# Intelligent Scheduler, Prioritize on the Fly

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**Abstract**

Honeywell Technology Solutions Inc. (HTSI) is developing a new mission planning and scheduling software package for NASA. This new, Intelligent Scheduler, which is based on the HTSI developed scheduler used by the Matera Laser Ranging Observatory (MLRO), will improve on the current NASA SATCOP Mission Scheduling software by allowing the dynamic prioritizing of satellites. The current scheduling scenario assigns static priorities to satellites and schedules the satellites according to those priorities. The new scheduler will allow the priority of a satellite to change according to criteria, such as, a satellite's position and the amount of data recently tracked. Additional features will be included, such as, fine interleaving and sun zone avoidance. The tracking schedule will alternate between a selected satellite and lower priority satellites at given time intervals when using fine interleaving. The Intelligent Scheduler will be a useful tool for generating optimal tracking strategies for the increasing number and variety of satellite missions. This paper will provide an overview of the Intelligent Scheduler and demonstrate its capabilities.

**Introduction**

Honeywell Technology Solutions Inc. (HTSI) is developing a new mission planning and scheduling software for NASA. This new, Intelligent Scheduler, which is based on the HTSI developed scheduler used by the Matera Laser Ranging Observatory (MLRO), will improve on the current NASA SATCOP Mission Scheduling software by incorporating several new features into the scheduling criteria. The new scheduling software will include the dynamic prioritizing of satellites. The scheduling scenario used by the SATCOP Mission Scheduling software assigns static priorities to satellites and schedules the satellites according to those priorities. The intelligent scheduler will allow the priority of a satellite to change according to some user assigned criteria.

A satellite's position and the amount of data recently tracked are among the criteria that may be considered when changing the priority of satellite. The SATCOP software had knowledge of only the start and end time of the visible of arc and had no knowledge of previously track data. The intelligent scheduler will know the position of a satellite during its entire visible arc and will have access to a satellite's recently tracked data. Several optimization applications have been developed which utilize these new features. The remainder of this paper will describe each optimization application and demonstrate its capabilities. A brief functional overview of the software will also be presented.

**Functional Description**

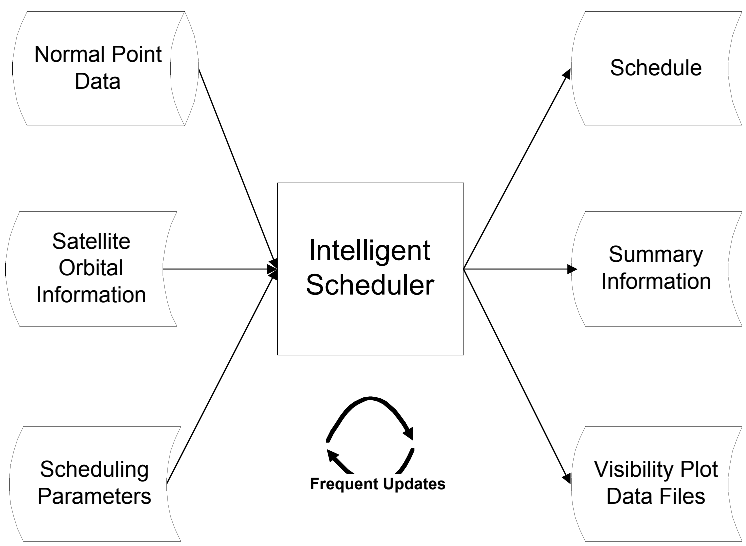


**Figure 1**. Intelligent scheduler functional diagram.

Figure 1 displays a schematic diagram of the main input and output data used by the intelligent scheduler. The intelligent scheduler inputs include normal point data or recently tracked pass information, satellite orbital information, and scheduling parameters. The normal point data may be downloaded from the CDDIS periodically. The scheduling parameters may be input from an ASCII file or using a GUI. The scheduler outputs the schedule, summary information, and data files used for visibility plots. The summary information will consist of the total number of passes and minutes each satellite is available versus the number of passes and minutes which the satellite is scheduled. When an optimization option is selected for a satellite the schedule is generated with and without the optimization applied and the net effects of the optimization will be output.

**Optimization Examples**

Several optimization applications have been developed which utilize the new features added to the intelligent scheduler. These feature include the following:

- Fine Interleaving Optimization
- Geodetic (sky coverage) Optimization
- AOS/PCA/LOS Optimization
- Ascending Descending Optimization

A description of each optimization application and a few examples are given below.

**Fine Interleaving Optimization**

When using the fine interleaving optimization for a satellite the schedule will alternate between that satellite and lower priority satellites at a given time interval. The use of fine interleaving optimization will help avoid scheduling scenarios where one satellite of several similarly prioritized satellites is scheduled a disproportionate amount of time. As an example, consider a scheduling scenario where Lageos-1, Lageos-2, Etalon-1, Etalon-2 are being scheduled with priorities 1,2,3, and 4 respectively. Figure 2 and 3 display a schedule and visibility plot for a two hour portion of a day.

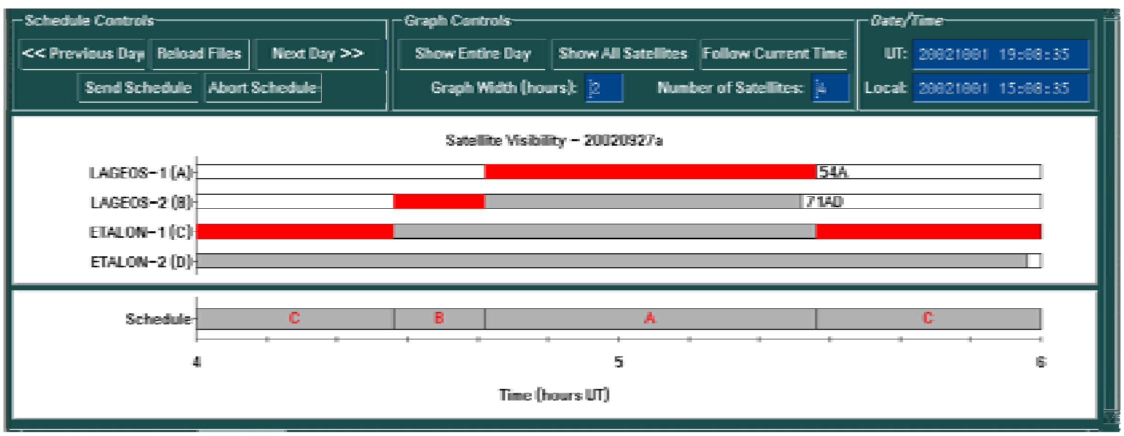


**Figure 2.** Visibility plot, fine interleaving NOT applied.

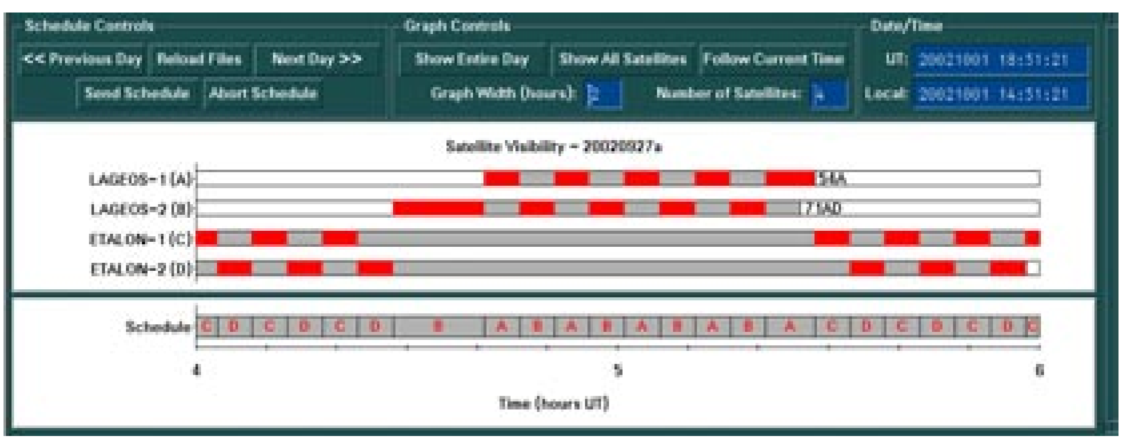


**Figure 3.** Visibility plot, fine interleaving applied to Lageos-1 and Etalon-1.

In both Figures 2 and 3, the lighter bars represent a satellite's visibility and the darker bars represents when the satellite is scheduled. Notice in Figure 2 that much more of the Lageos-1 and Elaton-1 are scheduled when compared to Lageos-2 and Etalon-2. When the schedule is regenerated with fine interleaving activated for Lageos-1 and Etalon-1 the resulting visibility plot is shown in figure 3. A fine interleaving interval of five minutes was used for both Lageos-1 and Etalon-1. The schedule now alternates between the optimized satellites and the other satellites in five-minute intervals. The resulting schedule produces a more even distribution between the satellites and each satellite's complete arc is more fully covered.

**AOS/PCA/LOS Optimization**

AOS/PCA/LOS optimization will allow the user to raise the priority of a satellite at the beginning, end, and the PCA of a pass. As example consider the scheduling scenario where a Etalon-1 is scheduled at a higher priority than Etalon-2. Figures 4 and 5 display a visibility plot

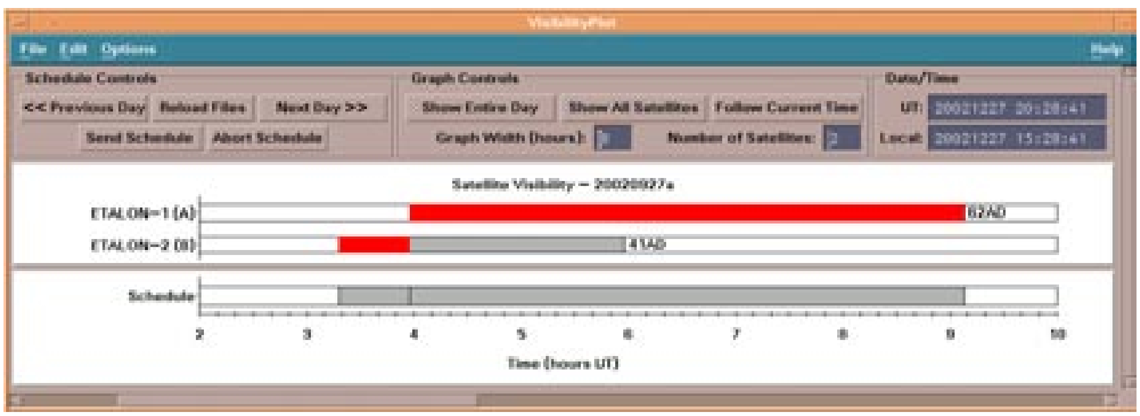


**Figure 4**. Visibility plot, AOS/PCA/LOS optimization NOT applied.

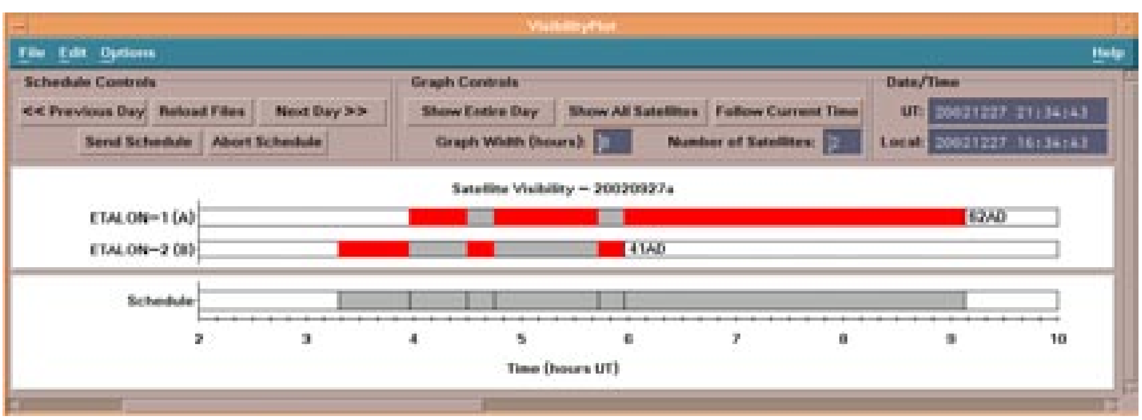


**Figure 5.** Visibility plot AOS/PCA/LOS optimization applied to Etalon-1.

and schedule for an eight-hour portion of the day. As expected, Etalon-1 is always scheduled when both the satellites are available. Figure 6 displays the visibility plot and schedule when the schedule is regenerated with AOS/PCA/LOS optimization activated for Etalon-2. In this example, the AOS/PCA/LOS priority for Etalon-2 is set to a higher priority than Etalon-1 and the track time is set to fifteen minutes. Notice that Etalon-2 is now scheduled for the fifteen minutes surrounding the PCA of the satellite and for the first and last fifteen minutes of the pass.

## Geodetic (Sky Coverage) Optimization

Geodetic optimization may be used to assist in obtaining complete sky coverage for a satellite. When using geodetic optimization the sky is divided into sections based on azimuth and elevation. An example of the sectioning of the sky is shown in Figure 6. The user is able to set a

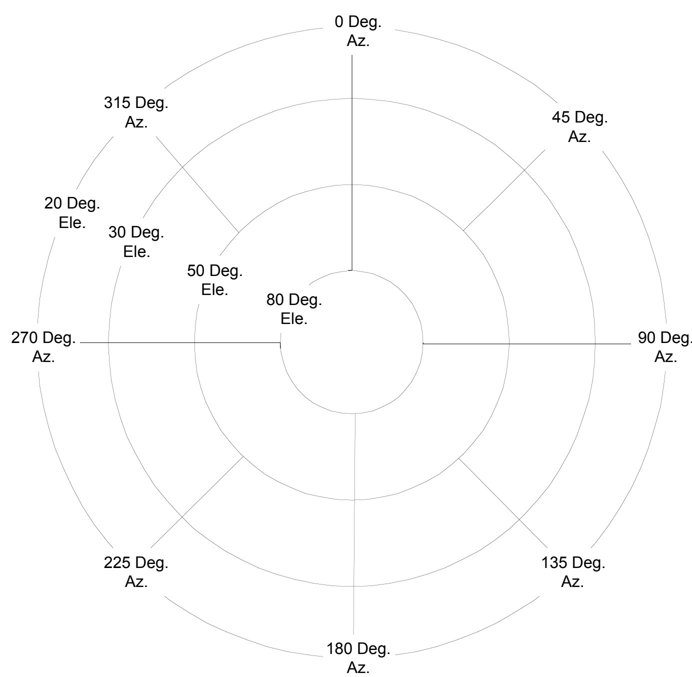


**Figure 6.** Sectioning of sky used for geodetic optimization.

minimum number minutes per sky section and a number of days of previously tracked data to be considered. The software will first calculate the number minutes that a satellite has been tracked in each sky section based on the previously tracked data. As the software is scheduling, the number of minutes a satellite has been tracked in a sky section plus the number of minutes a satellite is scheduled to be tracked in that sky section will be calculated. If this number is less then the minimum threshold set by the user, the priority of the satellite will be raised when it is in that sky section. As an example, consider Lageos-1 where geodetic optimization is activated with the following parameters:

Priority: 6
Days of previously tracked data: 14
Minimum minutes per sky section: 10
Raised priority 3:

The software would calculate the number minutes that Lageos-1 was tracked in each sky section during the previous 14 days. While generating the schedule, if the number minutes Lageos-1 was tracked in a sky section was less than 10, then during each minute that the position of Lageos-1 is in that sky section the priority of Lageos-1 would be raised to 3. The priority of Lageos-1 would set to its normal priority of 6, when the number of minutes tracked in that sky section plus the number minutes scheduled in that sky section becomes greater than 10.

**Ascending/Descending Optimization**:

Ascending/Descending optimization may be used to assist in obtaining even distribution data in ascending and descending nodes. Ascending/Descending optimization operates similarly to geodetic optimization. When using ascending/descending optimization for a satellite, the user enters the minimum number minutes per node and the number of days of previously tracked data to be considered. The software will first calculate the number of minutes a satellite has been tracked in each of the ascending and descending node. As the software is generating a schedule, the number of minutes a satellite has been tracked in each node plus the number of minutes a satellite is scheduled to be tracked in each node will be calculated. If this number is less then the minimum threshold set by the user, the priority of the satellite will be raised when the satellite is in that node. As an example, consider a scheduling scenario involving TOPEX and Jason. Figure 7 displays the summary of an eight-day schedule where TOPEX is scheduled at higher priority than Jason and ascending/descending optimization is not applied.

| Satellite or Event Name | Passes Available | Passes Scheduled | % | Pass Segments Scheduled | Minutes Available | Minutes Scheduled | % |
|---|---|---|---|---|---|---|---|
| TOPEX | 34 | 34 | 100 | 34 | 384 | 384 | 100 |
| JASON | 35 | 35 | 100 | 35 | 385 | 243 | 63 |

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* JASON * SUMMARY *
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| Descript. of Row Sub-Total | Passes Available | Passes Scheduled | % | Pass Segments Scheduled | Minutes Available | Minutes Scheduled | % |
|---|---|---|---|---|---|---|---|
| Total | 35 | 35 | 100 | 35 | 385 | 243 | 63 |
| Ascending | 18 | 18 | 100 | 18 | 194 | 124 | 64 |
| Descending | 17 | 17 | 100 | 17 | 191 | 119 | 62 |

**Figure 7.** Scheduling summary, ascending/descending optimization NOT applied.

Notice all the TOPEX is scheduled while only 63% of the available Jason is scheduled. Figure 8 displays the summary when ascending optimization is applied to Jason with a minimum threshold of 200 minutes. Notice all the ascending Jason is now scheduled.

| Satellite or Event Name | Passes Available | Passes Scheduled | % | Pass Segments Scheduled | Minutes Available | Minutes Scheduled | % |
| --- | --- | --- | --- | --- | --- | --- | --- |
| TOPEX | 34 | 34 | 100 | 34 | 384 | 325 | 85 |
| JASON | 35 | 35 | 100 | 35 | 385 | 320 | 83 |

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* JASON      * SUMMARY *
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ascending/descending optimization activated
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| Descript. of Row Sub-Total | Passes Available | Passes Scheduled | % | Pass Segments Scheduled | Minutes Available | Minutes Scheduled | % |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Total | 35 | 35 | 100 | 35 | 385 | 320 | 83 |
| Ascending | 18 | 18 | 100 | 18 | 194 | 194 | 100 |
| Descending | 17 | 17 | 100 | 17 | 191 | 119 | 62 |

**Figure 8.** Scheduling summary, ascending/descending optimization applied to JASON.

## Conclusion / Future Developments

The intelligent scheduler has enhanced capabilities from the current scheduling software. Among these capabilities are the dynamic prioritizing of satellites, incorporation of recently tracked data into the scheduling criteria, and the inclusion or the satellite's position during the entire visible arc into the scheduling criteria. Using these new capabilities several optimization application have been developed. These applications include fine interleaving, geodetic (sky coverage), AOS/PCA/LOS, and ascending/descending optimization. Several areas for future development have been identified. One of these areas is multi-system optimization. The optimization applications currently consider each system individually. Modifications could be made to consider groups of systems. The intelligent scheduler will useful tool for handling scheduling issues regarding the ever increasing number and variety of satellite missions.