DYNAMIC SCHEDULING SYSTEM

The GBT Dynamic Scheduling System: An Update

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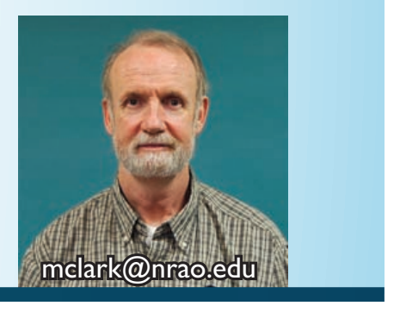
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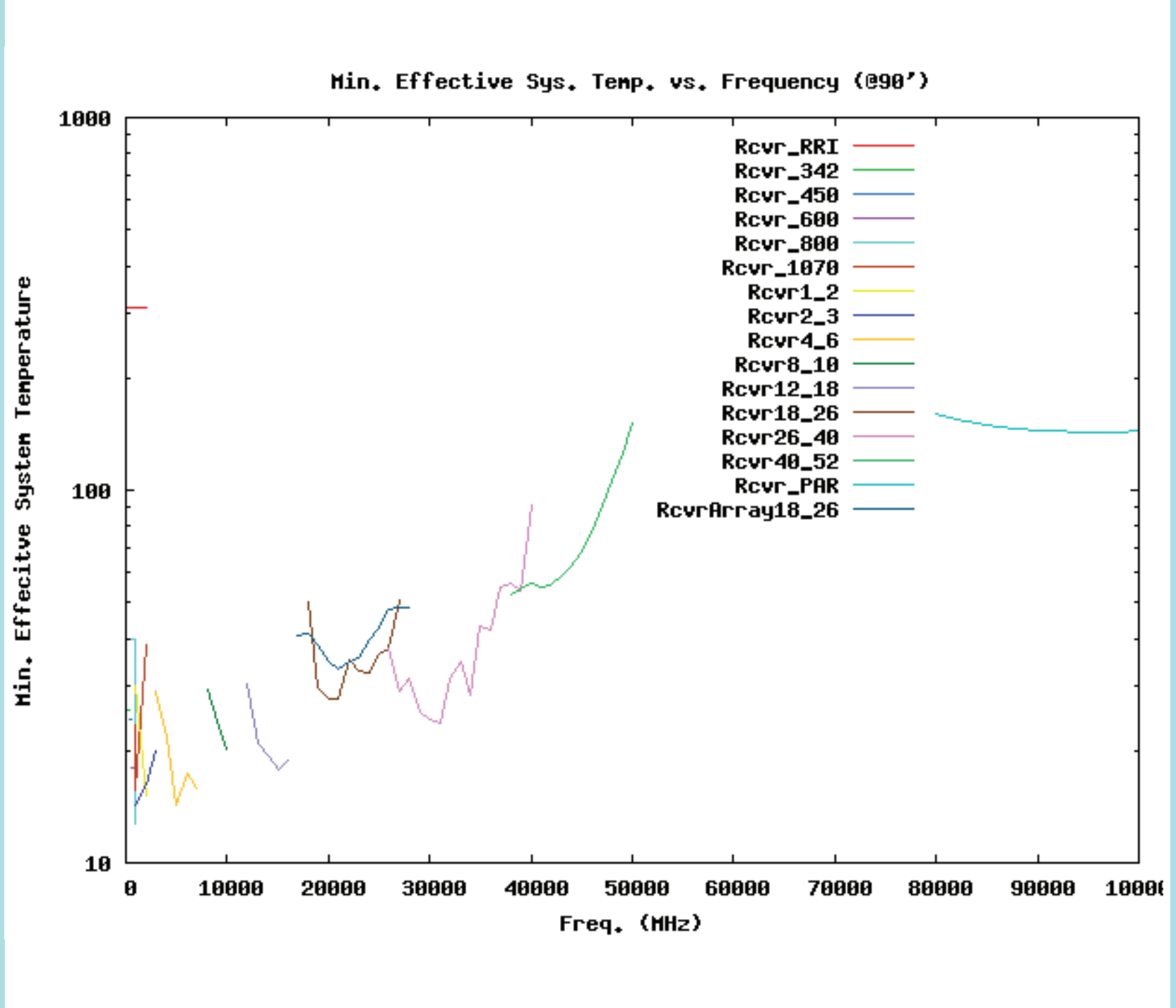
The Robert C. Byrd Green Bank Telescope.

Abstract

The Robert C. Byrd Green Bank Telescope's (GBT) Dynamic Scheduling System (DSS), in production use since September 2009, was designed to maximize observing efficiency while not sacrificing telescope flexibility, data quality, or generate undue adversity for the observers. Using observing criteria, observer availability and qualifications, three-dimensional weather forecasts, and telescope state, the DSS software is capable of optimally scheduling observers 24 to 48 hours in advance on a telescope having a wide-range of capabilities in a geographical location with variable weather patterns. Recent improvements include an expanded frequency coverage (0.390-90 GHz), proper treatment of fully sampled array receivers and increasingly diverse observing criteria, accounting for atmospheric instability from clouds, and new tools for scheduling staff to control and interact with generated schedules and the underlying database.

Expanded Frequency Coverage

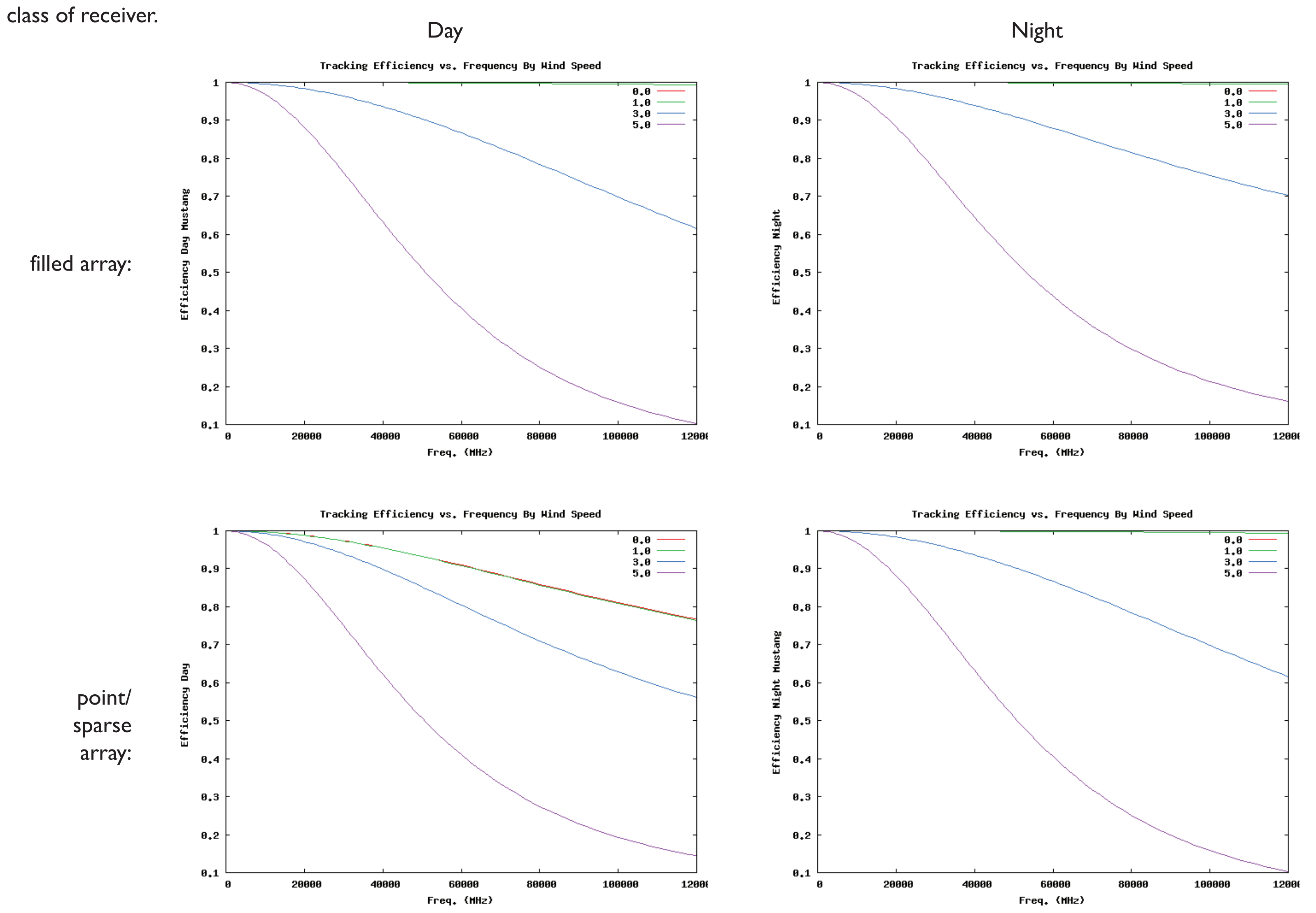
New instrumentation, especially receivers, and improved antenna pointing have made it practical to observe on the GBT at higher frequencies. The original DSS provided accurate scheduling only for frequencies between 2 and 50 GHz, but now the DSS handles frequencies up to 90 GHz and provides better scheduling below 2 GHz.



Plot showing the minimum effective system temperature as a function of frequency and receiver, i.e., the historically best system temperature one can expect in Green Bank. Earlier versions of the DSS used fewer receivers and a narrower frequency range.

Fully-Sampled Array Receivers

The advent of filled-array receivers makes the GBT less vulnerable to the effects of wind. Modifications to the ranking algorithm account for use of this class of receiver.

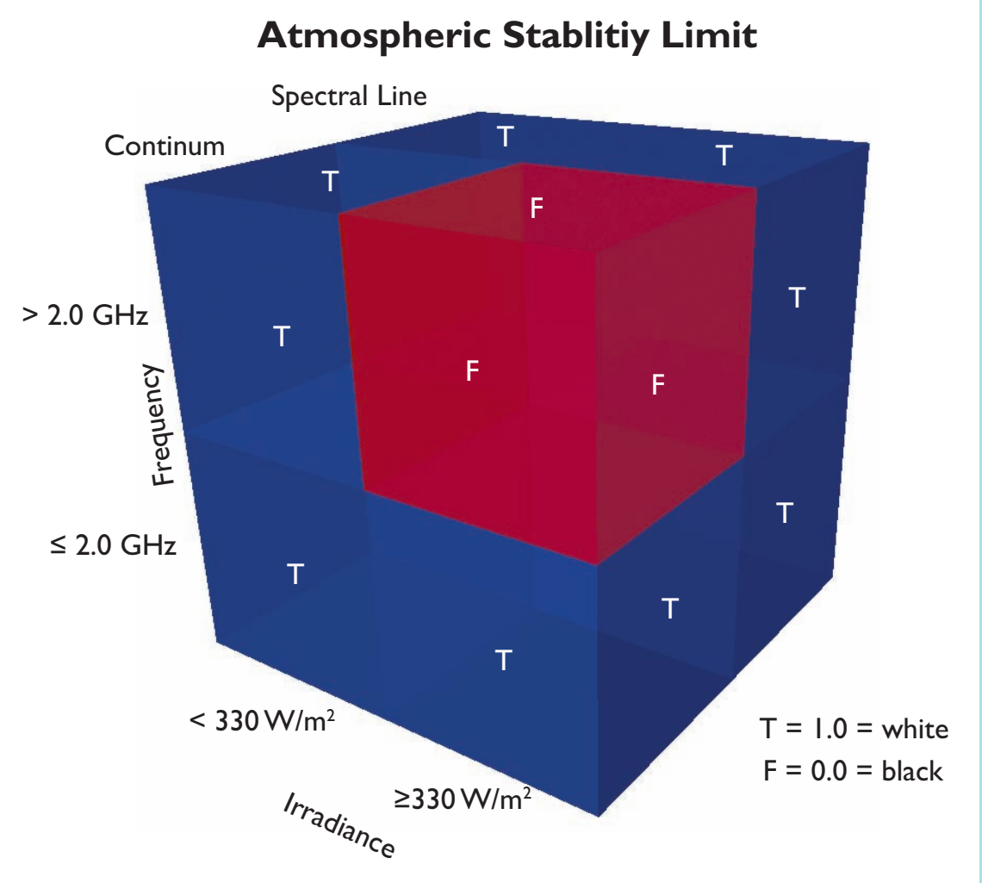


Plots showing the effects of sun on the telescope (day/night), frequency, wind speed (m/s), and our one example of a filled-array receiver: the Penn Array Receiver ("Mustang").

New Atmospheric Instability Limit

Scheduling of continuum observing (as opposed to spectral line) requires modification to the go/no-go factor **atmospheric stability limit**.

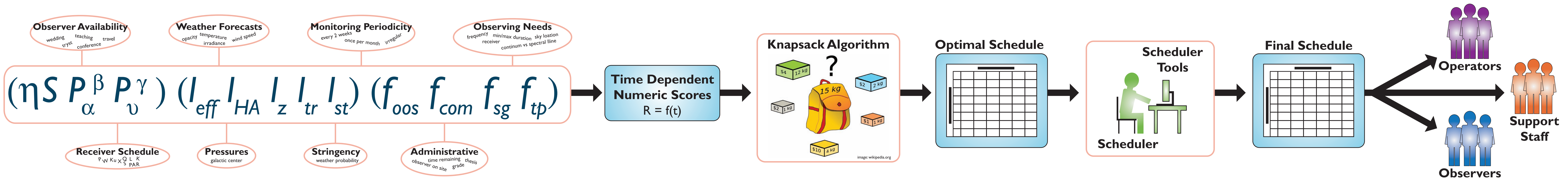
Hydrosols are water droplets in clouds. They are not well mixed in the atmosphere, so they cause short-term fluctuations in the total power detected by the antenna that are proportional to frequency squared and can degrade single-dish continuum observations at frequencies higher than about 2 GHz. These relatively slow, broadband fluctuations have little effect on pulsar and spectral-line observations. Continuum observations at frequencies above about 2 GHz should normally be scheduled only when there are no hydrosols; that is, when the sky is clear. We can use the forecast downward atmospheric irradiance at long wavelengths (4.5-40 microns) to estimate cloud cover and hence atmospheric stability.



(Balser 2010) recommends that when the downward atmospheric irradiance is less than 330 W/m2 the atmosphere is acceptable for radio continuum observations. Thus, for continuum observations above 2 GHz, stability limit = 1 when Idown < 330 W/m2; else stability limit= 0. For all other observations, stability limit= 1regardless of cloud cover or downward irradiance.

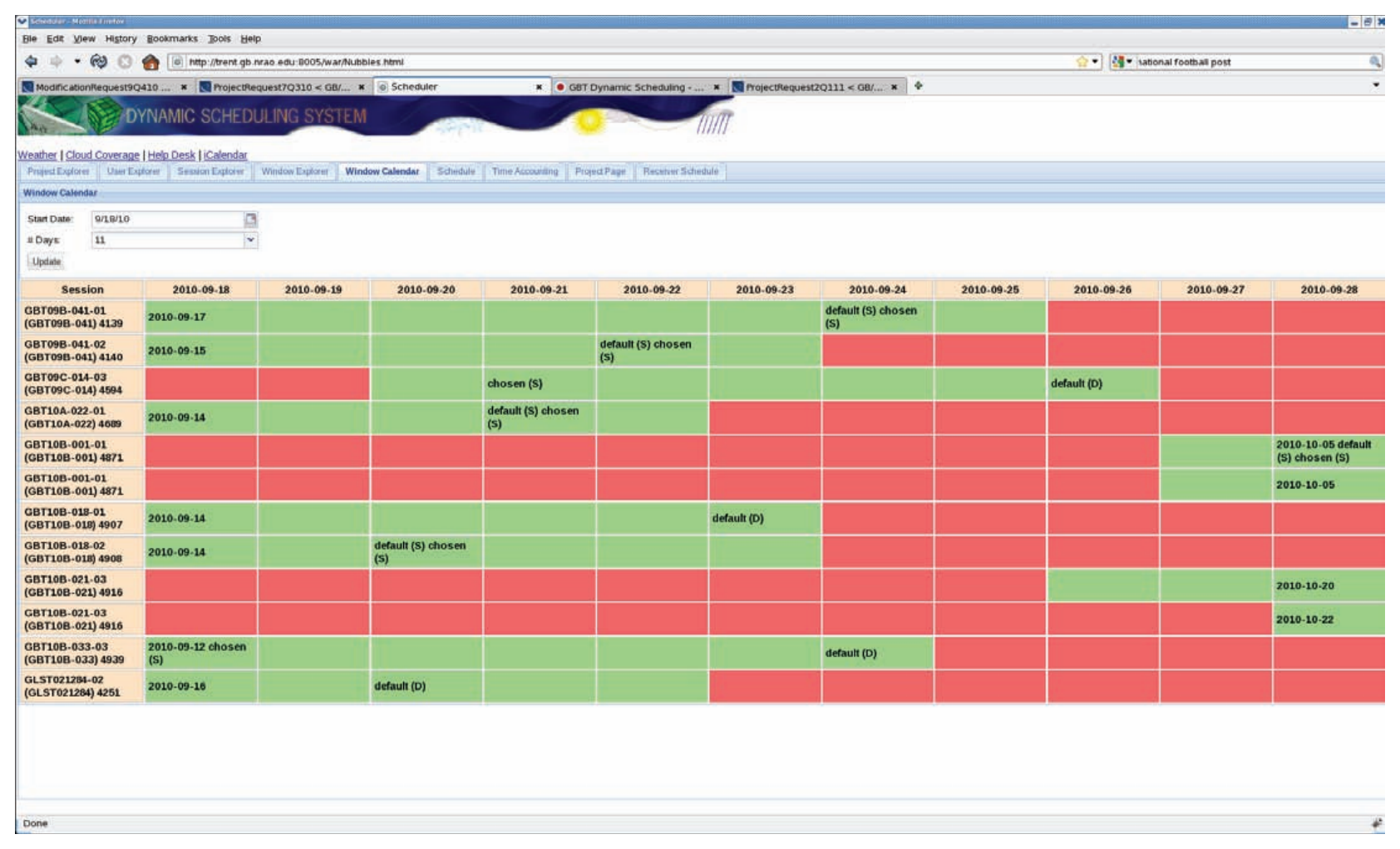
Overview

Our original ranking algorithm provided a mathematical basis for compressing observing needs and weather forecasts to a single, time-dependent numeric value (R) thus allowing optimal scheduling by algorithm. Further experience allowed us to enhance the mapping...


$$(\eta S\, P_{\alpha}^{\beta}\, P_{\upsilon}^{\gamma})\,(l_{eff}\, l_{HA}\, l_{z}\, l_{tr}\, l_{st})\,(f_{oos}\, f_{com}\, f_{sg}\, f_{tp})$$

Handle Monitoring Projects

A major area where telescope efficiency is sacrificed to accommodate observer needs is in monitoring projects, i.e., where observational data is obtained on pre-defined intervals, e.g., pulsar timing experiments. The implication is that the observer is guaranteed telescope time within a specific time range or window which necessarily limits scheduling options, especially if the density of the windows can cause complicated interference among the scheduling options. Currently 40% of GBT time is consumed by windowed observing.



Window Calendar

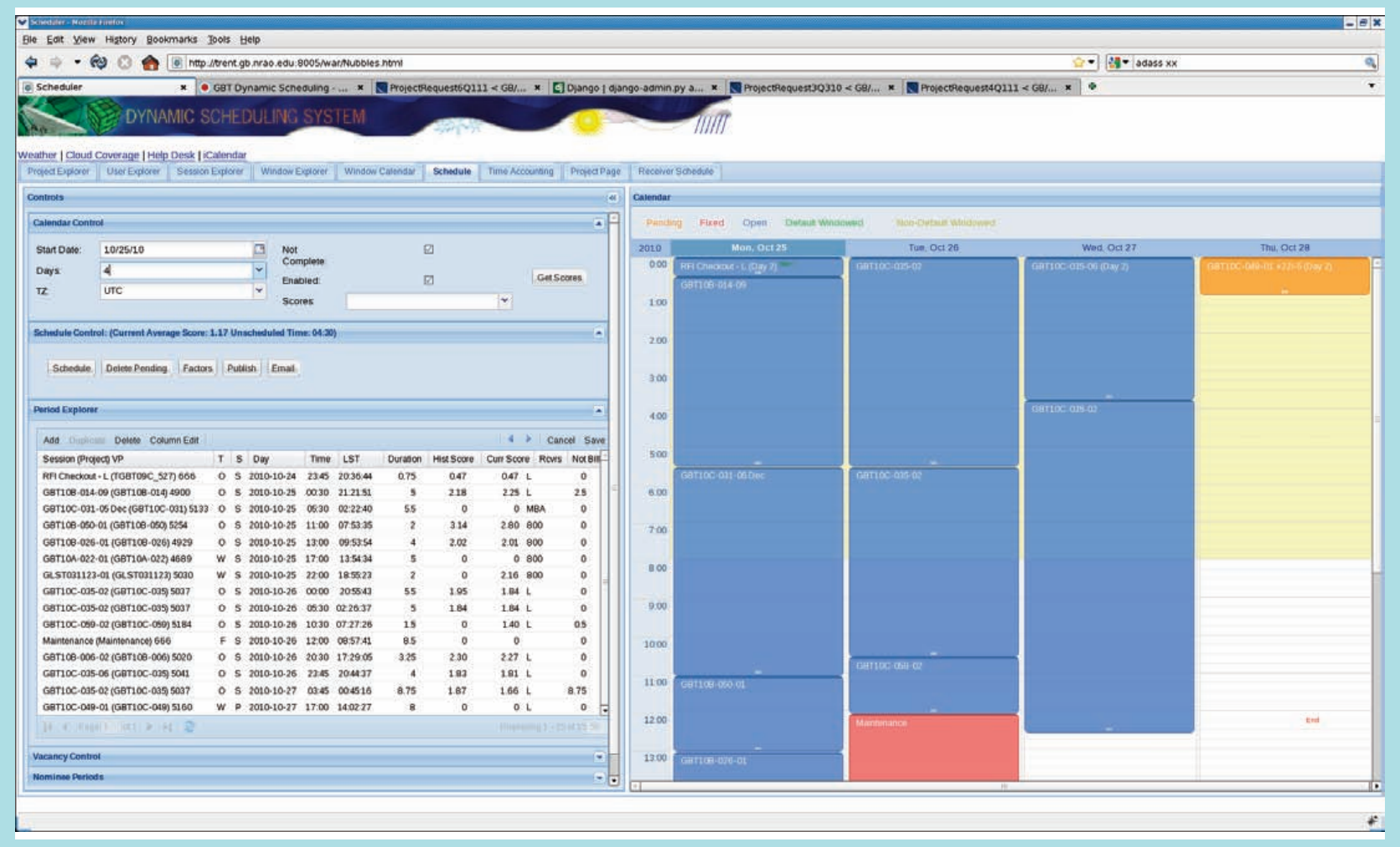
Start Date: 9/18/10
Days: 11

Session	2010-09-18	2010-09-19	2010-09-20	2010-09-21	2010-09-22	2010-09-23	2010-09-24	2010-09-25	2010-09-26	2010-09-27	2010-09-28
GBT09B-041-01 (GBT09B-041) 4139	2010-09-17						default (S) chosen (S)				
GBT09B-041-02 (GBT09B-041) 4140	2010-09-15				default (S) chosen (S)						
GBT09C-014-03 (GBT09C-014) 4594				chosen (S)					default (D)		
GBT10A-022-01 (GBT10A-022) 4689	2010-09-14			default (S) chosen (S)							
GBT10B-001-01 (GBT10B-001) 4871											2010-10-05 default (S) chosen (S)
GBT10B-001-01 (GBT10B-001) 4871											2010-10-05
GBT10B-018-01 (GBT10B-018) 4907	2010-09-14					default (D)					
GBT10B-018-02 (GBT10B-018) 4908	2010-09-14		default (S) chosen (S)								
GBT10B-021-03 (GBT10B-021) 4916											2010-10-20
GBT10B-021-03 (GBT10B-021) 4916											2010-10-22
GBT10B-033-03 (GBT10B-033) 4939	2010-09-12 chosen (S)						default (D)				
GLST021284-02 (GLST021284) 4251	2010-09-16		default (D)								

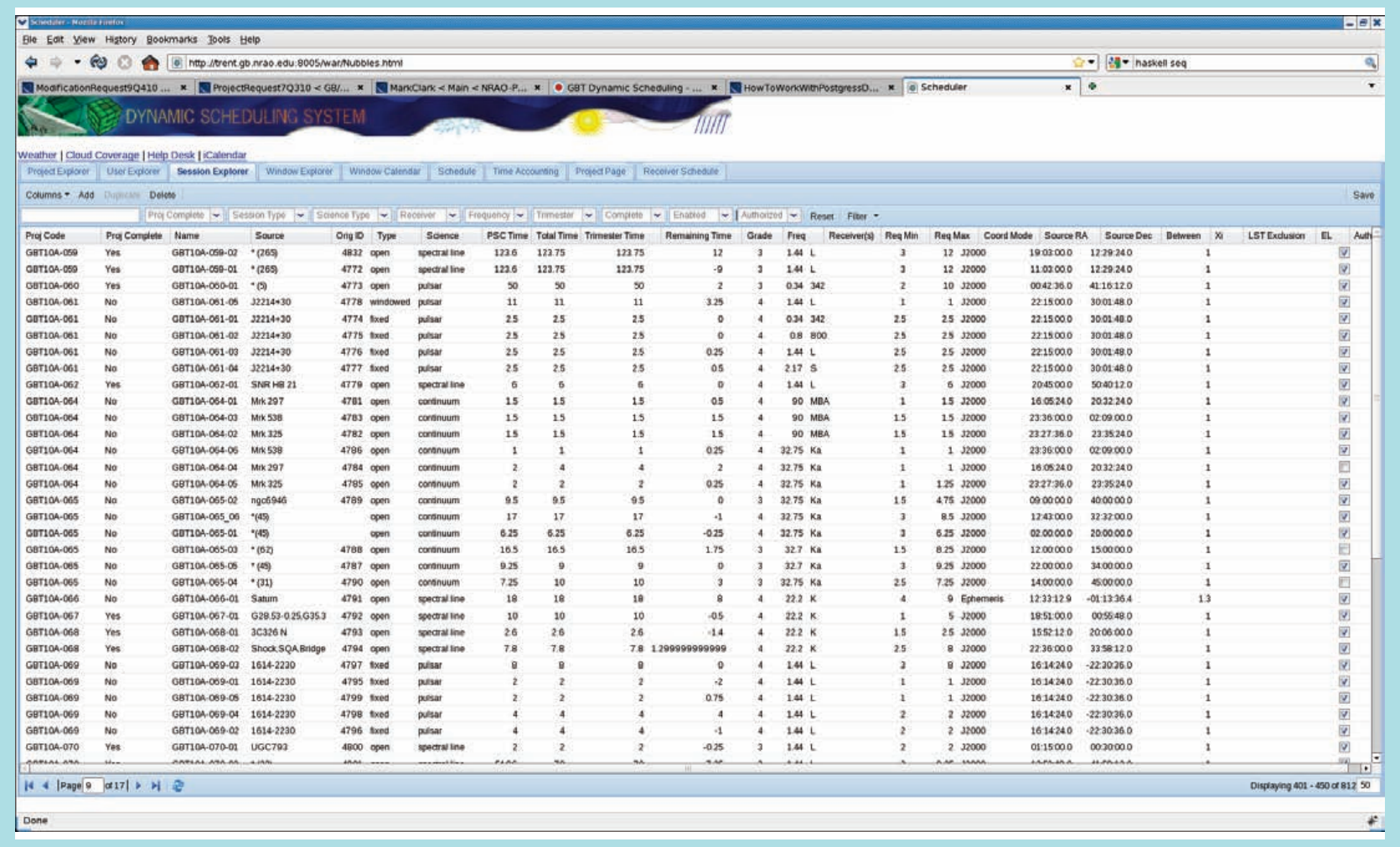
The approach for scheduling windowed observations is conceptually simple. All monitoring windows are selected a priori along with an associated default telescope (or observing) period near the end of the window. The default period is when the observing will take place regardless of weather forecasts, unless a period with a better ranking score wins a time earlier in the window. This process guarantees observations within the window, while providing the scheduling algorithms an opportunity to provide appropriate weather. Movement of the telescope period to an earlier slot occurs about half the time. The calendar display, as used by the scheduler, represents the process by showing both chosen and default periods and whether each period is pending (P), scheduled (S), or deleted (D).

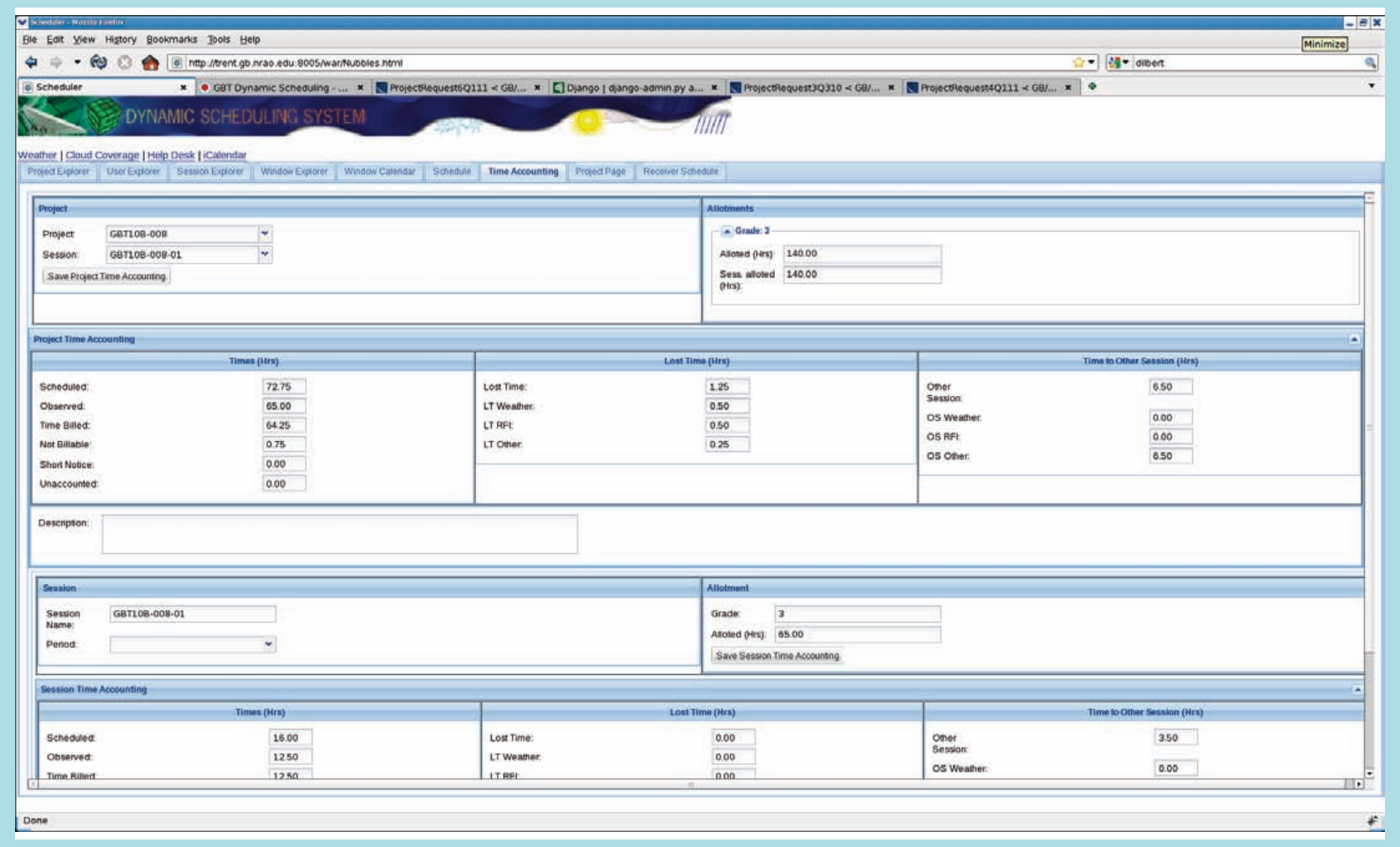
New Scheduler Tools

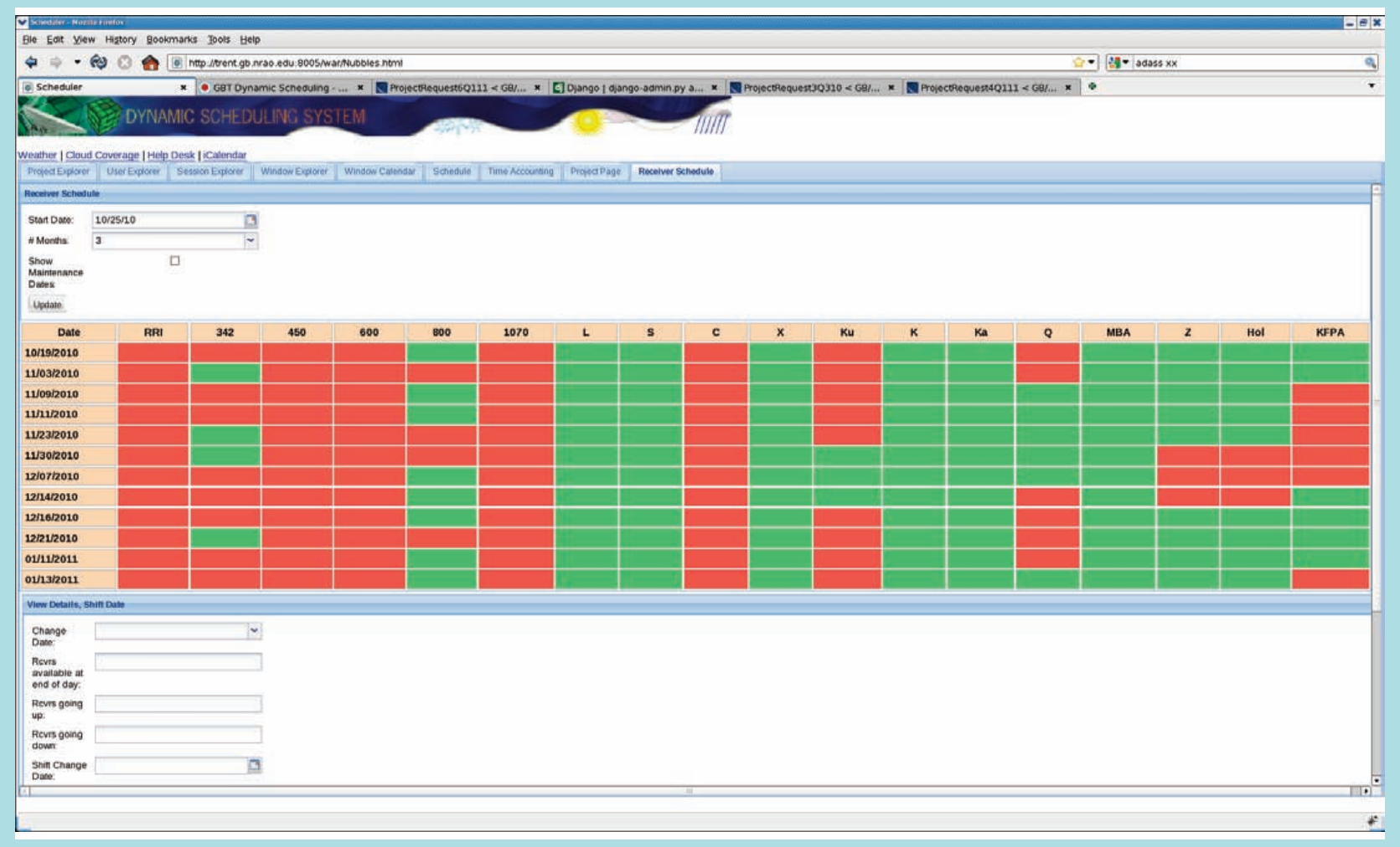
Through rigorous definitions of efficiency and application of the knapsack algorithm, the software is able to produce optimal schedules. However, there are examples where the scheduler desires to sacrifice efficiency in order to achieve special needs. The tools available in the scheduler's interface to the DSS provide the information and means to make these tradeoffs. In addition, tools are provided to aid the scheduler in updating observer qualifications, session observing criteria, window specifications, receiver schedule, and time accounting.



Start Date: 10/25/10
Days: 4
TZ: UTC
Schedule Control: (Current Average Score: 1.17 Unscheduled Time: 04:30)







Extended Weather History

Solitary weather forecasts are insufficient to generate realistic scheduling measures. Any metric must be weighed against the best possible weather and the likelihood of a specific weather measurement occurring. This information is drawn from historical weather. Previously, we extracted these measures from 2004-2007 forecasts. We now have added weather forecasts since 2007 providing a more reliable baseline.

Unexpected Benefits

Finally, the use of dynamic scheduling has provided additional benefits not originally targeted.

- disabling of pulsar sessions to allow adjustment to unexpected timing parameters
- unexpected equipment failures handled more readily with dynamic scheduling
- minimize downtime for major repair/maintenance activities
- target-of-opportunities projects are not invasive to other projects' schedules

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