Apr 1st, 8:00 AM

USAFs Role in Space Surveillance

Robert M. Kronebusch
Director of Missile and Space Defense, Plans and Programs, Headquarters Aerospace Defense Command, Colorado Springs, Colorado

Scholarly Commons Citation

Kronebusch, Robert M., "USAFs Role in Space Surveillance" (1979). *The Space Congress® Proceedings*. 3.
https://commons.erau.edu/space-congress-proceedings/proceedings-1979-16th/session-2/3

USAF'S ROLES IN SPACE SURVEILLANCE

Colonel Robert M. Kronebusch
Director of Missile and Space Defense
Plans and Programs
Headquarters Aerospace Defense Command
Colorado Springs, Colorado

ABSTRACT

Currently USAF SPACETRACK supports the U. S. space effort in a variety of ways. Space surveillance permits space objects to be detected, identified, located continuously, analyzed, avoided, monitored for status changes, and to have their decay impacts predicted. These functions are performed in compliance with international agreement and national space policy. As the U. S. and other nations venture forward in space, new requirements will be levied on USAF to defend our space investments. The USAF SPACETRACK System is evolving to meet this challenge.

INTRODUCTION

Projects MERCURY, GEMINI, APOLLO, VOYAGER, SKYLAB, and VIKING are just a few of the exciting space projects of the recent past that most people will readily recognize. "Live via satellite," is a television byline that people have come to take for granted. In the future, SPACELAB and flights of the shuttle ORBITER, among other projects, will elicit profound attention. Meanwhile, quietly behind the scenes, the United States Air Force (USAF) SPACETRACK System tracks, catalogs, identifies, and monitors over 4,600 objects in space; calculates whether satellites might collide; predicts where reentry debris might fall; and provides various amounts and types of data to many government and non-government organizations.

THE SPACETRACK SYSTEM

Within the Department of Defense, the Commander in Chief, Aerospace Defense Command, has been charged with overall space surveillance responsibility. The Aerospace Defense Command (ADCOM) operates USAF SPACETRACK, an integrated worldwide single manager system, and represents Headquarters USAF as the operational planning agency for space surveillance.(1) When the USAF SPACETRACK System is coupled with other systems, such as the U. S. Navy's Space Surveillance System and the Canadian Baker-Nunn cameras, the total network is known as the Space Detection and Tracking System or SPADATS. The SPADAT System which has evolved over the years is made up of a wide variety of sensors; some, such as the powerful optical Baker-Nunn cameras, are dedicated to this mission; others, such as the phased array radars and Ballistic Missile Early Warning System, play a major role in space object tracking while performing the uninterrupted primary mission of surveillance for ballistic missile warning.(2) All data from the SPADATS network enters the Space Defense Center located inside the North American Air Defense Command (NORAD) Cheyenne Mountain Complex near Colorado Springs, Colorado. The Space Defense Center is a 24 hours-per-day, 7 days-per-week operation which processes more than 30,000 observations daily on the over 4,600 objects in orbit. Since SPUTNIK I in 1957, the Space Defense Center has cataloged over 11,000 space objects, more than half of which have been deorbited or have naturally decayed from orbit.(3)

DOD INTEREST

With the rapid technical evolution of space activity has come a U. S. dependence on space for communications, weather information, attack indications and warning, and navigation aids. Future applications, such as the Global Positioning Satellite System, will increase this dependence even more. Trends in space activity indicate that there is a growing awareness of this fact both in the U. S. and in other countries. As a result, the evolution of space activity over the 21 1/2 years since SPUTNIK I has been matched by the development of a sophisticated tracking network.

ORBIT DETERMINATION

A satellite's elliptical orbit is classically described by six parameters: semimajor axis of the ellipse; eccentricity of the ellipse; inclination of the orbit with respect to the equatorial plane; right ascension; argument of perigee; and true anomaly at some epoch time. Any other orbital elements can be defined in terms of this set of six independent variables. As can be discerned, a satellite's position should be precisely defined by these orbital elements. This would be true if it were not for perturbations due to the earth's oblateness, nonuniform gravitational fields, solar radiation pressure, and atmospheric drag. In general, space objects virtually "dance around" in their basic orbit due to the effects these anomalies have on their motion. Additionally, some of these anomalies are difficult to predict. For example, the atmospheric model in the motion equation provides only an estimate of the drag effects because of the uncertainty in solar activity.

For routine studies, general perturbation techniques normally provide orbital element set accuracies on the order of 12 kilometers or less in positional error. When extremely accurate results are required, special perturbation routines (which consider more of the forces that affect satellite motion) can be used. For example, element sets on selected satellites in nearly circular 800 kilometer altitude orbits can normally be maintained with a position error of less than 1 kilometer for a three day prediction.

IMPORTANT "ROUTINE" FUNCTIONS

With the magnitude of operation in space surveillance, many tasks performed by the Aerospace Defense Command have become routine. The word "routine," however, must be differentiated from "unimportant." The importance of ADCOMs routine functions can be partially substantiated by international agreements. By United Nations agreement, the country which launches a satellite is solely responsible for any damage resulting from decaying satellite debris. Additionally, any recovered objects remain the property of the originating nation regardless of impact area. The comprehensive SPACETRACK system provides one method of monitoring compliance with this treaty. Article 3 of the 1971 Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War between the U. S. and U.S.S.R. requires the parties to undertake to notify each other immediately in the event of unidentified objects if such occurrences could create a risk of outbreak of nuclear war.(4) The interpretation of this Article, of course, is that these unidentified objects may appear to the missile warning sensor system as incoming ballistic missiles. The Space Defense Center catalog, made available via the World Data Centers, helps to bring many potentially unidentified objects into the identifiable realm. In accordance with a memorandum of agreement between NORAD and NASAs Goddard Space Flight Center, the NORAD Space Defense Center provides Goddard with data and information concerning U. S. and foreign launches. Goddard, in turn, is responsible for the release of unclassified scientific and technical information on space vehicles and their behavior.(5)

In addition to routine surveillance and cataloging, the Aerospace Defense Command also performs other valuable functions. Consider, for a moment, the spectacular disaster if a manned mission were to collide with another satellite at the velocities of space vehicles.

THE SATELLITE COLLISION RISK

The Space Defense Center helps to protect against such collisions with a program called COMBO. COMBO is the acronym for Computation of Miss Between Orbits and is a program designed to compute the points of closest approach between any satellite and one or more other satellites. Generally, any two satellites in orbit will have two points of close approach during each orbital revolution. These two points are referred to as relative minima, and the smaller of the two is the absolute minimum. The absolute minimum, then, is the closest approach between the satellites in question.

The COMBO program can give a motion history and path prediction for each satellite for any points that fall within a certain specified minimum separation. The relative minima are determined by computing the relative positions at a predetermined interval using an orbit representation subroutine. When the program recognizes that the distance between the two objects of interest is near minimum, it iterates using a Newton-Raphson technique to determine where, in the time interval, the relative minimum will actually occur. The data output gives satellite positions in various coordinate systems, including inertial coordinates, and relative position and velocity of one satellite with respect to the other.(6)

The important consideration in this regard is that COMBO provides a predicted separation distance between two predicted satellite positions. The actual accuracy of COMBO, is, therefore, directly related to the accuracy of observations provided by the SPADATS sensors and the accuracy of the orbit representation model used. In general, miss distance prediction accuracies have an uncertainty on the order of two kilometers under ideal conditions, so these data can serve to alert of a dangerous proximity but cannot definitely predict a collision.

Although the probability of collision between satellites is remote, COMBO is run before and during all manned missions to provide an extra measure of safety for our astronauts in space. As the space population continues to grow, the value of COMBO also rises.

As pointed out earlier, the space population is increasing, but there is also an applicable decay rate among satellites. Of the nearly 11,000 objects placed into space since SPUTNIK I, only about 4,600 remain. The rest have either been intentionally deorbited, as in recovery of astronaut vehicles, or have re-entered the atmosphere in classical orbit decay.

DECAY PREDICTIONS

A decay prediction program is used by the Space Defense Center to forecast the eventual decay of satellites in orbit. For decay purposes, we classify satellites into two general categories: (1) small objects, known as "normal decays," usually less than one square meter in size and expected to burn up completely in the earth's atmosphere; and (2) larger objects which have a good chance of surviving reentry to earth impact. We call satellites in this second category TIP decays.

TIP is an acronym for Tracking and Impact Prediction, a task formally levied on Aerospace Defense Command by the Air Force Chief of Staff in 1967.(7) The Chief originally called the function Terminal Impact Prediction, and although the name has evolved to Tracking and Impact Prediction, the acronym survived. TIP supports the international agreements, mentioned earlier, regarding liability for damage caused by debris and measures to prevent risk of outbreak of nuclear war.

Normally, thirty days prior to decay, the Space Defense Center will begin to closely monitor a TIP satellite. Before the final prediction is made, seven TIP decay messages will be transmitted at established intervals to various government agencies. At six and again at two hours prior to decay, the Space Defense Center recommends to the NORAD Command Post whether or not to report the TIP to the National Military Command Center as a "significant space event." The criterion for a significant space event is simply any TIP satellite whose predicted impact falls within plus or minus 15 minutes of the Soviet landmass. Because a satellite pending decay travels approximately 250 nautical miles per minute, the criterion envelope extends 3,750 nautical miles from the U.S.S.R. When the National Military Command Center is advised of a significant space event, it, in turn, notifies various agencies up to and including the President if certain reporting criteria are met.

The complexity of TIP prediction can be appreciated by briefly analyzing some of the associated limitations and technical problems. These fall into the following general categories: limitations due to sensor locations; atmospheric density model errors; satellite altitude changes and the resultant "drag effects;" and ballistic re-entry phenomena.

Despite the proliferation of optical and radar sensors, the fact remains that we can observe a satellite for only small arcs along its total elliptical path. Additionally, all but two of our current sensors are in the northern hemisphere; therefore, balanced orbit coverage is also not possible. Consequently, a TIP satellite could actually go unobserved for five or six hours, a significant limitation for an object within a few hours of decay. Hence, the ability to predict a satellite's position when it is not in sensor coverage is vitally important. Unfortunately, prediction is also affected by the orbit determination problems mentioned earlier.

Because of these limitations, impact prediction is not an exact science. Therefore, a credence or confidence window is assigned to each TIP prediction. Confidence in decay prediction is defined as plus or minus 20 percent of the elapsed time between the last sensor observation and the predicted time of decay. Because of the limited number of sensors, this figure has historically translated to an average window of plus or minute 5,700 nautical miles. Even if we consider the best possible case for the two hour prediction (i.e., a sensor observation exactly two hours before the predicted decay), the best confidence window that could be associated with this is 20% of two hours, or plus or minus 24 minutes, which translates to about 12,000 nautical miles along the satellite's course of travel.

To complicate this situation, unpredictable anomalies can occur which drastically change a satellite's decay. For example, in one actual case, the satellite "skipped" off the upper reaches of the atmosphere and remained in orbit for one and a half revolutions beyond the two-hour predicted decay point. An opposite effect is seen when a stable satellite suddenly becomes unstable and commences to tumble as it impinges upon the atmosphere in which case it is very likely to decay earlier than predicted.

To focus on these aspects of the TIP program, let's consider what is, to date, the decay that has attracted the greatest public attention: the decay of the Soviet COSMOS 954 and its impact in Canada.

COSMOS 954

Space Detection and Tracking System sensors observed the degenerating orbit of COSMOS 954 during October and November of 1977, and original calculations produced a decay date in mid-April 1978. These predictions persisted as late as January 4, 1978, when the Space Defense Center analysts still predicted an April re-entry. They did, however, caveat their prediction with, "If it remains stable." Two days later, the stability criterion was violated--COSMOS 954 had begun tumbling at about one-quarter revolution per minute. Historically, re-entry of near earth satellites occurs between two and five weeks after the onset of tumble.

An average TIP satellite requires about 20 computer runs or about five hours of computation time. COSMOS 954 was averaging three times normal due to high national interest.

On January 21, the prediction was for a 40 hour confidence window spanning January 24 and 25. Two days later, the prediction was for 7:55AM Eastern Standard Time (EST) on the 24th. Although this prediction eventually proved to be "right on," the plus or minus 10 hour confidence window left considerable uncertainty as to impact location.

One day before re-entry, the decay prediction time was plus or minus five hours from 10:03 AM EST on the 24th. At 10 hours prior to decay, the prediction was for 8:43 AM EST on the 24th, plus or minus three hours. The six and two hour predictions showed a 95% probability that if the debris struck a landmass, it would not be the Soviet Union. The decay of COSMOS 954 did not meet the previously mentioned criteria for a significant space event.

The final prediction came after the fact and chiefly as a result of visual sighting and data from a Hawaiian site; 7:56 AM EST plus or minus three minutes; area indicated--Great Slave Lake in Canada.

As stated earlier, sensor coverage is one limitation of the SPADATS system that affects our TIP capability. For COSMOS 954s last nine hours of flight, only 25 minutes of observational data was obtained. That is, sensors "saw" only 4.8 percent of the last nine hours flight path--everything else was prediction.

SKYLAB

The preceding figures may give some insight into the concern over the decay and re-entry of SKYLAB later this year. While probability favors an insignificant impact into the ocean, the Aerospace Defense Command will apply more man hours and more computer time to TIP predictions for SKYLAB than for any previous decay. Data sharing with other agencies will jump from routine to maximum.

SUPPORT TO OTHER AGENCIES

Routine data sharing and support to other agencies by Aerospace Defense Command (ADCOM) is handled by the NORAD Combat Operations Center Technical and Data Support Division. This is the single point of contact for SPADATS requests from all agencies involved in DOD activities. Support requests from civilian scientific organizations are made via NASA/Goddard Space Flight Center. NASA/ADCOM interface is via the Aeronautics and Astronautics Coordinating Board, a highly effective means of maximizing the benefits derived from NASA programs for defense use, and, in turn, assuring that the technology developed in military programs is available for civil applications.

CONCLUSION

The USAF SPACETRACK System, as an integrated worldwide single manager system, will continue to be an active partner in the overall U. S. space program. Looking ahead, Aerospace Defense Command is currently planning and programming additional radar and optical sensors to add to the SPADATS network and to decrease some of the limitations pointed out in this discussion. Economic constraints prevent us from ever having sufficient ground-based sensors to see a satellite everywhere in its orbit; however, long-range future plans put state-of-the-art sensor technology on satellites in deep space. This space-based system will have an unrestricted view of all objects in earth orbit and a down-link data system to what will by then be the Space Operations Center (a planned evolution of the Space Defense Center). And, this future system will continue the mission precedent established by the present system, monitoring activities in space to help preserve the use of outer space by all nations for peaceful purposes and for the benefit of mankind.(9)

APPENDIX

The SPADATS Sensors:(10)
Dedicated sensors--NORAD/ADCOM assigned sensors whose primary mission is satellite detection and tracking:

- Edwards Air Force Base, California: Baker-Nunn camera
- Pulmosan, Korea: Baker-Nunn camera
- San Vito, Italy: Baker-Nunn camera
- Mt John, New Zealand: Baker-Nunn camera
- The Navy Space Surveillance System (NAVSPASUR): a radiometric interferometer consisting of transmitters and receivers across the width of the U. S. at the 33rd parallel.

Collateral sensors--ADCOM assigned sensors whose primary mission is other than SPACETRACK:

- Ballistic Missile Early Warning System: detection and tracking radars at Thule, Greenland; Clear, Alaska; and Fylingdales, England (Royal Air Force).
- Shemya, Aleutian Islands, Alaska: phased array radar.
- Eglin Air Force Base, Florida: phased array radar.
- Concrete, North Dakota: phased array radar.

Contributing sensors--those sensors not assigned to ADCOM which provide SPACETRACK data to ADCOM:

- Millstone Hill, Massachusetts: Lincoln Laboratory deep space tracking radar.
- Ascension Island and Antigua Island: Air Force Eastern Test Range (AFETR) tracking radars.
- Maui, Hawaii: electro-optical sensor.
- Socorro, New Mexico: active test station, optical sensor.
- Kwajalein Atoll: Air Force Western Test Range Tracking radars.
- Part-time contributors, including the Air Force Satellite Control Facility, other AFETR tracking radars, and NASA tracking and detection sensors.

ACKNOWLEDGEMENT

The author gratefully acknowledges information and assistance provided by the NORAD Space Defense Center; the Space Defense Activity Branch, Systems Control and Configuration Division, Headquarters Aerospace Defense Command; and by other highly professional Headquarters Aerospace Defense Command personnel, too numerous to mention.

REFERENCES

(1) NORAD/ADCOM Pamphlet 55-47, "SPACETRACK Users Pamphlet," 5 March 1977, p. 1-1.

(2) General James E. Hill, Commander in Chief, NORAD/ADCOM, address to the Air Force Association Symposium, Los Angeles; October 26, 1978.

(3) General James E. Hill, Commander in Chief, NORAD/ADCOM, address to the Rotary Club; Tulsa, Oklahoma; December 6, 1978.

(4) "Agreement on Measures to Reduce Risk of Outbreak of Nuclear War Between the U. S. and U.S.S.R.," U. S. Treaties and Other International Agreements, Vol 22, Part 2 (Washington D.C.: U.S. Government Printing Office, 1972).

(5) Memorandum of Agreement Goddard Space Flight Center and North American Air Defense Command, September 1977.

(6) NORAD/ADCOM Pamphlet 55-47, p. 7-4.

(7) Department of the Air Force, Memorandum of Agreement: "Satellite Skin Tracking and Terminal Impact Prediction Support," 15 November 1967.

(8) Robert M. Parker, Overview Statement for "The Department of Defense Activities in Space and Aeronautics" before the Subcommittee of Science and Space, 95th Congress, 9 March 1977, p. 18.

(9) Announcement of Administration Review, Administration of Jimmy Carter, 1978: "United States Space Activities," Washington D.C., June 20, 1978, pp. 1-3.

(10) NORAD/ADCOM Pamphlet 55-47, pp. 4-1 through 4-2.

BIBLIOGRAPHY

(1) "Agreement Between Department of Defense and National Aeronautics and Space Administration on Functions Involved in Space Surveillance of U. S. and Foreign Satellites and Space Vehicles," June 16, 1961.

(2) "Agreement on Measures to Reduce Risk of Outbreak of Nuclear War Between the U. S. and U.S.S.R." U. S. Treaties and Other International Agreements, Vol. 22, Part 2, (Washington, D.C.: U. S. Government Printing Office, 1972.)

(3) Announcement of Administration Review, Administration of Jimmy Carter, 1978: "United States Space Activities," Washington, D.C., June 20, 1978.

(4) Department of the Air Force, Memorandum of Agreement: "Satellite Skin Tracking and Terminal Impact Prediction Support," November 15, 1967.

(5) Hill, James E., General, USAF, (Commander in Chief NORAD/ADCOM); address to the Air Force Association Symposium, Los Angeles, October 26, 1978.

(6) Hill, James E., General, USAF (Commander in Chief NORAD/ADCOM); address to the Rotary Club; Tulsa Oklahoma; December 6, 1978.

(7) JCS Memorandum for the Commander in Chief, Continental Air Defense Command: "Assignment of Operational Control of the Space Detection and Tracking System," November 7, 1960.

(8) Memorandum of Agreement Goddard Space Flight Center and North American Air Defense Command, September 1977.

(9) NORAD/ADCOM Pamphlet 55-47, "SPACETRACK Users Pamphlet," March 5, 1977.

(10) Parker, Robert M., Overview Statement for "The Department of Defense Activities in Space and Aeronautics" before the Subcommittee of Science and Space, 95th Congress, March 9, 1977.

(11) Parker, Robert M., "The Department of Defense Activities in Space and Aeronautics, FY 1978," March 9, 1977.

(12) Presidential Directive/NSC-42: "Civil and Further National Space Policy;" Washington, D.C., October 10, 1978.