**Ground-based Space Object Surveillance System**

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**Research Background**

Since October 1957, the Space Age has begun. The utilization of man-made satellites has expanded from broadcasting radio pulses to habitable space stations for scientific experiments. At the same time, the number of the orbiting objects (roughly 10 centimeters or larger), commonly referred to as Resident Space Objects (RSOs), has also increased dramatically to approximately 21,000 in March 2012, according to NASA. Among these existing objects, only about 900 are active satellites [1]. The rest are called space debris. The task of monitoring the orbits of these RSOs is crucial to the safety of active satellites and success of future launches. In this research, we will focus on Ground-based space object surveillance systems that use ground-based facilities to monitoring RSOs residing between low earth orbit and geostationary orbit.

Space Debris Threats

Space debris is the collection of defunct objects in orbit around Earth. Included are spent rocket stages, retired satellites, and fragments from disintegration, erosion, and collision. Many early satellites orbit at relatively low altitude and when they reach the end-of-mission state, the drag from the upper reaches of the Earth’s atmosphere slowly cause them to reenter the atmosphere where most of the components “burn-up”. With the advancement of technology, these orbits expand into much higher altitudes. The natural self-cleaning nature of space because of atmospheric drag, however, becomes ineffective [1]. The orbits of those uncontrolled, out-of-service satellites are no longer under control. This imposes a risk on all the active satellites. For instance, on 10 February 2009, the derelict Soviet/Russian communications satellite Cosmos 2251 collided into the operational, commercial Iridium-33 satellite 790 kilometers above northern Siberia at a speed of nearly 7.5 km/sec. The collision demolished both, which created more debris, orbiting in an unknown trajectory [2]. In addition, on 15 March 2009, the last minute discovery of a piece of debris dangerously close to the International Space Station (ISS) caused an emergency evacuation of the crew into the docked Soyuz lifeboat. These events could have been treated differently if most of the RSOs were monitored more closely [3].

Current Surveillance System

Primarily, current space control and surveillance systems are under theh United States Strategic Command’s Joint Functional Component for Space mission. The surveillance of space is conducted by Joint Space Operation Center. They task the Space Surveillance Network (SSN), a worldwide network of 29 space surveillance sensors, to observe RSOs. These sensors include: phased-array radars, conventional radars, electro-optical sensors, space based space surveillance, and ground-based electro-optical deep space surveillance. The crews monitor the position of each RSO and update the Space Catalog, a comprehensive listing of the numbers, types, and orbits. The SSN uses a “predictive” technique to monitor RSOs. Instead of tracking them continually, it spot checks them periodically. This technique is used because of the limits of the SSN, such as number of sensors, geographic distribution, capability, and availability [4].

Problem

As mentioned above, most of the space observations are done by those 29 advanced space surveillance sensors. The primary problem is that SSN doesn’t have enough resources to track the massive number of RSOs. Currently, 380,000 to 420,000 observations are made each day [4]. Given the number of RSO, each RSO only has 20 observations each day on average; too few to adequately monitor these objects. At the same time, the amount of debris orbiting the Earth continues to increase. The continued increase of RSOs will eventually result overworked sensors and inaccurate data entries.

One Solution - Crowd-sourced, Optical RSO Tracking

One solution that was proposed by a senior design client that could address some of this problem is a crowdsourced[[1]](#footnote-1), optical RSO tracking system. This system would be a global network that consists of thousands of privately-owned, camera-based observation stations that are centrally-coordinated to take pictures of these RSOs. Once these images are captured and uploaded, the central system will process these images. If the RSO of interest is visible, the system will determine its location, trajectory, and speed. It is possible that the RSO may not be visible because of weather conditions, atmospheric conditions, changed course, or destruction. Finally, the processed information will be stored and shared publicly on the internet so that government, military, and civilian entities can download and use it.

This system can roughly be broken down into the following four parts:

1. a large collection of individual observation stations for capturing images,
2. a central system to task the image capture devices and gather the resulting images (the image capture devices are controlled by the system, not the owner, allowing greater coordination of data gathering),
3. an image processing system to process the collected imaged to determine the visible RSO’s location, trajectory, and speed, and
4. a distribution system to offer the data for public use

An electrical and computer engineering senior design project is currently underway and tasked with creating an image capture device (<https://sites.google.com/site/busattrak/>). (I am not a member of this team.) This project only covers the first component of the system, image capture devices, and not the other parts. One goal of my work is to continue the work on this project into the other parts of the system.

**Research Description**

As described in the previous section, my goal is to continue this project and explore the possibility of building such a system. My work will focus on the rest of the system: communication, control, image processing, and distribution. Some of these components have been developed and are used in similar ways. However the idea of applying them together to the area of RSO tracking is relatively new. My research will investigate the needs of such a system and the existing methods and work on these components and develop a solution specifically tailored to RSO tracking. In order to accomplish this, I will conduct a thorough literature review for each part during the summer. I will summarize, in a technical report, a list of the best solutions that can be used for our purpose, focusing on how these solutions meet the specific needs of RSO tracking. At the same time, I will develop an integrated solution to the RSO tracking system based on the knowledge from this report. This result will be used to identify the research area for the following Honors Thesis.

**Timeline and Research Goals**

Tentative Schedule

Week 1: Evaluate the results and final report from the current senior design project and the requirements of the system to support a device like theirs

Week 2-6: Research on the existing solutions to rest components of the system

* Crowdsourcing methods - conduct bidirectional data transfer with the local devices through internet
* Image processing techniques - identify the path of RSO and calculate its properties
* Information dissemination - gather the information from the system and share them to the public in an accessible way

Week 7-8: Based on the previous research, make a suggestion on the best solution to the RSO tracking system. Propose an approach and evaluation process for the following Honors Thesis work

Goals

* Review and evaluate projects and ideas related to parts 2, 3, and 4 in the context of the greater project. Specific focus on:
  + Crowdsourcing methods
  + Image processing techniques and methods
  + Information dissemination
* Propose an approach and evaluation process for honors thesis work

Successful completion of these milestones and goals will set the foundation for the honor thesis research in the following year. The proposed deliverable at the end of the summer is a thorough report on the literature review on the state-of-art ground-based space object surveillance systems.

**Research Environment**

The project will be done in the Electrical Engineering lab room, Breakiron163. Prof. Thompson and I will meet formally once a week to discuss progress/problems and set goals for the following week. Besides these formal meetings, there will be more informal opportunities to discuss problems with him throughout the summer.Prof. Thompson will provide all needed equipment for this work, as well.

# Works Cited

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1. Crowdsourcing is a process that involves outsourcing tasks to the undefined general public, often via the Internet and without compensation. [↑](#footnote-ref-1)