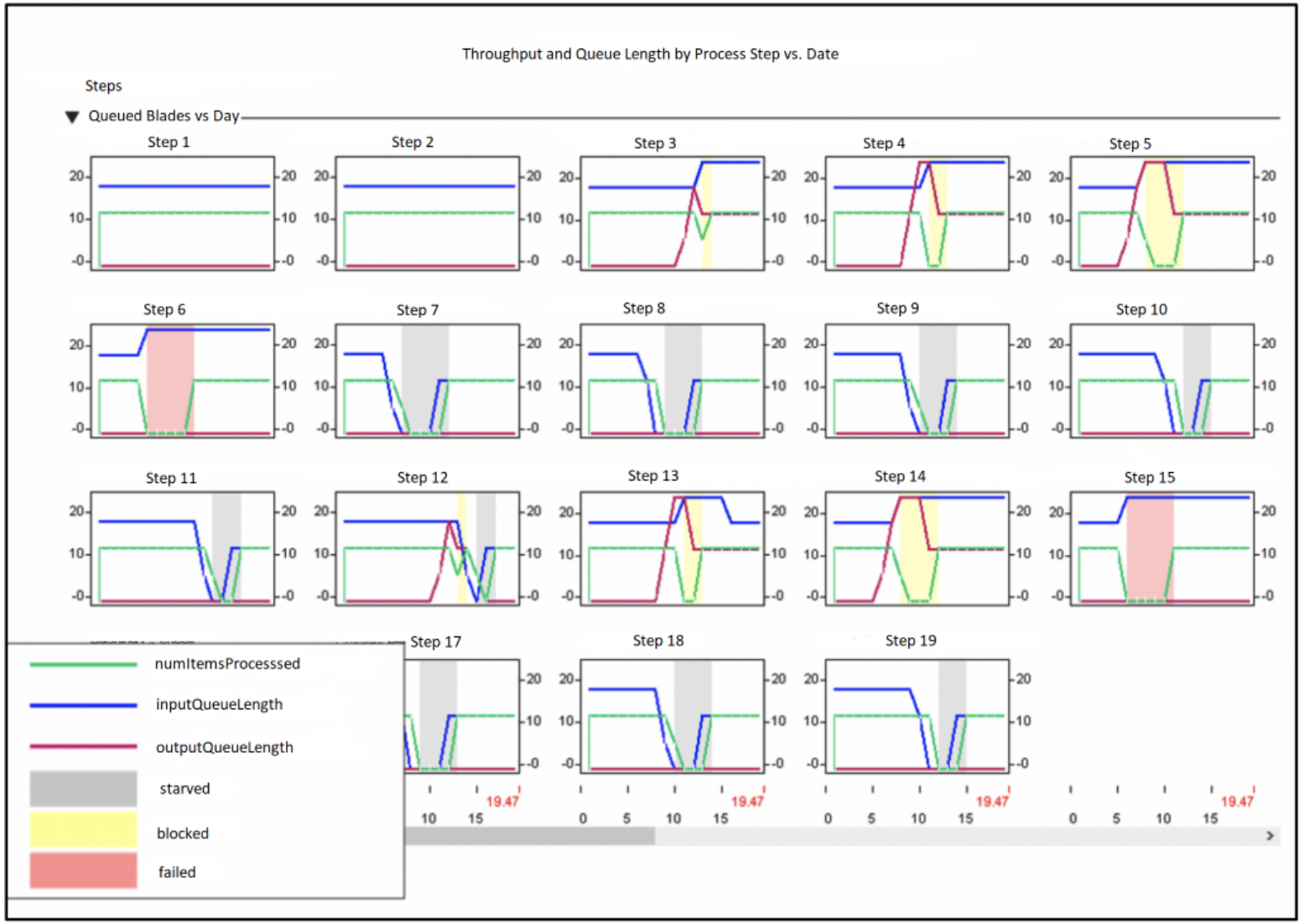
Intelligent scheduling adapts optimally to any updates to calendars during execution, each time the scheduler is updated (e.g., after each shift)

- Consider status updates of tasks,
- Changes known per future availability of people and equipment (via updates to their calendars).

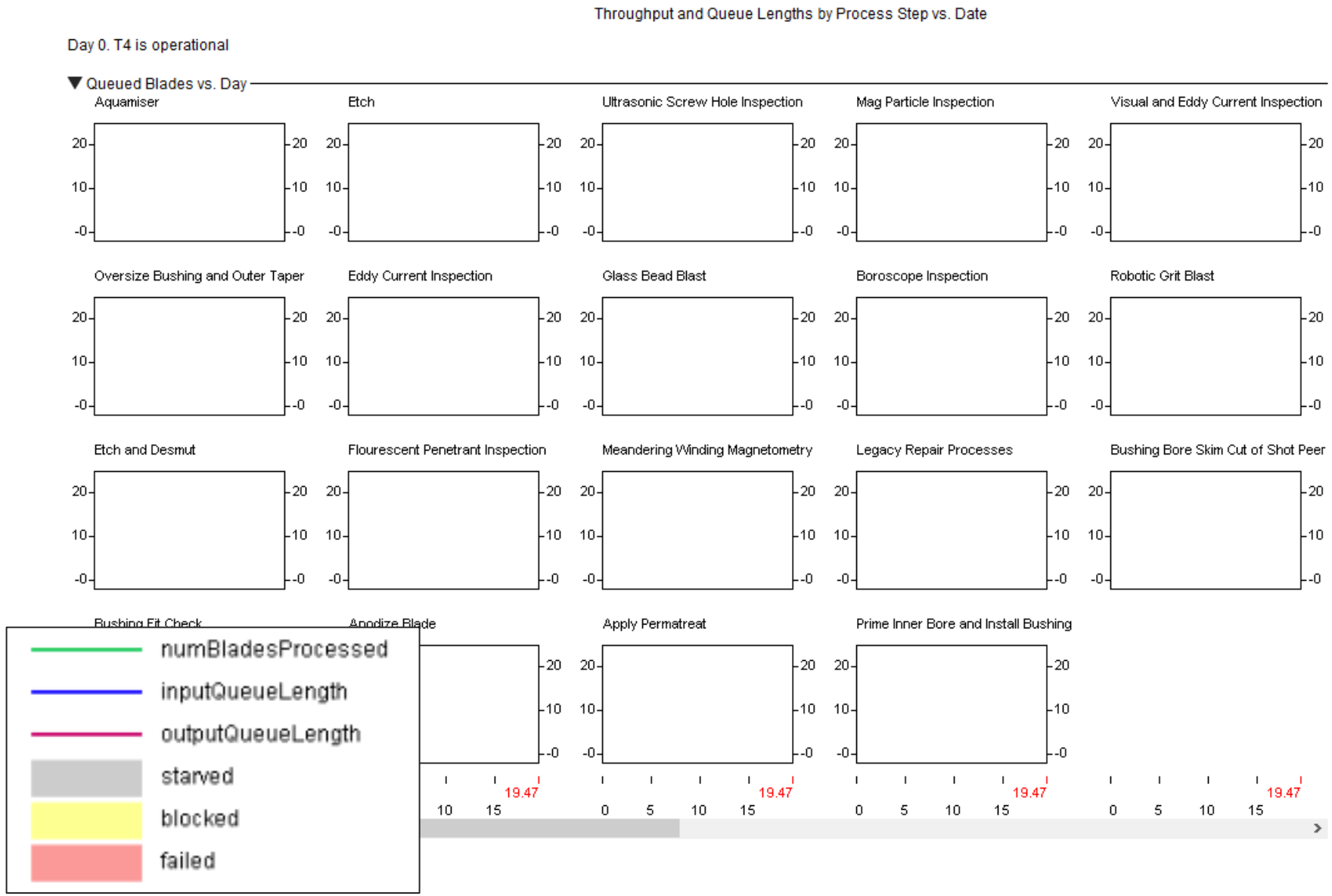
PHM helps improves the accuracy of each machine's calendar

- Allowing for the intelligent scheduling engine to adapt sooner, and thus better, to future conditions

Visualizations to Clarify Effects of Downtime



Equipment Outage: Production Blockage, Starvation



PHM knowledge Allows Intelligent Scheduling and People to Provide Resilience

Aids intelligent scheduling systems by discovering mishaps before they occur.

Provides more time so the intelligent scheduling system can reduce the impact, either alongside human schedulers, or autonomously.

Leverage PHM to take Advantage of Supply Chain or other Disruptions

Supply Chain or other disruptions may cause certain equipment to become idle.

Intelligent scheduling will leverage PHM knowledge and the the idle time to determine if advantageous to perform maintenance during unexpected idle time.

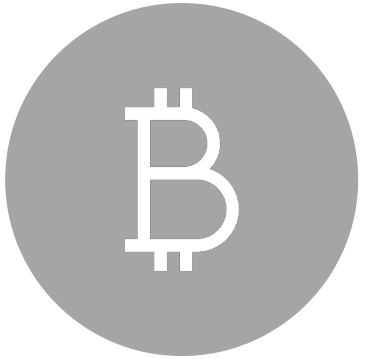
PHM & Timeframes to Perform Maintenance

PHM is the early warning system providing the intelligent scheduling system with options of when to perform maintenance to minimize disruption.

Intelligent scheduling solutions combine this information with the established deadlines, to create new scenarios to lower the impact of identified disruptions.

Conclusion

SCHEDULING, EVEN UNDER IDEAL SITUATIONS IS INCREDIBLY CHALLENGING, UNEXPECTED EVENTS, SUCH AS UNPLANNED EQUIPMENT DOWNTIME FURTHER COMPLICATES SCHEDULING



PHM IN CONJUNCTION WITH INTELLIGENT SCHEDULING & HUMAN SCHEDULERS, CAN MAXIMIZE THE EFFICIENCY AND THE EFFECTIVENESS OF LIMITED RESOURCES TO MAXIMIZE THROUGHPUT AND MINIMIZE COST