Rapidly deployable Raven-class systems
SSA Support in the Field

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ABSTRACT

This paper discusses the use of Raven-class telescopes to support Space Situational Awareness (SSA) observations at remote locations. Topics include why such a deployment of telescopes might be necessary, the planning for the deployment, and a description of a recent deployment.

1. RAVEN-CLASS SYSTEMS

A Raven-class system is not a specific combination of telescope, sensor, mount, and software. It is a paradigm where the goal and concept of operations of the mission, along with the desired data products, define the components that will be used in that system. The objective is to develop a cost-effective system consisting of commercial off-the-shelf (COTS)-based hardware and software. Examples of Raven-class systems with different missions and therefore different hardware and software configurations include operational Ravens which support the Space Surveillance Network (SSN) and research and development (R&D) Ravens. The former are optimized for deep-space metrics, while the latter are often optimized for photometry.

2. DEPLOYMENT DECISION

There are a number of reasons why one might wish to deploy a telescope to a location other than a fixed site. Some satellites (e.g., geosynchronous satellites) may not ever pass over an existing location. Even if a satellite passes over the site, the observing conditions may not be optimal. The satellite may not pass over the site during terminator period, that period where the satellite is illuminated by the Sun, but the observing site is in darkness. The satellite may be in a highly-elliptical orbit, such that its range is very large when it passes over a site. It may be that interesting events associated with a satellite take place over other locations. Examples of this include the recent deployment of the Atmospheric Neutral Density Experiment (ANDE), and the deployment of the Dual RF Astrodynamic GPS Orbital Navigator Satellite (DRAGONSat).

3. DEPLOYMENT PREPARATION

Choosing the right combination of hardware and software, as well as choosing the team of individuals to support the deployment, is critical. This is particularly important when the deployment will be to a location that may not have all of the infrastructure normally associated with a telescope deployment. In those situations, one must take advantage of whatever infrastructure is present, which is complementary to the Raven paradigm of taking advantage of what is already available. Choosing equipment that is both reliable and robust, as well as bringing spares whenever feasible, is an important part of good contingency planning. Choice of the deployment team is also important, in that the members of the team should have a wealth of experience and knowledge, and a clear understanding of the capabilities needed for successful execution. In addition, particularly when deploying to a remote location where there may be few if any outside diversions, it is important to choose a team that works well together under pressure. Unnecessary drama can have a negative impact on the success of the mission. Finally, it is important to test both the equipment and the concept of operations prior to deployment, so that all of the components, hardware, software, and personnel, are exercised under the expected deployment conditions.

4. HARDWARE AND SOFTWARE

A recent example of a deployment took place where the mission was to rapidly integrate and deploy Raven-class systems to several remote locations. This was a temporary deployment to collect astrometric and photometric data on low-Earth-orbit (LEO) satellites. This was to be accomplished in a cost-effective manner, using existing hardware and software, as well as using whatever infrastructure existed at the remote locations. The hardware chosen for this deployment was based on what was available which would support this particular mission. The mount chosen was a Software Bisque Paramount ME. Although this mount was not designed for tracking LEO satellites, tests prior to deployment demonstrated that the mount could track LEO satellites quite well. The telescope chosen was an 11-inch aperture Celestron C11 Schmidt-Cassegrain, while the camera was an Apogee Alta U47. The software used was TheSky Professional, CCDSoft Version 5, and TPOINT, all from Software Bisque.

5. DEPLOYMENT LOCATION CRITERIA

Although the general area of the remote locations was chosen, there was some latitude in determining the exact location for the equipment. The criteria used to decide those locations included weather, sky brightness, obscurations, and any local constraints that might be location-dependent. Good weather is an obvious criterion for an optical system, particularly the presence of clouds during the observation period. Even if there are no clouds, a location might be ruled out because of bright sky conditions, due either to nearby outdoor lights, or even the presence of a large town many miles away. Local obscurations also play a role in the choice of location, either due to large buildings, tall trees, or mountainous terrain. In addition, there may be local constraints. The perfect location might be in someone's field, but the owner may object to setting up a telescope on their property. There may also be local ordinances that affect where one can deploy.

6. FIRST LOCATION

Fig. 1. Location of first deployment

The first location chosen is shown in Fig. 1, a guest ranch that was quite isolated, located in a shallow valley. In this location, there was no cell-phone coverage. The nearest location where cell phone coverage was available was a 30-minute drive. There was internet capability, but it was intermittent. The surfaces where the telescopes were deployed was grassy terrain in one case, and an existing concrete pad that was uneven and cracked.

7. SECOND LOCATION

Fig. 2. Location of second deployment

The second location chosen is shown in Fig. 2, a home on several acres that was quite remote, although there was a road nearby. In this location there was cell phone coverage, but no internet capability. Because mission planning had to occur on a daily basis, access to the internet was an important consideration. This could have been solved by driving into the nearest town with an internet cafe (about 45 minutes away). However, accessing the internet using a Blackberry, combined with a Mac Powerbook acting as a server, everyone on the deployment team had internet access at the remote location. The surface where the telescope was deployed was a gravel road.

8. SYSTEM PERFORMANCE

The systems deployed exceeded all of our expectations, in spite of the challenging local conditions and the limited infrastructure. We routinely tracked LEO satellites that happened to pass overhead throughout the evening. Recall that this is in spite of the fact that the manufacturer emphasized that the mount was not designed for LEO tracking. The following is a list of some of the LEO satellites of opportunity that were routinely tracked, where the mass and altitude are also indicated:

Table 1: Representative list of LEO satellites routinely tracked

Satellite name	Mass (kg)	Altitude (km)
SaudiComSat 7	12	660
FormoSat 3B	70	700
Genesis 1	1360	560
Cosmos 2151	2000	550
Beijing 1	166	700
Calsphere 4A	4	1100
CP4	1	700
AAU CubeSat	1	820

Note that the last two satellites on the list are CubeSat-class satellites, 1 kg picosatellites.

9. COMMENTS

In this initial deployment, two telescopes were deployed side-by-side as shown in Fig. 3. In this case, duplicate systems turned out to be very useful, since there were occasions where there were equipment failures (shutter on one of the camera systems, GPS receiver). This planned redundancy ensured that at least one system was fully operational at any given time. This also allowed one telescope operator to manually hand off to the other operator if the satellite was observed with only one system. In future deployments, we may separate the telescope system by several hundred miles, effectively providing a stereo view of the satellite which can improve the analysis.

Fig. 3. Side-by-side telescopes

The entire system can be set up in one evening. This includes setting up and leveling the mount, polar aligning the telescope, and performing a mount model. The result is the ability to routinely track LEO satellites on the first night of operation.

10. CONCLUSIONS

We successfully demonstrated the proof of concept of deploying Raven-class satellites to remote locations in support of SSA observations. The COTS systems were easily sufficient to support these type of missions. The way forward is to collect data simultaneously from multiple sites separated by several hundred miles.