FIXED MODE vs. TARGETED MODES OF OPERATION: TESTING TWO EXTREME STRATEGIES FOR SPOT COVERAGE OF THE CONTERMINOUS UNITED STATES

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ABSTRACT

The SPOT satellite is a flexible data acquisition system. The early development of practical strategies for pointing the telescope and selecting the various modes of operation is the key to a successful adapation to our clients' future requirements.

Based in part on the experience acquired during the 1983 U.S. SPOT Simulation Campaign, we have tested, in a simulation mode, two distinct strategies for satellite acquisition:

Strategy # 1: SPOT instruments are operated in a fixed, near vertical mode.

Strategy # 2: Best efforts to acquire as many of the pre-identified sites as possible, in the modes requested.

In both cases, the satellite was operated continuously, whenever overflying the U.S. The exercise extended over one orbital cycle of 26 days, starting June 16, 1983, closely corresponding to the duration of the 1983 airborne simulation campaign.

The programming requests were formulated, for strategy #2, based on a list of 94 pre-identified sites as it stood when we started with the airborne acquisition. The results of the acquisition were assessed for cloud cover, using National Weather Service data and weather reports from "USA Today".

The strategies were compared to each other and to the aerial acquisition performance in terms of a single criterion:

- How many of the pre-committed and desirable sites were acquired?

As could be expected, Strategy # 1 (fixed) resulted in somewhat better areal coverage. Strategy # 2 (targeted) was considerably superior to # 1 for acquiring pre-identified sites as it reduced by 2 to 4 the time required to acquire 50% of such sites in the desired modes.

The study shows the feasibility and the effect of breaking of the set of pre-identified sites into higher and regular priority subsets.

Two different runs of strategy # 2 were made; one assumed perfect prior knowledge of the cloud situation, the other assumed that no forecast was available. It appears that the areal extension of cloud patterns is such that the effort of programming to the latest met forecast produces insignificant benefits.

Finally, the simulation illustrates the effect of increasing the number of sites pursued on the performance of targeted acquisition.

Considering that the benefits of site predesignation may be crucial for some important user categories, SPOT IMAGE Corporation intends to develop a SPOT targeting service.

INTRODUCTION

The 1983 U.S. SPOT Simulation Campaign, was a serious attempt to simulate a small number of crucial parameters of SPOT imagery. After the event, other analogies between the airborne and the space systems can be investigated. Among such parameters, timeliness of data acquisition (and delivery) is of special importance; in several areas it is expected to have a strong impact on the development of a commercial market. The present paper compares the two systems in that very respect. In the Simulation Campaign, it was necessary to cover a variety of sites within a minimum number of days and flight hours; it prompted us to request that potential clients designate for acquisition, and commit to purchase, specific target sites. From there on, the satisfaction of as many clients as possible and data sales went hand in hand. While the contractor and crew scored truly remarkable rates of success, a minority of sites still could not be acquired, resulting in client disapointment and lost sales. A free-flying satellite has over aircraft the obvious advantage of quasi-permanent availability, with a high level of ubiquity. Moreover, SPOT, as a pointable imaging system can potentially be programmed for priority acquisition of pre-designated sites or areas. How would it perform? Did the Simulation Campaign give too sweet an image? The answer to those questions is less than obvious, and was best approached by a simulation exercise.

ACQUISITION OF DATA BY SPOT OVER THE CONTERMINOUS UNITED STATES

Given its orbital parameters, the SPOT satellite overflies the conterminous United States two or three times a day. At a ground velocity of 6.6 kms/sec, there are 61 passes in a 26 day orbital cycle. Each pass is, on the average, about 4 minutes or 1,000 miles long, and would result in about 60 different scenes of data under perfect cloud cover conditions, should no changes be programmed into the observation modes. In practice, we programmed the observation modes in order to acquire predesignated sites on either side of the satellite ground track, within the 950 km corridor of access. The programming schedule is such that a particular pass is subdivided into up to 4 different time segments. The observation mode, and the mirror pointing angles are kept constant during each time segment. Because of the satellite system capabilities, successive time segments are separated by 10 to 20 seconds of unusable data, and the length of each time segment has to be at least 90 seconds. During one time segment, one of the following principal modes is selected:

- acquire the panchromatic and the color channels from a single instrument, the other instrument being idle.

- operate both instruments in the twin mode, with an overlap of about three kilometers yielding a combined swathwidth upwards of 117 km, the instruments being used either in the panchromatic or the color mode.

- both instruments used and pointed separately, each instrument being used either in the panchromatic or the color mode.

THE PROGRAMMING PROCEDURE

STEP 1:

A master site list is established. The 94 different sites are documented by name, geographic coordinates, SPOT reference system coordinates and mode desired (color only or color plus panchromatic). Two priority classes are defined: the higher priority class includes all sites that had either been prepaid or formally committed to on June 16, 1983. For any particular day, the candidate list of sites is derived from the master list by subtracting sites known to have already been acquired. No sites are added during the course of the exercise.

STEP 2:

Strategy # 2: The 61 U.S. SPOT passes are processed by chronological order. For each pass, the current list is screened, deleting all sites which are beyond observation range on both sides of the satellite track. For each of the remaining sites, the off-nadir viewing angle and time of observation are calculated.

STEP 3:

The best "pass schedule" is established, by breaking the pass into several time segments, and specifying for each segment the viewing angles and observation modes of the HRV instruments. The intent is to maximize the "estimated value" of the pass as well as the number of sites acquired, assigning greater weight to the high priority sites. The operator's knowledge of the application area for which the site is to be acquired is sometimes used to complete the optimization. For instance, some of the sites have to be acquired in a nearly vertical mode, whereas for others the viewing angle can be left open.

In one version of the exercise, the current weather is ignored. In the other version, it is known.

STEP 4:

After the day is programmed and completed, the acquisition results are assessed, using National Weather Service reports and "USA Today" weather reports. "Sunny" sites are removed from the candidate list, unless a second acquisition is necessary for stereo or other purposes. The "cloudy" sites are left on the list. "Partially cloudy" segments are tossed into one of the two previous categories, using a 30% probability that they be "sunny".

For Strategy 1 the whole exercise is done again but is considerably simpler since there is only one mode and no targeting.

RESULTS

The results obtained are illustrated by Figures 1 through 6 at the end of this paper.

RELATION OF THE SIMULATION TO THE ACTUAL PROGRAMMING OF SPOT:

The simulation, although addressing an oversimplified case, clearly shows that a customized programming service can significantly reduce the time needed to acquire data over specific sites. Customized programming may actually become mandatory for certain applications where the data can only be used if acquired during a specific period of time. The simulation also indicates that such customized programming will not be overly complex to implement. The numerical values derived from the simulation should not be construed as a forecast of performance. The situation will be more complex in the real case, and other constraints will have to be accommodated:

- The satellite may be unavailable at times of technical maintenance operation.

- The acquisition of remote areas of the world will either go through the circuits of foreign ground station acquisition, or will compete for space on the onboard tape recorders, a somewhat limiting resource.

- Finally, the heavy use of customized programming would automatically make the satellite less available for acquiring orderly, full coverage of extensive areas. Customized programming will result into a highly mode-diversified data archive of potentially lower value than would be obtained through more standard modes of operation. In practice, a compromise between customized and default programming will probably be established.

CONCLUSION:

This simulated acquisition exercise illustrates the potential of the targeting capability of SPOT for ensuring timely observation of specific small areas. SPOT IMAGE Corporation intends to develop this capability as part of high-quality services to the user community.

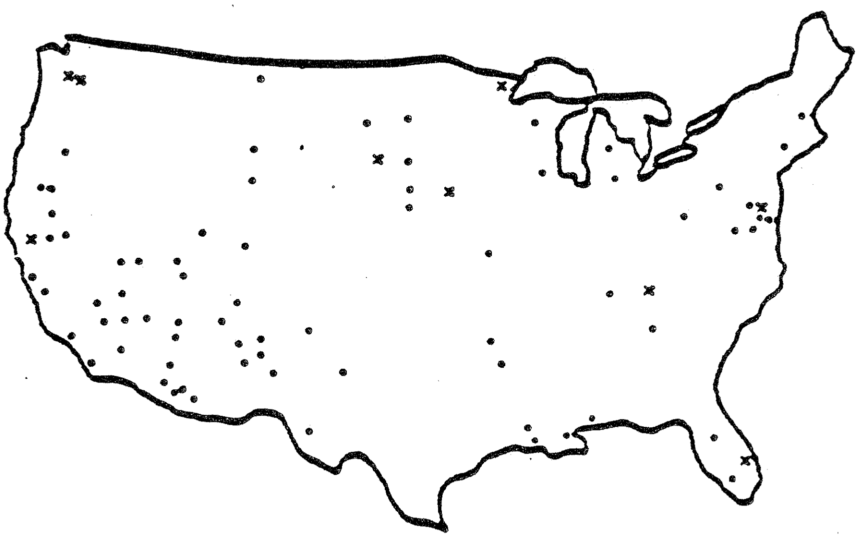
Figure 1. The Distribution of Sites over the U.S.

- 94 different sites were predesignated
- 61 were acquired by the aircraft
- 91 were acquired by the satellite with a targeting strategy (Strategy # 2), when the programming was done without meteorological forecast.
- 52 were acquired by the satellite, with fixed nadir pointing. In the twin mode, the sites were acquired either at 10 meter black and white or in 20 meter multispectral. The combined resolution requested by many users could not be provided. In an alternate substrategy, 31 sites were acquired with a single, nadir pointed instrument, providing both panchromatic and multispectral data.

Figure 1. The Distribution of 94 Predesignated Sites over the United States

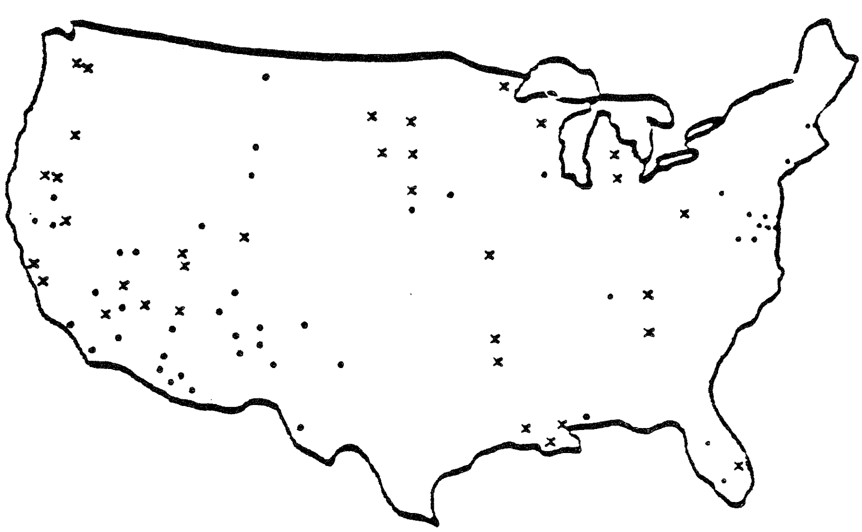
AIRCRAFT

- acquired
- × not acquired



SATELLITE POINTING STRATEGY (no meteorological forecast), Strategy #2

- acquired
- × not acquired



SATELLITE NADIR POINTING (twin mode, panchromatic or color), Strategy #1

- acquired
- × not acquired

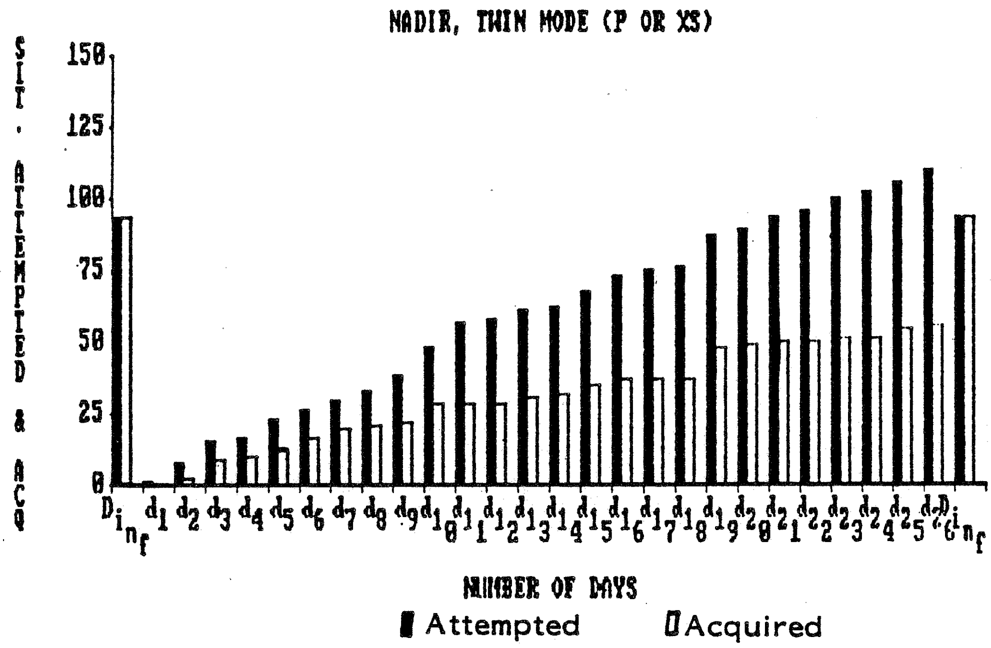


Figure 2. In the twin fixed targeting mode, within the list of 94 sites, about 4 sites a day are attempted and 2 sites a day are acquired, including a few which are acquired twice.

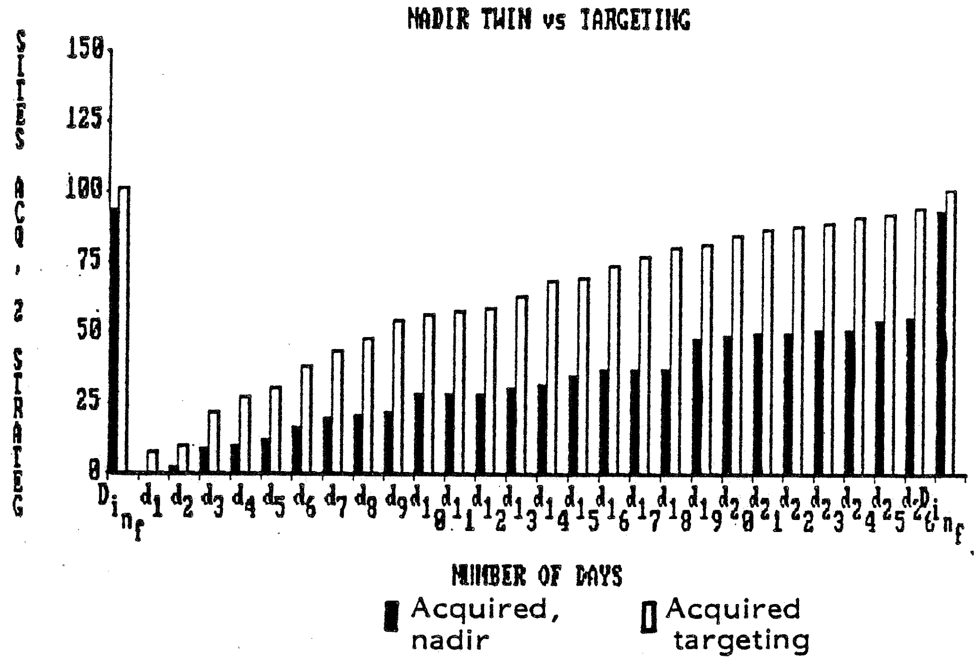


Figure 3. Using pointing Strategy # 2, not only are the required sites acquired in the mode preferred (usually panchromatic plus multispectral) but a significantly larger number of those sites is acquired. Early in the cycle about six new sites a day are acquired, but the rate slows to about three a day with the depletion of the list still to be acquired. At the end of the period, 89 sites are acquired.

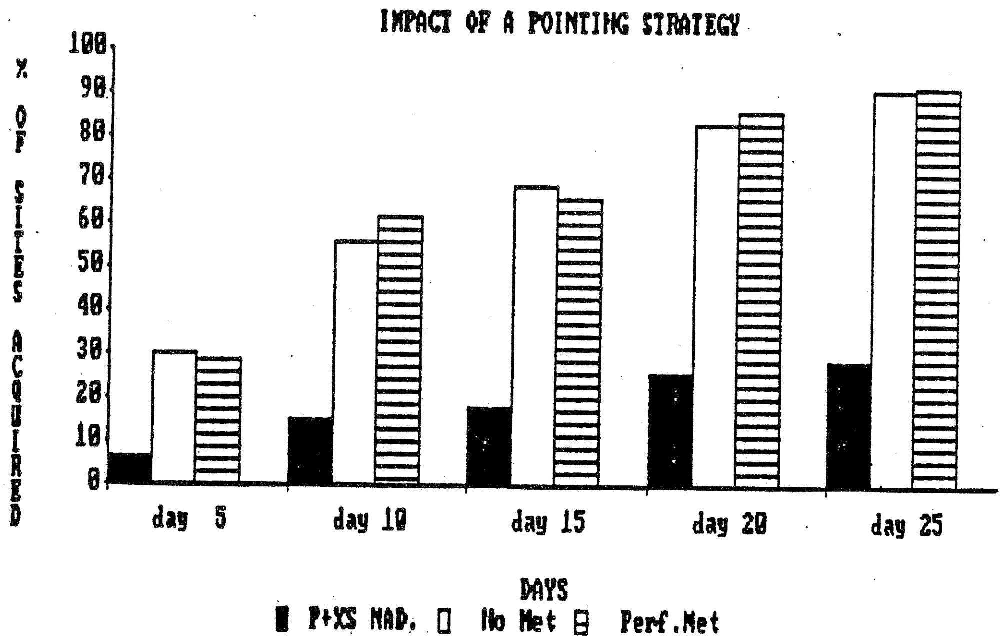


Figure 4. This cumulative display of the sites acquired with three different programs is displayed by breaking the orbital cycle into five day periods. Pointing Strategy # 2 is about three times more efficient than using one instrument in the nadir, providing both panchromatic and color information (swathwidth 60 km). The right hand bars correspond to hypothetically perfect prior knowledge of the cloud pattern at the time of overflight. This knowledge is used for acquiring the most valuable sites, and as many of the other sites as possible. Overall, it does not result into a significantly greater number of sites than an operation where we know nothing of the cloud pattern at the time when the programming takes place. Only where significant differences in the cloud cover occur across the corridor of access is anything to be gained by using the forecast in the present simulation.

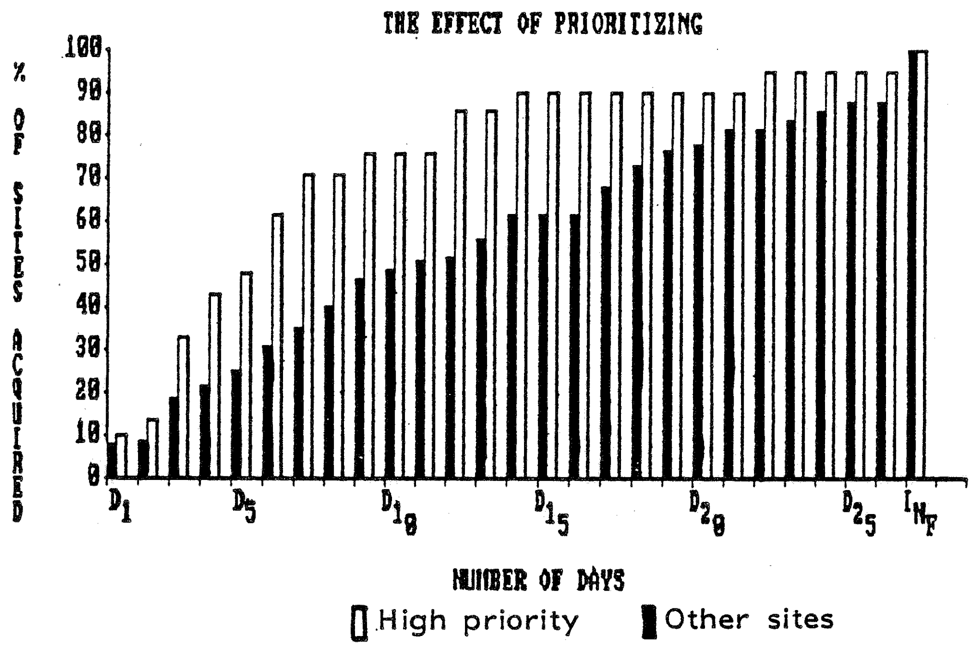


Figure 5. The twenty sites in the high priority sub-category are attempted again and again, resulting in faster acquisition than is possible for the regular priority ones. As a consequence, the time to acquisition of ten out of twenty high priority sites is five days, the time to acquisition of 50% of the regular priority sites is ten days.

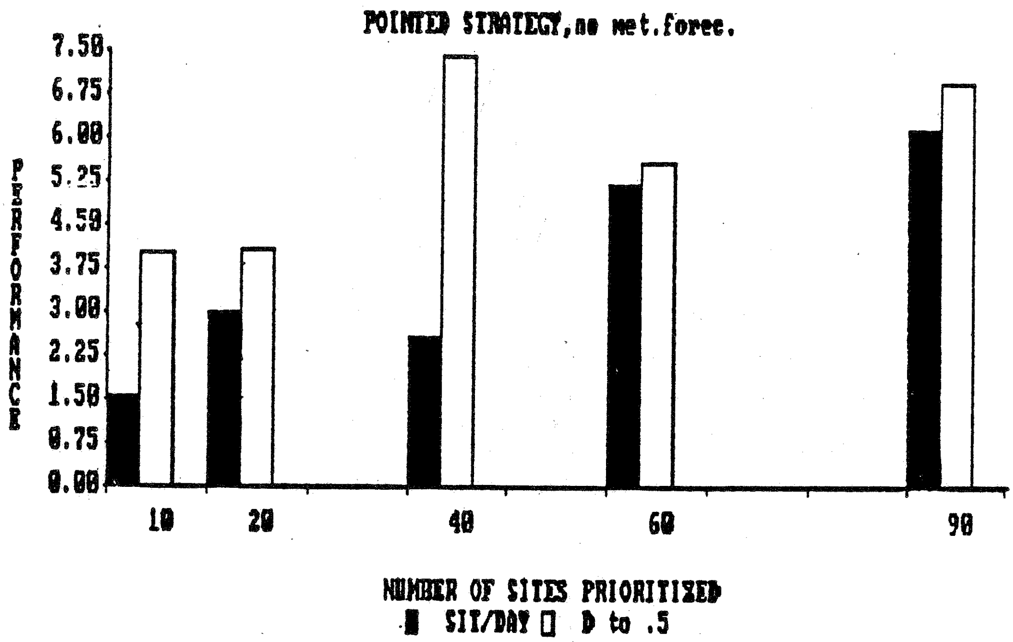


Figure 6. As the campaign progresses, the number of sites yet to be acquired is progressively reduced. This presentation of site acquisition in five day intervals provides an indication of the variation in performance of the acquisition as function of the size of the site list. As the number of sites grows, the number of daily acquisitions grows, as does the time to 50% acquisition. This diagram clearly reflects its statistical limitations: the cloud cover over most of the U.S. was considerable from June 26 through the end of the month, a fact which also marred the airborne acquisition.