Abstract

Narrowband (NB) and wideband (WB) radar signatures are used by the U.S. to improve the fidelity of the space catalog. Whereas space surveillance answers the question "Where is it?" using metric information, space object identification (SOI) answers the question "What is it?" using NB and WB radar signatures. NB radar signatures consist of either the radar cross-section (RCS) history or the range-time-intensity (RTI) history of a satellite. NB signatures of simple satellites are analyzed using known RCS scattering formulae to determine size and shape. NB signatures of more complex satellites are automatically compared to databases of signatures of known satellites to properly categorize them. WB radar signatures consist of range-Doppler images. If the motion of the satellite about its center-of-mass is known, range-Doppler images can be properly scaled to obtain accurate shape and size estimates of satellites. By using WB images, analysts can clearly distinguish between payloads and rocket bodies. Hence, cross-tagging in the space catalog is prevented.

1. Introduction

Narrowband (NB) and wideband (WB) signatures are used to support the space catalog on resident space objects (RSOs). This paper discusses the role of such signatures in the space object identification (SOI) process. It is divided into five sections. Section 2 defines the terms “space surveillance” and “space object identification” and gives some background. Section 3 gives a brief overview of the U.S. Space Surveillance Network (SSN) and satellite signature measurement facilities whose data MIT/LL uses to improve the fidelity of the space catalog. Section 4 discusses NB radar signature techniques and contains examples of both simulated and actual NB radar signatures. Section 5 discusses WB radar imaging techniques and shows an example of a simulated WB radar image. Section 6 summarizes the results.
2. Definitions

The term “space surveillance” is intended to answer the question “Where is it?”.

Towards this end, metric information describing the RSO’s orbit is generally used. Such metric information is provided by ground-based radars and optics, such as those of the U.S. SSN and, more recently, by space-based optics such as the space-based visible (SBV) sensor on the Midcourse Space Experiment (MSX). The term “space object identification” is intended to answer the question “What is it?”. Towards this end, the signature of the RSO is generally used. A satellite signature can either be a radar signature, an optical signature, or an infrared signature. A radar signature can be either NB or WB, depending upon the bandwidth (BW) of the radar. A NB radar signature (i.e., BW < 200 MHz), consists of a one-dimensional time series display of the radar cross-section (RCS) of the satellite. If the motion of the satellite about its center-of-mass (CM) can be determined, then the satellite RCS can be displayed as a function of aspect angle relative to the radar line-of-sight (RLOS). A WB radar signature (i.e., BW > 200 MHz) consists of a two-dimensional range-Doppler image. As will be discussed later, image resolution in the range direction is inversely proportional to the BW of the radar. Image resolution in the cross-range direction is inversely proportional to the aspect angle change Δθ relative to the RLOS that the satellite experiences during the time it takes to form the image (i.e., the coherent integration interval of the image). If the motion of the satellite about its CM can be determined, the Doppler scale can be “converted” to a cross-range scale. An infrared signature consists of a time series display of the radiant intensity of the satellite.
Infrared signatures of satellites are beyond the scope of this paper and will not be discussed.

Figure 1 illustrates the fundamentals of an optical search and tracking system. The power source is the Sun whose power density is 1360 Watts/m$^2$. A satellite in Earth orbit absorbs some of the Sun’s energy and scatters the rest in several directions. A fraction of this energy is observed by an optical system (i.e., telescope, electronics, display, etc) a distance R away. The power density at the optical system is proportional to R$^{-2}$. The optical system measures the azimuth and elevation of the satellite and the time. Depending upon its configuration, the optical system can also measure satellite brightness, polarization, and color. Optical systems rely on the good night-time seeing conditions which typically accompany a high altitude site with good weather.

Figure 1  Fundamentals of an optical search and tracking system
Figure 2 illustrates the fundamentals of a radar search and tracking system. The power source is the radar which transmits electromagnetic energy with a power $P_t$. The power density at the satellite is proportional to $P_t R^{-2}$, where $R$ is the distance from the radar to the satellite. The satellite scatters the radar’s energy in several directions. A small portion of this energy is scattered back towards the radar. The power density of this scattered energy received by the radar suffers an additional $R^{-2}$ loss and is thus proportional to $P_t R^{-4}$. Radar systems measure RCS, range, azimuth, elevation, range-rate, and time. In contrast to optical systems, radar systems are all-weather search and tracking systems.

![Diagram of a radar search and tracking system](image)

**Figure 2** Fundamentals of a radar search and tracking system
Earth orbiting satellites fall into one of the four classes of orbits illustrated in Figure 3. Satellites in low Earth orbit (LEO) generally have a perigee in the range 300 – 1000 km. Those in high Earth orbit (HEO) have a perigee and apogee of approximately 20,000 km (i.e., half-synchronous orbits). The high eccentricity orbits are HEO orbits whose perigee is approximately 500 km and whose apogee is approximately 40,000 km. The geosynchronous orbit (GEO) has both a perigee and an apogee equal to approximately 40,000 km. Additional information on these satellite orbits is contained in the 1998 US-Russia conference briefing by Banner.¹

<table>
<thead>
<tr>
<th>Orbit Class</th>
<th>Typical Orbital Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Objects (#)</td>
</tr>
<tr>
<td>Low Earth Orbit (LEO)</td>
<td>6500</td>
</tr>
<tr>
<td>High Earth Orbit (HEO)</td>
<td></td>
</tr>
<tr>
<td>Half-Synch</td>
<td>400</td>
</tr>
<tr>
<td>High Eccentricity</td>
<td>290</td>
</tr>
<tr>
<td>Geosynchronous (GEO)</td>
<td>630</td>
</tr>
</tbody>
</table>

Figure 3  Illustration of the four classes of typical satellite orbits
3. The U.S. Space Surveillance Network

Figure 4 shows the present-day U.S. SSN which consists of dedicated UHF NB radars (NAVSPASUR, Eglin), dedicated electro-optical sensors (AMOS/MOTIF (Maui), Socorro (New Mexico), MOSS (Moron, Spain), and Diego Garcia; collateral UHF radars (Clear, Beale, Parcs, Thule, Otis, and Fylingdales); contributing radar sensors (ALTAIR (UHF, VHF), TRADEX (L-Band, S-Band), ALCOR (C-Band), MMW (Ka-Band, W-Band), Kaena Point (C-Band), Millstone (L-Band), Haystack (X-Band), HAX (Ku-Band); and the SBV experimental sensor on MSX.

Figure 4. The U.S. Space Surveillance Network
Figure 5 shows the radar and optics sites which gather satellite signature data which MIT/LL uses to improve the space catalog. MIT/LL is the Scientific Advisor to the U.S Army Kwajalein Atoll (USAKA) situated in the Marshall Islands. At Kwajalein there are the following four radars: ALCOR (C-Band), MMW (Ka-Band and W-Band), ALTAIR (UHF and VHF), and TRADEX (L-Band and S-Band). ALCOR and MMW are WB radars capable of generating two-dimensional range-Doppler images of satellites, whereas ALTAIR and TRADEX are NB radars capable of generating metric information and one-dimensional radar cross-section (RCS) histories of satellites. These four radars gather signature data on near Earth satellites. ALTAIR can also gather UHF signature data on deep-space satellites.

Figure 5 Satellite Signature Measurement Facilities
At Socorro, New Mexico, there are the following six optical telescopes: two Ritchey-Chretien, two 1.5 m f/2.15 equatorial mount, a 59 cm folded Schmidt, and a 0.25 m refractor. Precise metric information and signatures are obtained on both near Earth and deep space satellites. The companion paper in this conference by Pearce discusses the SOI capabilities of the ETS in more detail.

At Westford, Massachusetts, there are the following five radars: Millstone (L-Band), Haystack (X-Band), HAX (Ku-Band), a moveable UHF radar, and a stationary zenith-pointing UHF ionospheric backscatter radar. Shown in Fig. 6, the Westford facility is commonly referred to as the Lincoln Space Surveillance Complex (LSSC) which consists of the Millstone, Haystack, and HAX radars. The Haystack and HAX radars are WB radars, whereas Millstone and the two UHF radars are NB radars. In addition to producing RCS histories of satellites, Millstone produces extremely precise metric information on satellites. Although Millstone is primarily used for deep space (it is a contributing sensor to the SSN), it can also track near-Earth satellites. Haystack can image both near-Earth and deep-space satellites, whereas HAX primarily images near-Earth satellites. It should be noted that a deep-space satellite is defined as a satellite whose orbital period exceeds 225 min. This corresponds to a satellite altitude of approximately 5000 km.
4. Narrowband Radar Signature Techniques

To illustrate some simple narrowband signature techniques, consider idealized satellites in the shape of a cylinder and a cone in different low Earth orbits. Table 1 lists several idealized cases with either a tumbling motion, an Earth referenced stable motion (i.e., a satellite with a fixed orientation with respect to an observer on the Earth), or an inertially stable motion (i.e., a satellite with a fixed orientation with respect to an observer in space).
Table 1  Sample Simulated Narrowband Signatures

<table>
<thead>
<tr>
<th>OBJECT</th>
<th>MOTION</th>
<th>TUMBLE PERIOD(s)</th>
<th>ORBITAL INCL (deg)</th>
<th>ORBITAL PERIOD (m)</th>
<th>APOGEE</th>
<th>PERIGEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder</td>
<td>Tumble</td>
<td>200</td>
<td>28.3</td>
<td>106.4</td>
<td>759</td>
<td>567</td>
</tr>
<tr>
<td>Cone</td>
<td>Tumble</td>
<td>200</td>
<td>28.3</td>
<td>106.4</td>
<td>759</td>
<td>567</td>
</tr>
<tr>
<td>Cylinder</td>
<td>Stable</td>
<td>-</td>
<td>97.4</td>
<td>94.9</td>
<td>340</td>
<td>295</td>
</tr>
<tr>
<td>Cylinder</td>
<td>Stable</td>
<td>-</td>
<td>97.4</td>
<td>94.9</td>
<td>340</td>
<td>295</td>
</tr>
<tr>
<td>Symmetric Turntable</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: 1 Earth-referenced
2 Inertially referenced
Apogee & Perigee in statute miles
Source: Fundamentals of Radar Target Analysis, RCA Training Text, Course No. 901, 1985

Figure 7 shows the simulated UHF (400 MHz) signature of a cylinder 6.1 m long and 2.44 m in diameter tumbling in a LEO orbit whose apogee is 759 nautical miles (nm) and perigee is 567 nm. The observed 25.8 dBsm peak return (labeled “side”) is consistent with the theoretical peak return expected of a cylinder of length \( L \) and radius \( a \) according to the formula \( \sigma_{\text{peak}} = \frac{2\pi a L^2}{\lambda} \), where \( \lambda \) is the wavelength of the radar. Note that the side “speculars” have sidelobes which are 13 dB down from the specular peak. This sidelobe level is consistent with the return expected of a cylinder. The clearest tumble period (corresponding to 360 deg of aspect angle change) is seen from the RCS history in the fourth panel. There one sees that the full width (2\( \theta \)) of the main lobe, estimated to be 8 deg, can be used to estimate the length \( L \) of the cylinder according to the formula \( L = \frac{\lambda}{2\sin \theta} \). Hence by observing the shape and repetitive pattern of characteristic radar returns, one can estimate physical characteristics of simple satellites.
Figure 7  Simulated NB UHF signatures of a tumbling cylinder

Figure 8 shows the simulated UHF (400 MHz) signature of a cone (side length = 2.3 m, base diameter = 1.73 m, apex angle = 40 deg) tumbling in the same LEO orbit as the cylinder seen in Fig 7. The asymmetric sidelobes of the peak radar return (labeled “side”) are characteristic of a cone. The best tumble period (corresponding to a 360 deg change in target aspect) is seen in the second panel which indicates a 200 sec tumble period between same side speculars. The aspect angle change $\Delta \theta$ between major lobes
attributed to adjacent sides of the cone is estimated to be 140 deg. From this estimate, the cone apex angle $2\phi$ can be estimated according to the formula $\phi = 90 - \Delta\theta /2$.

![Figure 8 Simulated NB UHF signature of a tumbling cone](image)

Figure 8 shows the simulated UHF (400 MHz) signature of a tumbling cone. Figure 9 shows the simulated UHF (400 MHz) signature of an Earth-referenced stable cylinder in low Earth orbit (apogee = 340 nm, perigee = 295 nm). The broad lobing structure near horizon break (0 – 120 sec) and horizon set (560 – 720 sec) and the narrow lobing structure near minimum range (320 – 400 sec) are characteristic of an Earth-referenced stable satellite. For this simulation, the longitudinal axis of the cylinder (i.e., its axis of symmetry) lies in the orbit plane and is always pointing towards the center of the Earth. The symmetry in the RCS signature is due to the axial symmetry of the cylinder and its orientation relative to the center of the Earth. Unlike the case of a tumbling cylinder, characteristic dimensions of an Earth-referenced stabilized cylinder cannot be reliably determined from the RCS signature alone.
Figure 9  Simulated NB  UHF signature of an Earth-stabilized cylinder

Figure 10 shows the simulated UHF (400 MHz) signature of an inertially stabilized cylinder in the same low Earth orbit as the cylinder seen in Fig 9. The cylinder is oriented with its axis of symmetry perpendicular to the plane of the orbit. The broad lobing structure of the RCS signatures throughout the pass (even near minimum range occurring between 360 – 400 s) is characteristic of an inertially stabilized satellite. Characteristic dimensions of an inertially stabilized cylinder also cannot be reliably determined from the RCS signature alone.
A physical optics NB simulated signature of a slightly more complex object at X band (10 GHz) is shown in Fig 11. In the regime of physical optics, the wavelength of the radar energy ($\lambda = 3$ cm at X-Band) is much less than the physical dimensions of the satellite. In this simulation, for simplicity, the object is rotating on a turntable. High RCS returns (i.e, speculars) occur when the RLOS is perpendicular to a flat surface. From Fig 11 we see that this occurs at the surface of the rear nozzle section (Aspect D), at the surface of the main body cylinder (Aspect B), at the surface of the transition region (Aspect C), and at the circular flat surface at the end of the cylinder (Aspect E) where the highest RCS (~ 30 dBsm) is observed. Note the nearly constant RCS at Aspect A where the RLOS is perpendicular to the curved front section of the object for approximately 20 degrees of aspect angle.

Fig 11  Simulated NB X-Band signature of a more complex object
A representation of a WB (1024 MHz) physical optics simulation is shown in Fig 12. In this range-time-intensity (RTI) representation, individual back-scattered pulse shapes are plotted one above the other as function of time (time increasing upwards). Increasing time corresponds to increasing aspect angle. Speculars are seen when the RLOS is perpendicular to the side of the main body (Aspect B), target rear (Aspect E), and nozzle side (Aspect D). Notice the appearance of range sidelobes when the RLOS is perpendicular to the rear of the target (Aspect E).

![WB range-time-intensity display (physical optics simulation)](image)

The NB signatures of actual RSOs are more complex than those previously illustrated for cylinders and cones. The goal of developing NB satellite signature techniques is to obtain a more accurate space catalog. In such a catalog, the cross-tagging which sometimes occurs between payloads and rocket bodies is minimized.
Towards this end, MIT/LL has gathered together over 190,000 NB satellite signatures from the U.S. SPACETRACK network consisting of C-Band, L-Band, and UHF radars (see Fig 4) and has developed an automatic signature processing algorithm to characterize them\(^4\).

Figure 13 illustrates a LEO satellite being tracked by a NB radar. The angle between the RLOS and the velocity vector of the satellite is defined as the “look angle”. The angle between the RLOS and a plane tangent to the Earth at the radar site is defined as the “elevation angle”. A five step algorithm has been developed to process NB satellite signatures. The first step involves pre-processing the satellite signatures to remove radar glitches, data drop-out, etc. The next step compares two signatures along the range of common look-angle and divides the signature into overlapping segments of about 10 deg of common look-angle. The third step divides individual signatures into overlapping segments of about 10 deg. The fourth step cross-correlates the segments in order to obtain a measure of segment similarity. The fifth step computes a “statistical distance” based upon the segment correlation and the shifts that the correlation process identifies as best aligning the segments. The result of this process applied to three typical UHF NB signatures A, B, and C (of unequal look-angle extent) is shown. Three statistical distances are computed by this method for signatures A and B. There are three distances, rather than one, because signatures A and B cover a wide range of common look angle. Only one statistical distance is computed by this method for signatures B and C because of their smaller range of common look angle. A distance less than zero implies that the two signature under consideration are similar, thus indicating that the two
signatures represent satellites of the same class. Signatures B and C are thus dis-similar by this method, and, hence, correspond to satellites of different classes.

**Procedure**
1. Pre-process the satellite signatures (remove glitches, smooth, etc)
2. Compare 2 signatures along their range of common look angle and divide the signatures into overlapping segments of about 35 deg
3. Divide individual signatures into overlapping segments of about 10 deg
4. Cross-correlate the segments to obtain measures of segment similarity
5. Use the segment correlation and the shifts that the correlation process identifies as best aligning the segments to compute an overall distance

**Results**
\[
\begin{align*}
\text{dist}(A, B) & : -4.79, -2.12, +2.05 \\
\text{dist}(A, C) & : -2.05 \\
\text{dist}(B, C) & : +0.80 \\
\text{dist} < 0 & \Rightarrow \text{similarity}
\end{align*}
\]

**Figure 13 Narrowband signature processing**

The Doppler signatures of three closely-spaced satellites (SDC Objects 24891, 25585, and 23764) which form a satellite cluster (i.e, multiple satellites in a single radar beam) are shown in Fig. 14 which is a screen-shot of the actual display used at Millstone. Each satellite occupies three range gate traces on the display (Note: two of the range gate traces have been truncated at the top of the screen). The three satellites are distinguished from one another on the basis of RCS, range, and Doppler shift. Zero relative Doppler shift appears in the middle of the display on the three lowest range gate traces containing the satellite.
Figure 14 Millstone display screen showing three satellites in a cluster

An RTI can also be used to distinguish between satellites in a cluster. Figure 15 shows another screen-shot of the actual display used at Millstone. Since all three satellites are stable, their corresponding Doppler widths are narrow. Due to their different distances from the radar, the satellites appear in different range gages in the RTI display. Range profiles are stacked one above the other, with time increasing upwards.
5. Wideband Radar Signature Techniques

Similar to the goal of NB signature technique development, the goal of WB radar signature technique development is to improve the quality of the space catalog and space surveillance by positively identifying satellites on the basis of their external appearance. As shown in Table 2, there are the following four WB space surveillance (SS) network assets that Lincoln Laboratory uses: ALCOR (C-Band), Haystack (X-Band), HAX (Ku-Band) and MMW (Ka-Band and W-Band). The ALCOR and MMW radars are U.S. Army assets located at Kwajalein, Marshall Islands. Lincoln Laboratory is the Scientific Advisor to the U.S. Army
Kwajalein Atoll (USAKA). The Haystack and HAX radars are located at the LSSC (see Fig 6) and are managed by Lincoln Laboratory. The operating frequency, bandwidth, and corresponding range resolution of each of these radars are shown. The large geographic separation between the LSSC and USAKA is illustrated in Figure 16.

Table 2. Wideband radars used by MIT / Lincoln Laboratory

<table>
<thead>
<tr>
<th>RADAR</th>
<th>FREQ (GHz)</th>
<th>BANDWIDTH (MHz)</th>
<th>RESOLUTION (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALCOR</td>
<td>5.6</td>
<td>500</td>
<td>54</td>
</tr>
<tr>
<td>HAYSTACK</td>
<td>10.0</td>
<td>1000</td>
<td>27</td>
</tr>
<tr>
<td>HAX</td>
<td>16.7</td>
<td>1000, 2000</td>
<td>27, 13.5</td>
</tr>
<tr>
<td>MMW</td>
<td>35, 95</td>
<td>1000, 1000</td>
<td>27, 27</td>
</tr>
</tbody>
</table>

Figure 16  Locations of ALCOR, MMW, Haystack, and HAX
Figure 17 traces the chronology of WB imaging radar technology in the U.S. ALCOR was the first WB radar to produce radar images of near-Earth satellite (with 54 cm range resolution) in 1972. Next came the Long Range Imaging Radar (LRIR), also known as Haystack, which produced radar images of both near-Earth and deep space satellites in 1978. Beam waveguide technology was introduced into the MMW radar in 1990 and WB radar images having 13.5 cm range resolution were produced. “On-demand imaging” (i.e., the ability to track satellites and obtain WB radar images at any desired time) was achieved when the Ku-Band HAX radar was introduced in 1993. Similar to the WB images produced by the MMW, HAX WB radar images also have 13.5 cm range resolution. A user-friendly radar imaging workstation was introduced at the LRIR and HAX in 1994 along with the ability to improve range resolution using the mathematical technique of bandwidth expansion.

Figure 17  Chronology of WB imaging radar technology in the U.S.
The formation of a WB radar image is illustrated in Figure 18. To form a WB radar image of an Earth-orbiting satellite, the Doppler variation of the received signal caused by the orbital motion of the satellite must first be estimated and removed. Once this has been accomplished, the problem of computing a radar image is reduced to that of imaging a stationary target on a rotating turntable.

- **Estimate target trajectory from radar metric information**
- **Remove trajectory dependency from target data**
- **Result**
  - Problem reduced to imaging a stationary target on a rotating table

Figure 18 Basic WB image generation steps
A radar image is a two-dimensional plot of the radar reflectivity of the target satellite. As shown in Figure 19, the two dimensions are range and cross-range.

Resolution in the range direction ($\Delta x_{\text{range}}$) is achieved by the wide BW of the radar according to the formula $\Delta x_{\text{range}} = 1.81 \frac{c}{2 \text{ BW}}$, where $c$ is the speed of light and the numerical factor of 1.81 is a spectral weighting factor (due to Hamming) which reduces the contributions of radar sidelobes while simultaneously broadening the contribution of the main lobe of the target response. In the U.S., range resolution is measured 6 dB down from the target peak response. For the LRIR with 1 GHz BW, $\Delta x_{\text{range}} = 27 \text{ cm}$, whereas for HAX with 2 GHz BW, $\Delta x_{\text{range}} = 13.5 \text{ cm}$.

- **Range resolution is provided by the radar bandwidth**

  $$\Delta x_{\text{Range}} = \frac{1.81 \lambda}{2 \text{BW}}$$

  LRIR: BW = 1 GHz, $\Delta x_{\text{Range}} = 27 \text{ cm}$
  HAX: BW = 2 GHz, $\Delta x_{\text{Range}} = 13.5 \text{ cm}$

- **Cross-range resolution is provided by the sampling of the target aspect angle $\Delta \theta$ caused by the relative motion between the radar and the target**

  $$\Delta x_{\text{Cross Range}} = \frac{1.81 \lambda}{2 \Delta \theta}$$

  LRIR: $\lambda = 3 \text{ cm}$, $\Delta x_{\text{Cross Range}} = 27 \text{ cm} (\Delta \theta =5.76^\circ)$
  HAX: $\lambda = 1.79 \text{ cm}$, $\Delta x_{\text{Cross Range}} = 13.5 \text{ cm} (\Delta \theta =6.87^\circ)$

Figure 19  WB range-Doppler radar imaging
Resolution in the cross-range direction is achieved by processing the radar data over a sufficiently wide target aspect angle change $\Delta \theta$. The formula for cross-range resolution is as follows: $\Delta x_{\text{cross-range}} = \frac{1.81}{2} \frac{\lambda}{\Delta \theta}$ where $\lambda$ is the wavelength of the radar ($\lambda = 3 \text{ cm}$ for Haystack, $\lambda = 1.79 \text{ cm}$ for HAX) and the numerical factor of 1.81 is the Hamming weighting factor. For the LRIR, 27 cm cross-range resolution is achieved by coherently integrating over an aspect angle change $\Delta \theta$ of 5.76 deg. For HAX, 13.5 cm cross-range resolution is achieved by coherently integrating over an aspect angle change $\Delta \theta$ of 6.87 deg.

Detailed images have been obtained on near Earth satellites such as the first U.S. space station SKYLAB shown in Figure 20. Figure 21 shows a simulated radar image of SKYLAB displayed next to a simple model (note: actual WB radar images of satellites are classified SECRET by the U.S. government and are not included in this paper). In the simulated SKYLAB image, strong radar returns are seen to emanate from the main body and solar panels. The overall shape and size of SKYLAB can be derived from a properly scaled radar image. Proper scaling is achieved when the motion of the satellite about its CM is known. From the visual appearance of a radar image, payloads can be distinguished from rocket bodies and cross-tagging in the space catalog can be prevented. Hence (see Figure 22) as far as the interpretation of WB radar images is concerned, the old U.S. saying "If it looks like a duck, and walks like a duck, and quacks like a duck, it's a duck" seems quite appropriate.
Figure 20  The first U.S. space-station SKYLAB in orbit

Figure 21 Simulated WB radar image of SKYLAB shown with simple model
ЕСЛИ ОНА ПОХОЖА НА УТКУ, ХОДИТ КАК УТКА И КРЯКАЕТ КАК УТКА ЗНАЧИТ ЭТО УТКА

IF IT LOOKS LIKE A DUCK AND WALKS LIKE A DUCK AND QUACKS LIKE A DUCK IT’S A DUCK

Figure 22 A familiar U.S. saying is appropriate to WB image interpretation

6. Summary

As part of a task to improve the fidelity of the space catalog, various SOI techniques are used. This paper has given a brief overview of the U.S. SSN and of the satellite signature measurement facilities whose data MIT/LL uses to accomplish this task. The identification of simple satellites can be accomplished by carefully examining the characteristics of NB RCS returns. The classification of actual satellites into particular known classes can be accomplished using correlation methods based on partial signature comparisons. If the motion of a satellite about its CM is known, two dimensional (i.e., range and cross-range) WB radar images can be used to determine the shape and size of that satellite. Resolution in the range direction is inversely proportional to the BW of the radar and resolution in the cross-range direction is inversely
proportional to the total aspect angle change. The function of satellites (i.e., payloads and rocket bodies) can be determined from the physical appearance of the resulting WB radar image. Both NB and WB radar techniques will continue to be improved in the future in order to insure the fidelity of the space catalog.

REFERENCES


3. Fundamentals of Radar Target Analysis, RCA Training Text, Course No. 901, 1965
