# Commentary: Designing and Evaluating an On-line On-board Autonomous Earth Observation Satellite Scheduling System

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## Abstract

The paper reviewed [1] presents a simple but useful demonstration of an engineering trade study between an off-line (ground) and on-line (on-board) autonomous scheduling system. Of particular interest are the algorithm used and the results pertaining to the need, if any, for examining alternate observation permutations as well as the required computing power.

## Review

The abstract mentions development of a "feasible optimal sequence." It is important to realize that the sequence built is not optimal in most cases. The goal is to optimize the observations, but this is rarely accomplished because of the uncertainties in actually executing the observations. Worst case (2 or 3 sigma) estimates of execution times must be used to guarantee that the specified data is collected. For example, the nominal time to turn or slew the spacecraft to the observing attitude may be only a few seconds, but in order to guarantee that the observation will occur at the proper time, this value may be padded to a minute or more. This results in substantial inefficiencies.

The author claims that an Earth-observing satellite may have an orbit of "about one hour." In fact, astrodynamics requires that any sustainable orbit be at least 1.5 hours in duration. A typical Earth-observing satellite (e.g., Landsat, TOPEX) at 828 km altitude has an orbital period of 1.7 hours (101.5 minutes). There is also an implication that current satellites do not maneuver in all three axes (roll, pitch and yaw). Actually, many current spacecraft can easily maneuver around all three principle axes.

An important factor in planning which is mentioned is the time required to repoint the instrument for the next observation. This is very often a source of substantial inefficiencies in spacecraft operations, especially when it is necessary to reorient the entire spacecraft. In order to guarantee the proper orientation, a worst-case estimate of the time required is usually used. In a nominal case, then, much time is wasted waiting for the appropriate imaging time to arrive. A system that could accurately estimate on-board what the current repositioning rate is would be able to substantially reduce this inefficiency.

The author notes that "the only benefit of an increase in the optimal sequence is a possible better choice of the next image to acquire." This is a keen insight and key attribute of the algorithm described. The algorithm seeks to maximize the sum benefit from each set of observations considered. Thus, for $k = 1$, it simply picks the single observation with the highest benefit function value. For $k = 2$, the observations with the two highest benefit functions are selected since these, naturally, give the largest sum. This reasoning continues for any arbitrary k. Increasing k, in the absence of any new information, adds observations of declining benefit. Since it is not possible to find an unselected observation that is of greater benefit than any of those already selected, there is no overall benefit to changing the order of observations (again, assuming that no new information has become available). Hence, the only time to re-evaluate the next image to acquire is when new information arrives.

The experiment performed demonstrated that the benefits of on-line scheduling are realized when the observation requests are most dynamic. This makes sense intuitively. It also makes sense that the trade of off-line vs. on-line is ineffective if the computing power of the ground system is much greater than that of the on-board system. The interesting result is that the on-board system must not be more than an order of magnitude slower than the ground system for there to be a positive benefit to performing the work on-board.

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## References

[1] Verfaille, G. and Bornschlegl, E. , 2000, "Designing and Evaluating an On-line On-board Autonomous Earth Observation Satellite Scheduling System," *Proceedings, 2nd International NASA Workshop on Planning and Scheduling for Space*, San Fransisco, CA.