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Inter-Agency Space Debris Coordination Committee

IADC Action Item 25.1

# International 24th LEO Space Debris Measurement Campaign 2008

Issued by Working Group 1 “Measurements”

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# 1 Introduction

The Inter-Agency Space Debris Coordination Committee (IADC) provides the forum for periodic international measurement campaigns of the space debris environment. The IADC has conducted two types of campaigns: high altitude campaigns designed to measure the debris environment at near-geostationary altitudes using mostly optical telescopes, and low altitude campaigns using primarily radars. One of the goals of the low altitude campaigns is to collect data for 24 contiguous hours. This way, all orbit planes can be sampled. Multiple sensors are used, each with its own strengths and weaknesses, to provide a more complete understanding of the environment. Comparing results between sensors also provides a better understanding of the potential biases resulting from any one sensor. Conducting the campaigns at roughly regular intervals over a long period also allows researchers to examine trends and growth of the environment over time. For this reason, low altitude campaigns are anticipated at two-year intervals. This is the 7th IADC low altitude campaign conducted. The first campaign was conducted in 1996 and two campaigns were conducted in 1999. The 2002 campaign was delayed until January 2003 because of scheduling conflicts, and the fifth and sixth campaigns were conducted in 2004 and 2006.

This report covers the results obtained from the low altitude campaign conducted in 2008. The Objectives of Action Item 25.1, "International 24 Hour LEO Space Debris Measurement Campaign 2008" included:

- Update statistical characterization of the dynamic low Earth orbit (LEO) debris population
- Compare data collected over a common collection period
- Encourage participation by organizations that may not have contributed in past campaigns
- Concentrate on altitudes less than 2000 km

The LEO debris population is not static. It changes over time because of loss of particles by atmospheric drag and reentry and by sudden injection of particles from explosions and collisions. The concept of conducting a LEO campaign every two years was adopted by Working Group 1 in 2002. The two-year schedule does not preclude member agencies from more frequent or continuous measurements. However, comparison of data collected during a common collection period is needed periodically.

The strategy of routinely measuring the LEO environment has been validated by events in 2007 and 2009. Significant on-orbit fragmentations occurred during those years. The 2006 campaign provided a good baseline to compare against later campaigns, which will show the effects on the environment from these major events.

Four of the five radars that participated in the 2006 24-hour campaign also participated in the 2008 campaign. The European Incoherent Scatter Scientific Association (EISCAT) Svalbard Radar (ESR) was not funded for participation in the 2008 campaign. However, the

FGAN/TIRA, Haystack, Haystack Auxiliary (HAX), and Cobra Dane radars participated in both the 2006 and 2008 campaigns. The data collection and processing for each of these radar systems was essentially the same for both campaigns. Therefore, to maintain these reports as stand-alone documents, but simultaneously reduce the repetitive nature of the report, details of the operation and data reduction for each radar will be moved to the appendices. This report will concentrate more on the results collected in 2008 and its comparison with the 2006 results.

Two different types of radars were used in the campaign: pencil-beam radars and phased-array radars.

# 2 Pencil-Beam Radars

Three pencil-beam radars were used during the 2008 24-hour campaign: the Tracking and Imaging (TIRA) radar sponsored by the European Space Agency (ESA) and operated by FGAN (now Fraunhofer) Research Institute for High Frequency Physics and Radar Techniques (FHR); and the Haystack and HAX radars sponsored by NASA and operated by the Massachusetts Institute of Technology's Lincoln Laboratory (MIT/LL). In addition to the TIRA radar operated in a mono-static mode, it also operated in a bi-static mode with TIRA acting as the transmitter, and the Effelsberg radio telescope operated by the Max-Planck Institute for Radioastronomy acting as a receiver. However, the Effelsberg data has not yet been processed and will not be included in this report.

Each of the pencil-beam radars was operated in a staring mode. In this mode, the radar was pointed at a fixed azimuth and elevation and recorded data on objects as they passed through the narrow beam of the radar.

The orbital inclination of an object detected by a monopulse radar operating in the staring mode can be measured from the time history of the position of the object through the beam determined from the open loop monopulse azimuth and elevation voltage ratios. The direction and angular velocity, along with the range, range rate, and time, are transformed into the classic orbital elements, including inclination. However, the narrow field-of-view of the radars provides a very small arc of the orbit and a relatively small amount of measurement noise quickly degrades the velocity determination making the derived values of inclination and eccentricity invalid. Inclination can also be estimated from range rate information if circular orbits are assumed. Inclination derived by this method will be referred to as Doppler inclination. The Doppler is the frequency shift from the transmitted signal to the received signal caused by the line-of-sight relative motion of the target, or range rate.

If the assumption of a circular orbit is used, the line-of-sight velocity can be related to the orbital inclination of the object for an antenna beam that is not pointed vertically. An error is introduced, of course, if the orbit is non-circular (i.e., ecc $\neq 0$). However, the error is not significant for modest eccentricities. In practice, the Doppler inclination has proved more accurate than determining inclination from the monopulse signals as the object passes through the main lobe of the radar beam.

## 2.1 TIRA Radar

The TIRA radar is located at 50.62º N. latitude, 7.13º E. longitude, at an elevation of 293 m. The radar was staring at azimuth 93.00º, elevation 76.12º during the campaign. The TIRA radar detected 786 objects in the 24 hours starting at ~12:30 GMT on 25 November 2008. Appendix A describes the operation and data processing used to collect the data. In addition, it also includes a list of the detections. The detection list provides the time of the detection, the slant range to the target, the range rate of the target relative to the line-of-site of the radar, and the radar cross section of the target. In addition to these raw measurements, the list also includes the derived parameters of altitude, Doppler inclination, and characteristic length. The characteristic length was derived from the NASA Size Estimation Model (SEM), described in Appendix E. Characteristic lengths for detections from all of the radars participating in the 2008 campaign are derived using the SEM.

In addition, NASA compared the measured detection time, range, and range rate against predicted values for objects in the United States Strategic Comman (USSTRATCOM) catalog using software provided by the U.S. Air Force Space Command. Possible correlations with tracked objects for appropriate detections are also noted in the detection list.

Figure 1 shows the cumulative size distribution collected over the entire range window from 300 – 2000 km. Figure 2 shows the altitude vs. Doppler inclination for each of the 786 detections.

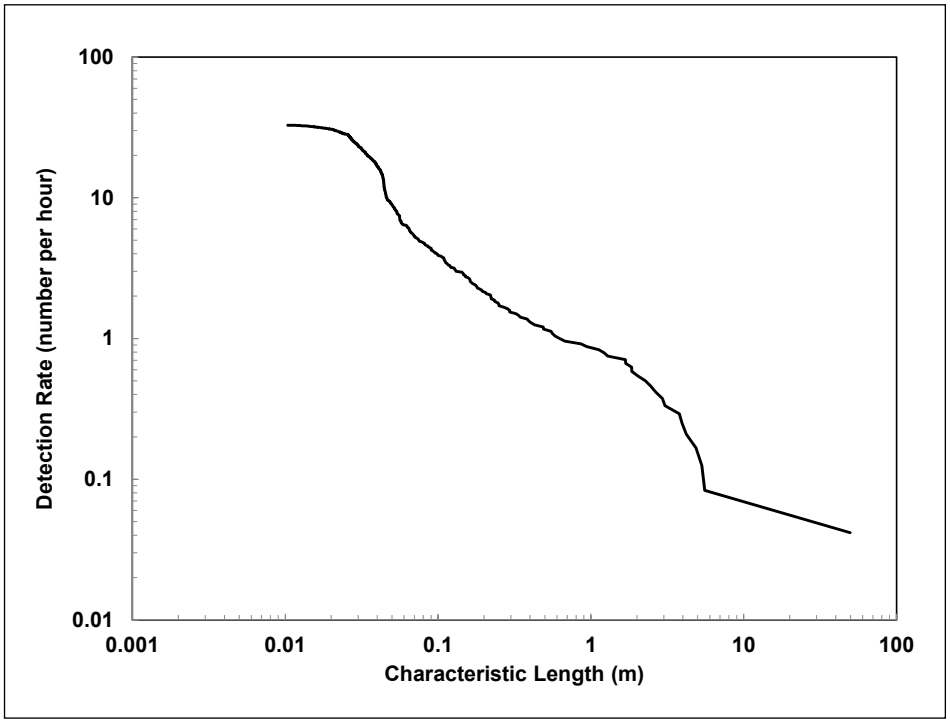


**Figure 1. Size distribution for all objects detected by TIRA in the 2008 campaign.**

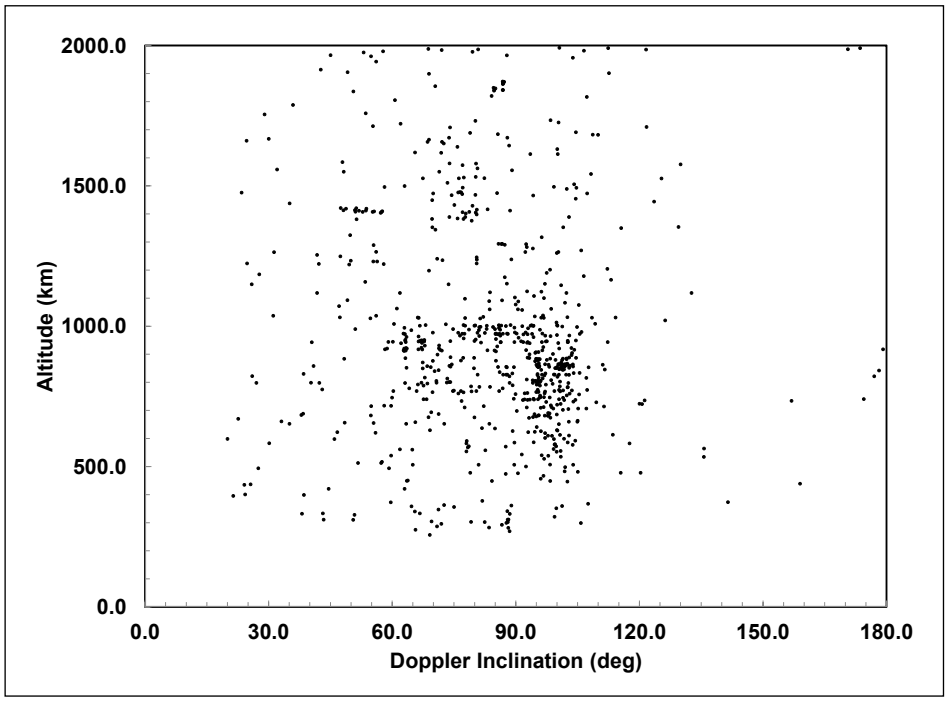


**Figure 2. Distribution of altitude vs. Doppler–inclination for TIRA detections in the 2008 campaign.**

There are two features of these results that appear unusual. There is one object that has a radar cross section (RCS) of 32.9 dBsm, corresponding to a characteristic length of ~50 m. The detection correlated to Satellite Number 16865, which is listed as SL-8 debris. The characteristic length in this case is obviously erroneous. A plausible potential explanation is that the radar observed a glint off of the debris which gave it an enhanced RCS.

The second feature is the near horizontal grouping in Figure 5 near 1400 km and an inclination of 50º. This grouping of detections is consistent with mainlobe and sidelobe detections of the GlobalStar constellation at 1414 km altitude and 52º inclination. This feature was also seen in the 2006 data.

## 2.2 Haystack Radar

The Haystack radar is located at 42.62º N. latitude, 71.49º W. longitude, at an elevation of 1157 m. The radar was staring at 90º azimuth and 75º elevation during the 24-hour campaign. The radar collected data for ~24 hours starting at 13:15 GMT on 18 November 2008. However, there were breaks in the data collection for calibration checks and other routine operations. During the 24 hours, 20.6 hours of staring data were collected and 328 objects were detected.

Appendix B describes the operation and data processing used to collect the data. Appendix B also includes a list of the detections. The detection list provides the same measured and derived parameters as reported for the TIRA radar.

Figure 3 shows the cumulative detection rate as a function of size for all valid detections observed by Haystack during the campaign. Figure 4 is a scatter plot of Doppler inclination vs. altitude.

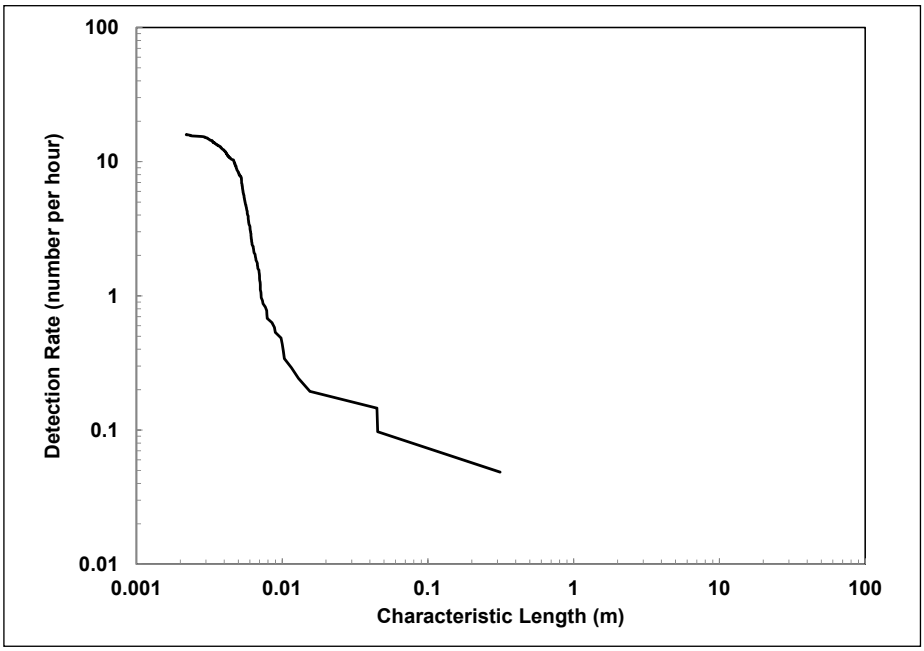


**Figure 3. Size distribution for all objects detected by Haystack in the 2008 campaign.**

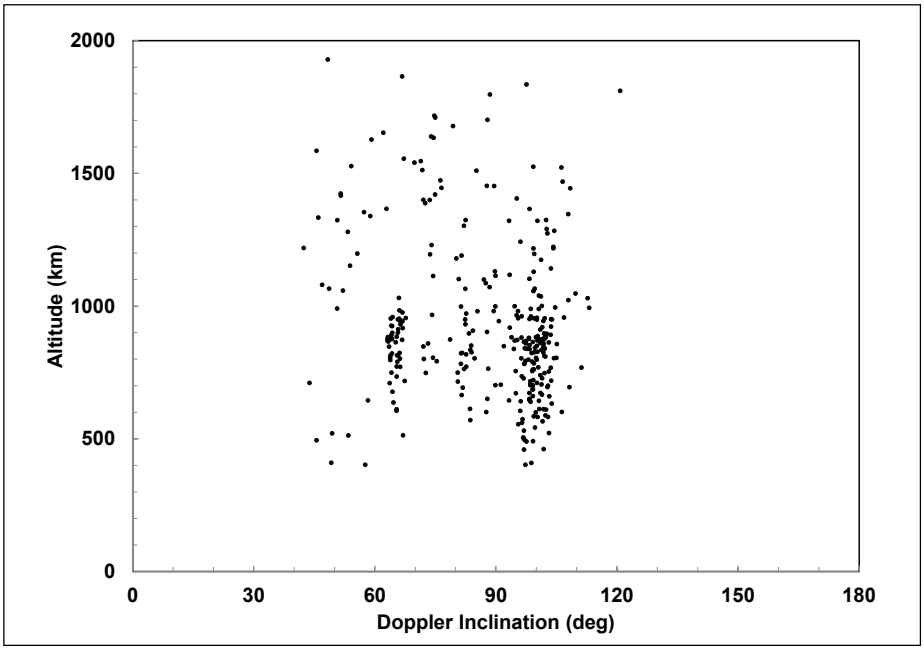


**Figure 4. Distribution of altitude vs. Doppler–inclination for Haystack detections in the 2008 campaign.**

## 2.3 HAX Radar

The HAX radar is located ~100 m southeast of the Haystack radar. HAX shares some of the data collection and processing hardware with Haystack; however, they can still be operated simultaneously.

For the 2008 24-hour campaign, HAX was pointed in the same direction as Haystack providing simultaneous observations of some of the larger objects detected by Haystack. HAX has much lower sensitivity than Haystack, but a wider beamwidth. HAX detected 31 objects in 19.0 hours of operation.

Appendix C provides operations and data processing descriptions along with the detection list.

Figure 5 shows the cumulative detection rate as a function of size for all valid detections observed by HAX during the campaign. Figure 6 is a scatter plot of Doppler inclination vs. altitude.

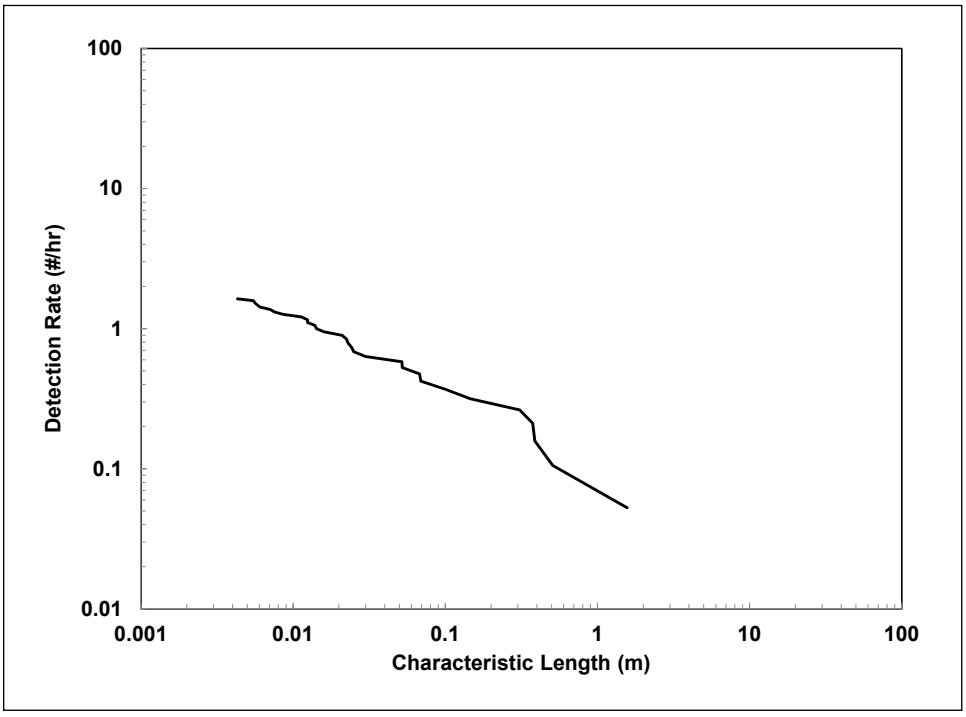


**Figure 5. Size distribution for all objects detected by HAX in the 2008 campaign.**

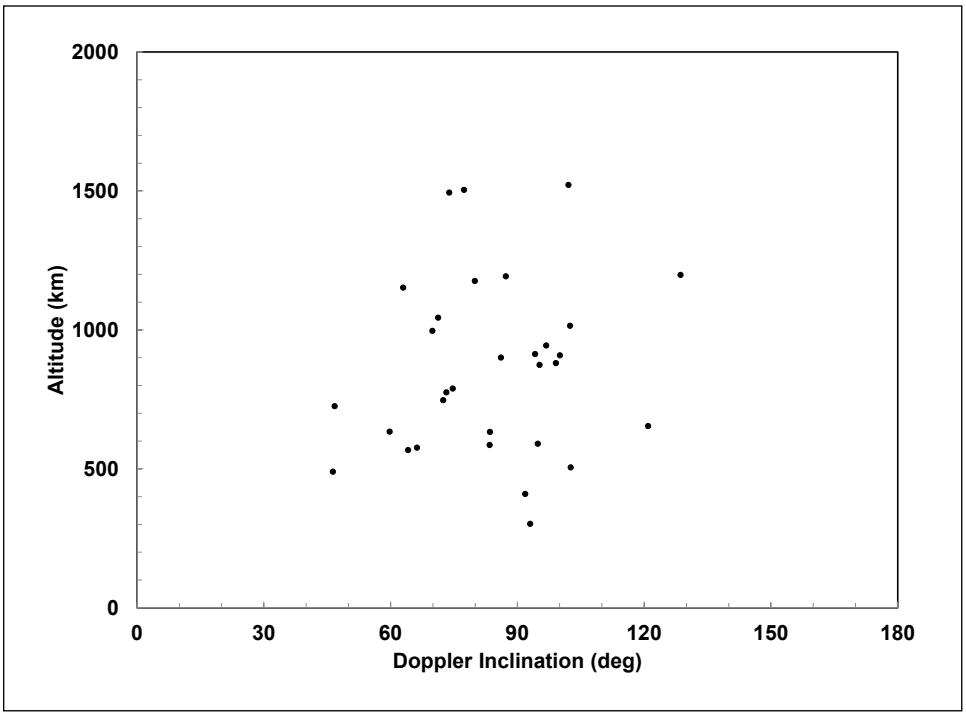


**Figure 6. Distribution of altitude vs. Doppler–inclination for HAX detections in the 2008 campaign.**

# 3 Phased-Array Radars

## 3.1 Cobra Dane

The AN/FPS-108 Cobra Dane radar (Figure 23) is operated by the U.S. Department of Defense. It is located on Shemya Island, Alaska at 52.7° N. latitude and 174.1° E. longitude. The face of the radar is aligned at an azimuth of 319°.

For the 24-hour campaign, the Cobra Dane is operated much differently from the pencil-beam radars discussed above. For pencil-beam radars, the entire dish, typically weighing hundreds to thousands of kg, must be moved to point the radar in a different direction. However, phased-array radars can be electronically steered almost instantaneously within some angular limits. For this campaign the antenna beam is rapidly moved in a long, narrow pattern to create a virtual fan beam, or fence. Each individual beam position in the fence is revisited often enough that orbiting objects cannot travel the width of the fence between revisits. The fence is therefore referred to as a "leak-proof" fence. When an object is detected in the fence, some of the radar's resources can be used to track the object while maintaining the fence. To maintain the leak-proof fence, only uncorrelated detections (objects not in the USSPACECOM catalog or analysts objects) were tracked.

During the campaign, a 40°-wide fence, at an elevation angle of 50.3° and covering the azimuth range from 299° – 339° was erected. The fence was one beamwidth wide, or 0.6°. The radar detected objects crossing this fence at slant ranges from 415 – 2501 km. Cobra Dane operated for 24 hours starting at 00:00:00 GMT on 17 November 2008. There were 1452 uncorrelated objects detected and tracked during the 24 hours. Using Air Force Space Command-provided software, 4702 objects in the USSPACECOM catalog should have passed through the fence during the same period. In addition, 1890 "analyst" satellites (satellites routinely tracked by the Space Surveillance Network [SSN], but not yet in the regular USSPACECOM catalog) were also predicted to pass through the fence. This provides a total of 8044 detections.

Information on the operation of the Cobra Dane and the list of uncorrelated detections collected during the campaign can be found in Appendix D.

Unfortunately, object size information is missing from the uncorrelated targets (UCTs) for ~ 2 hours during the campaign from 11:28 to 13:28 GMT. Therefore, when calculating detection rates for the campaign, all detections from this time period are excluded. Also, size information is missing for 1649 analyst satellites.

The size distribution for Cobra Dane detections is shown in Figure 7.

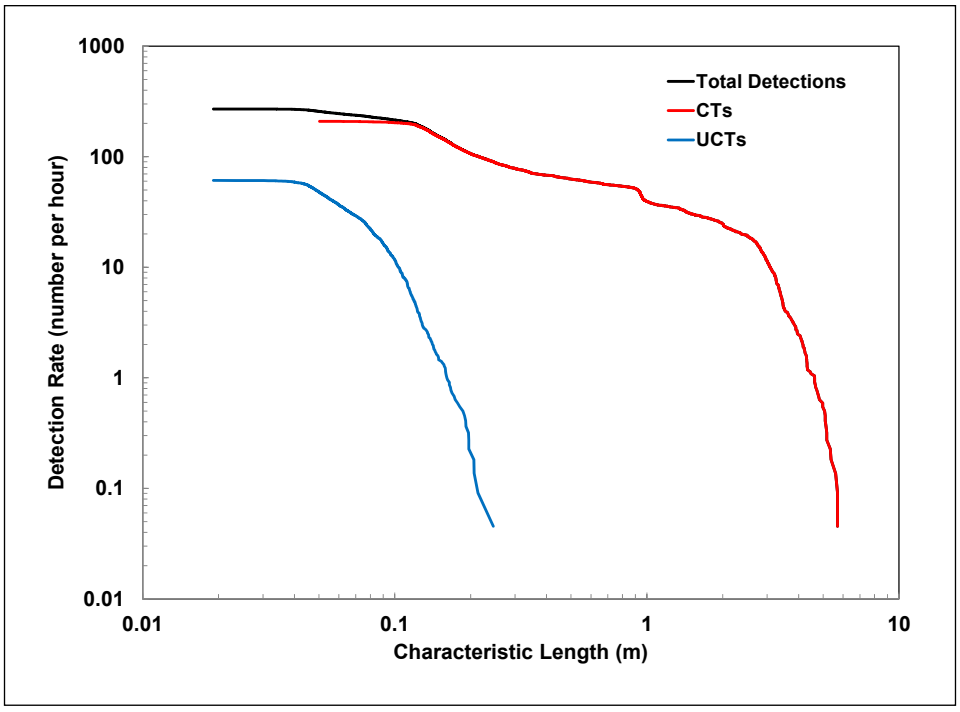


**Figure 7. Size distribution for all UCTs detected by Cobra Dane in the 2008 campaign. In addition, cataloged objects which were predicted to pass through the Cobra Dane fence are shown in a cumulative distribution.**

Figure 8 shows altitude as a function of inclination for regular, analyst, and uncorrelated detections.

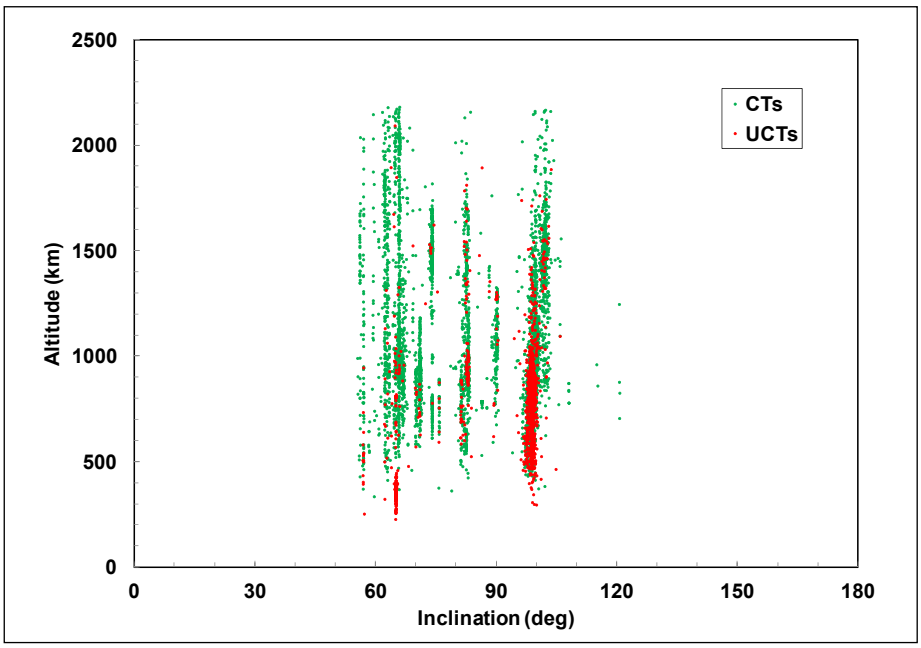


**Figure 8. Distribution of altitude vs. Doppler–inclination for Cobra Dane UCT detections and predicted known objects in the 2008 campaign.**

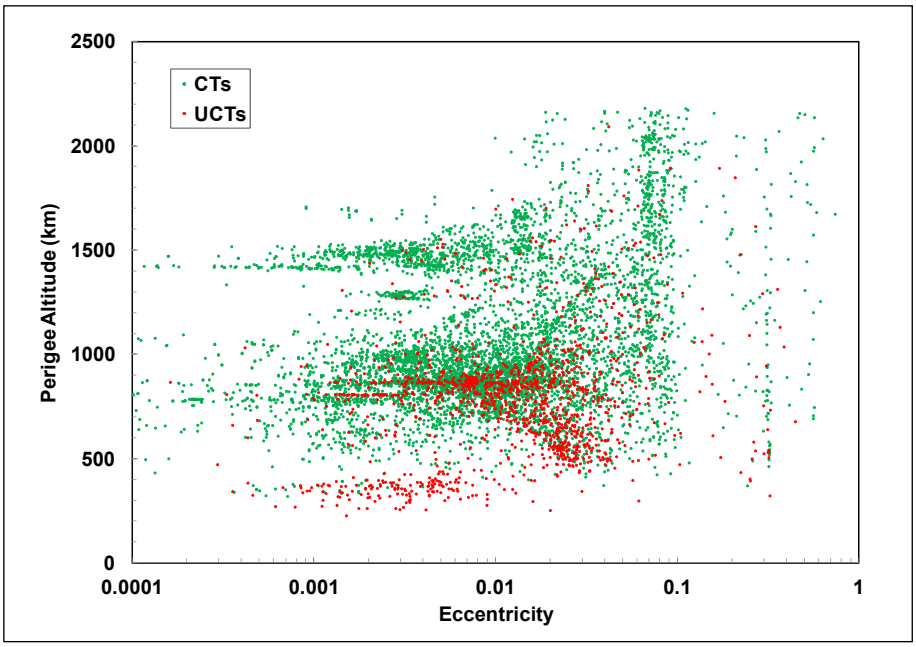


**Figure 9. Distribution of altitude vs. Eccentricity for Cobra Dane UCT detections and predicted known objects in the 2008 campaign.**

One of the unique attributes of a phased-array radar such as Cobra Dane is the ability to track a detected UCT while still maintaining the detection fence described above. This allows the radar to collect enough information to estimate the eccentricity of the object to an acceptable level. Figure 9 shows the altitude distribution of detections as a function of orbit eccentricity for those objects for which an orbit could be calculated. Figure 10 shows the inclination vs. eccentricity distribution.

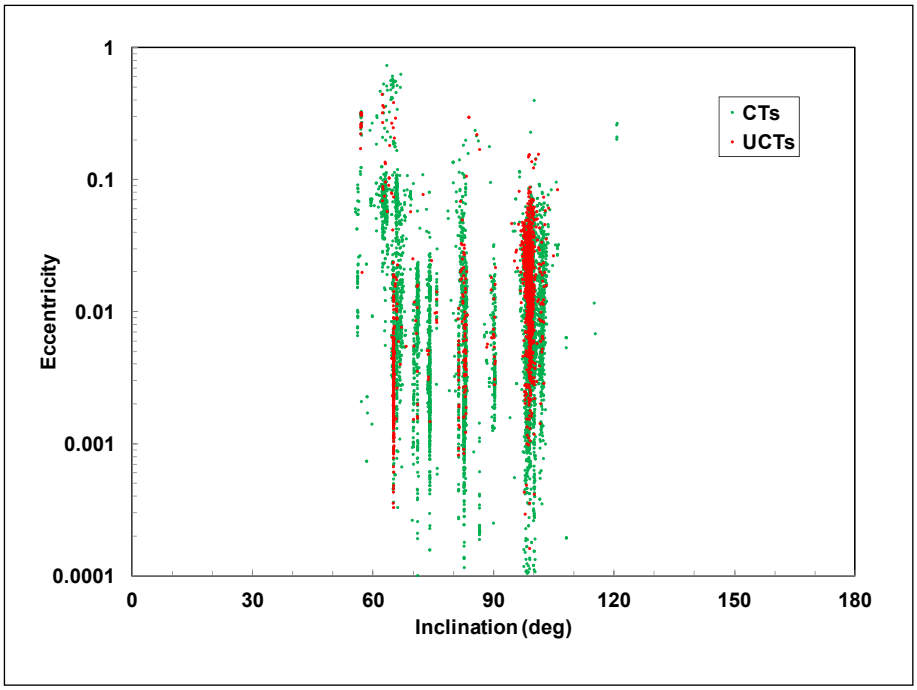


**Figure 10. Distribution of eccentricity vs. inclination for Cobra Dane UCT detections and predicted known objects in the 2008 campaign.**

# 4 Comparison with the 2006 24-Hour Campaign

## 4.1 On-orbit Fragmentations

In addition to the normal space traffic from launches and natural decays, 16 on-orbit fragmentations occurred between the time of the 2006 24-hour campaign and the 2008 campaign [1, 2]. A list of the fragmentations is provided in Table 1. Two fragmentations, the Beidou 1D rocket body and the USA 193 satellite, had inclinations (25.0º and 29.0º, respectively) that were too low to be seen by the configurations of any of the radars participating in the 2008 campaign.

Of the remaining fragmentations, the largest in terms of producing the largest number of cataloged objects was by far the fragmentation of Fengyun 1C at an inclination of 98.6º.

**Table 1. List of known on-orbit fragmentations that occurred between the 2006 and 2008 24 hour campaigns.**

| BREAKUP DATE | SATELLITE NAME | INTERNATIONAL DESIGNATOR | US SATELLITE NUMBER | SATELLITE OWNER | SATELLITE TYPE | SATELLITE MASS (KG) | LAUNCH DATE | APOGEE (KM) | PERIGEE (KM) | INCLINATION (DEG) | ASSESSED CAUSE | ADDITIONAL INFORMATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10-Jun-06 | COSMOS 2022-24 ULLAGE MOTOR | 1989-039G | 20081 | USSR | OP. DEBRIS | 55 | 31-May-89 | 18410 | 655 | 65.1 | PROPULSION | PROTON-K BLOCK DM SOZ |
| 8-Aug-06 | ALOS-1 R/B | 2006-002B | 28932 | JAPAN | ROCKET BODY | ~3000 | 24-Jan-06 | 700 | 550 | 98.2 | UNKNOWN | H-IIA SECOND STAGE |
| ~1-Sep-06 | COSMOS 2371 ULLAGE MOTOR | 2000-036E | 26398 | RF | OP. DEBRIS | 55 | 4-Jul-00 | 21320 | 220 | 46.9 | PROPULSION | PROTON-K BLOCK DM SOZ |
| 4-Nov-06 | DMSP 5D-3 F17 R/B | 2006-050B | 29523 | USA | ROCKET BODY | 2850 | 4-Nov-06 | 865 | 830 | 98.8 | UNKNOWN | DELTA IV SECOND STAGE |
| 17-Nov-06 | COSMOS 2423 | 2006-039A | 29402 | RF | PAYLOAD | ~6000 | 14-Sep-06 | 285 | 200 | 64.9 | DELIBERATE | SELF-DESTRUCT |
| 3-Dec-06 | COBE R/B | 1989-089B | 20323 | USA | ROCKET BODY | 920 | 18-Nov-89 | 790 | 685 | 97.1 | UNKNOWN | DELTA SECOND STAGE |
| 28-Dec-06 | IGS 3A R/B | 2006-037B | 29394 | JAPAN | ROCKET BODY | ~3000 | 11-Sep-06 | 490 | 430 | 97.2 | UNKNOWN | H-IIA SECOND STAGE |
| 11-Jan-07 | FENGYUN 1C | 1999-025A | 25730 | PRC | PAYLOAD | 950 | 10-May-99 | 865 | 845 | 98.6 | DELIBERATE | HYPERVELOCITY IMPACT |
| 2-Feb-07 | BEIDOU 1D R/B | 2007-003B | 30324 | PRC | ROCKET BODY | 2740 | 2-Feb-07 | 41900 | 235 | 25.0 | UNKNOWN | CZ-3A FINAL STAGE |
| 14-Feb-07 | KUPON ULLAGE MOTOR | 1997-070F | 25054 | RF | OP. DEBRIS | 55 | 12-Nov-97 | 14160 | 260 | 46.6 | PROPULSION | PROTON-K BLOCK DM SOZ |
| 18-Feb-07 | CBERS 1 | 1999-057A | 25940 | PRC/BRAZIL | PAYLOAD | 1450 | 14-Oct-99 | 780 | 770 | 98.2 | UNKNOWN | |
| 19-Feb-07 | ARABSAT 4 BRIZ-M R/B | 2006-006B | 28944 | RF | ROCKET BODY | 2600 | 28-Feb-06 | 14705 | 495 | 51.5 | PROPULSION | PROTON-K BRIZ-M STAGE |
| 11-Nov-07 | USA 197 R/B | 2007-054B | 32288 | USA | ROCKET BODY | 2850 | 11-Nov-07 | 1575 | 220 | 29.0 | UNKNOWN | DELTA IV SECOND STAGE |
| 21-Feb-08 | USA 193 | 2006-057A | 29651 | USA | PAYLOAD | 2275 | 14-Dec-06 | 255 | 245 | 58.5 | DELIBERATE | HYPERVELOCITY IMPACT |
| 14-Mar-08 | COSMOS 2421 | 2006-026A | 29247 | RF | PAYLOAD | 3000 | 25-Jun-06 | 420 | 400 | 65.0 | UNKNOWN | COSMOS 699 CLASS |
| 4-Jul-08 | COSMOS 1818 | 1987-011A | 17369 | USSR | PAYLOAD | 2500? | 1-Feb-87 | 800 | 775 | 65.0 | UNKNOWN | |

1. BREAKUP DATE AND ORBIT ARE FOR FIRST EVENT ONLY IF MULITPLE EVENTS OCCURRED
2. DOES NOT INCLUDE SATELLITE BREAKUPS IF VEHICLE WAS ON REENTRY TRAJECTORY AT THE TIME OF THE EVENT

Several other smaller fragmentations are listed that are close to the 98.6º inclinations and have overlapping altitudes with the Fengyun debris. Any uncorrelated targets detected in this inclination region could potentially be from any of these fragmentations. However, the vast majority are most likely from the Fengyun breakup.

### 4.2 TIRA Radar

Figure 11 shows the comparison of the cumulative size distributions collected in 2006 and 2008. As can be seen in the plot, there were more objects detected in 2006 with sizes above about 10 cm characteristic length. But for all sizes, the detection rate increased from just under 20 objects per hour in 2006 to more than 30 detections per hour in 2008, an ~50% increase above the 2006 rate.

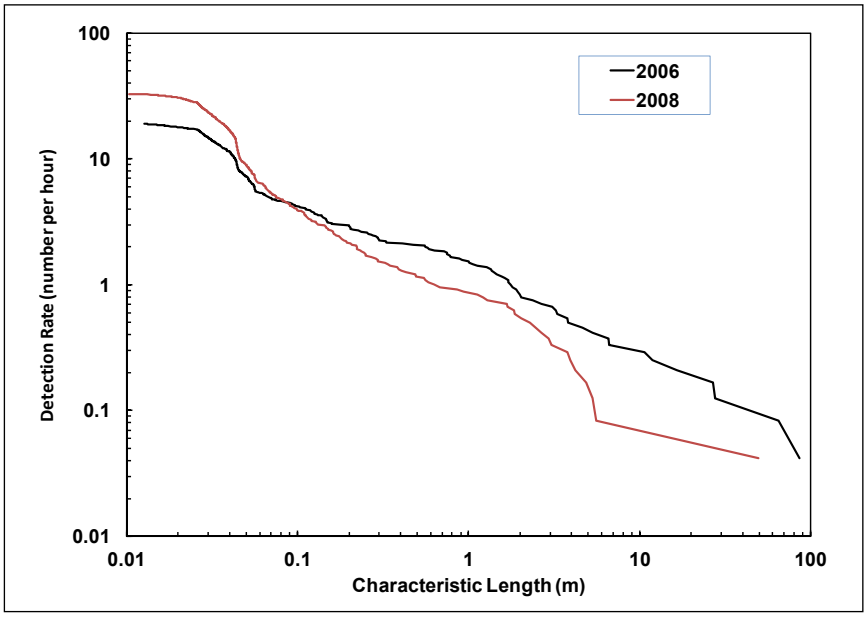


**Figure 11. Comparison of size distributions from the TIRA 2006 and 2008 campaigns.**

Figure 12 shows the altitude distributions for the two campaigns, while Figure 13 shows the inclination distributions. Major increases in detections between 550 - 1050 km altitude and 80º - 110º, peaking in the 95º - 100º bin, are apparent.

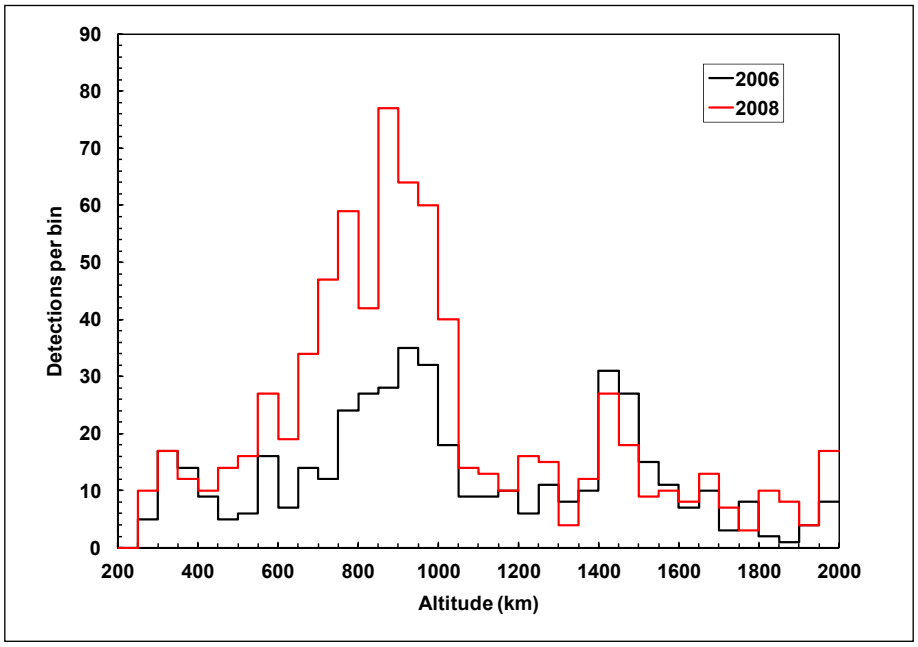


**Figure 12. Comparison of altitude distributions from the TIRA 2006 and 2008 campaigns.**

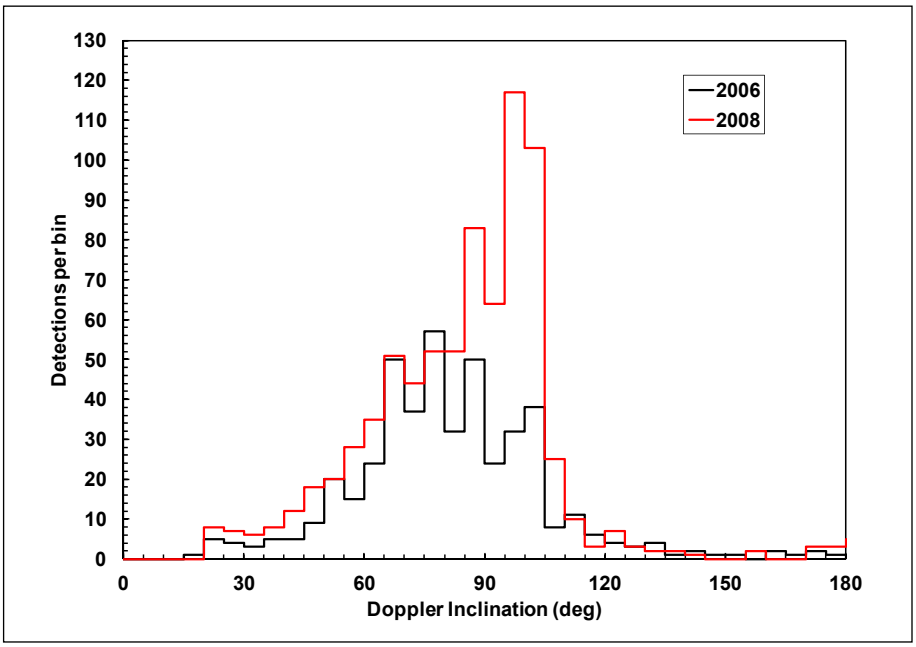


**Figure 13. Comparison of the Doppler-inclination distributions from the TIRA 2006 and 2008 campaigns.**

### 4.3 Haystack Radar

NASA has been reexamining its database of Haystack data. It has found that some calibration parameters collected during calibrations of the radar had been incorrectly applied. These errors resulted in the misreporting of the size (characteristic length) of objects in the 2006 24-hour campaign report. Figure 14 shows the cumulative size distribution for the new interpretation of the 2006 data (black line) compared to the 2008 data (red line). For completeness, the old, erroneous data from the 2006 report is shown as well. Like the TIRA data, Haystack shows more objects in 2006 above 10 cm characteristic length and more objects smaller than 10 cm in the 2008 data. Again, the detection rate for all sizes shows an ~50% increase above the 2006 detection rate.

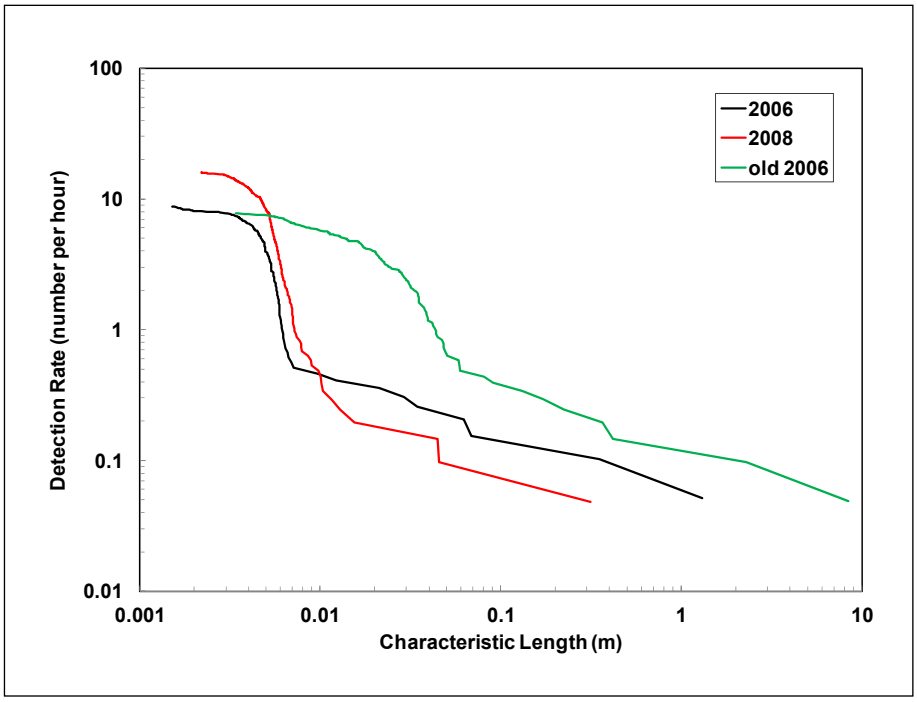


**Figure 14. Comparison of size distributions from the Haystack 2006 and 2008 campaigns. The green line is the size distribution originally reported in the 2006 campaign report. The black line is the 2006 size distribution after re-processing.**

Figure 15 shows the altitude distributions for the two campaigns, while Figure 16 shows the inclination distributions. Major increases in detections between 400- to 1000-km altitude and a tight grouping between 95º - 100º are apparent. The 2008 rates between 95º - 100º inclination are nearly 400% above the 2006 rates for the same inclination band.

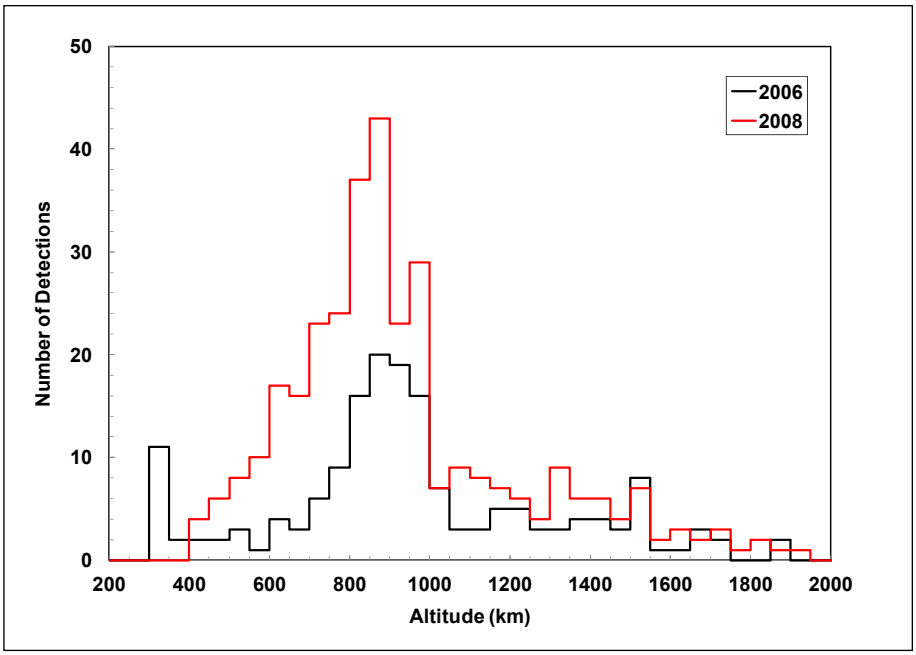


**Figure 15. Comparison of the altitude distributions from the Haystack 2006 and 2008 campaigns.**

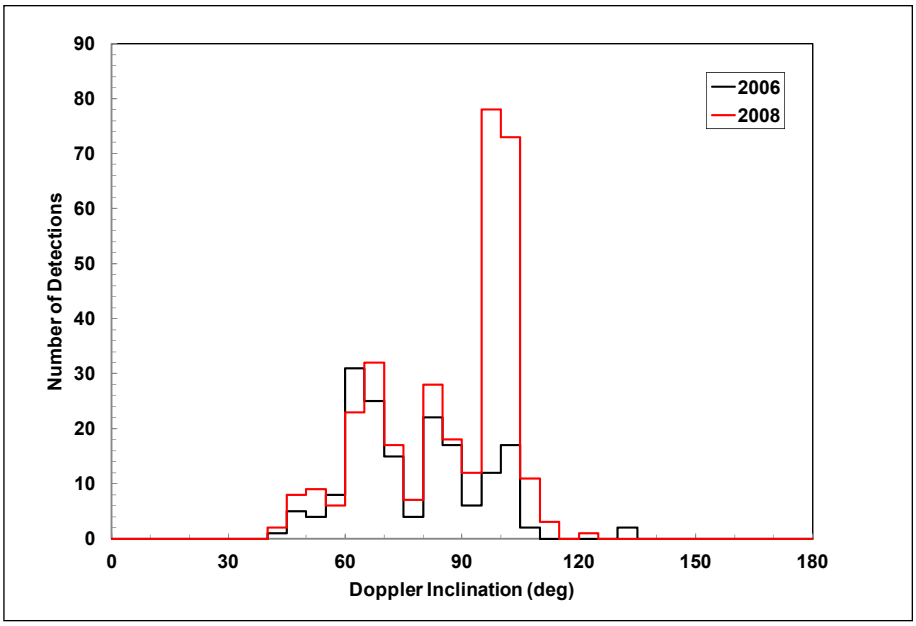


**Figure 16. Comparison of the Doppler-inclination distributions from the Haystack 2006 and 2008 campaigns.**

### 4.4 HAX Radar

With only 23 detections in 2006 and 31 detections in 2008, the statistics accumulated during the short 24 campaigns are not sufficient to show meaningful trends between the two campaigns.

### 4.5 Cobra Dane Radar

Figure 17 shows the cumulative size distributions measured by Cobra Dane for the 2006 and 2008 campaigns. The uncorrelated lines are not, by themselves, particularly meaningful. However, the process of cataloging can be painfully slow at times. Even in 2013, the SSN is still adding Fengyun 1C debris pieces from the January 2007 event to the official catalog. Therefore adding the uncorrelated objects and the analyst satellites to the cataloged population gives a more accurate picture of the on-orbit population at the time of the campaign. Cobra Dane shows more objects in 2006 above 2 m in size. At these larger sizes, the differences are due exclusively to cataloged objects. One possible explanation, other than a true decrease in this population, is a change in the way that the SSN calculates and reports radar cross section. The two populations are then nearly identical between 2 m and ~40 cm. There are more objects below 40 cm in the 2008 data. Once again, this radar shows a detection rate in 2008 for all objects that is ~50% above the rate measured in 2006.

Figure 18 shows the detection rate as a function of altitude for 2008. This plot compares favorably to the spatial density of cataloged objects shown in Figure 19.

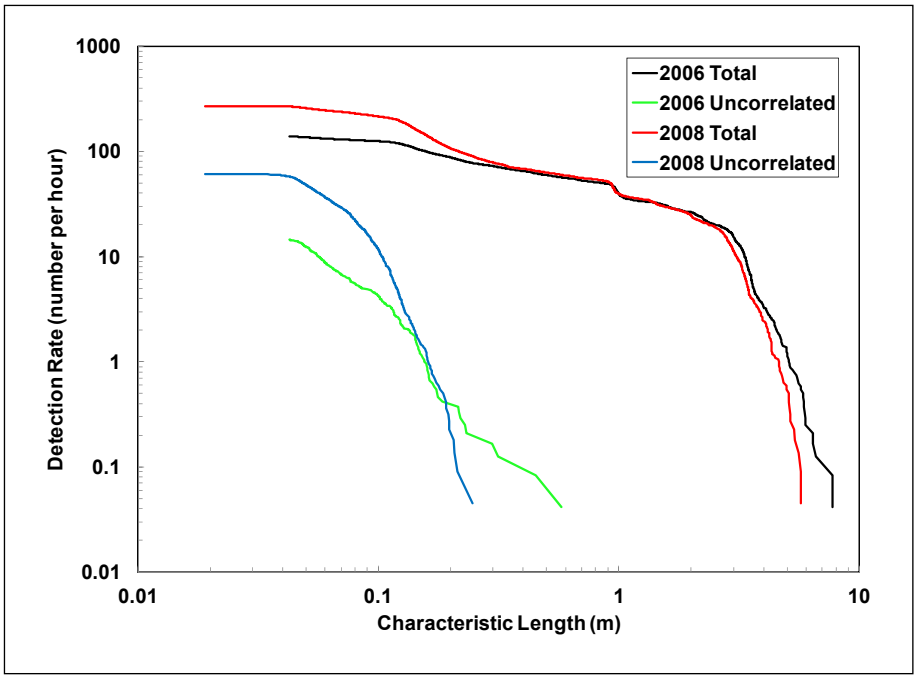


**Figure 17. Comparison of size distributions from the Cobra Dane 2006 and 2008 campaigns**

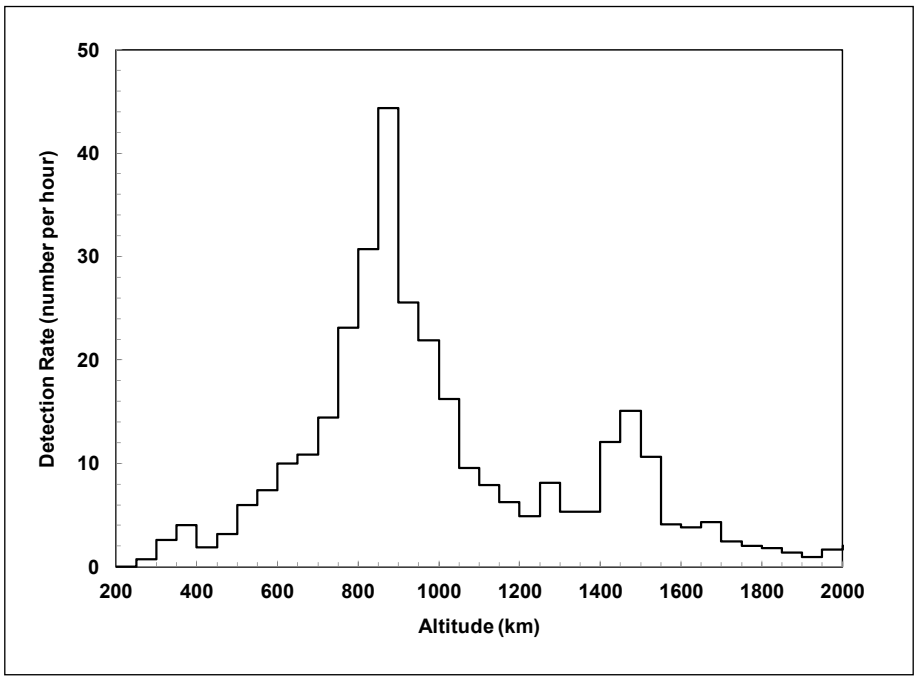


**Figure 18. Altitude distribution of Cobra Dane detections for the 2008 campaign.**

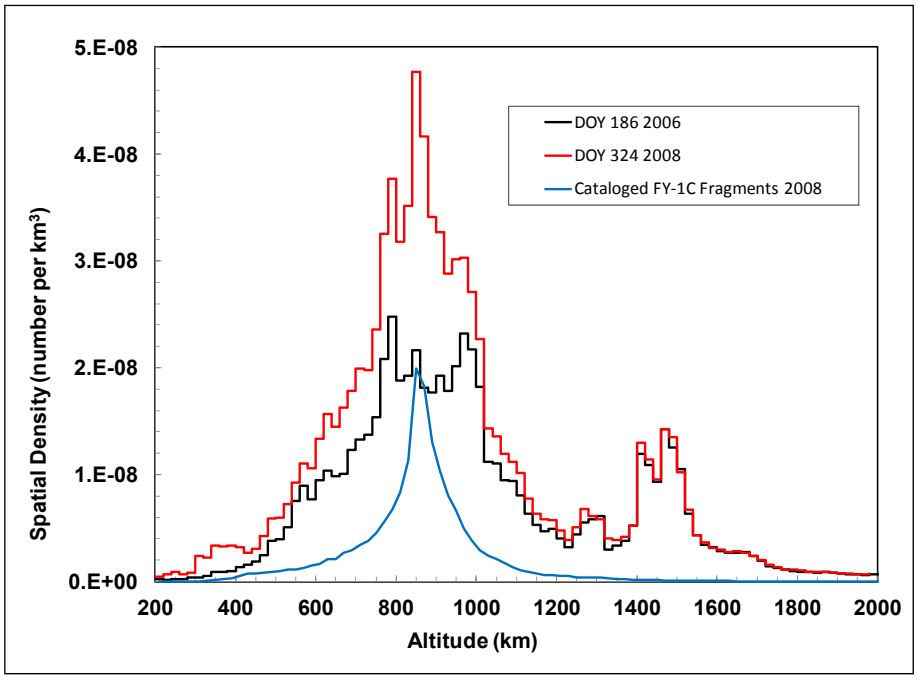


**Figure 19. Spatial density plot of catalog objects with epochs during the 2006 and 2008 campaigns.**

In 2006, the detection altitude was not provided for all cataloged and uncorrelated detections. In that report, perigee altitude calculated from the two-line element sets was used for plots. Figure 20 shows the difference between detected altitude and perigee altitude distributions for the 2008 campaign. Figure 21 then shows the comparison of perigee altitudes between the 2006 and 2008 campaigns.

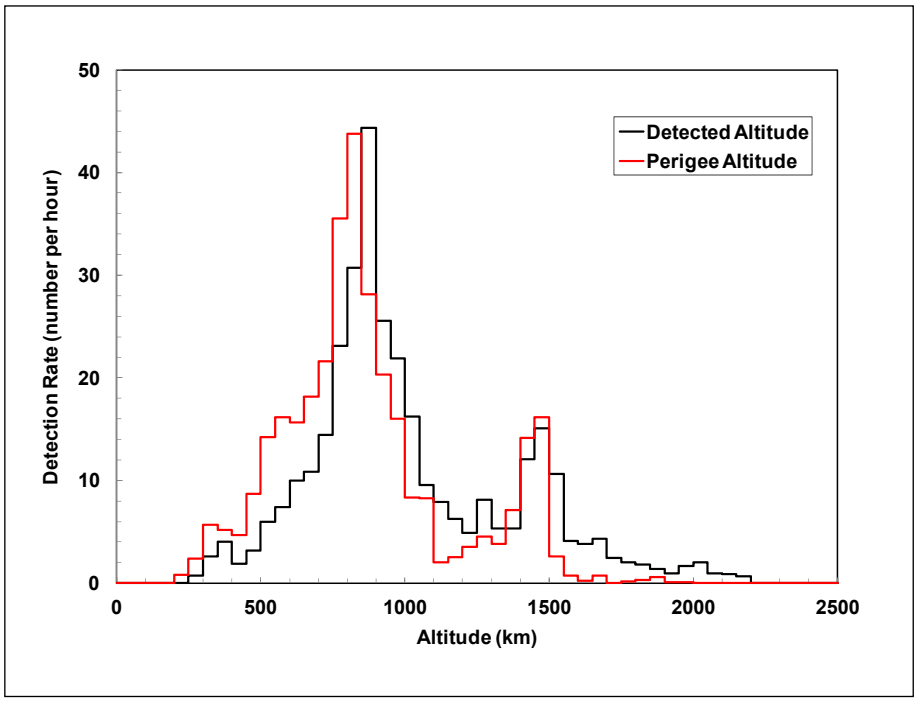


**Figure 20. Comparison of distribution of detected altitude and calculated perigee altitude for the Cobra Dane 2008 campaign.**

Figure 22 shows the inclination distribution for Cobra Dane from the two campaigns.

In addition to the large increase in the population of the orbits associated with Fengyun, there is also a population apparent in the uncorrelated targets shown in Figure 8. This population has an inclination of about 65º and altitudes below 500 km. Evidence of this population can also be seen in Figures 21 and 22, compared to 2006. These pieces are most likely from the multiple fragmentations of Cosmos 2421. Cosmos 2421 reportedly shed about 500 total debris objects during at least three different times from March to June 2008 [3]. Although the debris lifetimes of these objects would be relatively short at these altitudes, there was still a noticeable population in November 2008 when the Cobra Dane participated in the IADC campaign.

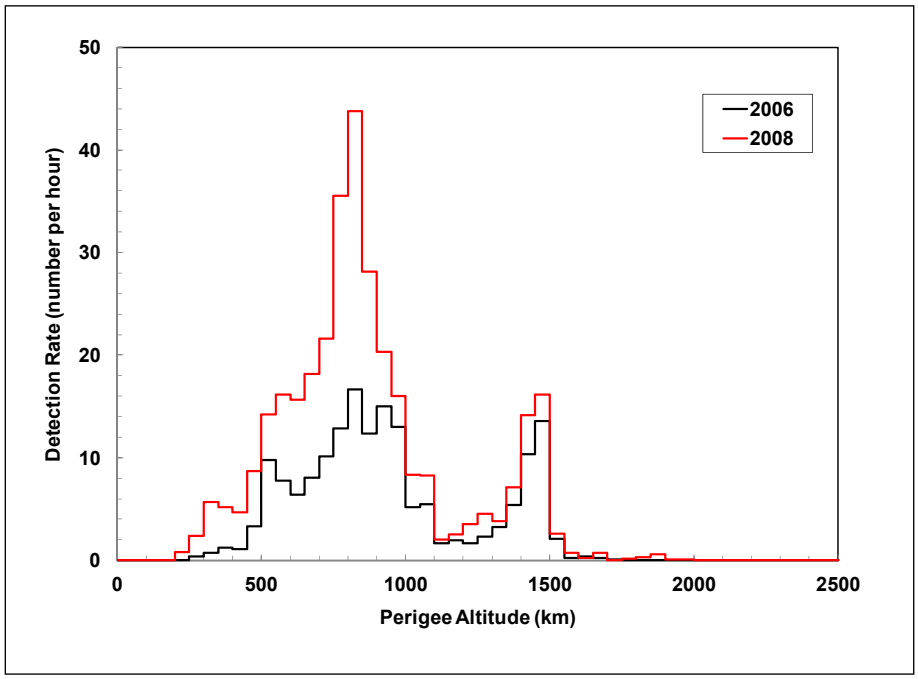


**Figure 21. Comparison of the perigee altitude distributions for Cobra Dane for the 2006 and 2008 campaigns,.**

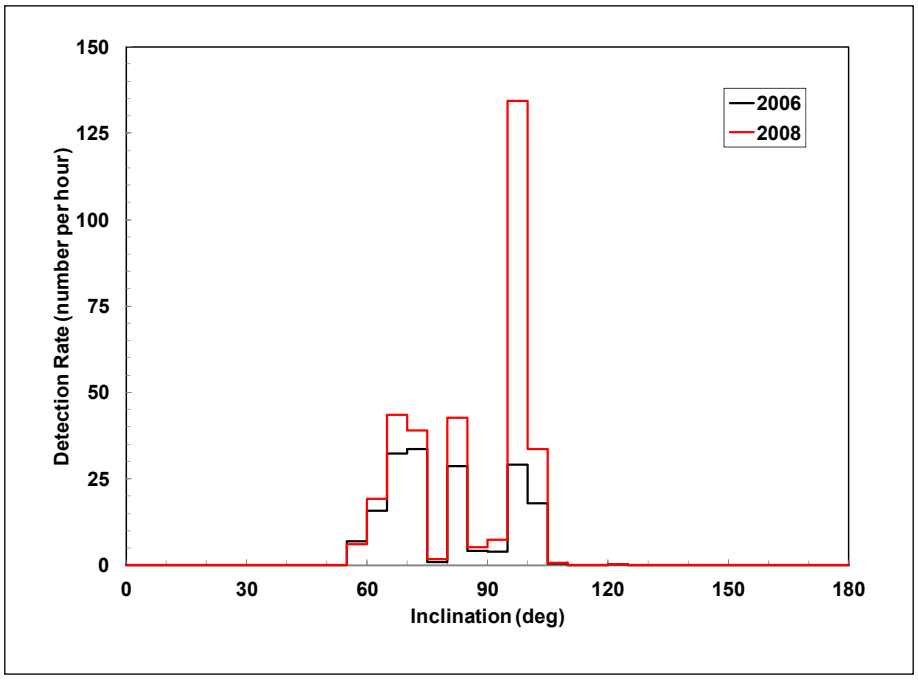


**Figure 22. Comparison of the inclination distributions for Cobra Dane for the 2006 and 2008 campaigns,.**

# 5 Conclusion

The IADC 24-hour campaigns provide snapshots of the dynamic LEO debris environment. Significant changes occurred between the time of the 2006 and 2008 campaigns. Each radar that participated in both campaigns, with the possible exception of HAX, showed similar results when comparing the measured environments. The 16 on-orbit fragmentations produced a measured environment up to ~50% higher in 2008, compared to 2006, for objects smaller than 10 cm. Much of the increase occurred in an inclination and altitude band consistent with the Fengyun fragmentation.

# References

[1] Johnson, N., Stansbery, E., Whitlock, D., Abercromby, K., and Shoots, D. *History of On-orbit Satellite Fragmentations, 14th Edition.* NASA/TM-2008-214779. NASA/JSC, Houston, TX, USA, June, 2008.

[2] Johnson, N., Private communication. Fragmentation list maintained by Johnson.

[3] *Orbital Debris Quarterly News*. Vol. 12, No. 3. July, 2008. http://orbitaldebris.jsc.nasa.gov/newsletter/pdfs/ODQNv12i3.pdf

# Appendix A

# TIRA Radar

## A.1 Introduction

The Tracking and Imaging Radar (TIRA) radar's participation in the Inter-Agency Space Debris Coordination Committee's (IADC) 2008 24-hour campaign was sponsored by the European Space Agency (ESA). The radar was operated by FGAN (now Fraunhofer) Research Institute for High Frequency Physics and Radar Techniques (FHR). At FGAN in Wachtberg, Germany, in the FHR, the TIRA system (see Figure A-1) was developed to support experimental radar research. TIRA consists of two monostatic coherent radars supported by one 34-m parabolic antenna: a narrow-band L-band tracking radar and a high-resolution Ku-band imaging radar. Both radars may operate simultaneously on the same object. TIRA has participated in many beam park experiments dating back to 1993. The data processing of beam-park experiments is thoroughly described in Rosebrock et al. [1] and Banka et al. [2].

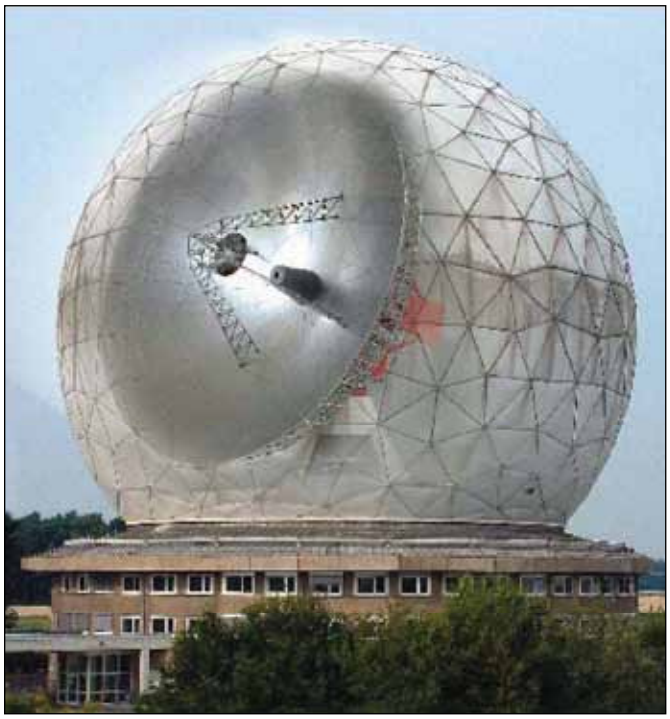

**Figure A-1. The TIRA System at Wachtberg, Germany.**

## A.2 Experiment Setup

Since BPE-1/2000, all beam-park experiments at TIRA have been performed with a virtually identical setup. Tables A-1 and A-2 list the instrument and campaign parameters for the 2008 campaign.

**Table A-1. Instrument parameters used by the TIRA radar for the 2008 campaign.**

| TIRA Instrument Parameters | | |
|---|---|---|
| Geocentric latitude of sensor | 50.62 | deg |
| Geocentric longitude of sensor | 7.13 | deg |
| Geodetic altitude | 0.293 | km |
| Wavelength | 0.225 | m |
| Beam width for incoherent integration | 0.49 | deg |
| Antenna constant (Gain) | 49.7 | dB |
| Transmitted power (peak) | 1500.0 | kW |
| Pulse period | 29 | msec |
| Pulse duration | 1 | msec |
| Desired false alarm time (Marcum) | 36000 | sec |
| Number of independent threshold decisions per pulse | 5667 | |
| Maximum number of pulses to integrate | 89 | |
| Noise equivalent RCS (NRCS) | -47.5 | dB $m^2$ |
| Transmitted power for NRCS | 1500 | kW |
| Pulse duration for NRCS | 1 | msec |
| Range for NRCS | 1000 | km |

**Table A-2. Campaign parameters for the TIRA radar for the 2008 campaign.**

| Campaign Parameters | | |
|---|---|---|
| Campaign Start | 25 Nov 2008 12:30 UT | |
| Maximum range | 2000 | km |
| Minimum range | 300 | km |
| Azimuth of line of site | 93.0 | deg |
| Elevation of line of site | 76.12 | deg |
| Duration of campaign | 24 | hrs |
| Total recorded data | 24.0 | hrs |

## A.3 Processing

In Figure A-2, an overview of the processing is given. It starts with detecting possible object echoes in raw radar data by incoherent integration over several pulse records. This is limited only by a false alarm time of 10 h. Consecutive pulse records containing possible object echoes are grouped.

During reprocessing of these grouped data, range and Doppler-frequency shift are determined more precisely, and tracks of the detections are kept. For each object, time, signal amplitude, range, and Doppler-frequency values, as well as the monopulse angle

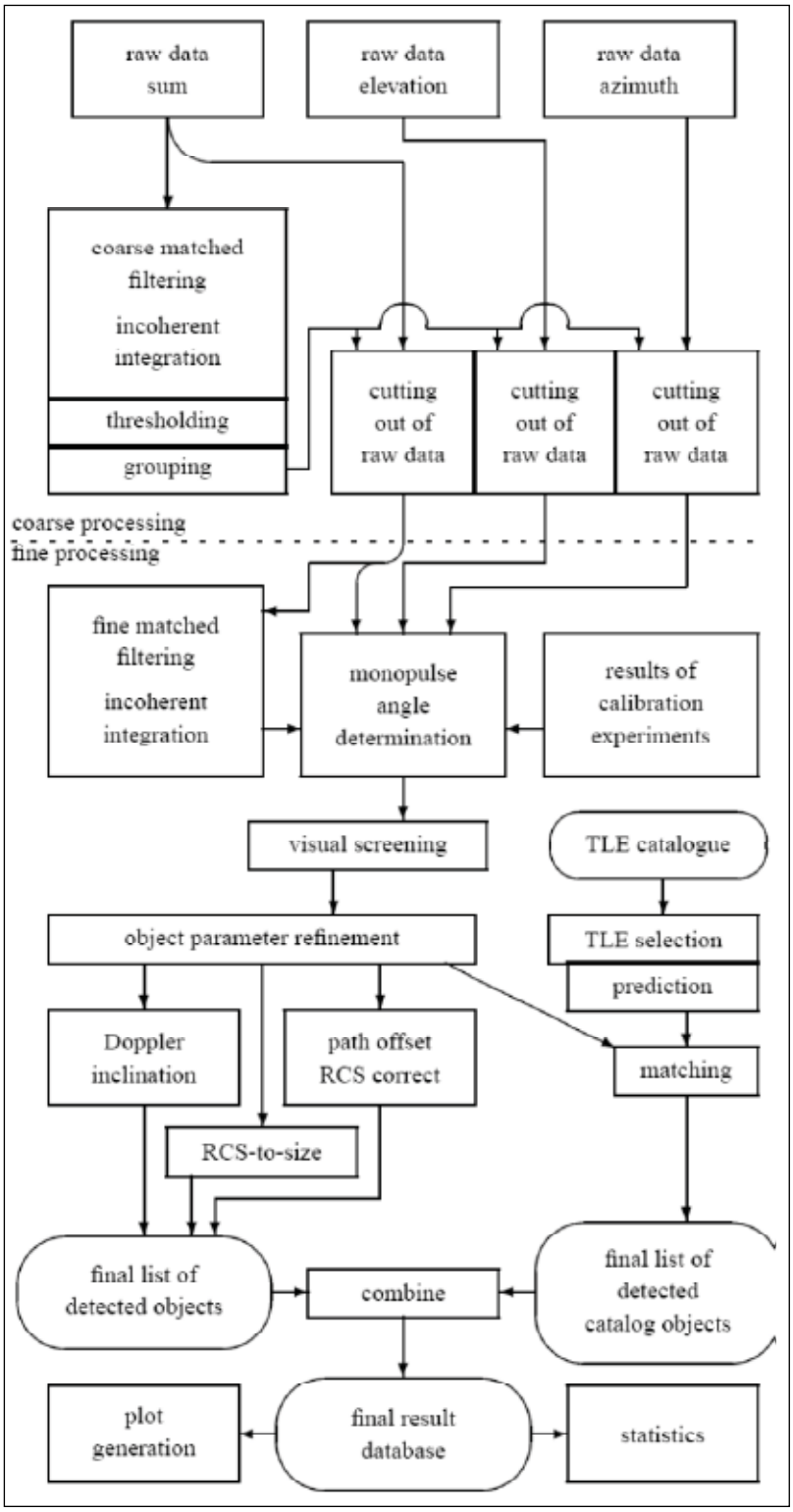


**Figure A-2. Processing flow chart.**

offsets of consecutive echoes, are determined. The squared amplitudes lead to the radar cross section (RCS) of the objects.

There is a problem of side lobe detections using radars for BPEs. The identification is difficult because, in many cases, the visual screening does not give any consistent clues that would not be plausible for main lobe detections also. Consider TIRA's L-band far field pattern in Figure A-3.

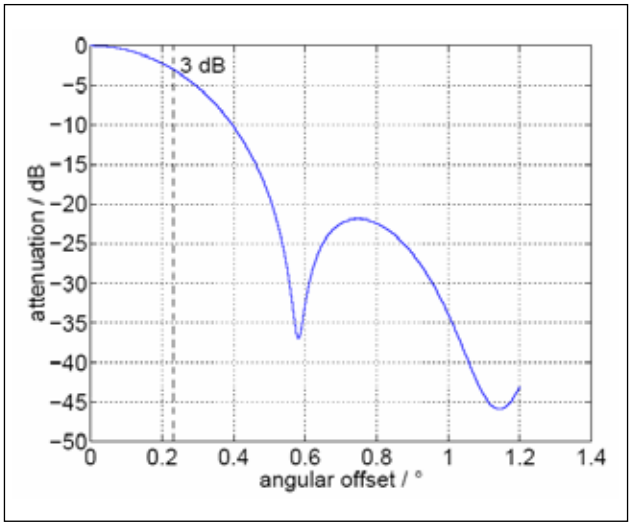


**Figure A-3. TIRA's L–band far field radiation pattern (one–way).**

The 3-dB beam width of the 34-m parabolic antenna at L-band frequency is 0.5°; the corresponding angular offset is half of this value, namely 0.25°. The first null of the antenna radiation pattern appears at an angular offset of 0.6°, and the maximum of the first side lobe at 0.74°. The maximum of the first side lobe is about 22 dB below the main beam (one-way pattern). For reliable monopulse angle measurements, the angular offset must be <0.35°. Side lobe detections might happen when a larger space object (which is most likely catalogued) passes outside the main beam but crossing, e.g., the first side lobe. It would appear as a small object passing the main beam. However, the maximum signal-to-noise ratio (SNR) is not generated at point of closest approach, but is generated when the object crosses, e.g., the maximum of TIRA's sidelobe several seconds before or after the time of closest approach (TCA), which is computed for the cross-check. Another hint for side lobe detections are look angle differences of more than 0.6°.

RCS is converted to a characteristic length using the NASA Size Estimation Model (SEM), which is described in Appendix E.

### A.4 Beamshape

From detailed analysis, it was found that TIRA's L-band beam is circular symmetric with respect to its line-of-sight (LOS) to sufficient accuracy. The (linear) intensity loss factor $L_I$ at positions off the LOS may thus be modelled as a 1-D radial function of the path

offset DF (combined azimuth and elevation offset). This function is fitted by polynomial of degree 10 with neglectable errors in the path offset range $0° \leq \Delta\Phi \leq 0{:}58°$:

$$L_I = \sum_{i=0}^{10} a_i \Delta\Phi^i ,$$

where $\Delta\Phi$ is given in degrees and the coefficients are provided in the Table A-3 .

## A.5 Detection List

**Table A-3. Coefficients for loss factor polynomial fit.**

| | |
|---|---|
| a10 | -3420.319965 |
| a9 | 10866.733826 |
| a8 | -12673.586251 |
| a7 | 4832.444768 |
| a6 | 2699.133493 |
| a5 | -3474.882785 |
| a4 | 1326.159178 |
| a3 | -163.994797 |
| a2 | -11.501799 |
| a1 | -0.457249 |
| a0 | 1.003540 |

The TIRA radar detected 786 objects in the 24 hours starting at ~12:30 GMT on 25 November 2008. Table A-4 provides the list of detections observed by the TIRA radar during the 2008 campaign. A determination of correlation between detections and known, or cataloged, objects was not provided by TIRA. Therefore, the column showing possible correlations with the U.S. Space Surveillance Network catalog of known objects was produced by NASA using U.S. Air Force Space Command-provided software.

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 1 | 330 | 12 | 32 | 18.4 | 1034.1 | 4.201 | -36.16 | 1003.9 | 68.1 | 0.031 | |
| 2 | 330 | 12 | 32 | 18.5 | 1871.7 | -0.678 | -19.39 | 1817.0 | 107.2 | 0.090 | |
| 3 | 330 | 12 | 32 | 18.5 | 1031.8 | -0.251 | -39.05 | 1001.7 | 94.3 | 0.028 | |
| 4 | 330 | 12 | 32 | 18.6 | 1068.5 | 2.609 | -31.39 | 1037.3 | 31.1 | 0.039 | |
| 5 | 330 | 12 | 42 | 2.9 | 1511.0 | 0.517 | -26.00 | 1466.8 | 74.4 | 0.045 | |
| 6 | 330 | 12 | 43 | 27.3 | 889.7 | 0.592 | -34.53 | 863.7 | 74.5 | 0.033 | |
| 7 | 330 | 12 | 47 | 16.6 | 1458.0 | 0.293 | -31.87 | 1415.4 | 80.5 | 0.038 | 22650 |
| 8 | 330 | 12 | 47 | 35.6 | 802.0 | 0.070 | -38.77 | 778.6 | 86.8 | 0.028 | 25342 |
| 9 | 330 | 12 | 47 | 39.7 | 807.6 | 0.315 | -40.56 | 784.0 | 81.2 | 0.026 | 25342 |
| 20 | 330 | 12 | 49 | 5.9 | 629.1 | -0.654 | -39.74 | 610.7 | 102.9 | 0.027 | |
| 21 | 330 | 12 | 50 | 44.0 | 656.1 | 0.299 | -34.09 | 636.9 | 81.8 | 0.034 | 22626 |
| 22 | 330 | 12 | 58 | 20.9 | 683.3 | -0.739 | -42.15 | 663.4 | 105.0 | 0.025 | |
| 23 | 330 | 12 | 59 | 14.2 | 841.3 | 0.868 | -38.00 | 816.8 | 67.9 | 0.029 | |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 24 | 330 | 13 | 5 | 29.7 | 872.5 | -0.524 | -34.22 | 847.0 | 100.5 | 0.034 | |
| 25 | 330 | 13 | 7 | 30.2 | 977.8 | 0.869 | -34.37 | 949.2 | 67.2 | 0.034 | |
| 26 | 330 | 13 | 14 | 41.8 | 879.6 | -0.822 | -37.97 | 853.9 | 107.7 | 0.029 | 12553 |
| 27 | 330 | 13 | 14 | 47.7 | 876.7 | -0.481 | -30.66 | 851.1 | 99.6 | 0.041 | 12553 |
| 28 | 330 | 13 | 15 | 11.5 | 2041.3 | -0.636 | -20.86 | 1981.7 | 106.5 | 0.067 | 21523 |
| 29 | 330 | 13 | 17 | 20.9 | 1017.1 | -0.316 | -31.28 | 987.4 | 95.8 | 0.040 | |
| 30 | 330 | 13 | 19 | 50.6 | 1257.9 | 1.150 | -31.75 | 1221.2 | 58.0 | 0.039 | |
| 31 | 330 | 13 | 20 | 1.4 | 1267.7 | 1.233 | -25.89 | 1230.7 | 55.4 | 0.045 | |
| 32 | 330 | 13 | 20 | 29.3 | 763.8 | -0.260 | -37.52 | 741.5 | 94.3 | 0.029 | 5560 |
| 33 | 330 | 13 | 22 | 33.1 | 1759.4 | 0.505 | -20.47 | 1708.0 | 74.0 | 0.072 | |
| 34 | 330 | 13 | 23 | 1.8 | 924.4 | -0.644 | -30.71 | 897.4 | 103.5 | 0.041 | |
| 35 | 330 | 13 | 27 | 19.5 | 974.0 | -0.379 | -30.83 | 945.6 | 97.3 | 0.040 | |
| 36 | 330 | 13 | 27 | 50.5 | 604.3 | -0.268 | -21.32 | 586.6 | 94.3 | 0.063 | |
| 37 | 330 | 13 | 31 | 12.1 | 886.2 | -0.587 | -37.04 | 860.3 | 102.1 | 0.030 | 12179 |
| 38 | 330 | 13 | 32 | 13.1 | 515.4 | -0.185 | -27.16 | 500.3 | 92.5 | 0.044 | 30586 |
| 39 | 330 | 13 | 32 | 13.6 | 372.0 | -0.019 | -57.31 | 361.1 | 88.9 | 0.014 | |
| 40 | 330 | 13 | 33 | 19.1 | 903.6 | 0.137 | -21.00 | 877.2 | 85.2 | 0.066 | |
| 41 | 330 | 13 | 33 | 57.7 | 910.7 | 1.568 | -38.16 | 884.1 | 48.3 | 0.028 | |
| 42 | 330 | 13 | 33 | 58.9 | 1577.9 | 0.295 | -28.80 | 1531.8 | 80.3 | 0.043 | 16593 |
| 43 | 330 | 13 | 34 | 5.3 | 1573.0 | 0.446 | 13.47 | 1527.1 | 76.2 | 5.322 | 16593 |
| 44 | 330 | 13 | 37 | 2.4 | 879.8 | 0.802 | -32.69 | 854.1 | 69.4 | 0.037 | 15334 |
| 45 | 330 | 13 | 42 | 11.3 | 1301.8 | 1.908 | -35.68 | 1263.8 | 31.3 | 0.032 | |
| 46 | 330 | 13 | 42 | 12.1 | 1220.6 | 2.434 | -40.24 | 1185.0 | 27.7 | 0.027 | |
| 47 | 330 | 13 | 42 | 39.5 | 871.8 | -0.553 | -38.93 | 846.4 | 101.2 | 0.028 | |
| 48 | 330 | 13 | 44 | 25.7 | 931.6 | -0.649 | -36.82 | 904.4 | 103.7 | 0.030 | |
| 49 | 330 | 13 | 44 | 47.1 | 1017.5 | 0.088 | -35.43 | 987.8 | 86.2 | 0.032 | |
| 50 | 330 | 13 | 49 | 32.8 | 1556.0 | 0.549 | -21.92 | 1510.6 | 73.4 | 0.057 | |
| 51 | 330 | 13 | 51 | 50.6 | 928.4 | -0.455 | -41.52 | 901.2 | 99.0 | 0.026 | |
| 52 | 330 | 13 | 56 | 14.0 | 1133.2 | -0.350 | -30.86 | 1100.1 | 96.8 | 0.040 | |
| 53 | 330 | 13 | 56 | 21.1 | 794.2 | -0.571 | -28.59 | 771.1 | 101.5 | 0.044 | 31291 |
| 54 | 330 | 14 | 5 | 36.1 | 703.0 | -0.321 | -39.53 | 682.5 | 95.6 | 0.027 | |
| 55 | 330 | 14 | 10 | 56.9 | 343.0 | 1.025 | -23.66 | 333.0 | 66.7 | 0.052 | 33421 |
| 56 | 330 | 14 | 15 | 34.2 | 1534.0 | -0.538 | -21.51 | 1489.2 | 102.4 | 0.062 | |
| 57 | 330 | 14 | 16 | 55.2 | 943.5 | -0.669 | -25.12 | 915.9 | 104.2 | 0.047 | |
| 58 | 330 | 14 | 17 | 29.2 | 820.0 | 0.847 | -28.64 | 796.1 | 68.5 | 0.044 | |
| 59 | 330 | 14 | 17 | 51.5 | 1109.9 | -0.069 | -36.72 | 1077.5 | 90.0 | 0.030 | |
| 60 | 330 | 14 | 21 | 16.5 | 788.0 | 0.802 | -35.50 | 764.9 | 69.8 | 0.032 | |
| 61 | 330 | 14 | 24 | 32.0 | 1183.6 | 2.405 | -35.04 | 1149.1 | 25.9 | 0.033 | |
| 62 | 330 | 14 | 27 | 30.7 | 977.5 | -0.682 | -37.30 | 948.9 | 104.6 | 0.029 | |
| 63 | 330 | 14 | 29 | 45.1 | 880.5 | 0.116 | -27.73 | 854.8 | 85.7 | 0.044 | |
| 64 | 330 | 14 | 30 | 53.6 | 588.1 | 0.042 | -25.37 | 571.0 | 87.6 | 0.046 | 19274 |
| 65 | 330 | 14 | 30 | 56.0 | 732.0 | -0.189 | -49.41 | 710.6 | 92.7 | 0.019 | |
| 66 | 330 | 14 | 30 | 56.9 | 462.0 | 0.201 | -52.20 | 448.5 | 84.2 | 0.017 | |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 67 | 330 | 14 | 30 | 58.3 | 589.6 | 0.449 | -43.34 | 572.4 | 78.6 | 0.024 | 19274 |
| 68 | 330 | 14 | 37 | 14.4 | 821.3 | 1.063 | -7.24 | 797.4 | 63.1 | 0.490 | 9982 |
| 69 | 330 | 14 | 37 | 47.2 | 1859.5 | 0.937 | -20.65 | 1805.2 | 60.7 | 0.069 | 19294 |
| 70 | 330 | 14 | 38 | 44.6 | 1430.7 | -0.568 | -27.45 | 1388.9 | 102.9 | 0.044 | |
| 71 | 330 | 14 | 39 | 19.8 | 452.5 | -2.620 | -45.41 | 439.3 | 159.0 | 0.022 | |
| 72 | 330 | 14 | 39 | 35.6 | 1027.3 | 0.160 | -34.49 | 997.3 | 84.5 | 0.033 | 22889 |
| 73 | 330 | 14 | 39 | 42.6 | 1034.4 | 0.457 | -35.67 | 1004.2 | 77.3 | 0.032 | |
| 74 | 330 | 14 | 41 | 46.1 | 556.4 | -0.361 | -19.25 | 540.2 | 96.3 | 0.093 | |
| 75 | 330 | 14 | 43 | 43.9 | 600.8 | 2.220 | -26.71 | 583.2 | 30.2 | 0.045 | |
| 76 | 330 | 14 | 43 | 53.0 | 976.2 | -0.601 | -36.58 | 947.7 | 102.6 | 0.030 | |
| 77 | 330 | 14 | 46 | 10.5 | 1430.8 | 0.402 | -24.78 | 1389.0 | 77.7 | 0.048 | |
| 78 | 330 | 14 | 46 | 25.3 | 975.3 | 0.890 | -36.71 | 946.8 | 66.7 | 0.030 | |
| 79 | 330 | 14 | 49 | 26.8 | 881.2 | -0.549 | -36.47 | 855.5 | 101.2 | 0.030 | |
| 80 | 330 | 14 | 49 | 50.8 | 882.8 | -0.580 | -27.19 | 857.0 | 101.9 | 0.044 | |
| 81 | 330 | 14 | 52 | 46.3 | 871.4 | -0.573 | -36.86 | 846.0 | 101.7 | 0.030 | |
| 82 | 330 | 14 | 53 | 25.2 | 736.5 | 0.275 | -37.49 | 715.0 | 82.2 | 0.029 | 25578 |
| 83 | 330 | 14 | 54 | 14.1 | 1667.7 | 0.810 | -12.56 | 1619.0 | 65.5 | 0.250 | 4621 |
| 84 | 330 | 14 | 57 | 4.4 | 876.3 | -0.498 | -30.48 | 850.7 | 99.9 | 0.041 | |
| 85 | 330 | 14 | 58 | 35.4 | 875.6 | 0.367 | -19.30 | 850.0 | 79.8 | 0.092 | 82004 |
| 86 | 330 | 14 | 59 | 2.9 | 759.8 | -0.704 | -20.07 | 737.6 | 104.5 | 0.079 | 29837 |
| 87 | 330 | 15 | 0 | 42.1 | 1811.6 | 1.163 | -30.99 | 1758.7 | 53.6 | 0.040 | |
| 88 | 330 | 15 | 0 | 42.5 | 1763.9 | 1.120 | -18.29 | 1712.4 | 55.3 | 0.111 | |
| 89 | 330 | 15 | 2 | 10.9 | 1706.2 | 0.579 | -25.35 | 1656.4 | 72.1 | 0.046 | 8295 |
| 90 | 330 | 15 | 2 | 53.7 | 886.5 | -0.556 | -30.83 | 860.7 | 101.3 | 0.040 | |
| 91 | 330 | 15 | 3 | 51.3 | 869.7 | -0.562 | -20.79 | 844.3 | 101.4 | 0.068 | |
| 92 | 330 | 15 | 7 | 24.2 | 883.4 | -0.575 | -24.35 | 857.6 | 101.8 | 0.050 | |
| 93 | 330 | 15 | 7 | 38.8 | 985.4 | 0.461 | -37.60 | 956.6 | 77.3 | 0.029 | |
| 94 | 330 | 15 | 8 | 2.1 | 977.5 | 0.878 | -32.75 | 949.0 | 67.0 | 0.037 | |
| 95 | 330 | 15 | 8 | 3.6 | 974.3 | 0.903 | -34.34 | 945.9 | 66.4 | 0.034 | |
| 96 | 330 | 15 | 10 | 41.2 | 1732.2 | -0.788 | -20.47 | 1681.6 | 110.0 | 0.072 | |
| 97 | 330 | 15 | 10 | 43.4 | 1733.1 | -0.744 | -19.88 | 1682.5 | 108.7 | 0.082 | |
| 98 | 330 | 15 | 12 | 6.5 | 1626.9 | 0.289 | -31.75 | 1579.4 | 80.3 | 0.039 | |
| 99 | 330 | 15 | 12 | 50.5 | 528.0 | 1.581 | -44.22 | 512.6 | 51.7 | 0.023 | |
| 100 | 330 | 15 | 16 | 58.9 | 758.0 | -1.390 | -25.37 | 735.9 | 121.3 | 0.046 | |
| 101 | 330 | 15 | 17 | 6.3 | 744.2 | -1.368 | -27.30 | 722.5 | 120.6 | 0.044 | |
| 102 | 330 | 15 | 17 | 15.7 | 1894.5 | 0.118 | -24.55 | 1839.2 | 84.7 | 0.049 | |
| 103 | 330 | 15 | 17 | 19.4 | 1902.4 | 0.104 | -30.12 | 1846.9 | 85.1 | 0.042 | |
| 104 | 330 | 15 | 17 | 39.6 | 1904.8 | 0.121 | -25.53 | 1849.2 | 84.6 | 0.046 | |
| 105 | 330 | 15 | 17 | 48.7 | 1897.9 | 0.115 | -21.89 | 1842.5 | 84.8 | 0.057 | |
| 106 | 330 | 15 | 18 | 13.0 | 762.0 | -0.533 | -47.03 | 739.7 | 100.5 | 0.020 | |
| 107 | 330 | 15 | 18 | 14.0 | 890.6 | -0.512 | -16.77 | 864.6 | 100.3 | 0.143 | 89268 |
| 108 | 330 | 15 | 20 | 24.5 | 852.0 | -0.598 | -33.01 | 827.1 | 102.2 | 0.036 | |
| 109 | 330 | 15 | 22 | 23.3 | 877.4 | 1.037 | -21.76 | 851.8 | 63.5 | 0.058 | 81162 |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 110 | 330 | 15 | 25 | 7.1 | 1039.2 | -0.863 | -26.45 | 1008.8 | 109.3 | 0.045 | |
| 111 | 330 | 15 | 27 | 23.2 | 883.5 | 0.837 | -29.33 | 857.7 | 68.5 | 0.043 | |
| 112 | 330 | 15 | 33 | 25.4 | 508.9 | 1.298 | -45.75 | 494.1 | 59.2 | 0.022 | |
| 113 | 330 | 15 | 41 | 53.4 | 1896.9 | 0.043 | -20.30 | 1841.5 | 86.8 | 0.075 | |
| 114 | 330 | 15 | 41 | 53.5 | 937.4 | 0.136 | -36.69 | 910.0 | 85.2 | 0.030 | |
| 115 | 330 | 15 | 42 | 10.1 | 1896.6 | 0.040 | -24.18 | 1841.2 | 86.9 | 0.050 | |
| 116 | 330 | 15 | 44 | 43.7 | 794.6 | -0.663 | -35.64 | 771.4 | 103.6 | 0.032 | |
| 117 | 330 | 15 | 46 | 59.9 | 1921.4 | 0.036 | -18.79 | 1865.3 | 87.0 | 0.101 | |
| 118 | 330 | 15 | 47 | 8.2 | 278.0 | 0.003 | -54.75 | 269.9 | 88.5 | 0.015 | |
| 119 | 330 | 15 | 47 | 11.6 | 1922.5 | 0.039 | -15.99 | 1866.3 | 86.9 | 0.162 | |
| 120 | 330 | 15 | 47 | 39.8 | 1926.8 | 0.030 | -18.36 | 1870.6 | 87.2 | 0.110 | |
| 121 | 330 | 15 | 52 | 11.6 | 1389.8 | -1.038 | -22.34 | 1349.3 | 115.6 | 0.056 | |
| 122 | 330 | 15 | 52 | 30.4 | 996.2 | -0.614 | -33.84 | 967.1 | 103.0 | 0.035 | |
| 123 | 330 | 15 | 53 | 18.7 | 880.4 | -0.502 | -39.48 | 854.7 | 100.0 | 0.027 | |
| 124 | 330 | 15 | 54 | 2.0 | 805.8 | -0.617 | -41.71 | 782.2 | 102.6 | 0.026 | |
| 125 | 330 | 15 | 56 | 15.0 | 968.7 | 0.872 | -35.62 | 940.4 | 67.2 | 0.032 | |
| 126 | 330 | 15 | 58 | 18.9 | 1068.2 | 1.260 | -20.87 | 1037.0 | 56.1 | 0.067 | 81337 |
| 127 | 330 | 16 | 0 | 10.4 | 1030.7 | 0.030 | -11.56 | 1000.6 | 87.6 | 0.285 | 12735 |
| 128 | 330 | 16 | 0 | 38.0 | 890.5 | -0.521 | -38.54 | 864.5 | 100.5 | 0.028 | |
| 129 | 330 | 16 | 1 | 57.1 | 776.0 | -0.612 | -35.14 | 753.4 | 102.4 | 0.032 | 26260 |
| 130 | 330 | 16 | 3 | 50.7 | 1962.0 | 2.683 | -17.81 | 1904.7 | 49.2 | 0.121 | |
| 131 | 330 | 16 | 4 | 12.2 | 768.4 | -0.330 | -34.17 | 746.0 | 95.9 | 0.034 | |
| 132 | 330 | 16 | 9 | 23.8 | 858.3 | -0.674 | -41.22 | 833.2 | 104.0 | 0.026 | |
| 133 | 330 | 16 | 13 | 26.1 | 890.3 | -0.585 | -34.49 | 864.3 | 102.0 | 0.033 | |
| 134 | 330 | 16 | 16 | 59.0 | 888.6 | -0.549 | -21.06 | 862.6 | 101.2 | 0.065 | |
| 135 | 330 | 16 | 17 | 57.6 | 319.9 | 1.701 | -41.77 | 310.5 | 50.5 | 0.026 | |
| 136 | 330 | 16 | 18 | 12.3 | 816.0 | 0.940 | -37.36 | 792.2 | 66.2 | 0.029 | |
| 137 | 330 | 16 | 18 | 13.1 | 1717.9 | 2.241 | -31.37 | 1667.8 | 30.0 | 0.040 | |
| 138 | 330 | 16 | 18 | 13.6 | 1807.4 | 2.174 | -31.50 | 1754.6 | 29.0 | 0.039 | |
| 139 | 330 | 16 | 18 | 13.7 | 1692.8 | -0.010 | -27.48 | 1643.4 | 88.4 | 0.044 | |
| 140 | 330 | 16 | 20 | 35.1 | 627.9 | -0.469 | -38.17 | 609.6 | 98.8 | 0.028 | 28413 |
| 141 | 330 | 16 | 21 | 32.5 | 1512.0 | 0.302 | -22.66 | 1467.8 | 80.2 | 0.056 | 21305 |
| 142 | 330 | 16 | 24 | 13.6 | 1277.4 | 0.678 | -16.07 | 1240.1 | 70.9 | 0.160 | 87038 |
| 143 | 330 | 16 | 28 | 28.8 | 1602.2 | -0.036 | -20.57 | 1555.4 | 89.1 | 0.070 | |
| 144 | 330 | 16 | 29 | 3.2 | 1384.2 | 0.678 | -27.95 | 1343.8 | 70.5 | 0.044 | 85377 |
| 145 | 330 | 16 | 37 | 53.9 | 906.2 | -0.482 | -22.77 | 879.8 | 99.6 | 0.056 | |
| 146 | 330 | 16 | 37 | 58.8 | 825.7 | -0.302 | -29.85 | 801.6 | 95.3 | 0.042 | |
| 147 | 330 | 16 | 44 | 25.9 | 847.1 | 2.216 | -39.22 | 822.3 | 26.0 | 0.027 | |
| 148 | 330 | 16 | 47 | 28.6 | 1034.2 | -0.018 | -29.15 | 1004.0 | 88.7 | 0.043 | 11736 |
| 149 | 330 | 16 | 47 | 33.9 | 1031.9 | 0.224 | -31.66 | 1001.8 | 83.0 | 0.039 | 11736 |
| 150 | 330 | 16 | 49 | 1.2 | 1006.7 | 0.761 | -34.51 | 977.3 | 69.9 | 0.033 | 87090 |
| 151 | 330 | 16 | 50 | 58.6 | 1521.0 | 0.457 | -26.61 | 1476.6 | 76.0 | 0.045 | |
| 152 | 330 | 16 | 53 | 44.0 | 976.0 | 0.353 | -28.73 | 947.5 | 80.0 | 0.043 | |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 153 | 330 | 16 | 59 | 29.3 | 893.0 | -0.605 | -31.37 | 866.9 | 102.5 | 0.040 | |
| 154 | 330 | 17 | 2 | 33.8 | 628.3 | -0.424 | -30.23 | 610.0 | 97.8 | 0.041 | |
| 155 | 330 | 17 | 5 | 30.3 | 1000.5 | 0.112 | -34.61 | 971.3 | 85.7 | 0.033 | 20578 |
| 156 | 330 | 17 | 5 | 37.5 | 1002.3 | 0.451 | -30.78 | 973.0 | 77.5 | 0.041 | |
| 157 | 330 | 17 | 9 | 5.0 | 639.0 | 1.386 | -41.21 | 620.4 | 56.0 | 0.026 | 5010 |
| 158 | 330 | 17 | 14 | 1.0 | 2050.2 | -0.828 | -14.24 | 1990.4 | 112.4 | 0.204 | |
| 159 | 330 | 17 | 16 | 4.5 | 796.2 | -0.529 | -31.48 | 772.9 | 100.5 | 0.039 | 31872 |
| 160 | 330 | 17 | 16 | 26.2 | 890.2 | -0.571 | -35.41 | 864.2 | 101.7 | 0.032 | |
| 161 | 330 | 17 | 26 | 28.8 | 1443.7 | 0.396 | -30.33 | 1401.5 | 77.8 | 0.041 | |
| 162 | 330 | 17 | 27 | 40.3 | 1425.2 | 0.473 | -27.77 | 1383.6 | 75.9 | 0.044 | |
| 163 | 330 | 17 | 30 | 52.5 | 1001.7 | 0.138 | -33.15 | 972.5 | 85.1 | 0.036 | 87608 |
| 164 | 330 | 17 | 31 | 14.2 | 993.4 | -0.426 | -19.57 | 964.4 | 98.5 | 0.087 | 31146 |
| 165 | 330 | 17 | 31 | 16.3 | 809.2 | -0.536 | -20.74 | 785.5 | 100.7 | 0.068 | 28064 |
| 166 | 330 | 17 | 35 | 58.7 | 570.5 | 0.479 | -43.77 | 553.9 | 78.0 | 0.023 | 13068 |
| 167 | 330 | 17 | 36 | 40.2 | 1125.6 | 1.475 | -26.99 | 1092.7 | 49.1 | 0.045 | |
| 168 | 330 | 17 | 39 | 12.0 | 896.7 | -0.542 | -28.82 | 870.5 | 101.0 | 0.043 | 85267 |
| 169 | 330 | 17 | 42 | 50.1 | 989.8 | -0.252 | -28.57 | 960.9 | 94.3 | 0.044 | |
| 170 | 330 | 17 | 45 | 12.1 | 806.7 | -0.619 | -36.56 | 783.1 | 102.6 | 0.030 | |
| 171 | 330 | 17 | 46 | 0.4 | 1550.9 | -0.603 | -21.92 | 1505.6 | 104.2 | 0.057 | |
| 172 | 330 | 17 | 47 | 37.7 | 949.9 | 1.025 | -21.12 | 922.2 | 63.3 | 0.065 | 26504 |
| 173 | 330 | 17 | 48 | 16.7 | 488.7 | -4.851 | -48.14 | 474.4 | 187.9 | 0.020 | |
| 174 | 330 | 17 | 48 | 45.6 | 384.7 | -2.223 | -39.67 | 373.5 | 141.5 | 0.027 | |
| 175 | 330 | 17 | 48 | 54.7 | 821.4 | -0.624 | -38.26 | 797.4 | 102.8 | 0.028 | 16969 |
| 176 | 330 | 17 | 48 | 58.5 | 361.9 | -0.541 | -46.70 | 351.3 | 99.8 | 0.021 | |
| 177 | 330 | 17 | 49 | 0.3 | 815.9 | -0.292 | -37.22 | 792.0 | 95.1 | 0.029 | 16969 |
| 178 | 330 | 17 | 49 | 4.0 | 492.2 | 0.444 | -53.29 | 477.8 | 79.0 | 0.016 | |
| 179 | 330 | 17 | 49 | 10.1 | 369.1 | 1.108 | -15.82 | 358.3 | 64.7 | 0.165 | |
| 180 | 330 | 17 | 49 | 27.9 | 410.9 | 3.272 | -26.79 | 398.9 | 38.6 | 0.045 | |
| 181 | 330 | 17 | 49 | 41.4 | 464.1 | 4.459 | -44.42 | 450.5 | 63.8 | 0.023 | |
| 182 | 330 | 17 | 50 | 51.2 | 825.1 | 0.615 | -39.76 | 801.0 | 74.1 | 0.027 | 13242 |
| 183 | 330 | 17 | 52 | 30.4 | 2038.6 | 0.992 | -25.22 | 1979.1 | 57.8 | 0.047 | |
| 184 | 330 | 17 | 53 | 0.6 | 948.5 | 1.018 | -23.34 | 920.8 | 63.5 | 0.054 | 26506 |
| 185 | 330 | 17 | 53 | 5.4 | 764.0 | -0.049 | -40.20 | 741.7 | 89.5 | 0.027 | |
| 186 | 330 | 17 | 53 | 42.5 | 1209.9 | 0.038 | -40.71 | 1174.5 | 87.3 | 0.026 | |
| 187 | 330 | 17 | 57 | 51.3 | 1363.9 | 1.386 | -26.11 | 1324.1 | 49.8 | 0.045 | 27772 |
| 188 | 330 | 17 | 58 | 54.1 | 915.3 | -0.621 | -23.30 | 888.5 | 103.0 | 0.054 | |
| 189 | 330 | 18 | 2 | 38.8 | 609.8 | -0.723 | -40.59 | 592.0 | 104.4 | 0.026 | 26121 |
| 190 | 330 | 18 | 3 | 53.4 | 782.6 | -0.641 | -36.26 | 759.8 | 103.1 | 0.031 | |
| 191 | 330 | 18 | 3 | 54.5 | 949.9 | -0.641 | -45.18 | 922.2 | 103.5 | 0.022 | |
| 192 | 330 | 18 | 3 | 54.8 | 726.0 | -0.634 | -47.19 | 704.8 | 102.8 | 0.020 | |
| 193 | 330 | 18 | 3 | 55.9 | 885.9 | -0.631 | -25.65 | 860.0 | 103.1 | 0.046 | 31756 |
| 194 | 330 | 18 | 5 | 13.2 | 1541.2 | 1.080 | -29.83 | 1496.2 | 58.1 | 0.042 | |
| 195 | 330 | 18 | 5 | 14.0 | 1721.7 | 0.517 | -23.20 | 1671.4 | 73.8 | 0.054 | 3874 |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 196 | 330 | 18 | 6 | 28.1 | 911.7 | -0.595 | -30.45 | 885.0 | 102.3 | 0.041 | |
| 197 | 330 | 18 | 9 | 45.1 | 823.0 | 0.755 | -32.17 | 799.0 | 70.8 | 0.038 | 10120 |
| 198 | 330 | 18 | 14 | 20.7 | 1666.6 | 0.591 | 0.66 | 1618.0 | 71.9 | 1.217 | 25365 |
| 199 | 330 | 18 | 16 | 48.3 | 1093.7 | -0.425 | -22.82 | 1061.8 | 98.6 | 0.055 | |
| 200 | 330 | 18 | 20 | 50.1 | 1451.2 | 1.182 | -29.33 | 1408.9 | 55.6 | 0.043 | 25771 |
| 201 | 330 | 18 | 28 | 25.3 | 1001.8 | 0.011 | -30.88 | 972.5 | 88.1 | 0.040 | 22782 |
| 202 | 330 | 18 | 31 | 34.4 | 1032.0 | 0.879 | -34.50 | 1001.8 | 66.7 | 0.033 | |
| 203 | 330 | 18 | 31 | 35.1 | 902.8 | 0.778 | -23.65 | 876.4 | 69.9 | 0.052 | 87386 |
| 204 | 330 | 18 | 31 | 41.7 | 861.9 | 0.099 | -21.75 | 836.7 | 86.1 | 0.058 | 87725 |
| 205 | 330 | 18 | 32 | 52.7 | 550.9 | -0.573 | -28.93 | 534.8 | 100.9 | 0.043 | |
| 206 | 330 | 18 | 42 | 11.7 | 1130.8 | 0.432 | -18.61 | 1097.8 | 77.7 | 0.105 | |
| 207 | 330 | 18 | 42 | 11.8 | 350.4 | 1.077 | -44.92 | 340.1 | 65.5 | 0.022 | |
| 208 | 330 | 18 | 45 | 7.5 | 679.4 | -0.646 | -38.38 | 659.6 | 102.9 | 0.028 | |
| 209 | 330 | 18 | 47 | 10.4 | 585.2 | 0.461 | -45.89 | 568.1 | 78.3 | 0.021 | |
| 210 | 330 | 18 | 47 | 10.9 | 600.0 | 0.474 | -48.64 | 582.5 | 78.0 | 0.019 | |
| 211 | 330 | 18 | 55 | 15.5 | 991.0 | 1.012 | -34.56 | 962.0 | 63.5 | 0.033 | |
| 212 | 330 | 18 | 59 | 14.2 | 877.8 | -0.626 | -22.76 | 852.2 | 103.0 | 0.056 | |
| 213 | 330 | 18 | 59 | 52.0 | 1135.6 | -0.061 | -33.32 | 1102.5 | 89.8 | 0.036 | 19071 |
| 214 | 330 | 19 | 4 | 10.6 | 714.1 | 0.827 | -38.53 | 693.3 | 69.5 | 0.028 | |
| 215 | 330 | 19 | 6 | 16.1 | 888.8 | -0.412 | -39.63 | 862.9 | 98.0 | 0.027 | 28050 |
| 216 | 330 | 19 | 6 | 20.1 | 982.8 | 0.133 | -25.91 | 954.1 | 85.2 | 0.045 | |
| 217 | 330 | 19 | 8 | 16.7 | 1043.5 | -0.481 | -21.90 | 1013.0 | 99.9 | 0.057 | |
| 218 | 330 | 19 | 8 | 16.9 | 822.5 | 3.038 | -29.19 | 798.5 | 40.3 | 0.043 | |
| 219 | 330 | 19 | 9 | 51.8 | 723.4 | -0.577 | -37.30 | 702.3 | 101.4 | 0.029 | |
| 220 | 330 | 19 | 12 | 16.3 | 645.4 | -0.036 | -40.75 | 626.6 | 89.2 | 0.026 | 16987 |
| 221 | 330 | 19 | 14 | 14.9 | 1002.8 | 0.019 | -36.03 | 973.5 | 87.9 | 0.031 | |
| 222 | 330 | 19 | 17 | 5.3 | 1722.0 | 0.004 | -28.47 | 1671.7 | 88.0 | 0.044 | |
| 223 | 330 | 19 | 22 | 58.8 | 822.0 | 2.201 | -35.65 | 798.0 | 27.0 | 0.032 | |
| 224 | 330 | 19 | 23 | 0.2 | 675.1 | 1.394 | 3.46 | 655.4 | 55.5 | 1.680 | |
| 225 | 330 | 19 | 23 | 1.2 | 822.0 | 1.789 | -45.27 | 798.0 | 42.3 | 0.022 | |
| 226 | 330 | 19 | 23 | 4.0 | 675.8 | 1.644 | -41.63 | 656.1 | 48.5 | 0.026 | |
| 227 | 330 | 19 | 24 | 23.0 | 378.5 | -0.900 | -48.99 | 367.4 | 107.6 | 0.019 | |
| 228 | 330 | 19 | 24 | 32.3 | 389.1 | 0.317 | -49.88 | 377.7 | 81.9 | 0.018 | |
| 229 | 330 | 19 | 24 | 39.7 | 383.8 | 1.318 | -51.86 | 372.6 | 59.6 | 0.017 | |
| 230 | 330 | 19 | 24 | 49.1 | 412.5 | 2.456 | -48.55 | 400.5 | 24.3 | 0.019 | |
| 231 | 330 | 19 | 24 | 51.8 | 407.6 | 2.774 | -50.40 | 395.7 | 21.4 | 0.018 | |
| 232 | 330 | 19 | 24 | 59.0 | 433.3 | 3.485 | -40.75 | 420.7 | 44.6 | 0.026 | |
| 233 | 330 | 19 | 26 | 23.8 | 735.8 | -1.002 | -39.28 | 714.3 | 111.4 | 0.027 | |
| 234 | 330 | 19 | 27 | 36.5 | 672.2 | 0.701 | -35.11 | 652.6 | 72.6 | 0.032 | 22477 |
| 235 | 330 | 19 | 28 | 35.9 | 616.9 | -0.600 | -21.82 | 598.9 | 101.7 | 0.058 | 31694 |
| 236 | 330 | 19 | 28 | 45.6 | 569.5 | -0.525 | -24.59 | 552.9 | 99.9 | 0.049 | |
| 237 | 330 | 19 | 32 | 26.6 | 1538.0 | -0.624 | -23.93 | 1493.1 | 104.7 | 0.052 | 81804 |
| 238 | 330 | 19 | 32 | 28.5 | 851.6 | -0.627 | -26.77 | 826.8 | 102.9 | 0.045 | |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 239 | 330 | 19 | 32 | 44.9 | 1423.8 | 0.703 | -27.95 | 1382.3 | 69.7 | 0.044 | |
| 240 | 330 | 19 | 40 | 22.8 | 1734.8 | 0.088 | -29.47 | 1684.2 | 85.7 | 0.043 | 29284 |
| 241 | 330 | 19 | 47 | 51.0 | 595.8 | -0.499 | -25.70 | 578.4 | 99.4 | 0.046 | |
| 242 | 330 | 19 | 48 | 17.0 | 1274.4 | 0.305 | -27.60 | 1237.2 | 80.6 | 0.044 | |
| 243 | 330 | 19 | 55 | 33.3 | 1156.7 | -0.324 | -23.33 | 1123.0 | 96.2 | 0.054 | |
| 244 | 330 | 19 | 56 | 14.7 | 320.7 | 0.016 | -54.24 | 311.4 | 88.2 | 0.016 | |
| 245 | 330 | 19 | 56 | 16.8 | 311.6 | 0.023 | -54.76 | 302.5 | 88.1 | 0.015 | |
| 246 | 330 | 19 | 56 | 58.7 | 1710.5 | 2.081 | -32.43 | 1660.6 | 24.6 | 0.037 | |
| 247 | 330 | 19 | 56 | 59.4 | 1260.7 | 2.329 | -18.89 | 1223.9 | 24.8 | 0.100 | |
| 248 | 330 | 19 | 57 | 0.6 | 1256.2 | 3.099 | -35.09 | 1219.5 | 49.5 | 0.032 | |
| 249 | 330 | 19 | 57 | 6.8 | 305.1 | 0.795 | -59.90 | 296.2 | 71.9 | 0.013 | |
| 250 | 330 | 19 | 57 | 8.6 | 671.8 | 1.087 | -51.56 | 652.2 | 63.4 | 0.017 | |
| 251 | 330 | 19 | 57 | 8.9 | 812.3 | 0.886 | -21.85 | 788.6 | 67.6 | 0.058 | 4311 |
| 252 | 330 | 19 | 58 | 16.8 | 1061.5 | -0.327 | -37.24 | 1030.5 | 96.2 | 0.029 | 8860 |
| 253 | 330 | 19 | 59 | 40.5 | 301.1 | 0.095 | -59.92 | 292.4 | 86.6 | 0.012 | |
| 254 | 330 | 20 | 0 | 10.0 | 823.5 | 0.650 | -38.81 | 799.5 | 73.3 | 0.028 | |
| 255 | 330 | 20 | 1 | 58.7 | 914.0 | -0.691 | -36.15 | 887.3 | 104.6 | 0.031 | |
| 256 | 330 | 20 | 3 | 15.0 | 337.7 | 1.682 | -47.59 | 327.8 | 50.9 | 0.020 | |
| 257 | 330 | 20 | 4 | 28.9 | 638.0 | -0.392 | -27.40 | 619.4 | 97.1 | 0.044 | |
| 258 | 330 | 20 | 6 | 33.8 | 791.9 | 0.592 | -35.68 | 768.8 | 74.8 | 0.032 | 13149 |
| 259 | 330 | 20 | 6 | 41.2 | 802.4 | 1.027 | -39.06 | 779.0 | 64.1 | 0.028 | |
| 260 | 330 | 20 | 8 | 12.3 | 858.6 | -0.734 | -39.93 | 833.5 | 105.5 | 0.027 | 29499 |
| 261 | 330 | 20 | 8 | 16.7 | 852.6 | -0.471 | -38.23 | 827.7 | 99.3 | 0.028 | 29499 |
| 262 | 330 | 20 | 9 | 14.3 | 574.7 | 0.268 | -20.99 | 557.9 | 82.6 | 0.066 | 5117 |
| 263 | 330 | 20 | 12 | 34.4 | 554.7 | -0.433 | -46.54 | 538.5 | 97.9 | 0.021 | |
| 264 | 330 | 20 | 13 | 24.7 | 1200.2 | -0.984 | -20.96 | 1165.2 | 113.1 | 0.066 | |
| 265 | 330 | 20 | 21 | 28.4 | 877.4 | -0.537 | -19.65 | 851.8 | 100.9 | 0.086 | 26821 |
| 266 | 330 | 20 | 23 | 21.2 | 707.8 | 0.752 | -25.61 | 687.1 | 71.3 | 0.046 | 5778 |
| 267 | 330 | 20 | 24 | 10.2 | 671.1 | -0.540 | -35.44 | 651.5 | 100.5 | 0.032 | |
| 268 | 330 | 20 | 24 | 47.0 | 690.3 | 2.611 | -41.65 | 670.2 | 22.6 | 0.026 | |
| 269 | 330 | 20 | 28 | 4.8 | 311.7 | 0.296 | -58.96 | 302.6 | 82.5 | 0.013 | |
| 270 | 330 | 20 | 30 | 42.4 | 459.9 | -0.657 | -54.22 | 446.4 | 102.5 | 0.016 | 27838 |
| 271 | 330 | 20 | 30 | 45.0 | 470.4 | -0.356 | -44.54 | 456.7 | 96.1 | 0.023 | 27838 |
| 272 | 330 | 20 | 32 | 43.5 | 973.3 | 1.139 | -24.17 | 944.9 | 60.2 | 0.050 | 81567 |
| 273 | 330 | 20 | 33 | 54.4 | 1332.4 | 0.060 | -26.23 | 1293.5 | 86.7 | 0.045 | |
| 274 | 330 | 20 | 34 | 50.9 | 2043.3 | 0.544 | -21.16 | 1983.6 | 72.0 | 0.064 | |
| 275 | 330 | 20 | 35 | 18.8 | 341.5 | 0.001 | -51.83 | 331.5 | 88.5 | 0.017 | |
| 276 | 330 | 20 | 35 | 22.2 | 737.9 | 1.214 | -40.82 | 716.3 | 59.7 | 0.026 | |
| 277 | 330 | 20 | 37 | 18.9 | 311.9 | 0.455 | -58.59 | 302.8 | 79.1 | 0.013 | |
| 278 | 330 | 20 | 38 | 26.3 | 906.6 | -0.394 | -21.88 | 880.1 | 97.5 | 0.057 | 31740 |
| 279 | 330 | 20 | 43 | 55.3 | 940.8 | 0.684 | -13.50 | 913.3 | 72.0 | 0.223 | 729 |
| 280 | 330 | 20 | 44 | 41.6 | 911.3 | -0.558 | -25.77 | 884.7 | 101.4 | 0.046 | |
| 281 | 330 | 20 | 44 | 47.2 | 798.1 | 1.777 | -39.93 | 774.8 | 43.0 | 0.027 | |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 282 | 330 | 20 | 47 | 44.6 | 1331.7 | 0.068 | -21.43 | 1292.8 | 86.5 | 0.062 | 18427 |
| 283 | 330 | 20 | 50 | 53.6 | 1455.9 | 1.325 | 8.30 | 1413.4 | 51.0 | 2.936 | 25770 |
| 284 | 330 | 20 | 55 | 55.4 | 977.3 | 1.026 | -34.24 | 948.8 | 63.2 | 0.034 | |
| 285 | 330 | 20 | 57 | 46.6 | 1033.6 | -0.231 | -33.32 | 1003.4 | 93.8 | 0.036 | |
| 286 | 330 | 20 | 58 | 10.2 | 1015.4 | 0.962 | -17.52 | 985.7 | 64.6 | 0.127 | 141 |
| 287 | 330 | 21 | 0 | 19.1 | 508.7 | 2.863 | -41.36 | 493.9 | 27.5 | 0.026 | |
| 288 | 330 | 21 | 0 | 37.7 | 578.5 | 4.229 | -43.69 | 561.6 | 61.9 | 0.023 | |
| 289 | 330 | 21 | 1 | 15.2 | 1332.3 | 0.095 | -20.40 | 1293.4 | 85.8 | 0.073 | 81705 |
| 290 | 330 | 21 | 6 | 27.7 | 1158.0 | -0.183 | -29.67 | 1124.2 | 92.8 | 0.042 | |
| 291 | 330 | 21 | 7 | 25.4 | 762.8 | -2.941 | -42.41 | 740.5 | 174.5 | 0.024 | |
| 292 | 330 | 21 | 7 | 26.4 | 647.2 | -0.526 | -32.73 | 628.3 | 100.1 | 0.037 | 28649 |
| 293 | 330 | 21 | 9 | 18.6 | 1498.2 | -0.622 | -16.44 | 1454.4 | 104.5 | 0.151 | 7134 |
| 294 | 330 | 21 | 10 | 38.7 | 357.4 | 0.819 | -56.35 | 346.9 | 71.2 | 0.014 | |
| 295 | 330 | 21 | 10 | 45.4 | 490.5 | -0.095 | -41.63 | 476.2 | 90.5 | 0.026 | 27392 |
| 296 | 330 | 21 | 11 | 15.9 | 480.9 | -0.386 | -47.12 | 466.8 | 96.7 | 0.020 | |
| 297 | 330 | 21 | 11 | 19.7 | 487.9 | 0.044 | -46.01 | 473.7 | 87.6 | 0.021 | 27391 |
| 298 | 330 | 21 | 11 | 30.2 | 1454.0 | -0.017 | -29.38 | 1411.6 | 88.6 | 0.043 | |
| 299 | 330 | 21 | 11 | 35.5 | 291.6 | 0.247 | -59.57 | 283.1 | 83.5 | 0.013 | |
| 300 | 330 | 21 | 11 | 37.9 | 1459.0 | 0.193 | -28.69 | 1416.4 | 83.2 | 0.043 | 21784 |
| 301 | 330 | 21 | 17 | 12.8 | 1061.4 | -0.827 | -26.53 | 1030.4 | 108.5 | 0.045 | |
| 302 | 330 | 21 | 19 | 18.9 | 787.5 | 0.483 | -39.13 | 764.5 | 77.3 | 0.028 | 24842 |
| 303 | 330 | 21 | 19 | 23.2 | 808.2 | -3.502 | -39.98 | 784.6 | 180.2 | 0.027 | |
| 304 | 330 | 21 | 19 | 31.0 | 741.8 | -0.514 | -32.04 | 720.1 | 100.0 | 0.038 | |
| 305 | 330 | 21 | 21 | 50.7 | 1069.8 | -0.344 | -32.41 | 1038.5 | 96.6 | 0.037 | 4980 |
| 306 | 330 | 21 | 26 | 23.9 | 1308.4 | -0.693 | -27.77 | 1270.2 | 105.9 | 0.044 | |
| 307 | 330 | 21 | 26 | 42.5 | 1005.4 | 0.245 | -28.39 | 976.0 | 82.5 | 0.044 | 15359 |
| 308 | 330 | 21 | 27 | 32.4 | 981.0 | 0.339 | -9.14 | 952.3 | 80.3 | 0.383 | 12964 |
| 309 | 330 | 21 | 30 | 26.7 | 694.3 | -0.447 | -19.90 | 674.1 | 98.4 | 0.082 | 87008 |
| 310 | 330 | 21 | 33 | 54.1 | 1521.2 | 0.431 | -23.08 | 1476.8 | 76.7 | 0.055 | |
| 311 | 330 | 21 | 40 | 32.7 | 1125.0 | 0.066 | -26.75 | 1092.1 | 86.7 | 0.045 | |
| 312 | 330 | 21 | 43 | 22.8 | 595.0 | -0.698 | -34.25 | 577.6 | 103.8 | 0.034 | |
| 313 | 330 | 21 | 43 | 24.4 | 603.3 | -0.643 | -33.04 | 585.7 | 102.6 | 0.036 | |
| 314 | 330 | 21 | 48 | 28.5 | 1573.1 | 0.216 | -29.53 | 1527.2 | 82.4 | 0.043 | |
| 315 | 330 | 21 | 48 | 36.6 | 949.0 | 0.710 | -39.18 | 921.3 | 71.3 | 0.027 | |
| 316 | 330 | 21 | 48 | 53.8 | 945.1 | 1.217 | -37.07 | 917.5 | 58.2 | 0.030 | |
| 317 | 330 | 21 | 49 | 19.5 | 1002.0 | 0.097 | -16.61 | 972.8 | 86.0 | 0.147 | 16510 |
| 318 | 330 | 21 | 52 | 1.5 | 1275.3 | -0.028 | -29.49 | 1238.0 | 88.9 | 0.043 | |
| 319 | 330 | 21 | 52 | 2.8 | 1328.8 | 0.035 | -18.41 | 1290.0 | 87.3 | 0.109 | |
| 320 | 330 | 21 | 52 | 39.4 | 779.6 | -0.740 | -23.53 | 756.9 | 105.4 | 0.053 | 31045 |
| 321 | 330 | 21 | 53 | 56.8 | 528.2 | 1.368 | -35.68 | 512.8 | 57.3 | 0.032 | 15354 |
| 322 | 330 | 21 | 59 | 46.8 | 330.7 | -0.524 | -56.01 | 321.1 | 99.4 | 0.015 | |
| 323 | 330 | 22 | 0 | 18.1 | 313.9 | 0.904 | -61.83 | 304.7 | 69.6 | 0.012 | |
| 324 | 330 | 22 | 0 | 21.1 | 1517.2 | 0.679 | -13.54 | 1472.9 | 70.0 | 0.222 | 13164 |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 325 | 330 | 22 | 5 | 42.3 | 825.3 | 0.628 | -22.10 | 801.2 | 73.8 | 0.057 | 87384 |
| 326 | 330 | 22 | 6 | 8.2 | 1461.6 | 1.239 | -31.72 | 1418.9 | 53.7 | 0.039 | |
| 327 | 330 | 22 | 6 | 9.0 | 1033.9 | -0.488 | -27.65 | 1003.7 | 100.0 | 0.044 | |
| 328 | 330 | 22 | 6 | 9.2 | 1480.8 | 1.754 | -31.68 | 1437.5 | 35.1 | 0.039 | |
| 329 | 330 | 22 | 6 | 9.5 | 1059.1 | 3.456 | -40.20 | 1028.1 | 54.7 | 0.027 | |
| 330 | 330 | 22 | 7 | 14.8 | 1233.8 | 0.760 | -27.78 | 1197.8 | 68.9 | 0.044 | |
| 331 | 330 | 22 | 9 | 1.8 | 1023.7 | 0.101 | -35.31 | 993.8 | 85.9 | 0.032 | |
| 332 | 330 | 22 | 9 | 8.4 | 1017.8 | 0.403 | -33.74 | 988.1 | 78.7 | 0.035 | |
| 333 | 330 | 22 | 11 | 43.4 | 1192.6 | 1.317 | -37.48 | 1157.8 | 53.4 | 0.029 | |
| 334 | 330 | 22 | 19 | 11.6 | 939.5 | 1.045 | -36.90 | 912.0 | 62.9 | 0.030 | |
| 335 | 330 | 22 | 20 | 31.7 | 295.5 | 0.847 | -56.79 | 286.8 | 70.9 | 0.014 | |
| 336 | 330 | 22 | 29 | 56.5 | 987.7 | -0.100 | -22.25 | 958.8 | 90.7 | 0.056 | |
| 337 | 330 | 22 | 30 | 36.9 | 366.7 | 0.643 | -54.80 | 356.0 | 75.0 | 0.015 | |
| 338 | 330 | 22 | 31 | 16.2 | 972.5 | 1.179 | -25.92 | 944.1 | 59.1 | 0.045 | |
| 339 | 330 | 22 | 33 | 27.5 | 831.7 | -0.249 | -19.66 | 807.4 | 94.1 | 0.086 | 30056 |
| 340 | 330 | 22 | 34 | 39.0 | 1089.6 | -0.134 | -27.81 | 1057.8 | 91.5 | 0.044 | |
| 341 | 330 | 22 | 36 | 25.8 | 1033.7 | 0.102 | -29.57 | 1003.5 | 85.9 | 0.042 | 12092 |
| 342 | 330 | 22 | 36 | 31.4 | 1033.2 | 0.340 | -35.56 | 1003.0 | 80.1 | 0.032 | |
| 343 | 330 | 22 | 36 | 53.7 | 791.9 | 0.510 | -35.93 | 768.8 | 76.7 | 0.031 | 10520 |
| 344 | 330 | 22 | 39 | 7.0 | 971.9 | 1.023 | -34.61 | 943.5 | 63.3 | 0.033 | |
| 345 | 330 | 22 | 40 | 19.3 | 992.6 | 0.899 | -35.21 | 963.6 | 66.4 | 0.032 | |
| 346 | 330 | 22 | 41 | 19.5 | 1062.0 | -1.050 | -14.62 | 1031.0 | 114.2 | 0.195 | 31861 |
| 347 | 330 | 22 | 47 | 13.0 | 914.6 | -0.193 | -28.40 | 887.9 | 92.9 | 0.044 | |
| 348 | 330 | 22 | 50 | 25.7 | 1029.2 | -0.541 | -30.53 | 999.2 | 101.3 | 0.041 | |
| 349 | 330 | 22 | 50 | 55.9 | 968.0 | -0.505 | -36.09 | 939.8 | 100.3 | 0.031 | |
| 350 | 330 | 22 | 55 | 7.4 | 815.6 | -0.390 | -40.39 | 791.8 | 97.3 | 0.027 | |
| 351 | 330 | 22 | 58 | 54.2 | 462.8 | 1.132 | -53.09 | 449.3 | 63.6 | 0.016 | |
| 352 | 330 | 23 | 3 | 44.0 | 1152.1 | -0.570 | -17.44 | 1118.5 | 102.3 | 0.129 | 31236 |
| 353 | 330 | 23 | 6 | 9.4 | 1019.4 | 0.561 | -36.86 | 989.7 | 74.8 | 0.030 | |
| 354 | 330 | 23 | 9 | 50.4 | 980.2 | 1.024 | -31.52 | 951.6 | 63.2 | 0.039 | |
| 355 | 330 | 23 | 13 | 8.0 | 857.1 | -0.381 | -10.32 | 832.1 | 97.2 | 0.336 | 5694 |
| 356 | 330 | 23 | 13 | 9.1 | 1002.0 | -0.717 | -44.17 | 972.7 | 105.5 | 0.023 | |
| 357 | 330 | 23 | 15 | 0.1 | 942.0 | 0.223 | -39.84 | 914.5 | 83.1 | 0.027 | |
| 358 | 330 | 23 | 15 | 0.9 | 807.7 | 0.203 | 4.31 | 784.2 | 83.8 | 1.853 | 25471 |
| 359 | 330 | 23 | 15 | 2.1 | 671.9 | 0.217 | -48.40 | 652.3 | 83.6 | 0.019 | |
| 360 | 330 | 23 | 20 | 7.0 | 1875.2 | 0.138 | -23.80 | 1820.5 | 84.1 | 0.052 | |
| 361 | 330 | 23 | 27 | 4.9 | 1002.3 | 0.062 | 7.43 | 973.1 | 86.9 | 2.653 | 9044 |
| 362 | 330 | 23 | 36 | 43.1 | 755.6 | 0.507 | -20.70 | 733.5 | 76.9 | 0.069 | 18274 |
| 363 | 330 | 23 | 38 | 52.0 | 945.0 | 0.909 | -35.65 | 917.5 | 66.4 | 0.032 | |
| 364 | 330 | 23 | 38 | 56.0 | 1032.1 | 0.094 | -36.41 | 1001.9 | 86.1 | 0.031 | |
| 365 | 330 | 23 | 44 | 25.2 | 1714.5 | 0.688 | -19.17 | 1664.4 | 68.9 | 0.094 | 22841 |
| 366 | 330 | 23 | 44 | 58.6 | 343.0 | 1.955 | -41.50 | 333.0 | 43.2 | 0.026 | |
| 367 | 330 | 23 | 46 | 41.2 | 727.8 | -0.737 | -30.14 | 706.6 | 105.1 | 0.042 | |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 368 | 330 | 23 | 49 | 42.8 | 967.7 | -0.213 | -26.02 | 939.5 | 93.4 | 0.045 | |
| 369 | 330 | 23 | 49 | 57.7 | 1270.4 | 1.407 | 6.09 | 1233.3 | 49.9 | 2.275 | |
| 370 | 330 | 23 | 56 | 46.2 | 1032.0 | 0.348 | -27.86 | 1001.9 | 80.0 | 0.044 | 12835 |
| 371 | 330 | 23 | 56 | 48.9 | 1463.6 | 1.427 | -32.66 | 1420.9 | 47.5 | 0.037 | |
| 372 | 330 | 23 | 57 | 19.8 | 1065.8 | -0.263 | -29.10 | 1034.7 | 94.6 | 0.043 | |
| 373 | 330 | 23 | 58 | 6.7 | 852.0 | -0.480 | -41.26 | 827.1 | 99.5 | 0.026 | |
| 374 | 330 | 23 | 58 | 9.4 | 852.0 | 0.030 | -45.61 | 827.1 | 87.7 | 0.022 | |
| 375 | 331 | 0 | 8 | 13.2 | 837.9 | 0.643 | -18.24 | 813.4 | 73.4 | 0.112 | 26968 |
| 376 | 331 | 0 | 9 | 47.3 | 941.0 | 0.150 | -20.37 | 913.5 | 84.8 | 0.074 | 14406 |
| 377 | 331 | 0 | 12 | 55.1 | 1452.0 | 1.118 | -30.19 | 1409.6 | 57.6 | 0.042 | 25873 |
| 378 | 331 | 0 | 19 | 48.3 | 581.5 | -1.958 | -34.66 | 564.5 | 135.7 | 0.033 | |
| 379 | 331 | 0 | 19 | 48.7 | 600.0 | -1.287 | -31.93 | 582.5 | 117.6 | 0.038 | |
| 380 | 331 | 0 | 19 | 49.0 | 616.5 | 2.558 | -49.93 | 598.5 | 20.0 | 0.018 | |
| 381 | 331 | 0 | 20 | 29.7 | 2051.7 | -0.434 | -22.94 | 1991.8 | 100.6 | 0.055 | |
| 382 | 331 | 0 | 31 | 6.1 | 512.6 | -0.626 | -25.84 | 497.7 | 102.0 | 0.046 | |
| 383 | 331 | 0 | 34 | 5.1 | 2020.4 | 2.861 | -14.13 | 1961.5 | 54.8 | 0.207 | |
| 384 | 331 | 0 | 34 | 6.5 | 579.4 | -0.491 | -44.53 | 562.5 | 99.2 | 0.023 | 28942 |
| 385 | 331 | 0 | 34 | 7.2 | 522.3 | -0.456 | -46.42 | 507.0 | 98.3 | 0.021 | |
| 386 | 331 | 0 | 36 | 55.6 | 1007.2 | -0.170 | -21.67 | 977.8 | 92.4 | 0.059 | 80932 |
| 387 | 331 | 0 | 37 | 47.8 | 1282.9 | 0.306 | -22.34 | 1245.5 | 80.5 | 0.056 | 81921 |
| 388 | 331 | 0 | 41 | 22.9 | 994.2 | 0.303 | -22.69 | 965.1 | 81.1 | 0.056 | 12753 |
| 389 | 331 | 0 | 48 | 2.5 | 1706.2 | 0.702 | -24.88 | 1656.4 | 68.6 | 0.048 | |
| 390 | 331 | 0 | 48 | 46.1 | 696.8 | -0.259 | -37.32 | 676.5 | 94.2 | 0.029 | |
| 391 | 331 | 0 | 48 | 55.0 | 695.8 | 0.377 | -36.62 | 675.4 | 80.0 | 0.030 | |
| 392 | 331 | 0 | 49 | 11.1 | 1062.0 | 0.893 | -40.75 | 1031.0 | 66.2 | 0.026 | |
| 393 | 331 | 0 | 53 | 47.1 | 1183.8 | 0.584 | -33.91 | 1149.2 | 73.7 | 0.035 | 4255 |
| 394 | 331 | 0 | 58 | 8.7 | 879.8 | -0.052 | -38.41 | 854.1 | 89.6 | 0.028 | 8845 |
| 395 | 331 | 0 | 59 | 30.9 | 1623.9 | -1.452 | -22.26 | 1576.5 | 130.0 | 0.056 | 32144 |
| 396 | 331 | 1 | 1 | 12.2 | 1393.0 | 0.705 | -22.48 | 1352.3 | 69.7 | 0.056 | |
| 397 | 331 | 1 | 1 | 33.9 | 679.5 | -0.735 | -27.45 | 659.6 | 104.9 | 0.044 | |
| 398 | 331 | 1 | 9 | 9.9 | 1031.5 | -0.248 | -26.57 | 1001.4 | 94.2 | 0.045 | |
| 399 | 331 | 1 | 12 | 24.1 | 1019.5 | 3.320 | -38.88 | 989.8 | 51.1 | 0.028 | |
| 400 | 331 | 1 | 13 | 43.6 | 696.4 | 0.858 | -33.78 | 676.0 | 68.8 | 0.035 | |
| 401 | 331 | 1 | 20 | 22.2 | 706.4 | -0.514 | -34.15 | 685.8 | 100.0 | 0.034 | 23605 |
| 402 | 331 | 1 | 20 | 23.9 | 852.0 | -0.523 | -46.65 | 827.1 | 100.5 | 0.021 | |
| 403 | 331 | 1 | 20 | 25.9 | 707.2 | -0.274 | 10.87 | 686.5 | 94.6 | 3.943 | 23605 |
| 404 | 331 | 1 | 20 | 26.8 | 852.0 | 0.062 | -45.86 | 827.1 | 87.0 | 0.021 | |
| 405 | 331 | 1 | 30 | 3.6 | 926.8 | -0.212 | -21.38 | 899.7 | 93.3 | 0.063 | |
| 406 | 331 | 1 | 30 | 18.4 | 1141.2 | -0.252 | -27.74 | 1107.8 | 94.4 | 0.044 | 7069 |
| 407 | 331 | 1 | 30 | 58.2 | 841.4 | -0.311 | -24.56 | 816.8 | 95.5 | 0.049 | 13569 |
| 408 | 331 | 1 | 31 | 13.4 | 2050.7 | -2.456 | -24.54 | 1990.8 | 173.6 | 0.049 | |
| 409 | 331 | 1 | 34 | 7.5 | 532.2 | 1.359 | -46.53 | 516.6 | 57.5 | 0.021 | |
| 410 | 331 | 1 | 34 | 7.8 | 969.5 | -0.187 | -24.05 | 941.2 | 92.8 | 0.051 | 89323 |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 411 | 331 | 1 | 34 | 34.6 | 909.7 | -0.596 | -35.35 | 883.1 | 102.3 | 0.032 | 13778 |
| 412 | 331 | 1 | 34 | 41.9 | 913.2 | -0.211 | -35.98 | 886.5 | 93.3 | 0.031 | |
| 413 | 331 | 1 | 34 | 51.8 | 1572.2 | -1.326 | -18.37 | 1526.3 | 125.4 | 0.110 | |
| 414 | 331 | 1 | 34 | 51.9 | 736.5 | 1.396 | -29.94 | 715.0 | 54.9 | 0.042 | |
| 415 | 331 | 1 | 36 | 22.5 | 702.0 | -0.384 | -39.43 | 681.5 | 97.0 | 0.027 | |
| 416 | 331 | 1 | 36 | 24.9 | 972.0 | -0.057 | -41.28 | 943.6 | 89.7 | 0.026 | |
| 417 | 331 | 1 | 36 | 25.1 | 829.9 | -0.276 | 10.53 | 805.7 | 94.7 | 3.791 | 23324 |
| 418 | 331 | 1 | 43 | 3.4 | 1538.5 | 0.416 | -5.12 | 1493.6 | 77.1 | 0.626 | 8891 |
| 419 | 331 | 1 | 52 | 20.3 | 780.9 | -0.068 | -36.85 | 758.1 | 89.9 | 0.030 | |
| 420 | 331 | 1 | 53 | 1.2 | 1000.9 | -0.191 | -24.15 | 971.7 | 92.9 | 0.050 | |
| 421 | 331 | 2 | 11 | 34.2 | 972.0 | -0.194 | -38.10 | 943.6 | 92.9 | 0.028 | |
| 422 | 331 | 2 | 11 | 34.6 | 972.0 | -0.600 | -41.96 | 943.6 | 102.6 | 0.026 | |
| 423 | 331 | 2 | 11 | 35.7 | 832.4 | -0.305 | -6.28 | 808.1 | 95.4 | 0.548 | 23753 |
| 424 | 331 | 2 | 11 | 36.8 | 972.0 | -0.147 | -36.77 | 943.6 | 91.8 | 0.030 | |
| 425 | 331 | 2 | 25 | 27.9 | 2037.0 | 0.292 | -15.23 | 1977.5 | 79.5 | 0.179 | |
| 426 | 331 | 2 | 26 | 40.9 | 572.3 | -0.569 | -31.26 | 555.6 | 100.9 | 0.040 | |
| 427 | 331 | 2 | 32 | 33.9 | 1060.9 | 0.884 | -27.73 | 1030.0 | 66.4 | 0.044 | |
| 428 | 331 | 2 | 32 | 56.1 | 825.3 | -0.325 | -19.74 | 801.2 | 95.8 | 0.084 | 87012 |
| 429 | 331 | 2 | 33 | 7.9 | 577.2 | 1.049 | -23.84 | 560.4 | 64.9 | 0.052 | |
| 430 | 331 | 2 | 35 | 56.1 | 1700.5 | 0.565 | -23.29 | 1650.8 | 72.5 | 0.054 | |
| 431 | 331 | 2 | 36 | 22.7 | 1225.9 | -0.373 | -27.76 | 1190.1 | 97.5 | 0.044 | 85081 |
| 432 | 331 | 2 | 38 | 7.8 | 1620.9 | 0.408 | -26.45 | 1573.6 | 77.1 | 0.045 | 7831 |
| 433 | 331 | 2 | 38 | 13.1 | 1627.5 | 0.523 | -27.98 | 1580.0 | 73.9 | 0.044 | 7831 |
| 434 | 331 | 2 | 42 | 7.4 | 699.2 | -0.293 | -24.13 | 678.8 | 95.0 | 0.051 | |
| 435 | 331 | 2 | 45 | 2.6 | 935.2 | -0.305 | -31.60 | 907.9 | 95.5 | 0.039 | |
| 436 | 331 | 2 | 45 | 4.3 | 932.2 | -0.272 | -31.34 | 905.0 | 94.7 | 0.040 | |
| 437 | 331 | 2 | 45 | 32.8 | 817.4 | -0.302 | -7.30 | 793.6 | 95.3 | 0.487 | 22828 |
| 438 | 331 | 2 | 45 | 33.5 | 942.0 | -0.345 | -44.29 | 914.5 | 96.5 | 0.023 | |
| 439 | 331 | 2 | 46 | 26.6 | 911.0 | -0.428 | -13.06 | 884.4 | 98.4 | 0.236 | 31084 |
| 440 | 331 | 2 | 52 | 0.1 | 307.8 | -0.831 | -57.04 | 298.8 | 105.8 | 0.014 | |
| 441 | 331 | 2 | 55 | 8.5 | 1687.9 | 0.449 | -24.01 | 1638.6 | 75.8 | 0.051 | 21403 |
| 442 | 331 | 2 | 56 | 4.6 | 1430.8 | 0.546 | -23.20 | 1389.0 | 73.9 | 0.054 | |
| 443 | 331 | 2 | 56 | 54.6 | 1327.5 | 1.215 | -25.78 | 1288.7 | 55.5 | 0.046 | |
| 444 | 331 | 2 | 57 | 23.6 | 1038.3 | 1.114 | -32.18 | 1007.9 | 60.4 | 0.038 | |
| 445 | 331 | 2 | 59 | 57.6 | 603.0 | -0.055 | -36.56 | 585.4 | 89.7 | 0.030 | |
| 446 | 331 | 3 | 0 | 3.8 | 609.0 | 0.470 | -45.99 | 591.2 | 78.1 | 0.021 | |
| 447 | 331 | 3 | 5 | 11.6 | 1315.4 | -0.235 | -24.02 | 1277.0 | 94.2 | 0.051 | |
| 448 | 331 | 3 | 6 | 11.3 | 1597.1 | 1.369 | -17.38 | 1550.5 | 48.2 | 0.130 | |
| 449 | 331 | 3 | 6 | 11.5 | 1632.0 | 1.370 | -31.90 | 1584.3 | 47.9 | 0.038 | |
| 450 | 331 | 3 | 14 | 26.0 | 1001.1 | 1.024 | -31.51 | 971.9 | 63.1 | 0.039 | |
| 451 | 331 | 3 | 17 | 57.9 | 1575.5 | 0.402 | -4.46 | 1529.5 | 77.4 | 0.676 | 5553 |
| 452 | 331 | 3 | 21 | 28.9 | 971.1 | 0.085 | -20.28 | 942.8 | 86.3 | 0.076 | 87714 |
| 453 | 331 | 3 | 22 | 10.2 | 901.8 | -0.272 | -31.83 | 875.5 | 94.7 | 0.039 | |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 454 | 331 | 3 | 27 | 35.6 | 1186.0 | 0.018 | -33.06 | 1151.4 | 87.8 | 0.036 | |
| 455 | 331 | 3 | 27 | 45.2 | 1003.1 | 1.037 | -32.95 | 973.8 | 62.7 | 0.036 | |
| 456 | 331 | 3 | 31 | 21.5 | 942.3 | -0.177 | -42.90 | 914.8 | 92.5 | 0.024 | |
| 457 | 331 | 3 | 31 | 21.7 | 1051.1 | -1.487 | -21.10 | 1020.4 | 126.3 | 0.065 | |
| 458 | 331 | 3 | 31 | 21.9 | 1002.0 | -0.237 | -26.07 | 972.7 | 93.9 | 0.045 | |
| 459 | 331 | 3 | 33 | 27.0 | 868.9 | 0.726 | 13.85 | 843.5 | 71.3 | 5.556 | 23705 |
| 460 | 331 | 3 | 33 | 27.5 | 732.0 | 0.478 | -44.83 | 710.6 | 77.6 | 0.022 | |
| 461 | 331 | 3 | 36 | 34.4 | 497.6 | -0.622 | -46.35 | 483.1 | 101.9 | 0.021 | |
| 462 | 331 | 3 | 38 | 20.2 | 995.5 | 0.088 | -33.71 | 966.4 | 86.2 | 0.035 | 11736 |
| 463 | 331 | 3 | 38 | 22.6 | 768.4 | -0.433 | -43.52 | 745.9 | 98.2 | 0.023 | |
| 464 | 331 | 3 | 41 | 2.7 | 972.0 | -0.602 | -39.71 | 943.6 | 102.6 | 0.027 | |
| 465 | 331 | 3 | 41 | 3.9 | 827.2 | -0.536 | 5.08 | 803.0 | 100.7 | 2.024 | 6788 |
| 466 | 331 | 3 | 41 | 5.5 | 972.0 | -0.994 | -43.08 | 943.6 | 112.3 | 0.024 | |
| 467 | 331 | 3 | 42 | 25.3 | 1772.9 | 0.909 | -15.32 | 1721.1 | 62.0 | 0.177 | |
| 468 | 331 | 3 | 42 | 58.8 | 1180.6 | -0.516 | -25.76 | 1146.1 | 101.0 | 0.046 | 4818 |
| 469 | 331 | 3 | 44 | 1.7 | 1060.5 | -0.353 | -28.61 | 1029.5 | 96.8 | 0.044 | |
| 470 | 331 | 3 | 45 | 11.2 | 701.5 | -0.417 | -27.09 | 681.1 | 97.8 | 0.044 | |
| 471 | 331 | 3 | 48 | 40.2 | 888.9 | -0.287 | -28.73 | 863.0 | 95.0 | 0.043 | 81352 |
| 472 | 331 | 3 | 50 | 40.2 | 857.0 | -0.035 | -39.87 | 831.9 | 89.2 | 0.027 | |
| 473 | 331 | 3 | 51 | 1.3 | 1302.4 | -0.480 | -18.91 | 1264.4 | 100.4 | 0.099 | 32362 |
| 474 | 331 | 3 | 53 | 4.7 | 854.9 | -0.300 | -15.69 | 829.9 | 95.3 | 0.168 | 30670 |
| 475 | 331 | 3 | 54 | 2.8 | 1032.5 | 0.077 | -27.72 | 1002.4 | 86.5 | 0.044 | 7593 |
| 476 | 331 | 3 | 59 | 2.8 | 1152.1 | 1.035 | 11.44 | 1118.5 | 61.9 | 4.210 | |
| 477 | 331 | 4 | 1 | 41.2 | 616.0 | -0.490 | -19.99 | 598.0 | 99.2 | 0.080 | 32137 |
| 478 | 331 | 4 | 2 | 7.2 | 1020.1 | 0.226 | -32.94 | 990.3 | 82.9 | 0.036 | 19826 |
| 479 | 331 | 4 | 3 | 16.2 | 875.5 | 0.881 | -30.47 | 849.9 | 67.4 | 0.041 | |
| 480 | 331 | 4 | 6 | 19.5 | 1572.6 | 0.760 | -24.55 | 1526.7 | 67.5 | 0.049 | |
| 481 | 331 | 4 | 6 | 51.7 | 829.1 | 4.560 | -34.11 | 804.8 | 70.7 | 0.034 | |
| 482 | 331 | 4 | 9 | 37.7 | 1662.0 | -0.448 | -32.55 | 1613.4 | 100.2 | 0.037 | |
| 483 | 331 | 4 | 9 | 39.6 | 1518.6 | 0.103 | 4.28 | 1474.3 | 85.4 | 1.846 | 23793 |
| 484 | 331 | 4 | 9 | 41.6 | 1662.0 | -0.202 | -32.48 | 1613.4 | 93.5 | 0.037 | |
| 485 | 331 | 4 | 11 | 18.0 | 850.2 | -0.300 | -40.68 | 825.4 | 95.3 | 0.026 | |
| 486 | 331 | 4 | 13 | 11.1 | 909.7 | -0.293 | -29.01 | 883.1 | 95.2 | 0.043 | |
| 487 | 331 | 4 | 15 | 19.3 | 631.1 | -0.555 | -38.85 | 612.7 | 100.7 | 0.028 | |
| 488 | 331 | 4 | 15 | 23.5 | 910.4 | -0.282 | -35.27 | 883.8 | 94.9 | 0.032 | |
| 489 | 331 | 4 | 16 | 32.3 | 1154.5 | 0.184 | -33.00 | 1120.8 | 83.8 | 0.036 | |
| 490 | 331 | 4 | 17 | 18.5 | 997.6 | -0.490 | -34.72 | 968.4 | 100.0 | 0.033 | |
| 491 | 331 | 4 | 18 | 36.5 | 783.4 | 0.538 | -28.82 | 760.5 | 76.0 | 0.043 | 17764 |
| 492 | 331 | 4 | 19 | 55.5 | 1588.9 | -0.746 | -26.35 | 1542.5 | 108.3 | 0.045 | |
| 493 | 331 | 4 | 20 | 1.1 | 941.6 | 1.049 | -31.22 | 914.1 | 62.8 | 0.040 | |
| 494 | 331 | 4 | 20 | 42.2 | 907.2 | -0.310 | -39.35 | 880.7 | 95.6 | 0.027 | |
| 495 | 331 | 4 | 21 | 15.7 | 884.4 | -0.316 | -33.39 | 858.6 | 95.7 | 0.035 | |
| 496 | 331 | 4 | 27 | 19.4 | 914.2 | 0.473 | -18.34 | 887.5 | 77.2 | 0.110 | 28953 |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 497 | 331 | 4 | 27 | 42.1 | 1958.4 | -0.847 | -22.35 | 1901.2 | 112.6 | 0.056 | |
| 498 | 331 | 4 | 29 | 46.2 | 769.6 | -0.372 | -24.30 | 747.2 | 96.8 | 0.050 | 27676 |
| 499 | 331 | 4 | 30 | 42.5 | 351.3 | 0.028 | -51.05 | 341.0 | 88.0 | 0.018 | |
| 500 | 331 | 4 | 38 | 59.0 | 883.3 | -0.294 | -31.51 | 857.5 | 95.2 | 0.039 | |
| 501 | 331 | 4 | 39 | 30.4 | 995.4 | 0.497 | -32.39 | 966.4 | 76.4 | 0.037 | |
| 502 | 331 | 4 | 40 | 32.7 | 909.5 | -0.306 | -32.02 | 882.9 | 95.5 | 0.038 | |
| 503 | 331 | 4 | 42 | 31.7 | 784.0 | -0.166 | -41.43 | 761.1 | 92.2 | 0.026 | |
| 504 | 331 | 4 | 45 | 59.5 | 1267.4 | 1.202 | -32.48 | 1230.4 | 56.3 | 0.037 | |
| 505 | 331 | 4 | 46 | 6.5 | 1151.9 | 1.688 | -40.47 | 1118.3 | 41.8 | 0.027 | |
| 506 | 331 | 4 | 46 | 8.6 | 1286.6 | 1.480 | 3.50 | 1249.1 | 47.4 | 1.688 | |
| 507 | 331 | 4 | 46 | 10.6 | 1422.5 | 1.323 | -34.64 | 1380.9 | 51.3 | 0.033 | |
| 508 | 331 | 4 | 46 | 13.9 | 1291.7 | 1.643 | -29.66 | 1254.0 | 41.8 | 0.042 | |
| 509 | 331 | 4 | 49 | 47.7 | 756.3 | -2.430 | -44.33 | 734.2 | 157.0 | 0.023 | |
| 510 | 331 | 4 | 52 | 20.7 | 522.0 | -0.712 | -46.67 | 506.7 | 103.9 | 0.021 | |
| 511 | 331 | 4 | 52 | 24.0 | 649.1 | -0.520 | -27.49 | 630.1 | 100.0 | 0.044 | 31598 |
| 512 | 331 | 4 | 52 | 50.2 | 762.1 | 0.865 | -33.72 | 739.9 | 68.4 | 0.035 | |
| 513 | 331 | 4 | 54 | 7.0 | 852.0 | 0.018 | -42.51 | 827.1 | 88.0 | 0.024 | |
| 514 | 331 | 4 | 54 | 9.5 | 852.0 | 0.330 | -46.22 | 827.1 | 80.7 | 0.021 | |
| 515 | 331 | 4 | 55 | 6.7 | 822.0 | -0.006 | -49.58 | 798.0 | 88.5 | 0.019 | |
| 516 | 331 | 4 | 55 | 7.1 | 1092.0 | -0.092 | -41.10 | 1060.1 | 90.5 | 0.026 | |
| 517 | 331 | 4 | 55 | 7.7 | 955.9 | 0.121 | -10.59 | 928.0 | 85.5 | 0.324 | 12671 |
| 518 | 331 | 4 | 55 | 8.6 | 1092.0 | 0.192 | -39.86 | 1060.1 | 83.6 | 0.027 | |
| 519 | 331 | 4 | 56 | 3.1 | 826.1 | -0.286 | -18.40 | 802.0 | 95.0 | 0.109 | |
| 520 | 331 | 4 | 57 | 7.6 | 767.8 | 1.197 | -32.35 | 745.4 | 60.0 | 0.037 | 89067 |
| 521 | 331 | 4 | 57 | 18.6 | 790.9 | 0.399 | -42.90 | 767.8 | 79.3 | 0.024 | |
| 522 | 331 | 4 | 57 | 18.9 | 745.5 | -1.345 | -28.00 | 723.7 | 120.0 | 0.044 | |
| 523 | 331 | 5 | 3 | 52.8 | 1356.4 | -0.317 | -30.64 | 1316.8 | 96.3 | 0.041 | |
| 524 | 331 | 5 | 7 | 59.9 | 744.7 | -0.552 | -38.76 | 723.0 | 100.9 | 0.028 | |
| 525 | 331 | 5 | 9 | 39.1 | 784.8 | -0.195 | -25.11 | 761.9 | 92.8 | 0.047 | 30206 |
| 526 | 331 | 5 | 11 | 20.6 | 811.9 | -0.326 | -21.39 | 788.2 | 95.9 | 0.063 | 80160 |
| 527 | 331 | 5 | 11 | 21.1 | 975.0 | -0.389 | -20.67 | 946.6 | 97.5 | 0.069 | 30365 |
| 528 | 331 | 5 | 11 | 42.1 | 979.8 | 0.847 | -33.30 | 951.2 | 67.8 | 0.036 | |
| 529 | 331 | 5 | 15 | 20.1 | 880.2 | -0.306 | -22.13 | 854.5 | 95.5 | 0.057 | |
| 530 | 331 | 5 | 16 | 38.9 | 904.2 | 0.496 | -31.59 | 877.8 | 76.7 | 0.039 | |
| 531 | 331 | 5 | 17 | 11.6 | 1417.0 | 0.343 | -29.89 | 1375.6 | 79.3 | 0.042 | |
| 532 | 331 | 5 | 19 | 58.4 | 834.3 | -0.188 | -35.98 | 809.9 | 92.7 | 0.031 | |
| 533 | 331 | 5 | 20 | 17.3 | 905.4 | -0.297 | -25.60 | 878.9 | 95.3 | 0.046 | |
| 534 | 331 | 5 | 22 | 28.6 | 710.2 | -0.436 | -41.40 | 689.5 | 98.2 | 0.026 | |
| 535 | 331 | 5 | 22 | 45.5 | 912.3 | -3.726 | -24.37 | 885.6 | 182.2 | 0.049 | |
| 536 | 331 | 5 | 22 | 45.5 | 971.0 | 1.789 | -27.15 | 942.6 | 40.5 | 0.044 | |
| 537 | 331 | 5 | 22 | 45.6 | 945.2 | -3.321 | -23.81 | 917.6 | 179.2 | 0.052 | |
| 538 | 331 | 5 | 22 | 45.9 | 555.1 | 1.265 | -50.94 | 538.9 | 59.7 | 0.018 | |
| 539 | 331 | 5 | 22 | 46.4 | 854.9 | 1.889 | -44.07 | 830.0 | 38.5 | 0.023 | |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 540 | 331 | 5 | 22 | 46.7 | 846.2 | -3.127 | -45.45 | 821.5 | 177.0 | 0.022 | |
| 541 | 331 | 5 | 23 | 48.0 | 865.0 | 0.767 | -23.47 | 839.8 | 70.3 | 0.053 | 81673 |
| 542 | 331 | 5 | 24 | 18.0 | 1891.2 | 1.231 | -19.90 | 1836.0 | 50.6 | 0.082 | |
| 543 | 331 | 5 | 27 | 7.4 | 1003.2 | -0.341 | -16.69 | 973.9 | 96.4 | 0.145 | 6160 |
| 544 | 331 | 5 | 27 | 40.7 | 825.5 | -0.293 | -29.27 | 801.3 | 95.1 | 0.043 | 23828 |
| 545 | 331 | 5 | 29 | 4.8 | 813.4 | -0.038 | -36.97 | 789.6 | 89.3 | 0.030 | 24945 |
| 546 | 331 | 5 | 29 | 13.2 | 881.5 | -0.312 | -28.21 | 855.8 | 95.6 | 0.044 | |
| 547 | 331 | 5 | 29 | 22.2 | 792.0 | 1.180 | -43.22 | 768.8 | 60.3 | 0.024 | |
| 548 | 331 | 5 | 29 | 22.2 | 648.2 | 0.852 | 32.87 | 629.3 | 69.2 | 49.672 | 16865 |
| 549 | 331 | 5 | 29 | 23.8 | 522.0 | 1.057 | -53.46 | 506.7 | 65.0 | 0.016 | |
| 550 | 331 | 5 | 35 | 39.8 | 678.0 | 0.994 | -24.63 | 658.2 | 65.6 | 0.048 | 4664 |
| 551 | 331 | 5 | 35 | 58.6 | 495.6 | -0.766 | -48.43 | 481.1 | 105.0 | 0.019 | |
| 552 | 331 | 5 | 36 | 8.1 | 290.3 | 0.018 | -56.67 | 281.8 | 88.2 | 0.014 | |
| 553 | 331 | 5 | 36 | 30.1 | 974.3 | 0.849 | -35.42 | 945.8 | 67.7 | 0.032 | |
| 554 | 331 | 5 | 36 | 54.3 | 550.8 | -1.969 | -31.71 | 534.7 | 135.7 | 0.039 | |
| 555 | 331 | 5 | 39 | 14.6 | 1185.4 | -0.357 | -21.07 | 1150.8 | 97.1 | 0.065 | |
| 556 | 331 | 5 | 40 | 29.5 | 1002.5 | 0.130 | 12.71 | 973.2 | 85.2 | 4.873 | 8874 |
| 557 | 331 | 5 | 45 | 59.6 | 909.5 | -0.320 | -20.63 | 882.9 | 95.8 | 0.070 | 31534 |
| 558 | 331 | 5 | 47 | 20.6 | 958.7 | 0.845 | -28.35 | 930.7 | 67.9 | 0.044 | 81497 |
| 559 | 331 | 5 | 48 | 40.0 | 1449.5 | 1.194 | -28.12 | 1407.1 | 55.2 | 0.044 | 25884 |
| 560 | 331 | 5 | 48 | 45.7 | 641.4 | 1.717 | -37.96 | 622.7 | 46.7 | 0.029 | |
| 561 | 331 | 5 | 48 | 48.6 | 1455.7 | 1.410 | -26.37 | 1413.2 | 48.2 | 0.045 | 25884 |
| 562 | 331 | 5 | 48 | 55.1 | 462.0 | -0.463 | -60.92 | 448.5 | 98.4 | 0.012 | |
| 563 | 331 | 5 | 48 | 56.1 | 597.1 | -0.505 | -27.22 | 579.7 | 99.5 | 0.044 | |
| 564 | 331 | 5 | 48 | 58.9 | 1544.7 | 0.917 | -25.33 | 1499.6 | 63.0 | 0.046 | |
| 565 | 331 | 5 | 58 | 13.9 | 1272.4 | 0.630 | -27.87 | 1235.2 | 72.2 | 0.044 | |
| 566 | 331 | 5 | 58 | 38.0 | 1463.1 | 1.314 | -32.44 | 1420.4 | 51.3 | 0.037 | |
| 567 | 331 | 5 | 58 | 59.9 | 1423.5 | 0.418 | -21.38 | 1382.0 | 77.3 | 0.063 | |
| 568 | 331 | 6 | 2 | 39.9 | 370.2 | -0.607 | -43.33 | 359.4 | 101.2 | 0.024 | |
| 569 | 331 | 6 | 2 | 39.9 | 373.8 | 0.753 | -45.26 | 362.9 | 72.6 | 0.022 | |
| 570 | 331 | 6 | 3 | 10.2 | 615.7 | 3.400 | -47.10 | 597.8 | 46.0 | 0.020 | |
| 571 | 331 | 6 | 3 | 15.0 | 830.1 | -0.334 | -27.03 | 805.8 | 96.0 | 0.044 | |
| 572 | 331 | 6 | 4 | 32.8 | 846.6 | -0.004 | -41.39 | 821.9 | 88.5 | 0.026 | |
| 573 | 331 | 6 | 5 | 55.6 | 882.5 | -0.317 | -31.38 | 856.7 | 95.7 | 0.040 | 31268 |
| 574 | 331 | 6 | 9 | 15.8 | 320.5 | 0.025 | -55.69 | 311.2 | 88.0 | 0.015 | |
| 575 | 331 | 6 | 10 | 59.9 | 1022.3 | -0.196 | -13.57 | 992.4 | 93.0 | 0.221 | 29819 |
| 576 | 331 | 6 | 11 | 0.5 | 882.0 | -0.302 | -44.95 | 856.2 | 95.4 | 0.022 | |
| 577 | 331 | 6 | 11 | 22.4 | 840.4 | -0.805 | -39.09 | 815.9 | 107.1 | 0.028 | |
| 578 | 331 | 6 | 11 | 26.1 | 972.0 | -0.338 | -44.77 | 943.6 | 96.3 | 0.022 | 31294 |
| 579 | 331 | 6 | 11 | 27.9 | 972.0 | 0.084 | -39.58 | 943.6 | 86.4 | 0.027 | |
| 580 | 331 | 6 | 12 | 26.1 | 1522.3 | 0.443 | -26.14 | 1477.8 | 76.4 | 0.045 | 13168 |
| 581 | 331 | 6 | 12 | 28.8 | 809.5 | 0.403 | -33.59 | 785.9 | 79.1 | 0.035 | |
| 582 | 331 | 6 | 12 | 43.0 | 308.5 | 0.041 | -54.27 | 299.5 | 87.7 | 0.016 | |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 583 | 331 | 6 | 15 | 8.2 | 1448.9 | 1.124 | -27.20 | 1406.6 | 57.4 | 0.044 | |
| 584 | 331 | 6 | 15 | 33.4 | 761.9 | -0.310 | -47.96 | 739.7 | 95.4 | 0.020 | |
| 585 | 331 | 6 | 15 | 33.8 | 1032.0 | -0.221 | -40.91 | 1001.8 | 93.6 | 0.026 | |
| 586 | 331 | 6 | 15 | 34.8 | 894.2 | -0.311 | -5.73 | 868.0 | 95.6 | 0.583 | 29891 |
| 587 | 331 | 6 | 15 | 36.2 | 1032.0 | -0.492 | -39.04 | 1001.8 | 100.1 | 0.028 | |
| 588 | 331 | 6 | 16 | 5.3 | 1472.1 | 0.332 | -22.36 | 1429.2 | 79.5 | 0.056 | 27056 |
| 589 | 331 | 6 | 16 | 11.2 | 1475.0 | 0.497 | -25.57 | 1432.0 | 75.1 | 0.046 | |
| 590 | 331 | 6 | 18 | 59.7 | 794.2 | 0.583 | -32.60 | 771.0 | 75.0 | 0.037 | 11112 |
| 591 | 331 | 6 | 22 | 26.2 | 1492.8 | 0.691 | -25.27 | 1449.2 | 69.7 | 0.047 | 87955 |
| 592 | 331 | 6 | 24 | 57.9 | 620.0 | -0.395 | -35.96 | 601.9 | 97.1 | 0.031 | 26703 |
| 593 | 331 | 6 | 30 | 14.5 | 791.2 | -0.542 | -29.96 | 768.1 | 100.8 | 0.042 | 82105 |
| 594 | 331 | 6 | 30 | 31.6 | 730.9 | -0.340 | -29.89 | 709.5 | 96.1 | 0.042 | |
| 595 | 331 | 6 | 38 | 49.2 | 849.6 | -0.372 | -16.43 | 824.8 | 96.9 | 0.151 | 29773 |
| 596 | 331 | 6 | 42 | 39.4 | 783.8 | -0.377 | -40.24 | 760.9 | 97.0 | 0.027 | |
| 597 | 331 | 6 | 43 | 47.3 | 1095.0 | 1.074 | -17.47 | 1063.0 | 61.1 | 0.128 | 537 |
| 598 | 331 | 6 | 46 | 22.0 | 1058.3 | 0.289 | -34.18 | 1027.4 | 81.4 | 0.034 | |
| 599 | 331 | 6 | 49 | 12.1 | 870.1 | -0.338 | -40.82 | 844.7 | 96.2 | 0.026 | |
| 600 | 331 | 6 | 51 | 37.6 | 890.4 | -0.375 | -38.08 | 864.4 | 97.1 | 0.028 | |
| 601 | 331 | 6 | 53 | 25.2 | 1103.8 | 1.545 | -32.21 | 1071.5 | 47.1 | 0.038 | |
| 602 | 331 | 6 | 54 | 52.0 | 788.5 | -0.289 | -36.69 | 765.5 | 95.0 | 0.030 | 22078 |
| 603 | 331 | 6 | 55 | 53.7 | 1911.1 | 0.610 | -19.09 | 1855.3 | 70.5 | 0.096 | |
| 604 | 331 | 6 | 57 | 3.8 | 492.0 | -1.425 | -52.92 | 477.6 | 120.3 | 0.016 | |
| 605 | 331 | 6 | 57 | 4.9 | 631.7 | -1.112 | -11.95 | 613.2 | 113.6 | 0.271 | |
| 606 | 331 | 6 | 57 | 5.8 | 492.0 | -1.224 | -56.40 | 477.6 | 115.5 | 0.014 | |
| 607 | 331 | 6 | 57 | 41.7 | 852.4 | -0.347 | -32.69 | 827.5 | 96.4 | 0.037 | |
| 608 | 331 | 7 | 4 | 7.4 | 790.4 | -0.383 | -22.47 | 767.3 | 97.1 | 0.056 | 30094 |
| 609 | 331 | 7 | 4 | 10.8 | 1121.0 | -0.096 | -32.13 | 1088.3 | 90.6 | 0.038 | |
| 610 | 331 | 7 | 4 | 44.1 | 890.1 | -0.662 | -37.12 | 864.1 | 103.9 | 0.030 | |
| 611 | 331 | 7 | 5 | 11.5 | 2047.4 | 0.649 | -27.88 | 1987.6 | 68.8 | 0.044 | |
| 612 | 331 | 7 | 5 | 11.6 | 2045.2 | -1.115 | -12.56 | 1985.5 | 121.6 | 0.250 | |
| 613 | 331 | 7 | 5 | 11.8 | 2046.5 | -2.291 | -6.08 | 1986.8 | 170.6 | 0.560 | |
| 614 | 331 | 7 | 5 | 40.4 | 880.8 | 0.030 | -38.10 | 855.1 | 87.7 | 0.028 | 14484 |
| 615 | 331 | 7 | 5 | 58.1 | 1597.0 | 0.616 | -2.36 | 1550.4 | 71.4 | 0.860 | 5554 |
| 616 | 331 | 7 | 6 | 32.5 | 832.2 | -0.444 | -28.08 | 807.9 | 98.6 | 0.044 | |
| 617 | 331 | 7 | 9 | 9.9 | 775.4 | -0.330 | -28.45 | 752.8 | 95.9 | 0.044 | 30997 |
| 618 | 331 | 7 | 10 | 2.8 | 796.9 | -0.304 | -41.00 | 773.7 | 95.3 | 0.026 | |
| 619 | 331 | 7 | 11 | 40.0 | 888.3 | -0.609 | -36.34 | 862.4 | 102.6 | 0.031 | |
| 620 | 331 | 7 | 15 | 13.3 | 769.3 | -0.332 | -34.58 | 746.8 | 95.9 | 0.033 | |
| 621 | 331 | 7 | 15 | 31.5 | 1786.0 | -0.376 | -25.24 | 1733.9 | 98.5 | 0.047 | |
| 622 | 331 | 7 | 15 | 38.7 | 1007.2 | -0.062 | -38.28 | 977.8 | 89.8 | 0.028 | |
| 623 | 331 | 7 | 15 | 47.5 | 1006.3 | 0.319 | -37.22 | 976.9 | 80.7 | 0.029 | 16368 |
| 624 | 331 | 7 | 21 | 50.0 | 719.0 | -0.081 | -28.36 | 698.0 | 90.2 | 0.044 | |
| 625 | 331 | 7 | 22 | 53.5 | 761.7 | -0.164 | -20.58 | 739.5 | 92.1 | 0.070 | |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 626 | 331 | 7 | 30 | 9.5 | 838.4 | -0.355 | -33.27 | 813.9 | 96.5 | 0.036 | |
| 627 | 331 | 7 | 30 | 46.9 | 1783.9 | 4.360 | -12.71 | 1731.8 | 80.2 | 0.246 | |
| 628 | 331 | 7 | 30 | 47.1 | 1956.3 | 0.655 | -13.63 | 1899.2 | 68.9 | 0.220 | |
| 629 | 331 | 7 | 31 | 7.2 | 733.4 | -0.370 | -20.16 | 712.0 | 96.8 | 0.078 | |
| 630 | 331 | 7 | 33 | 34.6 | 790.0 | -0.307 | -33.87 | 766.9 | 95.4 | 0.035 | 85090 |
| 631 | 331 | 7 | 35 | 22.3 | 948.5 | 1.041 | -35.72 | 920.8 | 62.9 | 0.032 | |
| 632 | 331 | 7 | 39 | 39.0 | 818.9 | -0.460 | -28.42 | 795.0 | 98.9 | 0.044 | |
| 633 | 331 | 7 | 43 | 21.8 | 1062.6 | 1.552 | -25.73 | 1031.6 | 47.3 | 0.046 | |
| 634 | 331 | 7 | 43 | 21.9 | 948.1 | 3.738 | -30.39 | 920.4 | 58.8 | 0.041 | |
| 635 | 331 | 7 | 43 | 52.4 | 944.7 | 0.873 | -30.90 | 917.1 | 67.3 | 0.040 | |
| 636 | 331 | 7 | 46 | 59.5 | 967.9 | 1.067 | -30.79 | 939.6 | 62.1 | 0.041 | 13243 |
| 637 | 331 | 7 | 49 | 31.0 | 1925.9 | 0.038 | -17.85 | 1869.6 | 86.9 | 0.120 | |
| 638 | 331 | 7 | 49 | 45.0 | 1928.0 | 0.042 | -27.91 | 1871.7 | 86.8 | 0.044 | |
| 639 | 331 | 7 | 49 | 54.4 | 1918.8 | 0.041 | -24.91 | 1862.7 | 86.8 | 0.048 | |
| 640 | 331 | 7 | 50 | 14.7 | 752.2 | -0.397 | -25.86 | 730.3 | 97.4 | 0.045 | |
| 641 | 331 | 7 | 50 | 18.9 | 871.4 | -0.984 | -35.54 | 845.9 | 111.6 | 0.032 | 7734 |
| 642 | 331 | 7 | 53 | 23.7 | 2034.5 | 1.129 | -19.85 | 1975.1 | 53.1 | 0.083 | 5240 |
| 643 | 331 | 7 | 54 | 30.7 | 1971.4 | 2.467 | -29.03 | 1913.8 | 42.7 | 0.043 | |
| 644 | 331 | 7 | 54 | 31.2 | 2011.5 | -3.441 | -14.70 | 1952.7 | 183.6 | 0.193 | |
| 645 | 331 | 7 | 54 | 31.4 | 2000.8 | 1.049 | -8.95 | 1942.4 | 56.1 | 0.392 | |
| 646 | 331 | 7 | 54 | 32.0 | 2024.7 | 2.515 | -29.94 | 1965.6 | 45.0 | 0.042 | |
| 647 | 331 | 7 | 57 | 8.5 | 934.6 | -0.279 | -35.91 | 907.3 | 94.9 | 0.031 | |
| 648 | 331 | 7 | 58 | 44.5 | 543.5 | -0.389 | -38.92 | 527.7 | 96.9 | 0.028 | |
| 649 | 331 | 8 | 3 | 37.4 | 995.1 | -0.371 | -29.70 | 966.1 | 97.1 | 0.042 | 4615 |
| 650 | 331 | 8 | 5 | 10.5 | 759.2 | -0.587 | -29.22 | 737.0 | 101.8 | 0.043 | |
| 651 | 331 | 8 | 5 | 15.9 | 760.7 | -0.221 | -35.53 | 738.5 | 93.4 | 0.032 | |
| 652 | 331 | 8 | 5 | 25.1 | 881.0 | -0.419 | -22.38 | 855.3 | 98.1 | 0.056 | |
| 653 | 331 | 8 | 7 | 9.2 | 1509.8 | -0.232 | -27.91 | 1465.7 | 94.2 | 0.044 | |
| 654 | 331 | 8 | 7 | 14.2 | 2046.1 | 0.245 | -23.81 | 1986.3 | 80.9 | 0.052 | |
| 655 | 331 | 8 | 8 | 38.8 | 1609.4 | 4.545 | -18.94 | 1562.4 | 80.7 | 0.099 | |
| 656 | 331 | 8 | 8 | 39.1 | 1520.0 | 2.090 | -18.27 | 1475.7 | 23.4 | 0.112 | |
| 657 | 331 | 8 | 10 | 2.5 | 1541.7 | -0.420 | -28.80 | 1496.7 | 99.2 | 0.043 | |
| 658 | 331 | 8 | 17 | 35.8 | 970.3 | 0.286 | -33.67 | 942.0 | 81.6 | 0.035 | 18821 |
| 659 | 331 | 8 | 17 | 42.3 | 975.3 | 0.595 | -38.01 | 946.8 | 74.1 | 0.029 | |
| 660 | 331 | 8 | 18 | 51.1 | 1487.1 | -1.289 | -17.89 | 1443.7 | 123.6 | 0.119 | |
| 661 | 331 | 8 | 20 | 24.3 | 282.9 | 1.088 | -64.72 | 274.7 | 65.6 | 0.010 | |
| 662 | 331 | 8 | 30 | 36.2 | 702.6 | 1.410 | -41.11 | 682.1 | 54.8 | 0.026 | |
| 663 | 331 | 8 | 34 | 3.8 | 1027.9 | 0.287 | -35.26 | 997.9 | 81.4 | 0.032 | 10355 |
| 664 | 331 | 8 | 39 | 53.8 | 1449.8 | 1.270 | -28.02 | 1407.5 | 52.8 | 0.044 | 32263 |
| 665 | 331 | 8 | 41 | 24.4 | 1450.3 | 1.324 | -30.99 | 1408.0 | 51.1 | 0.040 | |
| 666 | 331 | 8 | 41 | 36.0 | 759.2 | -0.148 | -20.33 | 737.0 | 91.7 | 0.075 | 31020 |
| 667 | 331 | 8 | 45 | 43.1 | 1302.3 | -0.162 | -27.56 | 1264.3 | 92.3 | 0.044 | |
| 668 | 331 | 8 | 46 | 18.6 | 759.5 | -0.197 | -37.33 | 737.3 | 92.9 | 0.029 | |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 669 | 331 | 8 | 48 | 7.3 | 1657.9 | -3.678 | -23.90 | 1609.5 | 184.3 | 0.052 | |
| 670 | 331 | 8 | 48 | 35.4 | 789.1 | -0.312 | -11.30 | 766.1 | 95.5 | 0.295 | 23277 |
| 671 | 331 | 8 | 48 | 45.7 | 1260.8 | 0.308 | -32.02 | 1223.9 | 80.5 | 0.038 | |
| 672 | 331 | 8 | 49 | 50.9 | 1320.6 | -0.175 | -28.20 | 1282.0 | 92.7 | 0.044 | |
| 673 | 331 | 8 | 51 | 14.4 | 1680.1 | -0.442 | -18.55 | 1631.1 | 100.1 | 0.106 | 12274 |
| 674 | 331 | 8 | 54 | 54.4 | 702.5 | -0.316 | -8.67 | 682.0 | 95.5 | 0.406 | 17316 |
| 675 | 331 | 8 | 57 | 8.2 | 1298.7 | -0.465 | -21.69 | 1260.8 | 100.0 | 0.059 | 82944 |
| 676 | 331 | 8 | 58 | 13.2 | 1331.2 | -0.170 | -17.35 | 1292.3 | 92.5 | 0.131 | 87509 |
| 677 | 331 | 8 | 59 | 9.5 | 796.1 | -0.820 | -34.10 | 772.8 | 107.3 | 0.034 | |
| 678 | 331 | 8 | 59 | 33.8 | 2023.8 | 0.004 | -20.34 | 1964.7 | 87.8 | 0.075 | |
| 679 | 331 | 8 | 59 | 44.6 | 953.7 | -0.354 | -27.20 | 925.8 | 96.7 | 0.044 | |
| 680 | 331 | 9 | 2 | 12.5 | 1024.9 | -0.057 | -33.87 | 994.9 | 89.7 | 0.035 | 7095 |
| 681 | 331 | 9 | 2 | 20.7 | 1026.8 | 0.300 | -30.07 | 996.8 | 81.1 | 0.042 | |
| 682 | 331 | 9 | 4 | 3.2 | 948.0 | -0.517 | -21.35 | 920.4 | 100.5 | 0.063 | |
| 683 | 331 | 9 | 4 | 42.1 | 974.7 | -0.126 | -33.72 | 946.2 | 91.3 | 0.035 | |
| 684 | 331 | 9 | 4 | 42.1 | 1302.7 | 3.349 | -26.85 | 1264.7 | 56.1 | 0.045 | |
| 685 | 331 | 9 | 6 | 3.0 | 1777.9 | -0.446 | -20.57 | 1726.0 | 100.4 | 0.070 | |
| 686 | 331 | 9 | 8 | 17.9 | 1019.4 | 0.141 | -24.80 | 989.6 | 85.0 | 0.048 | 10141 |
| 687 | 331 | 9 | 11 | 52.0 | 1741.7 | -0.599 | -21.14 | 1690.9 | 104.6 | 0.065 | |
| 688 | 331 | 9 | 15 | 11.5 | 559.1 | -0.138 | -42.36 | 542.8 | 91.5 | 0.025 | |
| 689 | 331 | 9 | 25 | 33.4 | 844.8 | -0.508 | -18.14 | 820.1 | 100.1 | 0.114 | 30350 |
| 690 | 331 | 9 | 25 | 42.1 | 879.2 | 0.023 | -0.03 | 853.5 | 87.8 | 1.124 | 22699 |
| 691 | 331 | 9 | 27 | 15.3 | 1002.5 | 0.472 | -30.81 | 973.2 | 77.0 | 0.041 | |
| 692 | 331 | 9 | 34 | 36.7 | 882.0 | 0.605 | -46.36 | 856.2 | 74.2 | 0.021 | |
| 693 | 331 | 9 | 34 | 37.8 | 738.3 | 1.279 | -18.03 | 716.8 | 58.0 | 0.117 | 3896 |
| 694 | 331 | 9 | 36 | 12.7 | 1003.3 | -0.079 | -33.45 | 974.0 | 90.2 | 0.035 | 20528 |
| 695 | 331 | 9 | 36 | 21.1 | 1015.9 | 0.304 | -36.23 | 986.2 | 81.1 | 0.031 | 20528 |
| 696 | 331 | 9 | 38 | 19.1 | 792.0 | -0.480 | -39.68 | 768.8 | 99.4 | 0.027 | |
| 697 | 331 | 9 | 38 | 20.9 | 660.2 | -0.300 | 8.64 | 641.0 | 95.1 | 3.050 | 29710 |
| 698 | 331 | 9 | 44 | 58.1 | 1008.9 | -0.733 | -22.53 | 979.5 | 105.9 | 0.056 | 80351 |
| 699 | 331 | 9 | 48 | 40.1 | 693.7 | -0.214 | -28.69 | 673.4 | 93.2 | 0.043 | 80710 |
| 700 | 331 | 9 | 57 | 27.3 | 1030.4 | -0.136 | -24.27 | 1000.3 | 91.6 | 0.050 | |
| 701 | 331 | 10 | 2 | 38.4 | 821.9 | -0.252 | -24.17 | 797.9 | 94.1 | 0.050 | |
| 702 | 331 | 10 | 3 | 54.0 | 681.0 | 2.905 | -38.19 | 661.1 | 33.1 | 0.028 | |
| 703 | 331 | 10 | 4 | 27.0 | 959.3 | 0.708 | -15.94 | 931.3 | 71.4 | 0.163 | 23707 |
| 704 | 331 | 10 | 6 | 15.8 | 642.6 | -0.280 | -30.65 | 623.9 | 94.6 | 0.041 | |
| 705 | 331 | 10 | 8 | 22.4 | 342.0 | 3.308 | -42.45 | 332.0 | 38.1 | 0.024 | |
| 706 | 331 | 10 | 8 | 23.1 | 264.4 | 0.935 | -43.27 | 256.7 | 69.1 | 0.024 | |
| 707 | 331 | 10 | 14 | 46.4 | 792.0 | 0.958 | -42.59 | 768.8 | 65.9 | 0.024 | |
| 708 | 331 | 10 | 14 | 47.3 | 925.9 | 0.728 | -13.13 | 898.9 | 71.0 | 0.234 | 22292 |
| 709 | 331 | 10 | 16 | 43.1 | 1237.5 | -0.404 | -11.31 | 1201.3 | 98.3 | 0.294 | 7179 |
| 710 | 331 | 10 | 17 | 42.6 | 1062.9 | -0.588 | -25.61 | 1031.8 | 102.5 | 0.046 | 4743 |
| 711 | 331 | 10 | 18 | 6.7 | 1006.1 | 0.513 | -33.94 | 976.7 | 76.0 | 0.035 | |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 712 | 331 | 10 | 20 | 47.9 | 1116.2 | -0.560 | -27.79 | 1083.6 | 102.0 | 0.044 | 4705 |
| 713 | 331 | 10 | 25 | 41.3 | 913.0 | 1.039 | -15.45 | 886.4 | 63.2 | 0.174 | 116 |
| 714 | 331 | 10 | 25 | 49.6 | 1448.6 | 0.425 | -8.40 | 1406.3 | 77.1 | 0.429 | 3840 |
| 715 | 331 | 10 | 25 | 54.0 | 641.4 | -0.208 | -34.20 | 622.6 | 93.0 | 0.034 | 28649 |
| 716 | 331 | 10 | 28 | 16.7 | 739.8 | -0.447 | -16.21 | 718.2 | 98.5 | 0.157 | 26127 |
| 717 | 331 | 10 | 28 | 33.1 | 1121.9 | 0.195 | -31.54 | 1089.1 | 83.5 | 0.039 | |
| 718 | 331 | 10 | 28 | 33.8 | 1064.4 | 0.257 | -21.14 | 1033.3 | 82.1 | 0.065 | 82893 |
| 719 | 331 | 10 | 30 | 31.1 | 905.7 | -0.551 | -26.13 | 879.2 | 101.2 | 0.045 | |
| 720 | 331 | 10 | 35 | 33.6 | 1060.1 | 0.438 | -23.20 | 1029.1 | 77.7 | 0.054 | 511 |
| 721 | 331 | 10 | 37 | 20.1 | 822.9 | 0.904 | -23.53 | 798.8 | 67.1 | 0.053 | |
| 722 | 331 | 10 | 40 | 13.5 | 1000.0 | 0.091 | -15.98 | 970.8 | 86.2 | 0.162 | 27437 |
| 723 | 331 | 10 | 43 | 3.2 | 672.0 | 2.969 | -44.01 | 652.4 | 35.0 | 0.023 | |
| 724 | 331 | 10 | 43 | 4.2 | 320.4 | 3.525 | -52.94 | 311.0 | 43.4 | 0.016 | |
| 725 | 331 | 10 | 43 | 4.5 | 704.6 | 3.040 | -29.65 | 684.0 | 38.0 | 0.042 | |
| 726 | 331 | 10 | 55 | 57.7 | 1739.2 | 0.333 | -24.42 | 1688.4 | 78.9 | 0.049 | |
| 727 | 331 | 10 | 57 | 3.3 | 761.9 | 0.895 | -43.07 | 739.6 | 67.6 | 0.024 | |
| 728 | 331 | 10 | 57 | 4.4 | 897.0 | 0.877 | -10.07 | 870.8 | 67.4 | 0.346 | 4135 |
| 729 | 331 | 10 | 57 | 4.7 | 1032.0 | 0.442 | -37.34 | 1001.9 | 77.7 | 0.029 | |
| 730 | 331 | 11 | 1 | 59.2 | 753.4 | -0.683 | -33.03 | 731.4 | 104.0 | 0.036 | 32206 |
| 731 | 331 | 11 | 3 | 59.2 | 1515.1 | 0.422 | -1.59 | 1470.9 | 77.0 | 0.939 | 14617 |
| 732 | 331 | 11 | 4 | 22.5 | 1392.8 | -0.517 | -25.80 | 1352.1 | 101.5 | 0.046 | |
| 733 | 331 | 11 | 7 | 43.0 | 1107.7 | -0.695 | -27.96 | 1075.4 | 105.3 | 0.044 | |
| 734 | 331 | 11 | 8 | 14.0 | 1842.1 | 2.337 | -15.17 | 1788.3 | 35.9 | 0.181 | |
| 735 | 331 | 11 | 8 | 14.2 | 1761.5 | -1.172 | -14.92 | 1710.1 | 121.7 | 0.187 | |
| 736 | 331 | 11 | 9 | 17.6 | 1000.4 | -0.148 | -29.96 | 971.2 | 91.8 | 0.042 | |
| 737 | 331 | 11 | 10 | 29.9 | 645.0 | -0.347 | -25.38 | 626.2 | 96.1 | 0.046 | |
| 738 | 331 | 11 | 16 | 12.6 | 1394.0 | -1.497 | -29.75 | 1353.3 | 129.5 | 0.042 | |
| 739 | 331 | 11 | 16 | 46.7 | 433.1 | 1.163 | -49.31 | 420.4 | 63.0 | 0.019 | |
| 740 | 331 | 11 | 16 | 46.7 | 450.0 | 2.855 | -51.20 | 436.9 | 25.6 | 0.017 | |
| 741 | 331 | 11 | 18 | 9.4 | 761.1 | -0.266 | -29.47 | 738.9 | 94.4 | 0.043 | 30864 |
| 742 | 331 | 11 | 21 | 57.6 | 1027.1 | -0.688 | -23.21 | 997.1 | 104.9 | 0.054 | 31198 |
| 743 | 331 | 11 | 23 | 3.3 | 1003.1 | 0.132 | -19.11 | 973.8 | 85.2 | 0.095 | 24678 |
| 744 | 331 | 11 | 23 | 54.1 | 940.9 | 1.029 | -33.18 | 913.4 | 63.3 | 0.036 | |
| 745 | 331 | 11 | 27 | 34.5 | 448.1 | 2.443 | -42.70 | 435.0 | 24.1 | 0.024 | |
| 746 | 331 | 11 | 30 | 26.4 | 884.9 | 0.617 | -26.61 | 859.0 | 73.9 | 0.045 | |
| 747 | 331 | 11 | 30 | 32.9 | 882.0 | -0.664 | -34.04 | 856.3 | 103.9 | 0.034 | |
| 748 | 331 | 11 | 32 | 24.7 | 1517.4 | -0.722 | -29.73 | 1473.1 | 107.3 | 0.042 | |
| 749 | 331 | 11 | 33 | 12.2 | 914.1 | 0.361 | -32.68 | 887.4 | 79.9 | 0.037 | 6393 |
| 750 | 331 | 11 | 33 | 16.8 | 916.5 | 0.601 | -36.73 | 889.7 | 74.1 | 0.030 | 6393 |
| 751 | 331 | 11 | 35 | 52.5 | 1037.4 | 0.630 | -23.14 | 1007.1 | 73.0 | 0.054 | |
| 752 | 331 | 11 | 37 | 14.5 | 709.4 | 3.050 | -34.80 | 688.6 | 38.4 | 0.033 | |
| 753 | 331 | 11 | 37 | 14.5 | 738.5 | -4.282 | -31.21 | 716.9 | 185.4 | 0.040 | |
| 754 | 331 | 11 | 39 | 9.7 | 1445.9 | 1.131 | -27.56 | 1403.7 | 57.2 | 0.044 | |
| 755 | 331 | 11 | 39 | 16.7 | 1453.7 | 1.296 | -25.90 | 1411.2 | 51.9 | 0.045 | 26084 |

**Table A-4. Detections observed by the TIRA radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 756 | 331 | 11 | 40 | 57.6 | 1259.0 | 2.829 | -34.36 | 1222.2 | 42.2 | 0.034 | |
| 757 | 331 | 11 | 40 | 57.7 | 1240.3 | -0.943 | -34.92 | 1204.1 | 112.2 | 0.033 | |
| 758 | 331 | 11 | 40 | 57.9 | 1202.4 | -3.331 | -24.17 | 1167.3 | 180.1 | 0.050 | |
| 759 | 331 | 11 | 40 | 58.2 | 727.8 | -0.823 | -41.95 | 706.6 | 107.1 | 0.026 | |
| 760 | 331 | 11 | 40 | 58.3 | 1151.9 | -1.662 | -34.61 | 1118.3 | 132.6 | 0.033 | |
| 761 | 331 | 11 | 41 | 1.8 | 1604.9 | 1.788 | -18.09 | 1558.1 | 32.0 | 0.115 | |
| 762 | 331 | 11 | 41 | 33.8 | 727.7 | -0.474 | -41.17 | 706.5 | 99.1 | 0.026 | |
| 763 | 331 | 11 | 41 | 59.0 | 1213.9 | -0.728 | -26.31 | 1178.4 | 106.5 | 0.045 | |
| 764 | 331 | 11 | 49 | 37.6 | 888.9 | -0.960 | -28.70 | 863.0 | 111.1 | 0.043 | |
| 765 | 331 | 11 | 49 | 37.6 | 883.8 | 1.808 | -28.42 | 858.0 | 40.9 | 0.044 | |
| 766 | 331 | 11 | 49 | 38.0 | 867.5 | -3.239 | -40.48 | 842.1 | 178.2 | 0.027 | |
| 767 | 331 | 11 | 50 | 42.0 | 1449.4 | 0.363 | 1.18 | 1407.1 | 78.7 | 1.292 | 18337 |
| 768 | 331 | 11 | 57 | 40.5 | 751.0 | -0.921 | -19.51 | 729.1 | 109.6 | 0.088 | 15615 |
| 769 | 331 | 12 | 5 | 43.1 | 1024.1 | 1.022 | -31.24 | 994.2 | 63.0 | 0.040 | |
| 770 | 331 | 12 | 5 | 55.2 | 1454.3 | 1.244 | -19.42 | 1411.9 | 53.6 | 0.090 | 32264 |
| 771 | 331 | 12 | 6 | 1.3 | 1461.6 | 1.389 | -25.99 | 1418.9 | 48.8 | 0.045 | 32264 |
| 772 | 331 | 12 | 6 | 58.5 | 2015.1 | -0.549 | -25.74 | 1956.3 | 103.8 | 0.046 | |
| 773 | 331 | 12 | 7 | 20.3 | 733.1 | -0.455 | -37.50 | 711.7 | 98.7 | 0.029 | |
| 774 | 331 | 12 | 21 | 16.5 | 711.6 | -0.421 | -34.89 | 690.8 | 97.9 | 0.033 | |
| 775 | 331 | 12 | 21 | 18.9 | 943.7 | 0.701 | -36.65 | 916.2 | 71.6 | 0.030 | |
| 776 | 331 | 12 | 21 | 39.5 | 521.9 | 0.348 | -51.15 | 506.6 | 81.0 | 0.017 | |
| 777 | 331 | 12 | 21 | 39.7 | 792.1 | 0.107 | -43.61 | 769.0 | 86.0 | 0.023 | |
| 778 | 331 | 12 | 21 | 40.8 | 655.0 | 0.157 | 6.78 | 635.9 | 85.0 | 2.464 | 21398 |
| 779 | 331 | 12 | 21 | 42.3 | 521.8 | -0.053 | -50.53 | 506.6 | 89.6 | 0.018 | |
| 780 | 331 | 12 | 21 | 42.7 | 792.0 | 0.348 | -43.90 | 768.8 | 80.4 | 0.023 | |
| 781 | 331 | 12 | 24 | 0.9 | 767.3 | -0.575 | -23.74 | 744.9 | 101.5 | 0.052 | |
| 782 | 331 | 12 | 25 | 6.7 | 951.0 | 0.878 | -23.27 | 923.3 | 67.1 | 0.054 | 4295 |
| 783 | 331 | 12 | 35 | 32.8 | 589.3 | -0.518 | -16.64 | 572.1 | 99.8 | 0.147 | 27158 |
| 784 | 331 | 12 | 35 | 33.2 | 702.2 | -0.427 | -40.95 | 681.7 | 98.0 | 0.026 | |
| 785 | 331 | 12 | 35 | 42.3 | 1440.2 | 0.296 | -28.60 | 1398.2 | 80.5 | 0.044 | |
| 786 | 331 | 12 | 35 | 43.6 | 1447.1 | 0.304 | -29.89 | 1404.8 | 80.3 | 0.042 | 22651 |

## References

[1] Rosebrock, J., Leushacke, L. and Mehrholz, D. *Cooperative Debris Tracking and Development of Algorithms for Mid-Size Debris Detection with Radar*, Final Report of Study Contracts, ESA/ESOC, Darmstadt, Germany, 1999.

[2] Banka, D., Leushacke, L. Mehrholz, D. Rosebrock, and J. Kübbeler, K.-H. Advanced Methods for Detection and Tracking of Small-Size Space Debris and Meteoroids and Radar Measurements of the Space Environment, Final Report of Study Contract, ESA/ESOC, Darmstadt, Germany, 2002.

# Appendix B

# Haystack Radar

## B.1 Introduction

The Haystack radar's participation in the Inter-Agency Space Debris Coordination Committee's (IADC) 2008 24-hour campaign was sponsored by NASA. The radar was operated by the Massachusetts Institute of Technology's Lincoln Laboratory (MIT/LL). In addition to the IADC campaigns, the Haystack radar has been routinely observing the orbital debris environment using a fixed-stare operational mode since 1990 (see Figure B-1).

**Figure B-1. Haystack radome on the right and the smaller HAX radome on the left.**

The Haystack measurements have provided orbital debris researchers with the ability to detect small debris from previously unknown sources and the ability to examine continuous size distributions for sizes ranging from cataloged objects to objects smaller than 1 cm diameter. Further, Haystack has shown that the debris environment is dynamic and can change rapidly. Historic Haystack results are contained in numerous references (for example [1], [2], and [3]).

## B.2 Experiment Setup

During the 2008 IADC 24-hour campaign, 20.6 hours of Haystack data were collected with the radar pointing at 75° elevation and at an azimuth of 90°. This pointing angle was chosen as a compromise between maximizing the sensitivity of the radar by minimizing the slant range to an altitude and providing enough off-vertical pointing to provide reasonable Doppler inclination resolution. The data were collected from ~13:15 GMT on 18 November 2008 until 13:15 on 19 November.

The Haystack radar is a high-power, X-band, monopulse tracking radar with very high sensitivity. To detect debris, a pulsed, single-frequency waveform is used. The operating parameters for the Haystack radar during the 2008 campaign are shown in Table B-1. For Haystack, the single pulse signal-to-noise ratio (SNR) on a 1-m2 target at 1000 km range is 59.7 dB. With Haystack, objects as small as 1 cm diameter can be observed at ranges greater than 1000 km under normal operations.

**Table B-1. Instrument parameters used by the Haystack radar for the 2008 campaign.**

| Instrument Parameters | | |
|---|---|---|
| Geocentric latitude of sensor | 42.62 | deg |
| Geocentric longitude of sensor | -71.49 | deg |
| Geodetic altitude | 0.1157 | km |
| Wavelength | 0.03 | m |
| Beam width for incoherent integration | 0.116 | deg |
| Antenna constant (Gain) | 67.2 | dB |
| Transmitted power (peak) | 400.0 | kW |
| Pulse period | 16.67 | msec |
| Pulse duration | 1.638 | msec |
| Desired false alarm time (Marcum) | 36000 | sec |
| Number of independent threshold decisions per pulse | 12126 | |
| Maximum number of pulses to integrate | 16 | |
| Noise equivalent RCS (NRCS) | -65.2 | dB $m^2$ |
| Transmitted power for NRCS | 400 | kW |
| Pulse duration for NRCS | 1.638 | msec |
| Range for NRCS | 1000 | km |

For debris observations, the radar is operated in a staring, or "beam-park," mode in which the antenna is pointed at a specified elevation and azimuth and remains there while debris objects randomly pass through the field-of-view. This operational mode provides a fixed detection volume important to the measurement of the debris flux, or number of objects detected per unit area per unit time. By operating the radar in a stare mode and not tracking detected debris objects, a precise measurement of the object's orbit is sacrificed. However, by examining the signals from the monopulse angle channels operating in an open-loop mode, position in the radar beam for each pulse can be determined. From this path through the beam, rough orbital elements are deduced.

## B.3 Processing

In the debris mode, the signal strength for each received pulse is recorded from four separate channels: the Principal Polarization (PP) sum channel, Orthogonal Polarization (OP) sum channel, Traverse Difference (TR) channel, and Elevation Difference (EL) channel (see Figure B-2). The radar processing software determines the signal strength, signal-to-noise ratio (SNR) ratio, TR and EL voltage ratios, range and range rate. Other parameters are derived from these measurements. For an orbiting object passing through the radar field-of-view, the key step in the data processing is determining the location of the debris object in the radar beam for each radar pulse. From these locations, the motion of the object through the beam can be recreated and used to estimate rough orbital elements. Also, the signal strength can be augmented by the relative antenna gain determined by the antenna beam-pattern calibration discussed below. Thus, the returned signal strength can be estimated as if the object were at the center of the radar beam. The radar cross section (RCS) is determined by applying the absolute radar calibration, antenna beam shape, and the range to the object.

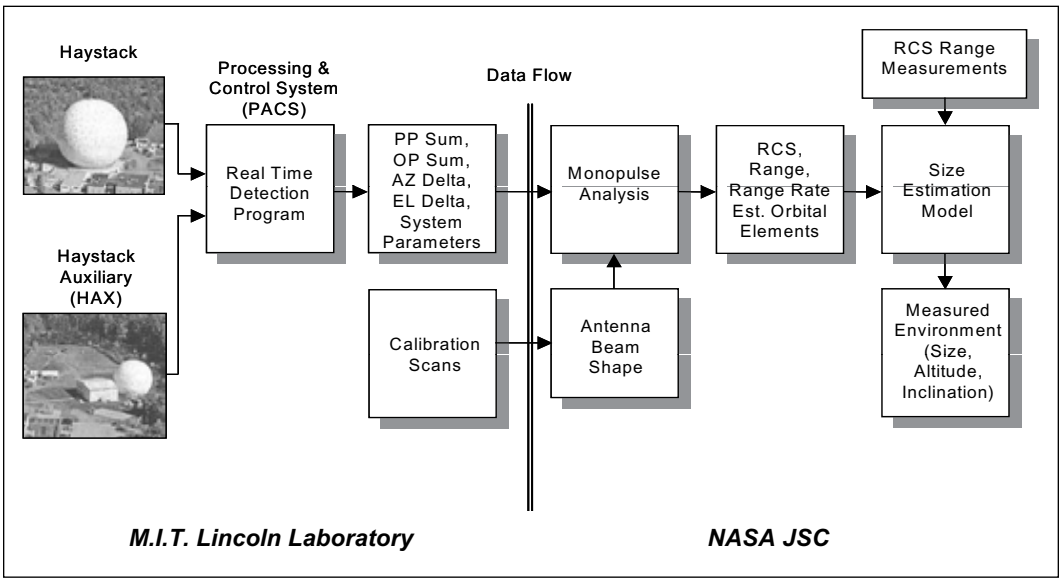


**Figure B-2. An overview of the data collection and analysis.**

The sensitivity of the antenna pattern is measured by scanning around a calibration sphere as it moves across the sky. This determines both the absolute calibration and the antenna beam pattern. Spheres return a circularly polarized signal with only a PP component. Test signals injected into the receiver preamplifiers are used to determine the absolute OP calibration.

A simple SNR threshold test is used for object detection. The noise floor varies, however, as a function of Doppler frequency. A "shape factor" representing the noise floor is subtracted from the signal emerging from the intermediate bandwidth filter. This shape factor is determined by averaging a large number of pulse returns which do not contain a valid detection. Figure B-3 shows the shape factor associated with the digital filter.

The Haystack radar primarily reports Doppler inclination, although the path through the beam is estimated to correct for antenna pattern loss when calculating RCS.

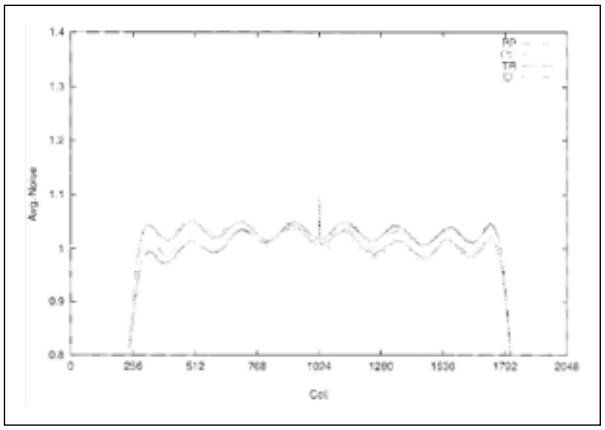


**Figure B-3. Noise floor with digital filter.**

## B.4 Beamshape

Table B-2 contains the coefficients from which the beam intensity loss from a nominal zero dB is calculated.

The dB loss from the beam center as a function of azimuth angle, *az,* and elevation angle, *el,* away from the center, is given by:

$$Loss = \sum_{i=0}^{2} \sum_{j=0}^{2-i} Coef_{i,j} az^{i} el^{j} ,$$

where *i* and *j* are indices for the coefficients and sums, but are exponents for azimuth and elevation values. Table B-2 lists the coefficients. Figure B-4 shows the RCS intensity distribution over the center of the Haystack beam.

**Table B-2. Coefficients for loss factor polynomial fit.**

| | C0,0 | C0,1 | C0,2 | C1,1 | C1,2 | C2,2 |
|---|---|---|---|---|---|---|
| Haystack | 0 | -31.16866 | -8124.115 | -12.03326 | -492.5722 | -8436.755 |

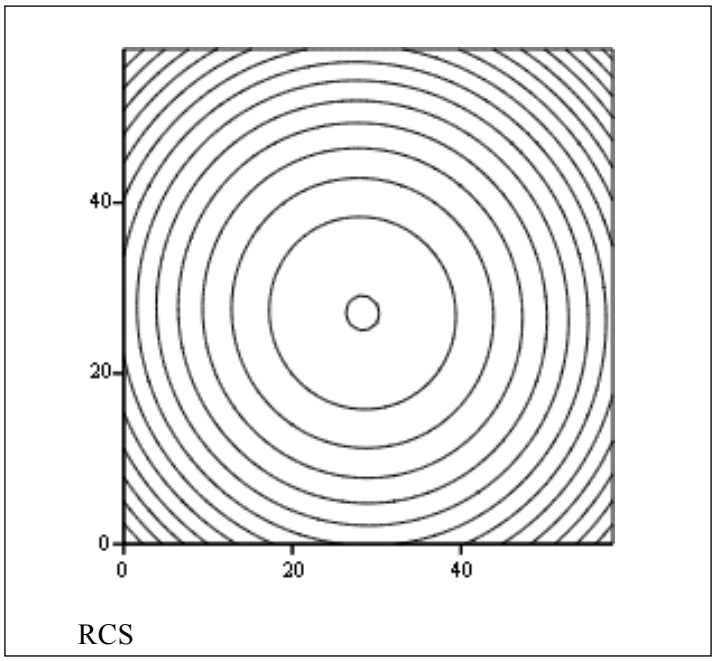


**Figure B-4. Haystack RCS intensity distribution over center of beam with 1 dB contours from -0.029° to +0.029°. Geometric center at indices 29,29. Az is x axis, El is y.**

## B.5 Campaign Parameters

Table B-3 lists the campaign parameters for the 2008 IADC campaign.

**Table B-3. Campaign parameters for the Haystack radar for the 2008 campaign.**

| Campaign Parameters | | |
|---|---|---|
| Campaign Start | 18 Nov 2008 13:15 GMT | |
| Maximum range | 1885 | km |
| Minimum range | 312 | km |
| Azimuth of line of site | 90 | deg |
| Elevation of line of site | 75 | deg |
| Duration of campaign | 24 | hrs |
| Total recorded data | 20.6 | hrs |

## B.6 Detection List

Table B-4 provides the list of detections observed by the Haystack radar during the 2008 campaign. The column showing possible correlations with the U.S. Space Surveillance Network catalog of known objects was produced using U.S. Air Force Space Command-provided software.

**Table B-4. Detections observed by the Haystack radar for the 2008 campaign.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 1 | 323 | 13 | 15 | 41.7 | 1383.8 | -0.760 | -47.16 | 1345.9 | 107.9 | 0.005 | |
| 2 | 323 | 13 | 22 | 4.5 | 1361.3 | -0.493 | -48.19 | 1324.0 | 102.5 | 0.005 | |
| 3 | 323 | 13 | 26 | 11.0 | 889.5 | 0.843 | -49.17 | 863.5 | 65.2 | 0.005 | |
| 4 | 323 | 13 | 26 | 39.9 | 1376.1 | 1.007 | -42.18 | 1338.5 | 58.9 | 0.007 | |
| 5 | 323 | 13 | 29 | 52.4 | 1483.5 | -0.685 | -45.42 | 1443.4 | 108.4 | 0.006 | |
| 6 | 323 | 13 | 34 | 12.9 | 659.1 | -0.431 | -47.84 | 639.3 | 98.6 | 0.005 | |
| 7 | 323 | 13 | 37 | 48.5 | 794.1 | 0.858 | -51.38 | 770.7 | 66.3 | 0.005 | |
| 8 | 323 | 13 | 38 | 6.9 | 742.7 | -0.448 | -60.70 | 720.7 | 99.3 | 0.003 | |
| 9 | 323 | 13 | 38 | 53.8 | 902.1 | -0.434 | -56.85 | 875.8 | 98.2 | 0.004 | |
| 10 | 323 | 13 | 43 | 41.7 | 1096.4 | -0.483 | -41.53 | 1065.2 | 99.6 | 0.007 | |
| 11 | 323 | 13 | 43 | 52.6 | 692.8 | -0.414 | -62.24 | 672.1 | 98.3 | 0.003 | |
| 12 | 323 | 13 | 46 | 29.7 | 888.9 | -0.579 | -51.32 | 863.0 | 103.1 | 0.005 | |
| 13 | 323 | 13 | 46 | 56.3 | 899.6 | 0.332 | -53.81 | 873.4 | 78.7 | 0.004 | |
| 14 | 323 | 13 | 49 | 44.5 | 618.0 | -0.511 | -53.31 | 599.3 | 99.9 | 0.004 | |
| 15 | 323 | 13 | 50 | 43.2 | 722.9 | -0.452 | -44.23 | 701.4 | 98.5 | 0.006 | |
| 16 | 323 | 13 | 52 | 37.7 | 1223.9 | 3.744 | -50.31 | 1189.8 | 81.5 | 0.005 | |
| 17 | 323 | 14 | 2 | 51.2 | 1568.7 | 1.103 | -52.67 | 1526.8 | 54.2 | 0.004 | |
| 18 | 323 | 14 | 6 | 28.7 | 670.2 | -0.445 | -50.06 | 650.2 | 98.3 | 0.005 | |
| 19 | 323 | 14 | 8 | 45.7 | 707.2 | -0.480 | -44.47 | 686.1 | 99.2 | 0.006 | |
| 20 | 323 | 14 | 10 | 1.1 | 737.2 | 0.312 | -61.26 | 715.3 | 80.6 | 0.003 | |
| 21 | 323 | 14 | 15 | 4.6 | 782.8 | -0.476 | -58.31 | 759.7 | 99.2 | 0.003 | |
| 22 | 323 | 14 | 20 | 28.3 | 1588.1 | 0.499 | -50.95 | 1545.8 | 71.4 | 0.005 | |

**Table B-4. Detections observed by the Haystack radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 23 | 323 | 14 | 24 | 46.6 | 1509.4 | -0.618 | -44.09 | 1468.7 | 106.6 | 0.006 | 18429 |
| 24 | 323 | 14 | 26 | 48.1 | 504.8 | -0.418 | -69.05 | 489.3 | 97.6 | 0.002 | |
| 25 | 323 | 14 | 27 | 42.5 | 1077.4 | -0.855 | -55.74 | 1046.8 | 109.8 | 0.004 | |
| 26 | 323 | 14 | 28 | 46.8 | 1439.0 | 0.499 | -50.57 | 1399.8 | 72.1 | 0.005 | |
| 27 | 323 | 14 | 29 | 25.5 | 908.8 | -0.265 | -37.48 | 882.3 | 93.9 | 0.010 | |
| 28 | 323 | 14 | 32 | 16.5 | 877.8 | -0.394 | -44.67 | 852.3 | 98.3 | 0.006 | |
| 29 | 323 | 14 | 32 | 58.5 | 1008.8 | 0.117 | -53.43 | 979.8 | 85.4 | 0.004 | |
| 30 | 323 | 14 | 33 | 8.5 | 1009.6 | -0.038 | -47.59 | 980.5 | 89.5 | 0.005 | |
| 31 | 323 | 14 | 33 | 15.9 | 909.0 | 0.908 | -40.80 | 882.6 | 63.3 | 0.007 | |
| 32 | 323 | 14 | 41 | 0.7 | 726.3 | -0.453 | -55.60 | 704.6 | 98.6 | 0.004 | |
| 33 | 323 | 14 | 42 | 20.6 | 884.7 | 0.590 | -62.54 | 858.9 | 73.2 | 0.003 | |
| 34 | 323 | 14 | 45 | 50.0 | 422.1 | 2.324 | -46.68 | 409.0 | 49.2 | 0.005 | |
| 35 | 323 | 14 | 54 | 1.9 | 918.4 | -0.593 | -53.31 | 891.7 | 103.6 | 0.004 | |
| 36 | 323 | 14 | 54 | 29.3 | 761.9 | -0.550 | -44.68 | 739.3 | 101.0 | 0.006 | |
| 37 | 323 | 14 | 54 | 53.2 | 846.0 | 0.887 | -47.40 | 821.2 | 64.3 | 0.005 | |
| 38 | 323 | 14 | 56 | 46.2 | 1978.6 | 1.304 | -46.67 | 1928.2 | 48.4 | 0.005 | |
| 39 | 323 | 14 | 59 | 13.1 | 983.6 | -0.509 | -55.38 | 955.2 | 100.2 | 0.004 | |
| 40 | 323 | 15 | 4 | 41.8 | 859.4 | -0.556 | -60.16 | 834.2 | 101.3 | 0.003 | |
| 41 | 323 | 15 | 5 | 0.1 | 692.8 | -0.556 | -46.03 | 672.1 | 101.1 | 0.006 | |
| 42 | 323 | 15 | 8 | 10.8 | 829.5 | 0.548 | -45.06 | 805.2 | 74.4 | 0.006 | |
| 43 | 323 | 15 | 11 | 59.8 | 1253.5 | -5.716 | -59.19 | 1218.6 | 42.4 | 0.003 | |
| 44 | 323 | 15 | 14 | 49.1 | 572.2 | -0.332 | -49.54 | 554.8 | 95.6 | 0.005 | |
| 45 | 323 | 15 | 15 | 59.9 | 939.9 | 0.854 | -47.22 | 912.7 | 65.8 | 0.005 | |
| 46 | 323 | 15 | 25 | 59.8 | 1131.8 | 0.058 | -55.15 | 1099.8 | 87.0 | 0.004 | |
| 47 | 323 | 15 | 26 | 48.6 | 1361.1 | 0.223 | -54.30 | 1323.7 | 82.5 | 0.004 | |
| 48 | 323 | 15 | 27 | 43.8 | 896.3 | -0.469 | -52.93 | 870.2 | 100.3 | 0.004 | |
| 49 | 323 | 15 | 29 | 27.0 | 1051.6 | -0.794 | -59.33 | 1021.6 | 108.0 | 0.003 | |
| 50 | 323 | 15 | 30 | 27.7 | 519.3 | -0.383 | -61.82 | 503.5 | 96.8 | 0.003 | |
| 51 | 323 | 15 | 35 | 59.4 | 1670.8 | 1.906 | -41.39 | 1626.7 | 59.2 | 0.007 | |
| 52 | 323 | 15 | 38 | 23.7 | 1230.7 | -0.474 | -47.70 | 1196.2 | 99.5 | 0.005 | |
| 53 | 323 | 15 | 41 | 37.6 | 1228.7 | 0.540 | -56.52 | 1194.4 | 73.7 | 0.004 | |
| 54 | 323 | 15 | 46 | 4.2 | 827.4 | -0.680 | -48.29 | 803.1 | 104.4 | 0.005 | |
| 55 | 323 | 15 | 46 | 46.3 | 1723.0 | 0.217 | -45.14 | 1677.8 | 79.4 | 0.006 | |
| 56 | 323 | 16 | 9 | 14.5 | 680.4 | -0.481 | -54.64 | 660.1 | 99.2 | 0.004 | |
| 57 | 323 | 16 | 11 | 33.6 | 606.0 | -0.590 | -50.92 | 587.8 | 102.3 | 0.005 | |
| 58 | 323 | 16 | 17 | 0.7 | 1581.9 | 0.553 | -47.38 | 1539.7 | 69.8 | 0.005 | |
| 59 | 323 | 16 | 18 | 9.2 | 1697.1 | 0.858 | -27.81 | 1652.5 | 62.1 | 0.045 | 6252 |
| 60 | 323 | 16 | 19 | 26.6 | 792.6 | -0.492 | -59.24 | 769.2 | 100.6 | 0.003 | |
| 61 | 323 | 16 | 19 | 40.3 | 894.9 | 0.914 | -45.13 | 868.9 | 63.2 | 0.006 | |
| 62 | 323 | 16 | 22 | 24.7 | 1019.5 | 1.327 | -54.85 | 990.4 | 50.7 | 0.004 | |
| 63 | 323 | 16 | 27 | 3.3 | 725.1 | -0.121 | -46.67 | 703.5 | 91.2 | 0.005 | |
| 64 | 323 | 16 | 28 | 30.3 | 519.4 | -0.374 | -57.97 | 503.5 | 96.9 | 0.003 | |
| 65 | 323 | 16 | 29 | 18.2 | 713.7 | 0.231 | -48.45 | 692.4 | 81.8 | 0.005 | |
| 66 | 323 | 16 | 34 | 5.1 | 670.1 | 0.013 | -51.71 | 650.0 | 87.9 | 0.005 | |
| 67 | 323 | 16 | 42 | 39.8 | 591.4 | -0.377 | -46.08 | 573.4 | 96.6 | 0.006 | |
| 68 | 323 | 16 | 49 | 25.0 | 1264.3 | 0.453 | -50.20 | 1229.1 | 74.1 | 0.005 | |

**Table B-4. Detections observed by the Haystack radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 69 | 323 | 16 | 58 | 31.0 | 1069.5 | -0.462 | -46.60 | 1039.1 | 100.7 | 0.005 | |
| 70 | 323 | 17 | 3 | 19.6 | 838.6 | 0.879 | -43.54 | 814.0 | 65.6 | 0.006 | |
| 71 | 323 | 17 | 8 | 57.8 | 473.3 | -0.386 | -46.77 | 458.8 | 97.0 | 0.005 | |
| 72 | 323 | 17 | 9 | 53.6 | 1319.9 | -0.571 | -48.30 | 1283.5 | 104.5 | 0.005 | |
| 73 | 323 | 18 | 22 | 5.6 | 1012.9 | 0.833 | -38.31 | 983.7 | 66.1 | 0.009 | |
| 74 | 323 | 18 | 23 | 16.8 | 951.2 | 0.861 | -43.09 | 923.8 | 64.3 | 0.006 | |
| 75 | 323 | 18 | 23 | 51.8 | 1277.5 | -0.272 | -52.42 | 1242.1 | 96.1 | 0.004 | |
| 76 | 323 | 18 | 25 | 54.0 | 619.8 | -0.753 | -60.85 | 601.1 | 106.4 | 0.003 | |
| 77 | 323 | 18 | 34 | 38.5 | 1095.5 | 0.167 | -44.60 | 1064.4 | 82.4 | 0.006 | |
| 78 | 323 | 18 | 38 | 27.3 | 662.4 | -0.542 | -62.59 | 642.6 | 100.7 | 0.003 | |
| 79 | 323 | 18 | 38 | 55.8 | 873.9 | -0.144 | -52.97 | 848.4 | 92.0 | 0.004 | |
| 80 | 323 | 18 | 50 | 24.9 | 971.4 | -0.570 | -42.64 | 943.5 | 101.8 | 0.006 | |
| 81 | 323 | 18 | 50 | 51.2 | 982.2 | -0.582 | -46.97 | 954.0 | 102.1 | 0.005 | |
| 82 | 323 | 18 | 56 | 40.6 | 838.0 | 0.871 | -63.33 | 813.5 | 65.8 | 0.003 | |
| 83 | 323 | 19 | 8 | 25.5 | 1022.6 | -0.980 | -53.73 | 993.3 | 113.1 | 0.004 | |
| 84 | 323 | 19 | 10 | 1.9 | 847.8 | 0.222 | -56.36 | 823.1 | 81.7 | 0.004 | |
| 85 | 323 | 19 | 10 | 16.1 | 890.2 | -0.563 | -55.43 | 864.2 | 101.5 | 0.004 | |
| 86 | 323 | 19 | 13 | 38.2 | 1492.0 | -0.119 | -50.82 | 1451.8 | 89.6 | 0.005 | |
| 87 | 323 | 19 | 18 | 33.8 | 885.3 | -0.404 | -48.55 | 859.4 | 97.4 | 0.005 | |
| 88 | 323 | 19 | 21 | 13.0 | 1144.9 | 0.457 | -55.23 | 1112.6 | 74.5 | 0.004 | |
| 89 | 323 | 19 | 27 | 48.6 | 899.8 | -0.488 | -48.29 | 873.6 | 100.8 | 0.005 | |
| 90 | 323 | 19 | 30 | 32.1 | 1009.9 | -0.270 | -44.73 | 980.9 | 95.5 | 0.006 | |
| 91 | 323 | 19 | 30 | 59.6 | 1404.7 | 2.259 | -45.71 | 1366.4 | 62.9 | 0.006 | |
| 92 | 323 | 19 | 33 | 2.7 | 1161.4 | -0.472 | -53.23 | 1128.7 | 99.4 | 0.004 | |
| 93 | 323 | 19 | 42 | 55.3 | 1017.5 | -0.467 | -44.03 | 988.5 | 100.6 | 0.006 | |
| 94 | 323 | 19 | 49 | 54.7 | 947.3 | -0.562 | -43.60 | 919.9 | 101.5 | 0.006 | |
| 95 | 323 | 19 | 53 | 3.4 | 917.1 | 0.876 | -46.47 | 890.4 | 64.1 | 0.006 | |
| 96 | 323 | 19 | 54 | 52.9 | 684.8 | 0.245 | -48.68 | 664.3 | 81.6 | 0.005 | |
| 97 | 323 | 19 | 57 | 58.6 | 850.7 | -0.443 | -51.04 | 825.7 | 99.5 | 0.005 | |
| 98 | 323 | 19 | 58 | 20.8 | 731.2 | 0.935 | -61.35 | 709.4 | 63.7 | 0.003 | |
| 99 | 323 | 20 | 4 | 32.5 | 977.3 | 0.851 | -41.68 | 949.2 | 65.7 | 0.007 | |
| 100 | 323 | 20 | 14 | 15.3 | 876.6 | 0.130 | -54.30 | 851.0 | 83.9 | 0.004 | |
| 101 | 323 | 20 | 15 | 0.7 | 1358.1 | -0.418 | -41.92 | 1320.8 | 100.3 | 0.007 | |
| 102 | 323 | 20 | 18 | 9.8 | 989.1 | -0.396 | -63.09 | 960.7 | 98.7 | 0.003 | |
| 103 | 323 | 20 | 18 | 14.5 | 852.3 | -0.519 | -54.26 | 827.3 | 100.3 | 0.004 | |
| 104 | 323 | 20 | 19 | 27.3 | 1023.5 | -0.620 | -52.33 | 994.2 | 104.7 | 0.004 | |
| 105 | 323 | 20 | 19 | 57.1 | 791.0 | -0.943 | -47.46 | 767.7 | 111.2 | 0.005 | |
| 106 | 323 | 20 | 20 | 55.0 | 1149.4 | -0.251 | -52.65 | 1117.0 | 93.4 | 0.004 | |
| 107 | 323 | 20 | 23 | 11.3 | 1563.7 | -0.688 | -43.36 | 1521.8 | 106.2 | 0.006 | |
| 108 | 323 | 20 | 27 | 8.7 | 900.2 | -0.533 | -42.78 | 874.0 | 102.0 | 0.006 | |
| 109 | 323 | 20 | 27 | 14.7 | 1134.1 | -0.434 | -48.30 | 1102.2 | 98.3 | 0.005 | |
| 110 | 323 | 20 | 38 | 16.6 | 958.7 | 0.178 | -57.93 | 931.1 | 82.5 | 0.003 | |
| 111 | 323 | 20 | 38 | 54.3 | 510.6 | -0.388 | -61.41 | 495.0 | 97.2 | 0.003 | |
| 112 | 323 | 20 | 48 | 20.1 | 980.1 | 0.840 | -51.53 | 951.8 | 66.0 | 0.005 | |
| 113 | 323 | 20 | 51 | 36.6 | 886.4 | -0.498 | -43.42 | 860.5 | 101.0 | 0.006 | |

**Table B-4. Detections observed by the Haystack radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 114 | 323 | 21 | 1 | 53.8 | 1914.2 | 1.659 | -43.23 | 1865.0 | 66.8 | 0.006 | |
| 115 | 323 | 21 | 40 | 23.0 | 536.8 | 2.109 | -55.91 | 520.5 | 49.4 | 0.004 | |
| 116 | 323 | 21 | 41 | 23.4 | 890.2 | -0.474 | -53.95 | 864.3 | 99.2 | 0.004 | |
| 117 | 323 | 21 | 42 | 30.4 | 848.2 | 0.855 | -51.05 | 823.3 | 66.2 | 0.005 | |
| 118 | 323 | 21 | 49 | 44.9 | 908.7 | -0.452 | -43.69 | 882.3 | 99.9 | 0.006 | |
| 119 | 323 | 21 | 51 | 34.0 | 806.0 | 0.239 | -57.96 | 782.2 | 81.3 | 0.003 | |
| 120 | 323 | 21 | 56 | 27.0 | 875.0 | -0.511 | -51.23 | 849.5 | 100.1 | 0.005 | |
| 121 | 323 | 21 | 58 | 18.6 | 1029.8 | -0.494 | -40.30 | 1000.3 | 101.4 | 0.007 | |
| 122 | 323 | 22 | 0 | 3.6 | 933.9 | 0.161 | -45.23 | 906.9 | 84.3 | 0.006 | |
| 123 | 323 | 22 | 2 | 11.0 | 860.2 | 0.140 | -53.62 | 835.0 | 83.7 | 0.004 | |
| 124 | 323 | 22 | 3 | 8.2 | 827.3 | -0.319 | -51.87 | 803.0 | 96.3 | 0.005 | |
| 125 | 323 | 22 | 8 | 43.3 | 722.7 | -0.446 | -56.91 | 701.2 | 99.2 | 0.004 | |
| 126 | 323 | 22 | 12 | 8.8 | 769.8 | -0.592 | -54.81 | 747.1 | 102.1 | 0.004 | |
| 127 | 323 | 22 | 16 | 47.7 | 1251.8 | -0.467 | -38.74 | 1217.0 | 99.3 | 0.009 | |
| 128 | 323 | 22 | 21 | 34.3 | 1459.3 | 0.397 | -50.42 | 1419.6 | 75.0 | 0.005 | |
| 129 | 323 | 22 | 22 | 59.6 | 715.5 | -0.809 | -55.48 | 694.2 | 108.3 | 0.004 | |
| 130 | 323 | 22 | 28 | 3.1 | 850.1 | -0.533 | -48.25 | 825.1 | 101.8 | 0.005 | |
| 131 | 323 | 22 | 30 | 23.8 | 871.6 | -0.530 | -48.24 | 846.1 | 101.8 | 0.005 | |
| 132 | 323 | 22 | 30 | 53.5 | 631.6 | 0.191 | -51.28 | 612.5 | 83.6 | 0.005 | |
| 133 | 323 | 22 | 36 | 41.4 | 1000.0 | 0.225 | -57.25 | 971.3 | 82.7 | 0.004 | |
| 134 | 323 | 22 | 37 | 34.8 | 953.6 | 0.867 | -44.14 | 926.0 | 64.1 | 0.006 | |
| 135 | 323 | 22 | 38 | 45.6 | 414.4 | 1.252 | -68.51 | 401.5 | 57.6 | 0.002 | |
| 136 | 323 | 22 | 46 | 17.7 | 908.1 | -0.538 | -39.44 | 881.7 | 102.1 | 0.008 | |
| 137 | 323 | 22 | 49 | 22.6 | 938.6 | -0.543 | -58.99 | 911.5 | 101.0 | 0.003 | |
| 138 | 323 | 22 | 49 | 52.9 | 882.0 | -0.658 | -47.49 | 856.4 | 105.1 | 0.005 | |
| 139 | 323 | 22 | 52 | 31.9 | 842.4 | 0.183 | -50.33 | 817.7 | 82.7 | 0.005 | |
| 140 | 323 | 22 | 54 | 23.5 | 989.6 | -0.307 | -51.64 | 961.1 | 96.4 | 0.005 | |
| 141 | 323 | 22 | 56 | 32.5 | 864.5 | -0.544 | -57.57 | 839.3 | 102.1 | 0.003 | |
| 142 | 323 | 23 | 8 | 23.0 | 1117.7 | 0.040 | -48.59 | 1086.1 | 87.5 | 0.005 | |
| 143 | 323 | 23 | 11 | 57.4 | 900.8 | -0.559 | -62.19 | 874.7 | 101.4 | 0.003 | |
| 144 | 323 | 23 | 11 | 59.2 | 680.3 | -0.615 | -47.86 | 660.0 | 103.2 | 0.005 | |
| 145 | 323 | 23 | 15 | 53.9 | 980.6 | 0.912 | -55.99 | 952.3 | 64.0 | 0.004 | |
| 146 | 323 | 23 | 18 | 13.2 | 1628.1 | 1.302 | -48.46 | 1584.9 | 45.6 | 0.005 | |
| 147 | 323 | 23 | 32 | 25.1 | 1089.1 | 1.268 | -44.72 | 1058.0 | 52.1 | 0.006 | |
| 148 | 323 | 23 | 38 | 27.7 | 977.4 | 0.178 | -52.52 | 949.3 | 82.4 | 0.004 | |
| 149 | 323 | 23 | 49 | 34.6 | 883.1 | -0.530 | -56.11 | 857.3 | 101.8 | 0.004 | |
| 150 | 323 | 23 | 57 | 21.2 | 1315.5 | 1.133 | -49.70 | 1279.3 | 53.3 | 0.005 | |
| 151 | 324 | 0 | 5 | 52.2 | 827.1 | 0.145 | -59.61 | 802.9 | 84.7 | 0.003 | |
| 152 | 324 | 0 | 9 | 28.2 | 863.2 | -0.242 | -48.37 | 837.9 | 94.5 | 0.005 | |
| 153 | 324 | 0 | 11 | 49.2 | 721.4 | -0.598 | -49.40 | 699.8 | 103.0 | 0.005 | |
| 154 | 324 | 0 | 12 | 21.6 | 716.2 | -0.592 | -60.50 | 694.8 | 102.8 | 0.003 | |
| 155 | 324 | 0 | 13 | 27.4 | 722.9 | -0.066 | -43.79 | 701.3 | 89.9 | 0.006 | |
| 156 | 324 | 0 | 16 | 25.5 | 958.2 | 0.831 | -40.92 | 930.6 | 66.4 | 0.007 | |
| 157 | 324 | 0 | 18 | 21.3 | 630.2 | -0.566 | -62.81 | 611.1 | 101.8 | 0.003 | |
| 158 | 324 | 0 | 19 | 31.2 | 1463.2 | 1.196 | -54.45 | 1423.6 | 51.6 | 0.004 | |

**Table B-4. Detections observed by the Haystack radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 159 | 324 | 0 | 21 | 15.4 | 1444.1 | -0.315 | -49.38 | 1404.9 | 95.2 | 0.005 | |
| 160 | 324 | 0 | 24 | 3.5 | 628.5 | -0.591 | -53.41 | 609.5 | 102.4 | 0.004 | |
| 161 | 324 | 0 | 32 | 7.9 | 697.6 | 0.919 | -66.30 | 676.7 | 64.4 | 0.003 | |
| 162 | 324 | 0 | 37 | 40.7 | 976.7 | -0.508 | -46.92 | 948.5 | 100.1 | 0.005 | |
| 163 | 324 | 0 | 43 | 17.9 | 757.7 | -0.368 | -59.10 | 735.3 | 96.4 | 0.003 | 28255 |
| 164 | 324 | 0 | 47 | 21.2 | 923.4 | -0.530 | -61.34 | 896.6 | 102.0 | 0.003 | |
| 165 | 324 | 0 | 55 | 57.6 | 795.5 | 0.889 | -45.72 | 772.1 | 65.5 | 0.006 | |
| 166 | 324 | 1 | 19 | 19.3 | 583.2 | -0.564 | -56.82 | 565.6 | 101.6 | 0.004 | |
| 167 | 324 | 1 | 25 | 33.6 | 1755.8 | 0.361 | -42.50 | 1709.8 | 75.0 | 0.006 | |
| 168 | 324 | 1 | 26 | 29.7 | 740.4 | -0.659 | -44.56 | 718.5 | 103.7 | 0.006 | |
| 169 | 324 | 1 | 27 | 21.2 | 421.6 | -0.471 | -64.06 | 408.6 | 98.8 | 0.003 | |
| 170 | 324 | 1 | 28 | 38.0 | 929.0 | 0.024 | -40.66 | 902.0 | 87.8 | 0.007 | |
| 171 | 324 | 1 | 29 | 9.8 | 559.0 | -0.489 | -50.02 | 542.0 | 99.7 | 0.005 | |
| 172 | 324 | 1 | 31 | 35.4 | 1102.0 | -0.063 | -49.04 | 1070.8 | 88.5 | 0.005 | |
| 173 | 324 | 1 | 31 | 37.6 | 1326.4 | -0.503 | -44.86 | 1289.8 | 102.6 | 0.006 | |
| 174 | 324 | 1 | 36 | 16.8 | 731.7 | -0.485 | -45.55 | 709.9 | 100.2 | 0.006 | |
| 175 | 324 | 1 | 37 | 38.9 | 828.5 | -0.663 | -60.58 | 804.2 | 105.0 | 0.003 | |
| 176 | 324 | 1 | 44 | 41.8 | 820.5 | 0.908 | -47.64 | 796.3 | 63.9 | 0.005 | |
| 177 | 324 | 1 | 45 | 14.7 | 830.2 | 0.907 | -51.68 | 805.8 | 63.8 | 0.005 | |
| 178 | 324 | 1 | 45 | 44.3 | 1762.9 | 0.465 | -43.57 | 1716.7 | 74.8 | 0.006 | |
| 179 | 324 | 1 | 52 | 42.8 | 599.9 | -0.531 | -61.04 | 581.8 | 100.4 | 0.003 | |
| 180 | 324 | 1 | 57 | 7.5 | 977.7 | -0.596 | -54.33 | 949.4 | 103.9 | 0.004 | |
| 181 | 324 | 1 | 57 | 23.9 | 600.2 | -0.616 | -49.91 | 582.0 | 102.9 | 0.005 | |
| 182 | 324 | 2 | 0 | 13.8 | 652.0 | -0.670 | -49.26 | 632.5 | 103.8 | 0.005 | |
| 183 | 324 | 2 | 2 | 33.6 | 749.9 | -0.534 | -49.53 | 727.6 | 101.5 | 0.005 | |
| 184 | 324 | 2 | 10 | 39.8 | 725.8 | -0.531 | -46.25 | 704.2 | 101.3 | 0.006 | |
| 185 | 324 | 2 | 18 | 56.4 | 790.8 | -0.614 | -39.75 | 767.5 | 103.6 | 0.008 | |
| 186 | 324 | 2 | 19 | 39.0 | 686.8 | -0.572 | -54.13 | 666.2 | 101.5 | 0.004 | |
| 187 | 324 | 2 | 29 | 52.9 | 794.7 | 0.227 | -45.11 | 771.2 | 82.7 | 0.006 | |
| 188 | 324 | 2 | 35 | 34.5 | 1391.6 | 1.049 | -47.79 | 1353.4 | 57.3 | 0.005 | |
| 189 | 324 | 2 | 37 | 55.2 | 1597.5 | 0.719 | -43.43 | 1554.9 | 67.2 | 0.006 | |
| 190 | 324 | 2 | 38 | 52.2 | 828.9 | -0.507 | -60.07 | 804.5 | 100.0 | 0.003 | |
| 191 | 324 | 2 | 40 | 27.3 | 706.4 | -0.444 | -48.26 | 685.3 | 99.1 | 0.005 | 25919 |
| 192 | 324 | 2 | 57 | 11.6 | 1514.1 | 0.432 | -40.16 | 1473.3 | 76.3 | 0.007 | |
| 193 | 324 | 2 | 57 | 39.6 | 623.9 | -0.329 | -41.44 | 605.1 | 96.1 | 0.007 | |
| 194 | 324 | 3 | 6 | 58.7 | 770.6 | 0.587 | -27.69 | 747.7 | 72.7 | 0.045 | 19102 |
| 195 | 324 | 3 | 8 | 16.5 | 814.0 | -0.470 | -48.38 | 790.1 | 99.0 | 0.005 | |
| 196 | 324 | 3 | 11 | 4.0 | 908.6 | -0.549 | -47.54 | 882.1 | 102.4 | 0.005 | |
| 197 | 324 | 3 | 13 | 28.3 | 619.1 | -0.001 | -67.66 | 600.4 | 87.7 | 0.002 | |
| 198 | 324 | 3 | 13 | 40.8 | 1252.4 | -0.571 | -48.43 | 1217.5 | 104.2 | 0.005 | |
| 199 | 324 | 3 | 16 | 10.4 | 898.8 | 0.825 | -41.07 | 872.7 | 66.8 | 0.007 | |
| 200 | 324 | 3 | 18 | 7.0 | 624.2 | 0.919 | -68.25 | 605.3 | 65.4 | 0.002 | |
| 201 | 324 | 3 | 29 | 17.8 | 1174.6 | -0.560 | -46.05 | 1141.6 | 103.7 | 0.006 | |
| 202 | 324 | 3 | 30 | 7.4 | 1027.6 | -0.054 | -41.52 | 998.1 | 89.9 | 0.007 | |
| 203 | 324 | 3 | 35 | 32.0 | 732.0 | 1.605 | -46.14 | 710.3 | 43.8 | 0.006 | |
| 204 | 324 | 3 | 39 | 22.8 | 1207.7 | -0.537 | -44.73 | 1174.0 | 101.2 | 0.006 | |

**Table B-4. Detections observed by the Haystack radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 205 | 324 | 3 | 42 | 32.5 | 739.6 | 0.825 | -54.88 | 717.5 | 67.4 | 0.004 | |
| 206 | 324 | 3 | 42 | 49.4 | 838.4 | 0.903 | -45.92 | 813.8 | 63.9 | 0.006 | |
| 207 | 324 | 3 | 53 | 4.4 | 414.4 | -0.407 | -70.20 | 401.6 | 97.3 | 0.002 | |
| 208 | 324 | 3 | 56 | 24.8 | 1257.4 | -0.643 | -46.39 | 1222.4 | 104.3 | 0.006 | |
| 209 | 324 | 4 | 0 | 13.4 | 895.7 | -0.297 | -35.51 | 869.7 | 94.7 | 0.016 | |
| 210 | 324 | 4 | 8 | 20.0 | 588.0 | 0.187 | -55.44 | 570.2 | 83.7 | 0.004 | |
| 211 | 324 | 4 | 8 | 36.0 | 969.4 | 0.830 | -40.99 | 941.5 | 66.4 | 0.007 | |
| 212 | 324 | 4 | 10 | 56.6 | 537.9 | -0.636 | -69.26 | 521.5 | 103.2 | 0.002 | |
| 213 | 324 | 4 | 19 | 24.9 | 602.8 | -0.492 | -59.07 | 584.5 | 99.4 | 0.003 | |
| 214 | 324 | 4 | 21 | 31.5 | 1370.1 | 1.358 | -51.60 | 1332.7 | 46.0 | 0.005 | |
| 215 | 324 | 4 | 23 | 23.2 | 945.4 | -0.250 | -50.80 | 918.0 | 93.5 | 0.005 | |
| 216 | 324 | 4 | 24 | 38.4 | 923.6 | 0.199 | -36.53 | 896.8 | 83.3 | 0.013 | |
| 217 | 324 | 4 | 35 | 29.1 | 1551.3 | 0.126 | -48.39 | 1509.6 | 85.2 | 0.005 | |
| 218 | 324 | 4 | 38 | 3.0 | 824.8 | 0.635 | -53.03 | 800.5 | 72.2 | 0.004 | |
| 219 | 324 | 4 | 41 | 37.9 | 912.9 | -0.519 | -50.88 | 886.4 | 100.4 | 0.005 | |
| 220 | 324 | 4 | 46 | 38.0 | 1438.3 | 0.446 | -47.14 | 1399.3 | 73.6 | 0.005 | |
| 221 | 324 | 5 | 1 | 21.0 | 1018.3 | -0.449 | -39.51 | 989.1 | 98.6 | 0.008 | |
| 222 | 324 | 5 | 3 | 56.8 | 1096.6 | 1.333 | -44.38 | 1065.5 | 48.7 | 0.006 | |
| 223 | 324 | 5 | 10 | 54.1 | 970.4 | 0.812 | -36.99 | 942.4 | 66.9 | 0.012 | |
| 224 | 324 | 5 | 13 | 53.8 | 475.4 | -0.592 | -57.36 | 460.7 | 101.9 | 0.004 | |
| 225 | 324 | 5 | 15 | 48.0 | 922.0 | -0.604 | -42.83 | 895.2 | 102.6 | 0.006 | |
| 226 | 324 | 5 | 20 | 42.7 | 978.3 | -0.642 | -45.41 | 950.1 | 103.7 | 0.006 | |
| 227 | 324 | 5 | 26 | 31.3 | 850.5 | 0.175 | -53.78 | 825.5 | 84.0 | 0.004 | |
| 228 | 324 | 5 | 27 | 38.1 | 825.5 | 0.854 | -49.67 | 801.3 | 66.3 | 0.005 | |
| 229 | 324 | 5 | 28 | 2.0 | 1358.3 | -0.248 | -51.43 | 1321.1 | 93.3 | 0.005 | |
| 230 | 324 | 5 | 37 | 27.8 | 1027.4 | 0.213 | -55.76 | 998.0 | 81.4 | 0.004 | |
| 231 | 324 | 5 | 43 | 34.0 | 872.8 | 0.635 | -43.66 | 847.3 | 72.0 | 0.006 | |
| 232 | 324 | 5 | 43 | 49.4 | 901.4 | 0.875 | -48.32 | 875.1 | 64.2 | 0.005 | |
| 233 | 324 | 5 | 53 | 50.6 | 506.1 | -0.475 | -68.62 | 490.6 | 99.2 | 0.002 | |
| 234 | 324 | 6 | 28 | 10.7 | 578.1 | -0.372 | -51.01 | 560.5 | 96.5 | 0.005 | |
| 235 | 324 | 6 | 30 | 29.6 | 1028.1 | -0.297 | -50.30 | 998.6 | 94.7 | 0.005 | |
| 236 | 324 | 6 | 32 | 4.9 | 1110.8 | 1.405 | -50.40 | 1079.3 | 47.0 | 0.005 | |
| 237 | 324 | 6 | 36 | 51.5 | 1339.0 | 0.237 | -41.03 | 1302.2 | 82.1 | 0.007 | |
| 238 | 324 | 6 | 37 | 54.1 | 1231.9 | 1.130 | -45.51 | 1197.5 | 55.7 | 0.006 | |
| 239 | 324 | 6 | 38 | 53.8 | 898.0 | -0.322 | -48.03 | 871.9 | 95.3 | 0.005 | |
| 240 | 324 | 6 | 43 | 56.1 | 776.0 | -0.633 | -48.99 | 753.0 | 103.1 | 0.005 | |
| 241 | 324 | 6 | 50 | 20.8 | 509.6 | 1.631 | -50.12 | 493.9 | 45.6 | 0.005 | |
| 242 | 324 | 6 | 50 | 26.3 | 1066.4 | -0.543 | -50.54 | 1036.1 | 101.2 | 0.005 | |
| 243 | 324 | 6 | 57 | 37.3 | 992.9 | -0.316 | -37.67 | 964.4 | 95.2 | 0.010 | |
| 244 | 324 | 7 | 3 | 12.4 | 787.2 | 0.008 | -54.54 | 764.0 | 88.1 | 0.004 | |
| 245 | 324 | 7 | 10 | 31.4 | 1309.5 | -0.587 | -46.52 | 1273.4 | 102.8 | 0.005 | |
| 246 | 324 | 7 | 10 | 44.9 | 813.8 | 0.881 | -47.60 | 789.8 | 65.6 | 0.005 | |
| 247 | 324 | 7 | 16 | 11.2 | 1163.3 | -0.115 | -54.58 | 1130.6 | 89.8 | 0.004 | |
| 248 | 324 | 7 | 18 | 6.8 | 970.8 | 0.819 | -40.58 | 942.9 | 66.7 | 0.007 | |
| 249 | 324 | 7 | 24 | 16.1 | 1682.9 | 0.402 | -52.15 | 1638.5 | 74.0 | 0.005 | |
| 250 | 324 | 7 | 25 | 12.9 | 927.2 | 0.858 | -43.27 | 900.2 | 65.8 | 0.006 | |

**Table B-4. Detections observed by the Haystack radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 251 | 324 | 7 | 25 | 59.9 | 985.0 | -0.760 | -44.52 | 956.6 | 106.9 | 0.006 | |
| 252 | 324 | 7 | 26 | 54.0 | 1492.6 | -0.055 | -47.55 | 1452.4 | 87.8 | 0.005 | |
| 253 | 324 | 7 | 30 | 58.5 | 986.7 | 0.849 | -44.71 | 958.3 | 64.4 | 0.006 | |
| 254 | 324 | 7 | 33 | 18.9 | 970.8 | -0.145 | -54.75 | 942.8 | 90.8 | 0.004 | |
| 255 | 324 | 7 | 38 | 46.7 | 1145.9 | -0.051 | -39.48 | 1113.8 | 89.9 | 0.008 | |
| 256 | 324 | 7 | 44 | 26.8 | 1133.7 | 0.223 | -55.72 | 1101.5 | 80.8 | 0.004 | |
| 257 | 324 | 7 | 47 | 34.1 | 978.8 | -0.439 | -58.06 | 950.6 | 98.4 | 0.003 | |
| 258 | 324 | 7 | 49 | 59.5 | 691.8 | -0.308 | -58.70 | 671.2 | 95.0 | 0.003 | |
| 259 | 324 | 7 | 52 | 19.7 | 907.7 | -0.362 | -57.27 | 881.3 | 96.3 | 0.004 | |
| 260 | 324 | 7 | 58 | 42.8 | 777.8 | -0.471 | -59.45 | 754.8 | 99.0 | 0.003 | |
| 261 | 324 | 7 | 59 | 50.0 | 1004.1 | 0.807 | -55.34 | 975.3 | 66.9 | 0.004 | |
| 262 | 324 | 8 | 10 | 32.6 | 1844.6 | 0.014 | -41.11 | 1796.9 | 88.5 | 0.007 | |
| 263 | 324 | 8 | 18 | 3.5 | 665.4 | -0.445 | -45.63 | 645.5 | 98.3 | 0.006 | |
| 264 | 324 | 8 | 19 | 10.5 | 902.2 | 0.873 | -42.03 | 876.0 | 64.3 | 0.007 | |
| 265 | 324 | 8 | 24 | 8.5 | 1360.7 | 1.198 | -53.97 | 1323.4 | 50.7 | 0.004 | |
| 266 | 324 | 8 | 25 | 51.9 | 528.9 | 0.873 | -70.16 | 512.7 | 67.0 | 0.002 | |
| 267 | 324 | 8 | 30 | 27.5 | 1455.2 | 1.197 | -50.37 | 1415.7 | 51.6 | 0.005 | |
| 268 | 324 | 8 | 47 | 35.8 | 982.1 | -0.330 | -43.81 | 953.9 | 95.5 | 0.006 | |
| 269 | 324 | 8 | 50 | 19.5 | 1746.9 | -0.070 | -49.79 | 1701.3 | 87.9 | 0.005 | |
| 270 | 324 | 9 | 0 | 28.6 | 892.0 | 0.909 | -40.79 | 866.1 | 63.4 | 0.007 | |
| 271 | 324 | 9 | 2 | 26.1 | 777.4 | -0.307 | -47.30 | 754.5 | 94.9 | 0.005 | |
| 272 | 324 | 9 | 3 | 25.9 | 785.9 | 0.248 | -43.67 | 762.7 | 82.1 | 0.006 | |
| 273 | 324 | 9 | 9 | 51.6 | 891.3 | -0.387 | -44.54 | 865.3 | 97.0 | 0.006 | |
| 274 | 324 | 9 | 47 | 4.4 | 815.8 | 0.513 | -40.82 | 791.8 | 75.4 | 0.007 | 16864 |
| 275 | 324 | 9 | 53 | 45.3 | 664.5 | -0.237 | -58.66 | 644.6 | 93.3 | 0.003 | |
| 276 | 324 | 9 | 59 | 16.4 | 656.1 | 0.919 | -60.74 | 636.3 | 64.7 | 0.003 | |
| 277 | 324 | 10 | 0 | 11.7 | 817.2 | -0.405 | -54.29 | 793.2 | 97.4 | 0.004 | |
| 278 | 324 | 10 | 3 | 20.8 | 872.6 | 0.906 | -41.95 | 847.1 | 63.6 | 0.007 | |
| 279 | 324 | 10 | 4 | 36.1 | 906.3 | -0.435 | -44.98 | 879.9 | 98.2 | 0.006 | |
| 280 | 324 | 10 | 7 | 44.4 | 889.2 | -0.397 | -46.35 | 863.4 | 97.2 | 0.006 | |
| 281 | 324 | 10 | 12 | 21.9 | 664.0 | 1.149 | -38.43 | 644.1 | 58.3 | 0.009 | 29006 |
| 282 | 324 | 10 | 18 | 58.5 | 1087.0 | -0.472 | -48.69 | 1056.2 | 99.3 | 0.005 | |
| 283 | 324 | 10 | 25 | 24.7 | 749.7 | -0.386 | -50.42 | 727.4 | 96.9 | 0.005 | |
| 284 | 324 | 10 | 34 | 27.1 | 836.3 | -0.585 | -53.84 | 811.8 | 102.0 | 0.004 | |
| 285 | 324 | 10 | 35 | 32.8 | 1212.8 | 0.238 | -44.01 | 1178.9 | 80.2 | 0.006 | 8326 |
| 286 | 324 | 10 | 36 | 45.3 | 630.9 | -0.522 | -49.21 | 611.8 | 100.8 | 0.005 | |
| 287 | 324 | 10 | 40 | 35.7 | 983.0 | 0.781 | -54.61 | 954.7 | 67.7 | 0.004 | 10531 |
| 288 | 324 | 10 | 40 | 45.1 | 756.5 | 0.865 | -56.51 | 734.1 | 65.4 | 0.004 | |
| 289 | 324 | 10 | 51 | 28.8 | 863.9 | -0.419 | -47.32 | 838.6 | 97.8 | 0.005 | |
| 290 | 324 | 10 | 52 | 47.9 | 995.1 | 0.489 | -48.24 | 966.5 | 74.2 | 0.005 | |
| 291 | 324 | 10 | 55 | 30.7 | 1060.5 | 0.829 | -42.13 | 1030.2 | 66.0 | 0.007 | |
| 292 | 324 | 10 | 56 | 19.6 | 981.9 | -0.425 | -57.52 | 953.6 | 99.4 | 0.004 | |
| 293 | 324 | 10 | 58 | 7.3 | 629.4 | 0.916 | -51.30 | 610.4 | 65.5 | 0.005 | |
| 294 | 324 | 11 | 4 | 52.0 | 893.2 | -0.406 | -53.94 | 867.2 | 97.5 | 0.004 | |
| 295 | 324 | 11 | 6 | 4.0 | 950.0 | -0.592 | -50.11 | 922.5 | 103.7 | 0.005 | |
| 296 | 324 | 11 | 6 | 18.6 | 821.4 | -0.432 | -50.90 | 797.4 | 98.1 | 0.005 | |

**Table B-4. Detections observed by the Haystack radar for the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | (m) | US SSN # |
| 297 | 324 | 11 | 6 | 56.8 | 1553.7 | 0.577 | -40.95 | 1512.1 | 71.8 | 0.007 | |
| 298 | 324 | 11 | 7 | 32.0 | 1882.6 | -0.389 | -40.60 | 1834.3 | 97.6 | 0.007 | |
| 299 | 324 | 11 | 12 | 31.5 | 868.4 | -0.495 | -46.90 | 843.0 | 99.7 | 0.005 | |
| 300 | 324 | 11 | 13 | 13.7 | 847.7 | -0.463 | -45.08 | 822.9 | 98.9 | 0.006 | |
| 301 | 324 | 11 | 18 | 34.7 | 833.9 | -0.597 | -59.59 | 809.5 | 102.3 | 0.003 | |
| 302 | 324 | 11 | 21 | 29.0 | 807.8 | -0.486 | -47.92 | 783.9 | 99.4 | 0.005 | |
| 303 | 324 | 11 | 22 | 39.5 | 863.0 | -0.396 | -49.42 | 837.7 | 98.4 | 0.005 | |
| 304 | 324 | 11 | 34 | 16.1 | 925.4 | 0.866 | -45.35 | 898.6 | 64.3 | 0.006 | |
| 305 | 324 | 11 | 38 | 31.6 | 806.8 | -0.391 | -37.79 | 783.0 | 97.0 | 0.010 | |
| 306 | 324 | 11 | 40 | 13.5 | 660.6 | -0.357 | -52.60 | 640.9 | 96.2 | 0.004 | |
| 307 | 324 | 11 | 42 | 15.7 | 1185.1 | 1.194 | -45.86 | 1151.8 | 53.9 | 0.006 | |
| 308 | 324 | 11 | 42 | 53.1 | 738.2 | -0.453 | -61.55 | 716.1 | 98.6 | 0.003 | |
| 309 | 324 | 11 | 42 | 54.5 | 1858.5 | -1.091 | -49.17 | 1810.5 | 120.8 | 0.005 | |
| 310 | 324 | 11 | 43 | 35.7 | 1426.0 | 0.486 | -37.58 | 1387.2 | 72.5 | 0.010 | |
| 311 | 324 | 11 | 44 | 9.7 | 865.7 | -0.396 | -47.00 | 840.3 | 97.2 | 0.005 | |
| 312 | 324 | 11 | 48 | 15.0 | 805.1 | -0.393 | -43.93 | 781.4 | 97.1 | 0.006 | |
| 313 | 324 | 11 | 58 | 17.4 | 784.5 | -0.488 | -53.67 | 761.3 | 99.5 | 0.004 | |
| 314 | 324 | 11 | 58 | 30.1 | 771.5 | 0.274 | -46.26 | 748.8 | 80.6 | 0.006 | |
| 315 | 324 | 11 | 59 | 19.6 | 822.0 | -0.512 | -47.88 | 797.8 | 100.1 | 0.005 | |
| 316 | 324 | 12 | 4 | 42.5 | 1678.1 | 0.477 | -46.36 | 1633.8 | 74.6 | 0.006 | |
| 317 | 324 | 12 | 6 | 49.5 | 973.1 | 0.826 | -55.81 | 945.1 | 66.5 | 0.004 | |
| 318 | 324 | 12 | 10 | 53.9 | 943.8 | 0.814 | -54.18 | 916.5 | 66.9 | 0.004 | |
| 319 | 324 | 12 | 20 | 40.7 | 1403.7 | -0.427 | -45.32 | 1365.3 | 98.4 | 0.006 | |
| 320 | 324 | 12 | 21 | 29.3 | 1566.5 | -0.455 | -11.15 | 1524.7 | 99.3 | 0.312 | 7029 |
| 321 | 324 | 12 | 34 | 4.2 | 910.8 | 0.830 | -42.71 | 884.5 | 65.4 | 0.006 | |
| 322 | 324 | 12 | 38 | 36.6 | 528.2 | 1.370 | -68.24 | 512.0 | 53.5 | 0.002 | |
| 323 | 324 | 12 | 40 | 20.5 | 902.0 | 0.913 | -42.58 | 875.7 | 63.2 | 0.006 | |
| 324 | 324 | 12 | 52 | 0.9 | 547.1 | -0.391 | -49.05 | 530.5 | 97.0 | 0.005 | |
| 325 | 324 | 12 | 52 | 50.8 | 1059.2 | -0.962 | -40.79 | 1029.1 | 112.7 | 0.007 | |
| 326 | 324 | 12 | 53 | 39.4 | 771.8 | 0.909 | -44.06 | 748.9 | 64.1 | 0.006 | |
| 327 | 324 | 13 | 0 | 39.9 | 846.4 | 0.232 | -54.98 | 821.6 | 81.4 | 0.004 | |
| 328 | 324 | 13 | 5 | 14.4 | 1484.9 | 0.425 | -49.98 | 1444.8 | 76.5 | 0.005 | |

## References

[1] Stansbery, E. G., Bohannon, G., Pitts, C., Tracy, T., and Stanley, J. "Radar Observations of Small Debris." *Adv. Space Res.* Vol. 13, No. 8, pp. (8)43 - (8)48, 1993.

[2] Settecerri, T. J., Stansbery, E. G., and Hebert, T. J. *Radar Measurements of the Orbital Debris Environment: Haystack and HAX Radars October 1990 – October 1998*; NASA/JSC Publications JSC-28744, JSC-27844A, JSC-27844B; Houston TX, October 1999.

[3] Stokely, C. L., Foster Jr., J. L., Stansbery, E. G., Benbrook, J. R., and Juarez, Q. *Haystack and HAX Radar Measurements of the Orbital Debris Environment; 2003*. NASA/JSC Publication JSC-62815, Houston TX, November 2006.

# Appendix C

# Haystack Auxiliary Radar

## C.1 Introduction

The Haystack Auxiliary (HAX) radar's participation in the Inter-Agency Space Debris Coordination Committee's (IADC) 2008 24-hour campaign was sponsored by NASA. The radar was operated by the Massachusetts Institute of Technology's Lincoln Laboratory (MIT/LL). HAX began routinely supplementing Haystack observations of the orbital debris environment in 1994. The HAX radar has a shorter wavelength but transmits and collects over a much smaller antenna, giving a reduced size detection capability but increased statistics for larger objects. HAX is located approximately 100 m southeast of Haystack (see Figure C-1).

**Figure C-1. Haystack radome on the right and the smaller HAX radome on the left.**

The Haystack and HAX measurements have provided orbital debris researchers with the ability to detect small debris from previously unknown sources and the ability to examine continuous size distributions for sizes ranging from cataloged objects to objects smaller than 1 cm diameter. Historic HAX results are contained in numerous references (for example [1] and [2]).

## C.2 Experiment Setup

During the 2008 IADC 24-hour campaign, 19.0 hours of HAX data were collected with the radar pointing at 75° elevation and at an azimuth of 90°. This is the same pointing angle as Haystack. The close proximity of the two radars means that the field-of-view should essentially overlap over the data collection window. HAX is not nearly as sensitive as Haystack and does not provide many additional detections. However, by overlapping the two fields-of-view, some of the larger Haystack detections are also seen by HAX, thereby providing a second estimate of size measured at a second wavelength. The Haystack pointing angle was chosen as a compromise between maximizing the sensitivity of the radar by minimizing the slant range to an altitude and providing enough off-vertical

pointing to provide reasonable Doppler inclination resolution. Both Haystack and HAX data were collected starting at ~13:15 GMT on 18 November 2008, and running until 13:15 on 19 November.

The operating parameters for the HAX radar during the 2008 campaign are shown in Table C-1.

**Table C-1. Instrument parameters used by the HAX radar for the 2008 campaign.**

| Instrument Parameters | | |
|---|---|---|
| Geocentric latitude of sensor | 42.62 | deg |
| Geocentric longitude of sensor | -71.49 | deg |
| Geodetic altitude | 0.1157 | km |
| Wavelength | 0.0167 | m |
| Beam width for incoherent integration | 0.2 | deg |
| Antenna constant (Gain) | 64.0 | dB |
| Transmitted power (peak) | 60.0 | kW |
| Pulse period | 16.67 | msec |
| Pulse duration | 1.638 | msec |
| Desired false alarm time (Marcum) | 36000 | sec |
| Number of independent threshold decisions per pulse | 12126 | |
| Maximum number of pulses to integrate | 16 | |
| Noise equivalent RCS (NRCS) | -44.5 | dB $m^2$ |
| Transmitted power for NRCS | 43.35 | kW |
| Pulse duration for NRCS | 1.638 | msec |
| Range for NRCS | 1000 | km |

For debris observations, the radar is operated in a staring, or "beam-park," mode in which the antenna is pointed at a specified elevation and azimuth and remains there while debris objects randomly pass through the field-of-view. This operational mode provides a fixed detection volume important to the measurement of the debris flux, or number of objects detected per unit area per unit time. By operating the radar in a stare mode and not tracking detected debris objects, a precise measurement of the object's orbit is sacrificed. However, by examining the signals from the monopulse angle channels operating in an open-loop mode, position in the radar beam for each pulse can be determined. From this path through the beam, rough orbital elements are deduced.

## C.3 Processing

In the debris mode, the signal strength for each received pulse is recorded from four separate channels: the Principal Polarization (PP) sum channel, Orthogonal Polarization (OP) sum channel, Traverse Difference (TR) channel, and Elevation Difference (EL) channel (see Figure C-2). The radar data processing software determines the signal strength, signal-to-noise ratio (SNR), TR and EL voltage ratios, range and range rate. Other parameters

are derived from these measurements. For an orbiting object passing through the radar field-of-view, the key step in the data processing is determining the location of the debris object in the radar beam for each radar pulse. From these locations, the motion of the object through the beam can be recreated and used to estimate rough orbital elements. Also, the signal strength can be augmented by the relative antenna gain determined by the antenna beam-pattern calibration discussed below. Thus, the returned signal strength can be estimated as if the object were at the center of the radar beam. The radar cross section (RCS) is determined by applying the absolute radar calibration, antenna beam shape, and the range to the object.

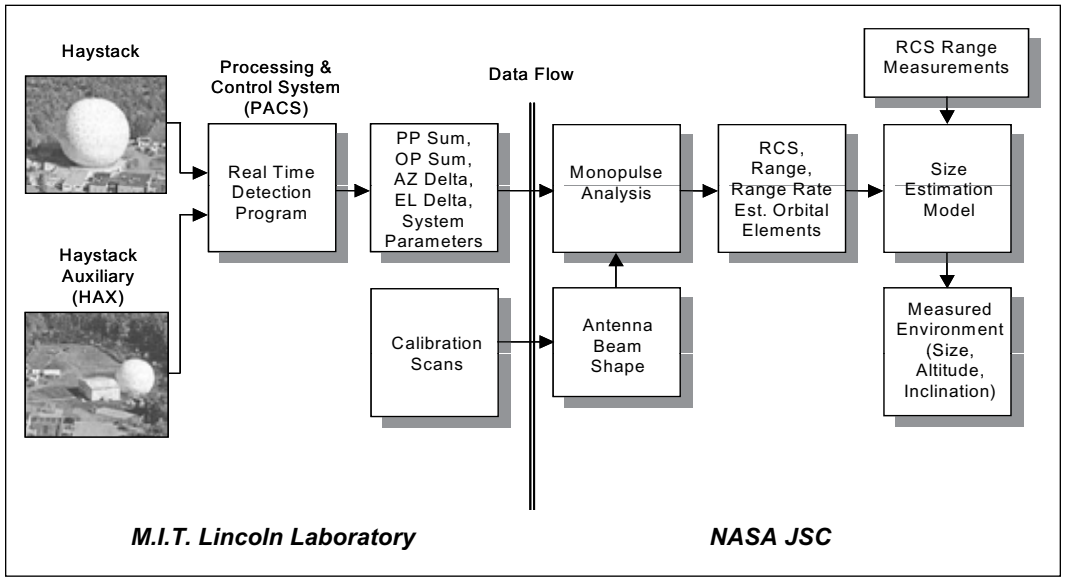


**Figure C-2. An overview of the data collection and analysis.**

The sensitivity of the antenna pattern is measured by scanning around a calibration sphere as it moves across the sky. This determines both the absolute calibration and the antenna beam pattern. Spheres return a circularly polarized signal with only a PP component. Test signals injected into the receiver preamplifiers are used to determine the absolute OP calibration.

A simple SNR threshold test is used for object detection. The noise floor varies, however, as a function of Doppler frequency. A "shape factor" representing the noise floor is subtracted from the signal emerging from the intermediate bandwidth filter. This shape factor is determined by averaging a large number of pulse returns, which do not contain a valid detection. Figure C-3 shows the shape factor associated with the digital filter.

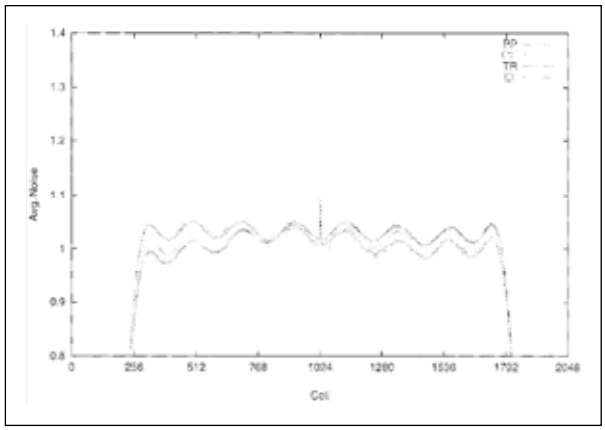


**Figure C-3. Noise floor with digital filter.**

Both the Haystack and HAX radars primarily report Doppler inclination, although the path through the beam is estimated to correct for antenna pattern loss when calculating RCS.

## C.4 Beamshape

Table C-2 contains the coefficients from which the beam intensity loss from a nominal zero dB is calculated.

The dB loss from the beam center as a function of azimuth angle, *az,* and elevation angle, *el,* away from the center, is given by:

$$Loss = \sum_{i=0}^{2} \sum_{j=0}^{2-i} Coef_{i,j} az^{i} el^{j} ,$$

where *i* and *j* are indices for the coefficients and sums but are exponents for azimuth and elevation values. Table C-2 lists the coefficients. Figure C-4 shows the RCS intensity distribution over the center of the HAX beam.

**Table C-2. Coefficients for loss factor polynomial fit.**

| | C0,0 | C0,1 | C0,2 | C1,1 | C1,2 | C2,2 |
|---|---|---|---|---|---|---|
| HAX | 0 | -8.301698 | -2056.675 | -0.065833 | 53.39635 | -2501.303 |

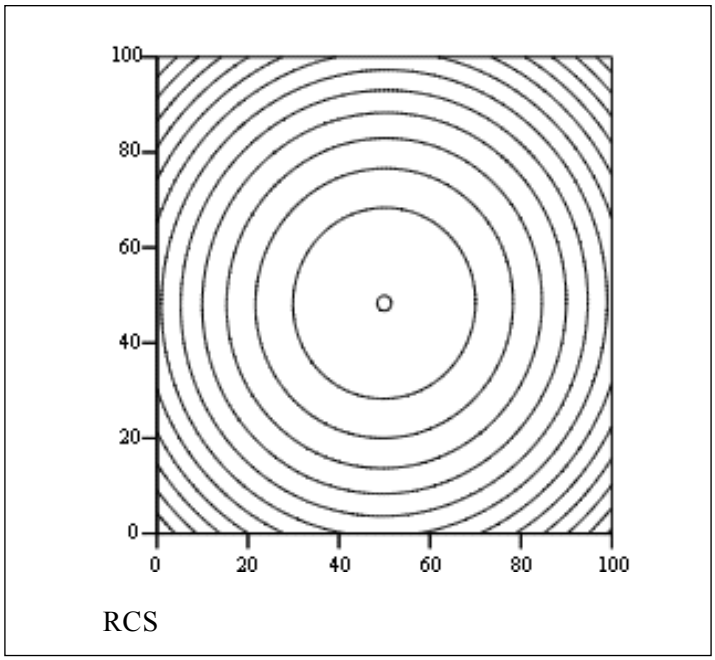


**Figure C-4. HAX RCS intensity distribution over center of beam with 1 dB contours from -0.05 to +0.05°. Geometric center at indices 50,50. Az is x axis, El is y.**

## C.5 Campaign Parameters

Table C-3 lists the campaign parameters for the 2008 IADC campaign.

**Table C-3. Campaign parameters for the HAX radar for the 2008 campaign.**

| Campaign Parameters | | |
|---|---|---|
| Campaign Start | 18 Nov 2008 13:15 GMT | |
| Maximum range | 1885 | km |
| Minimum range | 312 | km |
| Azimuth of line of site | 90 | deg |
| Elevation of line of site | 75 | deg |
| Duration of campaign | 24 | hrs |
| Total recorded data | 19.6 | hrs |

## C.6 Detection List

Table C-4 provides the list of detections observed by the HAX radar during the 2008 campaign. The column showing possible correlations with the U.S. Space Surveillance Network catalog of known objects was produced by using U.S. Air Force Space Command- provided software.

**Table C-4. Detections observed by the HAX radar for the 2008 campaign.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Doppler Inclination | Characteristic Length | Possible Correlation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/ sec) | (dBsm) | (km) | (deg) | (m) | US SSN # | | Comment |
| 1 | 324 | 4 | 25 | 58.259 | 311.7 | 4.173 | -42.51 | 301.6 | 93.1 | 0.006 | | | |
| 2 | 323 | 14 | 45 | 50.045 | 422.6 | 2.329 | -41.10 | 409.1 | 91.9 | 0.008 | | * | |
| 3 | 324 | 10 | 22 | 11.3 | 505.3 | 1.640 | -40.46 | 489.3 | 46.4 | 0.009 | | # | |
| 4 | 324 | 1 | 57 | 23.93 | 521.5 | -0.613 | -44.99 | 505.0 | 102.6 | 0.004 | | * | |
| 5 | 324 | 9 | 1 | 32.013 | 585.4 | 0.960 | -38.90 | 567.1 | 64.2 | 0.011 | | * | Haystack phase issue |
| 6 | 324 | 10 | 58 | 7.321 | 594.4 | 0.917 | -42.64 | 575.8 | 66.3 | 0.005 | | * | |
| 7 | 324 | 4 | 16 | 31.556 | 604.5 | 0.214 | -32.78 | 585.6 | 83.5 | 0.025 | 18214 | # | Haystack sidelobe detection |
| 8 | 324 | 2 | 57 | 39.554 | 608.9 | -0.322 | -42.30 | 589.9 | 94.9 | 0.006 | | * | |
| 9 | 324 | 11 | 52 | 42.36 | 652.7 | 0.210 | 2.86 | 632.4 | 83.6 | 1.568 | 18153 | | |
| 10 | 324 | 10 | 12 | 21.882 | 653.9 | 1.148 | -41.35 | 633.7 | 59.8 | 0.007 | 29006 | * | |
| 11 | 324 | 5 | 41 | 27.601 | 674.5 | -2.716 | -42.04 | 653.5 | 121.0 | 0.006 | | | |
| 12 | 323 | 23 | 2 | 12.332 | 747.7 | 1.547 | -38.22 | 724.7 | 46.8 | 0.012 | 25114 | * | Below Haystack threshold |
| 13 | 324 | 3 | 6 | 58.798 | 770.2 | 0.592 | -37.20 | 746.6 | 72.5 | 0.014 | 19102 | * | |
| 14 | 323 | 14 | 5 | 55.714 | 799.3 | 0.621 | -37.35 | 774.9 | 73.2 | 0.014 | 15482 | # | Haystack sidelobe detection |
| 15 | 324 | 9 | 47 | 4.045 | 813.4 | 0.495 | -24.41 | 788.7 | 74.7 | 0.068 | 16864 | * | |
| 16 | 323 | 14 | 29 | 25.584 | 900.8 | -0.261 | -33.43 | 873.6 | 95.3 | 0.023 | | * | |
| 17 | 324 | 11 | 56 | 2.111 | 906.9 | -0.415 | -26.75 | 879.7 | 99.1 | 0.052 | | | |
| 18 | 324 | 1 | 28 | 37.96 | 927.7 | 0.025 | -36.30 | 899.8 | 86.1 | 0.016 | | * | |
| 19 | 323 | 21 | 33 | 57.449 | 936.2 | -0.528 | -31.36 | 908.1 | 100.1 | 0.030 | 30656 | | |
| 20 | 324 | 4 | 0 | 13.371 | 940.7 | -0.297 | -33.04 | 912.7 | 94.2 | 0.024 | | * | |
| 21 | 324 | 6 | 57 | 37.282 | 972.7 | -0.318 | -38.19 | 943.7 | 96.8 | 0.012 | | * | |
| 22 | 323 | 21 | 34 | 13.182 | 1026.2 | 0.641 | -6.91 | 995.8 | 69.9 | 0.509 | | | |
| 23 | 323 | 18 | 24 | 30.368 | 1045.3 | -0.529 | -26.69 | 1014.1 | 102.5 | 0.052 | 4992 | # | |
| 24 | 323 | 19 | 20 | 32.608 | 1075.1 | 0.664 | -34.14 | 1043.4 | 71.3 | 0.021 | | | |
| 25 | 323 | 15 | 19 | 42.499 | 1186.3 | 0.936 | -24.26 | 1151.8 | 63.0 | 0.069 | | | |
| 26 | 324 | 10 | 35 | 32.785 | 1211.0 | 0.239 | -21.01 | 1175.9 | 80.0 | 0.100 | 8326 | * | |
| 27 | 323 | 14 | 8 | 9.814 | 1227.7 | 0.063 | -9.28 | 1192.1 | 87.3 | 0.388 | 15935 | * | Haystack noise spike |
| 28 | 323 | 21 | 39 | 6.066 | 1232.7 | -2.721 | -33.60 | 1197.1 | 128.6 | 0.022 | | | |
| 29 | 324 | 7 | 30 | 25.253 | 1536.8 | 0.529 | -11.28 | 1493.9 | 73.9 | 0.308 | 16451 | # | |
| 30 | 323 | 21 | 34 | 55.249 | 1546.4 | 0.410 | -17.80 | 1503.6 | 77.4 | 0.145 | 14999 | | |
| 31 | 324 | 12 | 21 | 29.281 | 1564.1 | -0.455 | -9.55 | 1521.0 | 102.1 | 0.376 | 7029 | * | |
| | | | | | | | | | | | | | |
| * Seen by Haystack simultaneously | | | | | | | | | | | | | |
| # Seen by Haystack but past the 1/2 power contour | | | | | | | | | | | | | |

## References

[1] Settecerri, T. J., Stansbery, E. G., and Hebert, T. J. *Radar Measurements of the Orbital Debris Environment: Haystack and HAX Radars October 1990 – October 1998*; NASA/ JSC Publications JSC-28744, JSC-27844A, JSC-27844B; Houston TX, October 1999.

[2] Stokely, C. L., Foster Jr., J. L., Stansbery, E. G., Benbrook, J. R., and Juarez, Q. *Haystack and HAX Radar Measurements of the Orbital Debris Environment; 2003*. NASA/ JSC Publication JSC-62815, Houston TX, November 2006.

# Appendix D

# Cobra Dane Radar

## D.1 Introduction

The AN/FPS-108 Cobra Dane radar is located on Shemya Island, Alaska at 52.7° N latitude, and 174.1° E longitude, and is operated by the U.S. Department of Defense. As such, some of the parameters associated with the operation of the radar are not available to the general public.

## D.2 Experiment Setup

Cobra Dane (Figure D-1) is an L-band (23-cm wavelength) phased-array radar, which first became operational in 1977. The radar generates approximately 15.4 MW of peak RF power (0.92 MW average) from 96 Traveling Wave Tube (TWT) amplifiers arranged in 12 groups of 8. This power is radiated through 15,360 active array elements. The face of the radar is aligned at an azimuth of 319°, true.

**Figure D-1. Cobra Dane phased array radar.**

The Cobra Dane is different from the pencil-beam radars in that it is an electronically steered, phased-array radar. This means that the antenna beam can be instantaneously moved within some angular limits. What is typically done with phased-array radars is to rapidly move the beam in a long, narrow pattern to create a virtual fan beam, or fence. If

each individual beam position in the fence is revisited often enough that orbiting objects cannot travel the width of the fence between revisits, then the fence is referred to as a "leak-proof" fence. While maintaining the fence, some radar time and transmit power is typically allocated for tracking objects detected by the fence. The instrument parameters for Cobra Dane used in the 2008 campaign are shown in Table D-1.

**Table D-1. Instrument parameters for the Cobra Dane radar used during the 2008 campaign.**

| Instrument Parameters | | |
|---|---|---|
| Geocentric latitude of sensor | 52.737 | deg |
| Geocentric longitude of sensor | 174.091 | deg |
| Geodetic altitude | 0.091 | km |
| Wavelength | 0.23 | m |
| Beam width (fence) | 0.6 x 40 | deg |
| Antenna constant (Gain) | unavailable | |
| Transmitted power (peak) | 15.4 | MW |
| Pulse period | varies | msec |
| Pulse duration | 1.5 | msec |
| Desired false alarm time (Marcum) | unavailable | |
| Number of independent threshold decisions per pulse | unavailable | |
| Maximum number of pulses to integrate | unavailable | |
| Noise equivalent RCS (NRCS) | unavailable | |
| Transmitted power for NRCS | unavailable | |
| Pulse duration for NRCS | unavailable | |
| Range for NRCS | unavailable | |

## D.3 Data Collection

Cobra Dane operated for 24 hours from ~00:00:00 GMT on 17 November to 00:00:00 GMT on 18 November 2008. During the campaign, a 40°-wide fence at an elevation angle of 50.3° and covering the azimuth range from 299° – 339° was erected. The fence was one beamwidth wide, or 0.6°. The radar detected objects crossing this fence at slant ranges from 415 – 2501 km. A 1500-µsec pulse was used for detection. Objects passing through the fence were checked against known objects in the U.S. Space Surveillance Network (SSN) catalog (including analyst, or 80,000 series satellites). If the detection was correlated with a known object, then no further tracking was done. In this way, radar resources (time and transmit power) could be conserved for use with UCTs. UCTs detected crossing the fence would be tracked to estimate orbital elements and to acquire RCS information. Campaign parameters for Cobra Dane during the 2008 campaign are shown in Table D-2.

It should be noted that RCS data for the uncorrelated targets are missing for about 2 hours.

**Table D-2. Campaign parameters for the Cobra Dane radar used during the 2008 campaign.**

| Campaign Parameters | | |
|---|---|---|
| Campaign Start | 17 Nov 2008 00:00 GMT | |
| Maximum range | 2501 | km |
| Minimum range | 415 | km |
| Azimuth of line of site | 299 - 339 | deg |
| Elevation of line of site | 50.3 | deg |
| Duration of campaign | 24 | hrs |
| Total recorded data | 24 (22 RCS) | hrs |

## D.4 Detection List

Table D-3 provides the list of detections of uncorrelated objects observed by the Cobra Dane radar during the 2008 campaign. In order to conserve radar resources for a leak-proof fence, only objects that did not correlate to the USSPACECOM catalog were tracked and recorded.

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 1 | 322 | 0 | 1 | 29.3 | 1680.5 | 5.315 | -19.399 | 738.3 | 98.5 | 0.060 | 0.087 |
| 2 | 322 | 0 | 1 | 54.3 | 1366.4 | -1.418 | -31.738 | 620.5 | 99.1 | 0.017 | 0.037 |
| 3 | 322 | 0 | 3 | 40.3 | 1520.8 | -1.173 | -18.773 | 551.5 | 99.1 | 0.022 | 0.101 |
| 4 | 322 | 0 | 4 | 17.3 | 1128.9 | -1.454 | -26.918 | 681.9 | 98.8 | 0.025 | 0.045 |
| 5 | 322 | 0 | 5 | 22.2 | 2065.7 | 5.893 | -19.433 | 492.9 | 99.7 | 0.061 | 0.086 |
| 6 | 322 | 0 | 5 | 22.0 | 1379.0 | 4.896 | -26.598 | 866.4 | 98.0 | 0.021 | 0.046 |
| 7 | 322 | 0 | 6 | 35.3 | 1656.4 | -0.906 | -19.363 | 1003.4 | 98.6 | 0.149 | 0.089 |
| 8 | 322 | 0 | 7 | 53.0 | 730.0 | -1.121 | -26.028 | 563.9 | 99.3 | 0.002 | 0.047 |
| 9 | 322 | 0 | 8 | 6.3 | 1405.7 | -1.224 | -24.658 | 677.8 | 99.1 | 0.028 | 0.050 |
| 10 | 322 | 0 | 9 | 46.0 | 2001.6 | 5.157 | -19.730 | 851.9 | 98.0 | 0.024 | 0.080 |
| 11 | 322 | 0 | 9 | 52.3 | 798.0 | -1.559 | -20.025 | 495.7 | 99.2 | 0.026 | 0.076 |
| 12 | 322 | 0 | 10 | 59.0 | 950.5 | -1.740 | -35.257 | 554.4 | 98.6 | 0.007 | 0.033 |
| 13 | 322 | 0 | 11 | 30.3 | 1394.8 | 3.253 | -20.838 | 1056.9 | 90.2 | 0.009 | 0.067 |
| 14 | 322 | 0 | 14 | 23.3 | 1128.1 | 0.962 | -21.540 | 831.2 | 70.1 | 0.012 | 0.062 |
| 15 | 322 | 0 | 15 | 29.3 | 1095.7 | -1.957 | -24.111 | 400.2 | | | 0.051 |
| 16 | 322 | 0 | 17 | 2.3 | 1551.1 | -3.950 | -20.726 | 1001.9 | 82.1 | 0.050 | 0.068 |
| 17 | 322 | 0 | 17 | 23.3 | 696.7 | -1.344 | -30.387 | 501.4 | 99.2 | 0.030 | 0.039 |
| 18 | 322 | 0 | 18 | 38.3 | 1403.2 | 4.844 | -22.195 | 863.3 | 98.2 | 0.009 | 0.058 |
| 19 | 322 | 0 | 20 | 15.0 | 2266.1 | 0.197 | -18.096 | 575.6 | 99.1 | 0.024 | 0.115 |
| 20 | 322 | 0 | 22 | 20.3 | 1072.3 | 5.061 | -21.178 | 662.9 | 98.0 | 0.003 | 0.064 |
| 21 | 322 | 0 | 30 | 26.3 | 1503.6 | -1.127 | -18.899 | 559.1 | 99.1 | 0.023 | 0.100 |
| 22 | 322 | 0 | 31 | 25.3 | 2425.7 | 0.151 | -17.605 | 540.4 | | | 0.123 |
| 23 | 322 | 0 | 32 | 40.4 | 999.5 | -1.718 | -19.427 | 500.7 | 99.2 | 0.027 | 0.086 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 24 | 322 | 0 | 32 | 45.5 | 2319.3 | -0.486 | -16.027 | 1605.7 | 101.1 | 0.031 | 0.159 |
| 25 | 322 | 0 | 32 | 50.3 | 2119.8 | -0.225 | -19.242 | 804.8 | 99.5 | 0.007 | 0.093 |
| 26 | 322 | 0 | 33 | 47.3 | 1720.6 | -3.858 | -24.748 | 989.3 | 82.8 | 0.007 | 0.049 |
| 27 | 322 | 0 | 35 | 51.3 | 2115.3 | 3.617 | -18.630 | 1474.3 | 99.3 | 0.068 | 0.103 |
| 28 | 322 | 0 | 35 | 59.5 | 1699.0 | -0.918 | -20.984 | 623.1 | 99.3 | 0.019 | 0.066 |
| 29 | 322 | 0 | 36 | 15.5 | 1639.2 | -0.951 | -18.798 | 850.2 | 99.9 | 0.006 | 0.101 |
| 30 | 322 | 0 | 36 | 37.3 | 635.3 | -1.553 | -19.772 | 470.7 | 98.1 | 0.019 | 0.080 |
| 31 | 322 | 0 | 37 | 0.5 | 1427.1 | -1.283 | -22.909 | 797.2 | 99.8 | 0.010 | 0.055 |
| 32 | 322 | 0 | 38 | 15.3 | 1739.6 | 2.575 | -19.819 | 950.2 | 83.2 | 0.020 | 0.079 |
| 33 | 322 | 0 | 40 | 45.5 | 1220.2 | -3.450 | -26.561 | 898.8 | 83.1 | 0.004 | 0.046 |
| 34 | 322 | 0 | 40 | 47.0 | 1145.6 | 3.951 | -28.668 | 872.5 | 98.0 | 0.027 | 0.043 |
| 35 | 322 | 0 | 41 | 44.3 | 1784.1 | -0.956 | -15.731 | 1037.0 | 65.0 | 0.385 | 0.165 |
| 36 | 322 | 0 | 41 | 58.5 | 884.7 | -1.200 | -35.708 | 701.4 | 98.9 | 0.021 | 0.032 |
| 37 | 322 | 0 | 42 | 10.3 | 1930.8 | -3.792 | -15.333 | 682.9 | 65.0 | 0.009 | 0.174 |
| 38 | 322 | 0 | 44 | 2.5 | 1704.2 | -0.845 | -17.727 | 544.8 | 99.1 | 0.021 | 0.120 |
| 39 | 322 | 0 | 44 | 10.3 | 845.2 | -1.319 | -21.785 | 628.0 | 99.5 | 0.016 | 0.060 |
| 40 | 322 | 0 | 44 | 45.5 | 1314.7 | -1.523 | -25.266 | 790.4 | 98.6 | 0.001 | 0.048 |
| 41 | 322 | 0 | 44 | 51.3 | 1650.6 | -1.028 | -19.619 | 656.3 | 98.9 | 0.027 | 0.082 |
| 42 | 322 | 0 | 45 | 28.3 | 1793.7 | -0.776 | -22.190 | 712.5 | 98.8 | 0.030 | 0.058 |
| 43 | 322 | 0 | 47 | 47.0 | 849.5 | -1.566 | -25.169 | 490.4 | 99.2 | 0.027 | 0.048 |
| 44 | 322 | 0 | 49 | 54.0 | 1825.5 | 3.706 | -22.170 | 1479.6 | 99.1 | 0.081 | 0.058 |
| 45 | 322 | 0 | 51 | 18.3 | 2085.6 | -0.142 | -18.354 | 553.8 | 99.0 | 0.023 | 0.110 |
| 46 | 322 | 0 | 52 | 38.3 | 1676.0 | 4.572 | -21.317 | 1138.7 | 102.2 | 0.006 | 0.063 |
| 47 | 322 | 0 | 53 | 56.2 | 1585.6 | -1.089 | -18.771 | 692.6 | 98.9 | 0.023 | 0.101 |
| 48 | 322 | 0 | 54 | 0.3 | 1506.9 | 5.728 | -21.748 | 586.6 | 97.8 | 0.040 | 0.061 |
| 49 | 322 | 0 | 57 | 40.3 | 2141.6 | 4.925 | -19.181 | 1004.5 | 100.0 | 0.062 | 0.095 |
| 50 | 322 | 0 | 59 | 27.3 | 1567.8 | 5.287 | -20.435 | 738.7 | 98.0 | 0.018 | 0.071 |
| 51 | 322 | 1 | 0 | 19.0 | 1798.9 | 3.957 | -21.406 | 1372.5 | 101.9 | 0.012 | 0.063 |
| 52 | 322 | 1 | 0 | 46.3 | 1071.9 | -1.520 | -29.739 | 693.7 | | | 0.040 |
| 53 | 322 | 1 | 1 | 54.3 | 1874.4 | 1.947 | -22.227 | 874.0 | 81.3 | 0.003 | 0.058 |
| 54 | 322 | 1 | 3 | 0.3 | 2074.2 | 5.080 | -18.236 | 789.9 | 98.9 | 0.069 | 0.112 |
| 55 | 322 | 1 | 5 | 26.3 | 1104.3 | -1.445 | -29.095 | 696.9 | 98.9 | 0.021 | 0.041 |
| 56 | 322 | 1 | 6 | 2.3 | 2364.2 | 1.646 | -16.589 | 1811.4 | 82.6 | 0.032 | 0.149 |
| 57 | 322 | 1 | 7 | 35.3 | 1181.8 | 3.764 | -28.13 | 923.5 | 97.9 | 0.024 | 0.043 |
| 58 | 322 | 1 | 8 | 28.3 | 2055.6 | -0.426 | -17.699 | 824.2 | 99.3 | 0.025 | 0.121 |
| 59 | 322 | 1 | 9 | 46.3 | 1757.3 | -0.826 | -19.367 | 491.5 | 99.2 | 0.043 | 0.089 |
| 60 | 322 | 1 | 11 | 30.0 | 1346.3 | 2.616 | -25.641 | 1021.8 | 83.0 | 0.004 | 0.047 |
| 61 | 322 | 1 | 12 | 2.3 | 1349.1 | 2.833 | -21.853 | 924.0 | 83.0 | 0.005 | 0.060 |
| 62 | 322 | 1 | 15 | 49.3 | 1979.2 | -3.017 | -18.61 | 1504.7 | 82.7 | 0.004 | 0.104 |
| 63 | 322 | 1 | 16 | 8.3 | 1021.5 | 4.214 | -25.656 | 778.7 | 97.9 | 0.015 | 0.047 |
| 64 | 322 | 1 | 16 | 11.3 | 1782.4 | 5.122 | -22.199 | 850.5 | 98.3 | 0.009 | 0.058 |
| 65 | 322 | 1 | 17 | 2.3 | 700.3 | -1.361 | -18.706 | 470.6 | 99.3 | 0.028 | 0.102 |
| 66 | 322 | 1 | 19 | 32.3 | 1111.4 | -1.410 | -23.929 | 663.7 | 99.0 | 0.032 | 0.052 |
| 67 | 322 | 1 | 20 | 16.3 | 1748.6 | 4.105 | -19.437 | 1289.1 | 99.5 | 0.033 | 0.085 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 68 | 322 | 1 | 20 | 33.5 | 1303.2 | -1.382 | -29.020 | 539.3 | 99.5 | 0.011 | 0.041 |
| 69 | 322 | 1 | 20 | 42.3 | 1689.3 | -0.850 | -19.278 | 567.4 | 99.1 | 0.025 | 0.092 |
| 70 | 322 | 1 | 24 | 47.0 | 1482.0 | 5.085 | -19.122 | 843.2 | 98.4 | 0.015 | 0.096 |
| 71 | 322 | 1 | 26 | 3.3 | 1209.7 | 2.877 | -21.741 | 764.7 | 81.2 | 0.003 | 0.061 |
| 72 | 322 | 1 | 26 | 6.3 | 1289.2 | 4.892 | -20.412 | 881.2 | 99.9 | 0.055 | 0.071 |
| 73 | 322 | 1 | 27 | 11.3 | 1398.9 | 5.026 | -22.608 | 829.1 | 98.4 | 0.016 | 0.056 |
| 74 | 322 | 1 | 30 | 44.3 | 1897.7 | 5.560 | -17.844 | 589.2 | 97.8 | 0.038 | 0.118 |
| 75 | 322 | 1 | 31 | 46.0 | 1546.1 | 3.928 | -20.587 | 1140.8 | 98.9 | 0.026 | 0.069 |
| 76 | 322 | 1 | 32 | 20.0 | 1651.3 | 5.911 | -24.086 | 466.6 | 98.9 | 0.005 | 0.051 |
| 77 | 322 | 1 | 32 | 55.3 | 1352.4 | -1.472 | -21.093 | 640.7 | 98.8 | 0.015 | 0.065 |
| 78 | 322 | 1 | 38 | 30.3 | 1527.8 | 5.219 | -19.378 | 858.3 | 98.3 | 0.044 | 0.089 |
| 79 | 322 | 1 | 39 | 25.3 | 1449.5 | -1.149 | -17.012 | 543.7 | 99.2 | 0.028 | 0.140 |
| 80 | 322 | 1 | 42 | 53.3 | 2321.0 | 0.372 | -17.476 | 552.6 | 99.0 | 0.034 | 0.125 |
| 81 | 322 | 1 | 43 | 19.3 | 1572.0 | 5.005 | -21.820 | 794.4 | 97.7 | 0.023 | 0.060 |
| 82 | 322 | 1 | 46 | 28.5 | 2068.1 | -0.065 | -19.262 | 498.7 | 99.1 | 0.028 | 0.093 |
| 83 | 322 | 1 | 46 | 33.3 | 2194.6 | 4.405 | -17.421 | 1326.9 | 99.0 | 0.038 | 0.129 |
| 84 | 322 | 1 | 47 | 10.2 | 1050.6 | -1.670 | -24.845 | 472.2 | 99.5 | 0.025 | 0.049 |
| 85 | 322 | 1 | 48 | 47.3 | 2066.0 | 3.516 | -22.005 | 1616.9 | 103.0 | 0.036 | 0.059 |
| 86 | 322 | 1 | 49 | 35.3 | 1961.6 | 5.177 | -19.597 | 835.3 | 98.5 | 0.015 | 0.083 |
| 87 | 322 | 1 | 51 | 23.3 | 836.5 | -1.050 | -26.799 | 690.5 | 99.9 | 0.014 | 0.045 |
| 88 | 322 | 1 | 53 | 19.3 | 1715.1 | 4.493 | -23.139 | 1243.7 | | | 0.054 |
| 89 | 322 | 1 | 54 | 56.3 | 1130.0 | 4.012 | -20.103 | 876.9 | 98.7 | 0.008 | 0.075 |
| 90 | 322 | 1 | 55 | 51.3 | 1580.4 | 5.692 | -21.783 | 558.5 | 97.6 | 0.028 | 0.060 |
| 91 | 322 | 1 | 56 | 25.3 | 1185.0 | 4.160 | -21.953 | 889.9 | 98.0 | 0.005 | 0.059 |
| 92 | 322 | 1 | 57 | 28.3 | 895.8 | -2.509 | -22.674 | 734.2 | 56.9 | 0.324 | 0.056 |
| 93 | 322 | 1 | 58 | 10.3 | 2095.4 | 4.282 | -19.426 | 1323.4 | 98.8 | 0.031 | 0.086 |
| 94 | 322 | 1 | 58 | 16.3 | 1445.1 | 4.582 | -23.627 | 903.5 | 98.0 | 0.022 | 0.052 |
| 95 | 322 | 2 | 0 | 7.3 | 1251.2 | 5.007 | -26.827 | 789.3 | 100.0 | 0.003 | 0.045 |
| 96 | 322 | 2 | 0 | 30.3 | 1514.5 | -3.999 | -21.880 | 897.5 | 82.7 | 0.006 | 0.060 |
| 97 | 322 | 2 | 1 | 1.3 | 2495.2 | 0.436 | -14.555 | 858.6 | 98.8 | 0.155 | 0.197 |
| 98 | 322 | 2 | 1 | 27.3 | 1607.5 | -4.093 | -23.889 | 908.1 | 82.9 | 0.008 | 0.052 |
| 99 | 322 | 2 | 2 | 29.0 | 1624.9 | 5.473 | -24.026 | 775.7 | 98.6 | 0.045 | 0.051 |
| 100 | 322 | 2 | 4 | 53.5 | 1675.2 | -0.869 | -19.347 | 751.9 | 99.8 | 0.011 | 0.090 |
| 101 | 322 | 2 | 5 | 16.3 | 1777.2 | 5.236 | -19.894 | 735.1 | 97.4 | 0.022 | 0.078 |
| 102 | 322 | 2 | 6 | 23.3 | 870.1 | 4.997 | -24.973 | 588.0 | 98.3 | 0.040 | 0.049 |
| 103 | 322 | 2 | 6 | 57.5 | 1592.5 | -1.724 | -20.870 | 1219.7 | 99.4 | 0.137 | 0.067 |
| 104 | 322 | 2 | 8 | 46.3 | 2276.1 | -0.353 | -14.581 | 918.3 | 98.4 | 0.012 | 0.196 |
| 105 | 322 | 2 | 8 | 59.3 | 2273.3 | -0.076 | -19.397 | 970.2 | | | 0.087 |
| 106 | 322 | 2 | 10 | 9.3 | 2127.0 | 5.296 | -16.198 | 512.4 | 97.5 | 0.028 | 0.157 |
| 107 | 322 | 2 | 11 | 8.3 | 1852.0 | 5.217 | -19.228 | 685.8 | 97.6 | 0.019 | 0.094 |
| 108 | 322 | 2 | 11 | 29.3 | 1288.1 | -1.268 | -25.389 | 725.4 | 99.9 | 0.013 | 0.048 |
| 109 | 322 | 2 | 12 | 3.0 | 1853.9 | 5.158 | -23.746 | 844.4 | 98.7 | 0.017 | 0.052 |
| 110 | 322 | 2 | 13 | 10.3 | 1024.5 | -1.527 | -20.146 | 468.3 | 99.4 | 0.026 | 0.075 |
| 111 | 322 | 2 | 15 | 17.2 | 1528.8 | -1.012 | -19.695 | 344.3 | 99.2 | 0.030 | 0.081 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 112 | 322 | 2 | 15 | 16.3 | 1122.4 | 5.695 | -29.765 | 500.1 | 96.8 | 0.012 | 0.040 |
| 113 | 322 | 2 | 15 | 24.3 | 2241.7 | -3.376 | -19.384 | 1711.0 | | | 0.088 |
| 114 | 322 | 2 | 15 | 50.0 | 1261.3 | 1.507 | -24.761 | 778.1 | 74.1 | 0.001 | 0.049 |
| 115 | 322 | 2 | 17 | 33.3 | 1319.4 | 5.607 | -20.064 | 650.9 | 97.9 | 0.035 | 0.076 |
| 116 | 322 | 2 | 18 | 42.3 | 1754.9 | 4.414 | -22.329 | 1225.8 | 99.4 | 0.043 | 0.057 |
| 117 | 322 | 2 | 19 | 43.9 | 1696.1 | -1.018 | -17.067 | 822.3 | 99.1 | 0.003 | 0.138 |
| 118 | 322 | 2 | 20 | 5.3 | 1905.2 | 4.704 | -18.023 | 1046.3 | 98.3 | 0.029 | 0.116 |
| 119 | 322 | 2 | 23 | 14.5 | 1209.2 | -1.415 | -14.716 | 710.1 | 99.0 | 0.026 | 0.191 |
| 120 | 322 | 2 | 23 | 14.3 | 1318.1 | 4.638 | -22.939 | 896.2 | 100.0 | 0.007 | 0.055 |
| 121 | 322 | 2 | 24 | 55.0 | 1236.9 | 5.655 | -27.604 | 581.0 | 97.4 | 0.024 | 0.044 |
| 122 | 322 | 2 | 25 | 25.3 | 1126.5 | -1.680 | -17.655 | 507.7 | 98.9 | 0.012 | 0.122 |
| 123 | 322 | 2 | 25 | 39.3 | 1909.5 | -0.445 | -19.376 | 507.0 | 99.1 | 0.039 | 0.089 |
| 124 | 322 | 2 | 26 | 28.0 | 1851.0 | 4.721 | -21.830 | 1017.2 | 98.9 | 0.019 | 0.060 |
| 125 | 322 | 2 | 27 | 19.3 | 2046.8 | 5.158 | -19.375 | 842.2 | 98.6 | 0.014 | 0.089 |
| 126 | 322 | 2 | 27 | 52.3 | 2183.8 | 4.416 | -19.451 | 1249.5 | 99.0 | 0.025 | 0.085 |
| 127 | 322 | 2 | 28 | 1.3 | 1558.0 | -1.413 | -26.112 | 472.7 | 97.8 | 0.000 | 0.047 |
| 128 | 322 | 2 | 29 | 15.0 | 1708.3 | 5.203 | -19.981 | 851.0 | 98.7 | 0.011 | 0.077 |
| 129 | 322 | 2 | 29 | 18.3 | 1444.3 | 4.341 | -22.480 | 1080.7 | 99.7 | 0.041 | 0.057 |
| 130 | 322 | 2 | 35 | 6.3 | 1469.4 | 5.036 | -24.691 | 833.5 | 97.9 | 0.009 | 0.050 |
| 131 | 322 | 2 | 35 | 30.5 | 2349.3 | 0.266 | -17.678 | 694.5 | 98.8 | 0.021 | 0.121 |
| 132 | 322 | 2 | 35 | 34.3 | 1260.6 | -0.050 | -19.853 | 931.1 | 65.9 | 0.009 | 0.078 |
| 133 | 322 | 2 | 36 | 57.3 | 1793.8 | 5.356 | -23.259 | 750.2 | | | 0.054 |
| 134 | 322 | 2 | 40 | 50.0 | 1729.8 | 4.515 | -21.319 | 1067.5 | 98.8 | 0.019 | 0.063 |
| 135 | 322 | 2 | 42 | 50.5 | 1366.2 | -3.797 | -26.493 | 917.2 | 82.7 | 0.005 | 0.046 |
| 136 | 322 | 2 | 42 | 55.3 | 1778.3 | 5.101 | -22.005 | 873.3 | 99.3 | 0.018 | 0.059 |
| 137 | 322 | 2 | 43 | 25.3 | 687.8 | 4.674 | -20.100 | 503.0 | 97.8 | 0.007 | 0.075 |
| 138 | 322 | 2 | 48 | 25.3 | 1917.2 | -0.504 | -17.775 | 573.6 | 98.8 | 0.016 | 0.119 |
| 139 | 322 | 2 | 49 | 30.3 | 1770.9 | 4.206 | -21.642 | 1181.5 | 98.6 | 0.023 | 0.061 |
| 140 | 322 | 2 | 53 | 43.3 | 2071.0 | -0.050 | -18.162 | 544.7 | 99.3 | 0.024 | 0.114 |
| 141 | 322 | 2 | 54 | 11.3 | 1222.6 | 4.173 | -23.533 | 883.6 | 98.2 | 0.026 | 0.053 |
| 142 | 322 | 2 | 56 | 1.3 | 1149.6 | 5.908 | -19.558 | 503.3 | 97.6 | 0.028 | 0.083 |
| 143 | 322 | 3 | 1 | 13.3 | 1694.9 | 4.822 | -19.948 | 957.7 | 99.0 | 0.016 | 0.077 |
| 144 | 322 | 3 | 1 | 32.3 | 1343.9 | 3.987 | -27.492 | 1041.7 | 100.1 | 0.002 | 0.044 |
| 145 | 322 | 3 | 2 | 16.3 | 1776.3 | 3.685 | -22.274 | 1407.7 | 101.3 | 0.009 | 0.058 |
| 146 | 322 | 3 | 2 | 19.3 | 2093.0 | -3.168 | -17.576 | 1541.9 | 82.5 | 0.017 | 0.123 |
| 147 | 322 | 3 | 2 | 52.3 | 1805.6 | 4.525 | -20.591 | 1106.4 | 98.2 | 0.039 | 0.069 |
| 148 | 322 | 3 | 3 | 4.0 | 1665.7 | 4.692 | -21.42 | 971.6 | 99.1 | 0.027 | 0.063 |
| 149 | 322 | 3 | 6 | 3.3 | 1007.8 | 0.369 | -24.566 | 810.1 | 65.0 | 0.002 | 0.050 |
| 150 | 322 | 3 | 7 | 41.0 | 1447.2 | 4.794 | -23.372 | 849.2 | 98.1 | 0.026 | 0.053 |
| 151 | 322 | 3 | 7 | 59.3 | 1016.9 | 0.314 | -25.506 | 809.2 | 65.0 | 0.001 | 0.048 |
| 152 | 322 | 3 | 9 | 7.3 | 1304.5 | -4.917 | -30.593 | 799.4 | 75.7 | 0.012 | 0.039 |
| 153 | 322 | 3 | 9 | 25.3 | 1256.4 | 3.985 | -24.777 | 956.1 | 99.1 | 0.020 | 0.049 |
| 154 | 322 | 3 | 9 | 39.3 | 1026.0 | 0.293 | -25.356 | 808.1 | 65.0 | 0.002 | 0.048 |
| 155 | 322 | 3 | 10 | 48.3 | 1044.0 | 0.242 | -26.750 | 805.9 | 65.0 | 0.002 | 0.045 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 156 | 322 | 3 | 11 | 16.3 | 1317.5 | 4.702 | -19.984 | 867.0 | 98.6 | 0.005 | 0.077 |
| 157 | 322 | 3 | 11 | 35.3 | 1470.0 | 5.151 | -19.710 | 795.1 | 99.2 | 0.039 | 0.081 |
| 158 | 322 | 3 | 12 | 0.3 | 1054.8 | 0.178 | -26.604 | 807.1 | 65.0 | 0.003 | 0.046 |
| 159 | 322 | 3 | 13 | 53.5 | 1037.4 | -1.459 | -18.473 | 670.7 | 100.1 | 0.014 | 0.107 |
| 160 | 322 | 3 | 13 | 55.3 | 1901.7 | 5.554 | -20.556 | 533.6 | | | 0.070 |
| 161 | 322 | 3 | 15 | 11.3 | 1063.8 | 0.164 | -26.387 | 809.1 | 65.0 | 0.002 | 0.046 |
| 162 | 322 | 3 | 15 | 29.3 | 1018.1 | 6.296 | -34.424 | 397.1 | 98.1 | 0.057 | 0.034 |
| 163 | 322 | 3 | 15 | 51.0 | 1769.8 | 5.332 | -19.672 | 703.5 | 97.9 | 0.007 | 0.081 |
| 164 | 322 | 3 | 16 | 40.3 | 1070.8 | 0.146 | -25.169 | 808.6 | 65.0 | 0.001 | 0.048 |
| 165 | 322 | 3 | 18 | 32.0 | 2210.7 | 5.211 | -21.289 | 626.7 | 97.7 | 0.030 | 0.063 |
| 166 | 322 | 3 | 18 | 37.3 | 1999.3 | 1.968 | -20.655 | 1521.0 | 82.0 | 0.018 | 0.069 |
| 167 | 322 | 3 | 19 | 1.3 | 2173.8 | 4.640 | -18.501 | 1257.6 | 99.6 | 0.037 | 0.106 |
| 168 | 322 | 3 | 19 | 46.3 | 827.2 | 5.462 | -20.418 | 503.8 | 97.7 | 0.027 | 0.071 |
| 169 | 322 | 3 | 20 | 48.5 | 1144.4 | -4.642 | -36.208 | 850.0 | 69.8 | 0.025 | 0.031 |
| 170 | 322 | 3 | 21 | 21.0 | 1102.1 | -0.005 | -24.853 | 809.9 | 65.0 | 0.002 | 0.049 |
| 171 | 322 | 3 | 22 | 18.3 | 1108.9 | -0.000 | -24.675 | 808.9 | 65.0 | 0.001 | 0.050 |
| 172 | 322 | 3 | 23 | 43.3 | 1127.6 | -0.123 | -24.511 | 805.4 | 65.0 | 0.003 | 0.050 |
| 173 | 322 | 3 | 23 | 54.3 | 1130.1 | -0.127 | -26.535 | 806.1 | 65.0 | 0.002 | 0.046 |
| 174 | 322 | 3 | 24 | 6.0 | 1153.5 | 4.336 | -25.697 | 848.5 | 99.0 | 0.016 | 0.047 |
| 175 | 322 | 3 | 24 | 40.3 | 1407.3 | 4.963 | -20.871 | 833.0 | 98.6 | 0.012 | 0.067 |
| 176 | 322 | 3 | 25 | 37.0 | 1132.0 | -0.055 | -26.078 | 808.7 | 65.0 | 0.002 | 0.047 |
| 177 | 322 | 3 | 25 | 36.5 | 1134.5 | 4.686 | -30.400 | 782.8 | 99.6 | 0.004 | 0.039 |
| 178 | 322 | 3 | 26 | 22.3 | 1137.3 | -0.155 | -24.638 | 810.5 | 65.0 | 0.001 | 0.050 |
| 179 | 322 | 3 | 27 | 58.3 | 1353.2 | 4.931 | -24.361 | 817.5 | 98.6 | 0.013 | 0.050 |
| 180 | 322 | 3 | 28 | 16.5 | 1467.9 | -1.232 | -21.270 | 792.6 | 99.1 | 0.005 | 0.064 |
| 181 | 322 | 3 | 29 | 37.3 | 1158.5 | -0.250 | -26.827 | 809.4 | 65.0 | 0.002 | 0.045 |
| 182 | 322 | 3 | 29 | 54.3 | 1155.8 | 4.159 | -19.754 | 871.6 | 98.8 | 0.007 | 0.080 |
| 183 | 322 | 3 | 32 | 46.2 | 1358.9 | 4.489 | -29.804 | 931.3 | 99.1 | 0.015 | 0.040 |
| 184 | 322 | 3 | 32 | 46.3 | 1178.4 | -0.294 | -25.394 | 810.2 | 64.9 | 0.004 | 0.048 |
| 185 | 322 | 3 | 34 | 2.0 | 1196.2 | -0.345 | -24.626 | 805.5 | 65.0 | 0.003 | 0.050 |
| 186 | 322 | 3 | 34 | 36.3 | 1204.3 | -0.397 | -26.728 | 807.8 | 65.0 | 0.003 | 0.045 |
| 187 | 322 | 3 | 35 | 26.3 | 1206.9 | -0.350 | -24.523 | 807.6 | 65.0 | 0.002 | 0.050 |
| 188 | 322 | 3 | 35 | 48.3 | 1211.6 | -0.468 | -24.671 | 808.5 | 65.0 | 0.002 | 0.050 |
| 189 | 322 | 3 | 35 | 49.3 | 1530.0 | 5.021 | -19.223 | 861.2 | 99.1 | 0.016 | 0.094 |
| 190 | 322 | 3 | 36 | 47.3 | 1216.5 | -0.483 | -26.067 | 806.5 | 65.0 | 0.002 | 0.047 |
| 191 | 322 | 3 | 37 | 7.3 | 1220.7 | -0.440 | -25.013 | 807.7 | 65.0 | 0.002 | 0.049 |
| 192 | 322 | 3 | 37 | 25.3 | 2081.3 | 5.115 | -18.324 | 808.5 | 98.4 | 0.010 | 0.110 |
| 193 | 322 | 3 | 38 | 17.3 | 1255.1 | 4.339 | -20.033 | 906.1 | 99.0 | 0.011 | 0.076 |
| 194 | 322 | 3 | 39 | 49.3 | 1224.9 | -0.454 | -24.811 | 809.1 | 65.0 | 0.002 | 0.049 |
| 195 | 322 | 3 | 40 | 11.3 | 1603.0 | 4.723 | -21.655 | 1081.4 | 99.8 | 0.040 | 0.061 |
| 196 | 322 | 3 | 41 | 41.3 | 1250.7 | -0.585 | -26.777 | 807.0 | 65.0 | 0.002 | 0.045 |
| 197 | 322 | 3 | 42 | 15.5 | 1024.1 | -1.386 | -24.441 | 687.7 | 100.2 | 0.018 | 0.050 |
| 198 | 322 | 3 | 42 | 20.3 | 1542.6 | 4.515 | -20.250 | 1003.6 | 99.2 | 0.017 | 0.073 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 199 | 322 | 3 | 43 | 46.3 | 1346.9 | 3.736 | -27.214 | 1060.0 | 99.2 | 0.018 | 0.045 |
| 200 | 322 | 3 | 45 | 6.3 | 2034.6 | -0.471 | -16.743 | 780.7 | 99.0 | 0.031 | 0.146 |
| 201 | 322 | 3 | 49 | 15.0 | 2333.9 | 4.788 | -20.157 | 1286.1 | 99.5 | 0.054 | 0.074 |
| 202 | 322 | 3 | 50 | 21.3 | 1241.6 | -3.799 | -26.805 | 1014.5 | 64.8 | 0.006 | 0.045 |
| 203 | 322 | 3 | 50 | 29.3 | 1545.5 | -1.725 | -22.214 | 965.4 | 95.8 | 0.022 | 0.058 |
| 204 | 322 | 3 | 50 | 53.5 | 2022.8 | -0.445 | -21.795 | 1546.8 | 101.7 | 0.020 | 0.060 |
| 205 | 322 | 3 | 52 | 3.3 | 1162.6 | 4.281 | -23.248 | 862.3 | 98.8 | 0.005 | 0.054 |
| 206 | 322 | 3 | 52 | 14.3 | 1131.5 | 4.179 | -26.561 | 863.3 | 98.8 | 0.004 | 0.046 |
| 207 | 322 | 3 | 52 | 37.0 | 1326.0 | -0.906 | -25.447 | 806.9 | 65.0 | 0.002 | 0.048 |
| 208 | 322 | 3 | 55 | 31.3 | 1228.8 | 4.623 | -26.012 | 835.2 | 98.7 | 0.008 | 0.047 |
| 209 | 322 | 3 | 55 | 31.5 | 1683.8 | 5.115 | -20.180 | 869.1 | 98.9 | 0.007 | 0.074 |
| 210 | 322 | 3 | 55 | 50.3 | 1348.7 | -1.007 | -27.135 | 808.4 | 65.0 | 0.002 | 0.045 |
| 211 | 322 | 3 | 56 | 45.3 | 1627.6 | 5.193 | -21.911 | 841.4 | 99.0 | 0.011 | 0.060 |
| 212 | 322 | 3 | 57 | 42.3 | 1722.4 | 4.983 | -18.38 | 917.6 | 99.0 | 0.011 | 0.109 |
| 213 | 322 | 3 | 58 | 15.3 | 1656.6 | 5.088 | -24.539 | 869.4 | 98.8 | 0.005 | 0.050 |
| 214 | 322 | 3 | 58 | 34.3 | 1304.3 | -0.175 | -24.179 | 957.9 | 65.9 | 0.003 | 0.051 |
| 215 | 322 | 3 | 58 | 35.3 | 1366.5 | -1.047 | -25.289 | 808.6 | 65.0 | 0.004 | 0.048 |
| 216 | 322 | 3 | 59 | 10.3 | 1357.7 | -1.011 | -25.525 | 808.8 | 65.0 | 0.002 | 0.048 |
| 217 | 322 | 3 | 59 | 57.3 | 1371.9 | -1.046 | -26.067 | 808.1 | 65.0 | 0.002 | 0.047 |
| 218 | 322 | 4 | 1 | 33.3 | 1824.8 | 5.163 | -20.004 | 861.8 | 98.9 | 0.007 | 0.076 |
| 219 | 322 | 4 | 3 | 26.4 | 1594.7 | -6.372 | -25.676 | 645.0 | 65.0 | 0.013 | 0.047 |
| 220 | 322 | 4 | 4 | 47.3 | 1516.4 | 2.583 | -24.201 | 722.0 | 81.1 | 0.006 | 0.051 |
| 221 | 322 | 4 | 6 | 38.3 | 1626.4 | 4.960 | -19.398 | 915.5 | 98.7 | 0.013 | 0.087 |
| 222 | 322 | 4 | 7 | 8.3 | 1984.4 | 5.104 | -19.646 | 884.4 | 98.9 | 0.008 | 0.082 |
| 223 | 322 | 4 | 7 | 24.3 | 1423.9 | -6.249 | -21.771 | 641.6 | 65.1 | 0.012 | 0.060 |
| 224 | 322 | 4 | 7 | 37.3 | 1350.8 | 4.775 | -25.817 | 870.9 | 98.8 | 0.004 | 0.047 |
| 225 | 322 | 4 | 7 | 37.5 | 1523.5 | 5.472 | -19.346 | 637.5 | 97.9 | 0.002 | 0.090 |
| 226 | 322 | 4 | 7 | 58.5 | 1024.5 | -1.348 | -21.169 | 681.6 | 99.3 | 0.025 | 0.064 |
| 227 | 322 | 4 | 8 | 8.0 | 2104.3 | 4.791 | -19.570 | 1004.9 | 99.0 | 0.018 | 0.083 |
| 228 | 322 | 4 | 9 | 28.3 | 1699.6 | -0.762 | -23.256 | 672.8 | 100.1 | 0.015 | 0.054 |
| 229 | 322 | 4 | 10 | 8.3 | 1419.1 | -1.364 | -16.050 | 307.2 | 99.0 | 0.009 | 0.159 |
| 230 | 322 | 4 | 11 | 17.5 | 1192.7 | 4.801 | -19.617 | 760.1 | 97.6 | 0.030 | 0.082 |
| 231 | 322 | 4 | 11 | 48.5 | 1498.5 | -1.283 | -24.523 | 406.4 | 99.0 | 0.009 | 0.050 |
| 232 | 322 | 4 | 11 | 50.3 | 1174.8 | 4.313 | -29.064 | 863.9 | 98.8 | 0.002 | 0.041 |
| 233 | 322 | 4 | 13 | 19.3 | 1530.5 | -4.054 | -18.924 | 863.3 | 83.0 | 0.004 | 0.099 |
| 234 | 322 | 4 | 14 | 18.3 | 1274.7 | 4.700 | -26.646 | 845.1 | 98.8 | 0.007 | 0.046 |
| 235 | 322 | 4 | 15 | 29.3 | 1045.7 | -1.839 | -17.154 | 369.5 | 98.8 | 0.003 | 0.136 |
| 236 | 322 | 4 | 18 | 20.3 | 1193.2 | 3.835 | -23.564 | 927.6 | 98.5 | 0.026 | 0.053 |
| 237 | 322 | 4 | 20 | 2.0 | 1432.4 | 5.129 | -22.501 | 836.6 | 98.5 | 0.035 | 0.057 |
| 238 | 322 | 4 | 20 | 3.3 | 1420.9 | -1.151 | -23.812 | 522.0 | 99.4 | 0.022 | 0.052 |
| 239 | 322 | 4 | 20 | 20.3 | 1670.1 | 5.089 | -20.500 | 861.6 | 98.8 | 0.006 | 0.070 |
| 240 | 322 | 4 | 20 | 41.3 | 2004.6 | 3.968 | -20.636 | 1319.9 | 99.6 | 0.058 | 0.069 |
| 241 | 322 | 4 | 23 | 11.3 | 2198.9 | 4.951 | -19.337 | 905.8 | 99.1 | 0.013 | 0.091 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 242 | 322 | 4 | 24 | 59.3 | 1355.8 | -1.162 | -17.721 | 633.1 | 99.6 | 0.027 | 0.120 |
| 243 | 322 | 4 | 25 | 52.1 | 1357.2 | -1.429 | -22.822 | 479.4 | 98.9 | 0.011 | 0.055 |
| 244 | 322 | 4 | 25 | 52.3 | 1638.1 | 4.957 | -20.135 | 914.8 | 99.1 | 0.016 | 0.075 |
| 245 | 322 | 4 | 26 | 26.0 | 2024.9 | -3.419 | -19.603 | 1062.7 | 62.9 | 0.136 | 0.082 |
| 246 | 322 | 4 | 26 | 40.3 | 1553.3 | -1.791 | -24.883 | 809.1 | 65.1 | 0.004 | 0.049 |
| 247 | 322 | 4 | 27 | 2.3 | 1614.7 | -4.859 | -25.892 | 613.9 | 81.0 | 0.009 | 0.047 |
| 248 | 322 | 4 | 27 | 55.3 | 1451.6 | 5.484 | -18.982 | 690.5 | 98.4 | 0.014 | 0.099 |
| 249 | 322 | 4 | 28 | 50.5 | 1835.1 | 5.212 | -20.941 | 856.1 | 99.0 | 0.009 | 0.066 |
| 250 | 322 | 4 | 28 | 50.3 | 1566.8 | -1.848 | -25.294 | 809.1 | 65.0 | 0.002 | 0.048 |
| 251 | 322 | 4 | 28 | 57.3 | 1146.3 | 4.135 | -32.668 | 876.1 | 99.1 | 0.006 | 0.036 |
| 252 | 322 | 4 | 29 | 32.5 | 1583.9 | -0.998 | -19.817 | 613.5 | 99.3 | 0.020 | 0.079 |
| 253 | 322 | 4 | 29 | 35.3 | 1663.6 | -3.934 | -19.879 | 1327.0 | 65.8 | 0.018 | 0.078 |
| 254 | 322 | 4 | 30 | 9.3 | 1576.7 | -1.905 | -24.921 | 808.2 | 65.0 | 0.000 | 0.049 |
| 255 | 322 | 4 | 30 | 37.3 | 1666.2 | 5.179 | -20.757 | 852.2 | 99.1 | 0.007 | 0.068 |
| 256 | 322 | 4 | 30 | 45.0 | 1410.7 | 5.161 | -22.024 | 774.9 | 98.8 | 0.017 | 0.059 |
| 257 | 322 | 4 | 31 | 8.0 | 1572.7 | 5.121 | -22.759 | 860.0 | 98.9 | 0.006 | 0.056 |
| 258 | 322 | 4 | 34 | 47.3 | 1497.4 | 4.969 | -18.820 | 875.9 | 99.0 | 0.008 | 0.101 |
| 259 | 322 | 4 | 35 | 50.0 | 1448.8 | 4.593 | -22.431 | 955.8 | 99.4 | 0.015 | 0.057 |
| 260 | 322 | 4 | 37 | 40.3 | 1648.2 | 5.115 | -19.386 | 845.6 | 98.8 | 0.007 | 0.088 |
| 261 | 322 | 4 | 38 | 13.3 | 1664.5 | 5.061 | -24.079 | 882.7 | 99.1 | 0.007 | 0.051 |
| 262 | 322 | 4 | 38 | 23.3 | 2055.9 | -0.810 | -18.583 | 1292.1 | 65.5 | 0.294 | 0.104 |
| 263 | 322 | 4 | 38 | 32.3 | 1078.1 | 4.087 | -17.427 | 831.7 | 98.7 | 0.006 | 0.128 |
| 264 | 322 | 4 | 38 | 35.3 | 1252.7 | 4.573 | -20.112 | 867.2 | 99.0 | 0.001 | 0.075 |
| 265 | 322 | 4 | 39 | 7.0 | 1317.1 | 4.734 | -27.945 | 867.8 | 98.8 | 0.008 | 0.044 |
| 266 | 322 | 4 | 39 | 25.3 | 1838.0 | 4.882 | -22.326 | 996.1 | 98.7 | 0.028 | 0.057 |
| 267 | 322 | 4 | 39 | 29.0 | 1665.0 | 4.641 | -20.969 | 1018.4 | 98.8 | 0.025 | 0.066 |
| 268 | 322 | 4 | 39 | 37.0 | 985.6 | 4.298 | -26.169 | 741.6 | | | 0.046 |
| 269 | 322 | 4 | 40 | 21.3 | 1146.7 | 4.178 | -19.250 | 867.4 | 98.9 | 0.003 | 0.093 |
| 270 | 322 | 4 | 41 | 43.3 | 1913.8 | 5.123 | -19.597 | 862.9 | 98.8 | 0.002 | 0.083 |
| 271 | 322 | 4 | 41 | 48.3 | 2421.5 | -3.064 | -18.533 | 1698.0 | 82.7 | 0.010 | 0.105 |
| 272 | 322 | 4 | 42 | 12.3 | 1344.6 | 4.716 | -23.832 | 889.6 | 98.9 | 0.008 | 0.052 |
| 273 | 322 | 4 | 45 | 43.3 | 1965.0 | 5.481 | -19.865 | 709.9 | 99.6 | 0.006 | 0.078 |
| 274 | 322 | 4 | 46 | 14.3 | 1696.3 | 5.085 | -22.573 | 860.7 | 98.9 | 0.013 | 0.056 |
| 275 | 322 | 4 | 46 | 35.3 | 1646.0 | 5.124 | -20.289 | 864.5 | 99.0 | 0.003 | 0.073 |
| 276 | 322 | 4 | 47 | 22.3 | 1436.3 | 4.793 | -23.471 | 853.9 | 98.4 | 0.027 | 0.053 |
| 277 | 322 | 4 | 48 | 26.2 | 1718.6 | 5.168 | -19.904 | 867.9 | 99.0 | 0.006 | 0.078 |
| 278 | 322 | 4 | 48 | 26.3 | 1571.5 | 2.571 | -27.147 | 675.3 | 82.1 | 0.025 | 0.045 |
| 279 | 322 | 4 | 50 | 39.3 | 2169.7 | 4.658 | -19.350 | 981.7 | 99.0 | 0.045 | 0.090 |
| 280 | 322 | 4 | 53 | 2.3 | 1315.8 | 4.976 | -21.165 | 874.6 | 100.5 | 0.044 | 0.064 |
| 281 | 322 | 4 | 53 | 10.3 | 2018.5 | 5.117 | -19.210 | 850.5 | 98.9 | 0.011 | 0.094 |
| 282 | 322 | 4 | 53 | 25.3 | 1444.5 | 4.929 | -18.201 | 865.8 | 98.8 | 0.002 | 0.113 |
| 283 | 322 | 4 | 53 | 58.3 | 1195.8 | 4.364 | -23.21 | 870.0 | 98.9 | 0.004 | 0.054 |
| 284 | 322 | 4 | 54 | 4.3 | 2441.1 | 1.346 | -15.469 | 968.6 | | | 0.172 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 285 | 322 | 4 | 54 | 18.3 | 1734.1 | -2.542 | -24.205 | 810.9 | 65.1 | 0.005 | 0.051 |
| 286 | 322 | 4 | 54 | 29.3 | 1843.3 | 5.160 | -19.993 | 845.8 | 98.9 | 0.008 | 0.077 |
| 287 | 322 | 4 | 54 | 32.3 | 1496.5 | 4.333 | -19.277 | 1015.1 | 98.6 | 0.033 | 0.092 |
| 288 | 322 | 4 | 57 | 13.3 | 1795.7 | 4.987 | -25.275 | 887.2 | 98.8 | 0.021 | 0.048 |
| 289 | 322 | 4 | 58 | 9.3 | 2404.0 | 4.876 | -19.744 | 885.4 | 98.9 | 0.007 | 0.080 |
| 290 | 322 | 4 | 58 | 38.3 | 2070.4 | -0.400 | -17.473 | 1462.9 | 102.6 | 0.020 | 0.125 |
| 291 | 322 | 4 | 59 | 47.3 | 1217.3 | 5.272 | -19.398 | 664.1 | 98.4 | 0.023 | 0.087 |
| 292 | 322 | 4 | 59 | 57.3 | 2381.8 | -6.036 | -18.005 | 918.2 | 65.6 | 0.011 | 0.116 |
| 293 | 322 | 5 | 1 | 6.3 | 1656.7 | 5.206 | -20.713 | 851.8 | 99.0 | 0.009 | 0.068 |
| 294 | 322 | 5 | 1 | 27.0 | 1685.5 | 5.103 | -24.426 | 815.5 | 98.2 | 0.009 | 0.050 |
| 295 | 322 | 5 | 2 | 10.3 | 2333.3 | 5.108 | -18.228 | 523.3 | 97.6 | 0.040 | 0.113 |
| 296 | 322 | 5 | 3 | 22.3 | 1888.6 | 5.323 | -18.556 | 723.9 | 98.5 | 0.012 | 0.105 |
| 297 | 322 | 5 | 3 | 32.3 | 1629.2 | 5.122 | -18.258 | 1094.9 | 105.8 | 0.084 | 0.112 |
| 298 | 322 | 5 | 3 | 42.3 | 1745.9 | 4.577 | -19.403 | 1075.4 | 99.5 | 0.018 | 0.087 |
| 299 | 322 | 5 | 5 | 57.0 | 1987.2 | 5.134 | -19.620 | 880.9 | 99.2 | 0.008 | 0.082 |
| 300 | 322 | 5 | 6 | 22.3 | 2357.1 | 4.541 | -19.788 | 1419.7 | 102.1 | 0.007 | 0.079 |
| 301 | 322 | 5 | 6 | 39.3 | 1542.1 | 3.655 | -21.614 | 1226.9 | 99.6 | 0.023 | 0.061 |
| 302 | 322 | 5 | 7 | 19.3 | 1461.8 | 2.707 | -24.395 | 693.4 | 81.2 | 0.011 | 0.050 |
| 303 | 322 | 5 | 7 | 24.3 | 1435.9 | -1.216 | -20.261 | 678.2 | 99.4 | 0.025 | 0.073 |
| 304 | 322 | 5 | 8 | 42.3 | 2212.0 | 5.282 | -20.414 | 473.4 | 98.5 | 0.022 | 0.071 |
| 305 | 322 | 5 | 10 | 3.0 | 1627.7 | 4.840 | -19.751 | 949.3 | 99.2 | 0.011 | 0.080 |
| 306 | 322 | 5 | 11 | 50.3 | 1405.3 | 4.971 | -28.790 | 857.9 | 99.1 | 0.006 | 0.042 |
| 307 | 322 | 5 | 12 | 26.0 | 1557.6 | 4.485 | -19.372 | 1002.4 | 98.7 | 0.027 | 0.089 |
| 308 | 322 | 5 | 14 | 51.3 | 1586.9 | 4.566 | -19.379 | 984.6 | 98.7 | 0.030 | 0.088 |
| 309 | 322 | 5 | 15 | 5.0 | 2253.0 | 4.995 | -19.188 | 865.6 | 98.8 | 0.005 | 0.095 |
| 310 | 322 | 5 | 16 | 5.3 | 1487.6 | -1.215 | -19.746 | 895.5 | 100.4 | 0.143 | 0.080 |
| 311 | 322 | 5 | 17 | 8.3 | 1639.5 | 5.573 | -20.064 | 644.4 | 98.8 | 0.038 | 0.076 |
| 312 | 322 | 5 | 17 | 11.0 | 2164.9 | 5.054 | -18.700 | 840.6 | 99.1 | 0.018 | 0.102 |
| 313 | 322 | 5 | 17 | 32.3 | 1445.3 | 4.936 | -17.628 | 865.3 | 99.1 | 0.004 | 0.122 |
| 314 | 322 | 5 | 18 | 3.3 | 1467.2 | 5.025 | -20.564 | 843.3 | 98.9 | 0.004 | 0.069 |
| 315 | 322 | 5 | 19 | 54.3 | 1447.0 | -1.432 | -23.387 | 787.0 | 98.9 | 0.019 | 0.053 |
| 316 | 322 | 5 | 20 | 30.3 | 2521.2 | 4.773 | -18.627 | 866.4 | 98.9 | 0.006 | 0.103 |
| 317 | 322 | 5 | 20 | 56.3 | 1129.6 | 3.142 | -30.659 | 626.9 | 81.7 | 0.018 | 0.039 |
| 318 | 322 | 5 | 21 | 17.0 | 2529.5 | 4.588 | -18.466 | 968.8 | 98.8 | 0.017 | 0.107 |
| 319 | 322 | 5 | 22 | 24.3 | 1138.4 | 4.146 | -22.421 | 869.6 | 99.1 | 0.004 | 0.057 |
| 320 | 322 | 5 | 23 | 12.3 | 2163.8 | 1.772 | -18.323 | 949.9 | 82.5 | 0.004 | 0.110 |
| 321 | 322 | 5 | 26 | 22.3 | 1591.7 | 5.253 | -19.634 | 803.7 | 99.4 | 0.027 | 0.082 |
| 322 | 322 | 5 | 26 | 24.3 | 950.2 | -6.011 | -27.294 | 518.1 | 62.7 | 0.075 | 0.044 |
| 323 | 322 | 5 | 27 | 27.3 | 2143.7 | 5.077 | -20.388 | 861.8 | | | 0.072 |
| 324 | 322 | 5 | 28 | 15.3 | 2190.6 | 5.085 | -18.050 | 845.3 | 98.9 | 0.009 | 0.115 |
| 325 | 322 | 5 | 28 | 20.3 | 1745.0 | -4.373 | -21.813 | 866.0 | 81.4 | 0.001 | 0.060 |
| 326 | 322 | 5 | 29 | 23.5 | 1989.1 | -0.678 | -19.503 | 498.2 | 97.7 | 0.005 | 0.084 |
| 327 | 322 | 5 | 29 | 32.3 | 2433.3 | 0.190 | -15.016 | 1560.4 | 103.0 | 0.016 | 0.177 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 328 | 322 | 5 | 30 | 31.3 | 2279.4 | 4.978 | -14.861 | 875.6 | 99.0 | 0.005 | 0.186 |
| 329 | 322 | 5 | 31 | 59.3 | 932.7 | 5.466 | -24.323 | 566.4 | 98.5 | 0.036 | 0.050 |
| 330 | 322 | 5 | 32 | 12.0 | 2118.0 | 5.082 | -20.768 | 842.3 | 98.8 | 0.005 | 0.068 |
| 331 | 322 | 5 | 32 | 42.3 | 1721.1 | 5.217 | -23.435 | 860.2 | 99.2 | 0.003 | 0.053 |
| 332 | 322 | 5 | 33 | 27.3 | 2348.5 | 4.916 | -20.281 | 878.5 | 99.1 | 0.007 | 0.073 |
| 333 | 322 | 5 | 34 | 14.5 | 1239.7 | -5.555 | -28.951 | 712.0 | 70.5 | 0.009 | 0.042 |
| 334 | 322 | 5 | 34 | 56.0 | 2447.1 | -0.143 | -16.940 | 1744.5 | 102.4 | 0.012 | 0.141 |
| 335 | 322 | 5 | 35 | 13.0 | 2024.2 | -0.649 | -18.283 | 1495.5 | 101.9 | 0.034 | 0.111 |
| 336 | 322 | 5 | 40 | 37.3 | 1355.0 | 0.664 | -24.554 | 868.5 | 70.9 | 0.011 | 0.050 |
| 337 | 322 | 5 | 40 | 49.3 | 1748.4 | 5.218 | -20.706 | 856.4 | 99.2 | 0.006 | 0.068 |
| 338 | 322 | 5 | 42 | 21.3 | 2306.9 | 4.960 | -18.206 | 864.8 | 98.6 | 0.010 | 0.113 |
| 339 | 322 | 5 | 42 | 22.3 | 1678.4 | 5.170 | -20.045 | 855.8 | 99.1 | 0.007 | 0.076 |
| 340 | 322 | 5 | 42 | 31.3 | 1195.0 | -4.156 | -26.221 | 935.0 | 65.1 | 0.004 | 0.046 |
| 341 | 322 | 5 | 44 | 58.3 | 1687.4 | 5.163 | -21.094 | 865.6 | 99.0 | 0.004 | 0.065 |
| 342 | 322 | 5 | 45 | 25.3 | 1180.9 | 4.261 | -19.432 | 891.7 | 99.1 | 0.015 | 0.086 |
| 343 | 322 | 5 | 46 | 30.3 | 1524.7 | 4.686 | -23.892 | 911.7 | 98.7 | 0.030 | 0.052 |
| 344 | 322 | 5 | 46 | 43.3 | 1869.4 | 5.087 | -17.462 | 875.3 | 98.9 | 0.006 | 0.126 |
| 345 | 322 | 5 | 47 | 8.3 | 1157.7 | 4.283 | -19.419 | 879.3 | 99.1 | 0.021 | 0.086 |
| 346 | 322 | 5 | 49 | 50.3 | 1342.1 | 4.794 | -25.666 | 865.7 | 99.1 | 0.002 | 0.047 |
| 347 | 322 | 5 | 49 | 58.3 | 868.4 | -3.816 | -25.124 | 716.9 | 71.0 | 0.002 | 0.049 |
| 348 | 322 | 5 | 50 | 17.3 | 2274.7 | -0.240 | -16.078 | 1462.8 | 101.6 | 0.009 | 0.159 |
| 349 | 322 | 5 | 52 | 7.3 | 2114.4 | 5.271 | -19.679 | 687.0 | 98.4 | 0.015 | 0.081 |
| 350 | 322 | 5 | 52 | 13.3 | 1104.0 | 4.344 | -26.417 | 813.3 | 98.8 | 0.003 | 0.046 |
| 351 | 322 | 5 | 53 | 6.0 | 1721.0 | -5.573 | -22.712 | 940.1 | 65.9 | 0.009 | 0.056 |
| 352 | 322 | 5 | 53 | 47.0 | 1500.0 | -5.182 | -23.224 | 941.2 | 65.9 | 0.012 | 0.054 |
| 353 | 322 | 5 | 54 | 24.3 | 1819.5 | 4.744 | -18.478 | 1093.5 | 100.2 | 0.004 | 0.107 |
| 354 | 322 | 5 | 58 | 39.3 | 1315.8 | 4.719 | -24.857 | 869.8 | 99.0 | 0.004 | 0.049 |
| 355 | 322 | 6 | 1 | 42.3 | 2120.6 | 5.368 | -18.221 | 529.4 | 98.2 | 0.040 | 0.113 |
| 356 | 322 | 6 | 3 | 50.3 | 2216.3 | 4.612 | -17.421 | 1205.5 | 99.8 | 0.022 | 0.129 |
| 357 | 322 | 6 | 7 | 36.5 | 2295.3 | -3.651 | -17.445 | 1285.6 | 82.5 | 0.028 | 0.127 |
| 358 | 322 | 6 | 8 | 4.3 | 1629.8 | 5.075 | -20.761 | 890.2 | 99.5 | 0.010 | 0.068 |
| 359 | 322 | 6 | 9 | 15.0 | 2174.2 | 5.076 | -19.662 | 864.9 | 99.1 | 0.004 | 0.081 |
| 360 | 322 | 6 | 9 | 54.3 | 1186.6 | 5.701 | -20.240 | 583.5 | 98.8 | 0.029 | 0.073 |
| 361 | 322 | 6 | 10 | 15.3 | 1275.4 | 4.076 | -22.322 | 986.3 | 99.0 | 0.030 | 0.057 |
| 362 | 322 | 6 | 10 | 22.3 | 1477.0 | 5.012 | -24.016 | 866.1 | 99.2 | 0.003 | 0.051 |
| 363 | 322 | 6 | 10 | 36.3 | 1445.0 | 4.766 | -19.267 | 935.1 | 99.1 | 0.021 | 0.093 |
| 364 | 322 | 6 | 11 | 6.3 | 639.3 | 0.638 | -34.125 | 227.3 | 64.9 | 0.002 | 0.034 |
| 365 | 322 | 6 | 11 | 27.3 | 497.1 | 1.523 | -23.181 | 323.5 | 65.0 | 0.002 | 0.054 |
| 366 | 322 | 6 | 13 | 46.3 | 1214.2 | 6.074 | -20.850 | 508.3 | 98.7 | 0.037 | 0.067 |
| 367 | 322 | 6 | 14 | 12.3 | 1343.0 | 4.908 | -21.535 | 860.6 | 99.2 | 0.016 | 0.062 |
| 368 | 322 | 6 | 14 | 42.5 | 2293.6 | -0.335 | -18.493 | 1251.7 | 99.9 | 0.015 | 0.106 |
| 369 | 322 | 6 | 16 | 11.3 | 489.1 | 1.644 | -23.981 | 326.1 | 65.0 | 0.000 | 0.051 |
| 370 | 322 | 6 | 16 | 58.0 | 1246.4 | 4.481 | -20.637 | 900.8 | 99.1 | 0.021 | 0.069 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 371 | 322 | 6 | 17 | 19.3 | 1368.0 | 4.722 | -25.817 | 902.1 | 99.1 | 0.013 | 0.047 |
| 372 | 322 | 6 | 17 | 32.3 | 2314.0 | 5.017 | -19.212 | 862.5 | 99.2 | 0.002 | 0.094 |
| 373 | 322 | 6 | 17 | 59.3 | 1663.5 | 4.851 | -21.564 | 935.0 | 98.7 | 0.018 | 0.062 |
| 374 | 322 | 6 | 18 | 52.0 | 473.8 | 1.684 | -23.865 | 353.4 | 65.0 | 0.000 | 0.052 |
| 375 | 322 | 6 | 18 | 57.0 | 1499.2 | -2.297 | -22.008 | 674.3 | 65.0 | 0.074 | 0.059 |
| 376 | 322 | 6 | 19 | 11.3 | 2203.0 | 0.616 | -16.868 | 1848.1 | 65.2 | 0.208 | 0.143 |
| 377 | 322 | 6 | 20 | 12.3 | 550.7 | 1.283 | -21.793 | 371.6 | 65.0 | 0.004 | 0.060 |
| 378 | 322 | 6 | 20 | 27.5 | 880.7 | 5.861 | -24.220 | 443.8 | 98.4 | 0.029 | 0.051 |
| 379 | 322 | 6 | 20 | 30.3 | 601.3 | 0.875 | -23.45 | 257.0 | 65.0 | 0.003 | 0.053 |
| 380 | 322 | 6 | 20 | 41.3 | 1346.5 | 6.053 | -25.676 | 476.6 | 98.2 | 0.029 | 0.047 |
| 381 | 322 | 6 | 22 | 4.0 | 1947.0 | 5.146 | -22.438 | 870.9 | 98.9 | 0.008 | 0.057 |
| 382 | 322 | 6 | 22 | 14.0 | 1193.6 | 5.767 | -27.363 | 532.9 | 98.6 | 0.027 | 0.044 |
| 383 | 322 | 6 | 24 | 26.0 | 1736.1 | 5.315 | -17.906 | 831.3 | 99.3 | 0.011 | 0.117 |
| 384 | 322 | 6 | 25 | 12.3 | 1149.6 | 2.543 | -34.132 | 884.0 | | | 0.034 |
| 385 | 322 | 6 | 26 | 6.3 | 2451.0 | 4.862 | -17.225 | 807.0 | 99.1 | 0.019 | 0.135 |
| 386 | 322 | 6 | 27 | 0.3 | 527.8 | 1.240 | -20.098 | 296.9 | 65.1 | 0.002 | 0.075 |
| 387 | 322 | 6 | 27 | 46.0 | 522.1 | 1.438 | -27.524 | 370.0 | 65.0 | 0.001 | 0.044 |
| 388 | 322 | 6 | 29 | 7.3 | 608.3 | 1.082 | -14.998 | 396.8 | 65.0 | 0.002 | 0.181 |
| 389 | 322 | 6 | 29 | 35.3 | 647.3 | 0.635 | -18.569 | 262.0 | 65.0 | 0.002 | 0.105 |
| 390 | 322 | 6 | 30 | 2.3 | 1207.1 | 3.795 | -19.139 | 923.6 | 98.7 | 0.047 | 0.096 |
| 391 | 322 | 6 | 31 | 44.3 | 1135.5 | -0.872 | -16.784 | 568.8 | 64.9 | 0.012 | 0.145 |
| 392 | 322 | 6 | 32 | 51.3 | 606.2 | 0.955 | -28.559 | 332.4 | 65.0 | 0.003 | 0.042 |
| 393 | 322 | 6 | 34 | 5.0 | 1685.9 | 5.155 | -25.646 | 876.7 | 99.5 | 0.008 | 0.047 |
| 394 | 322 | 6 | 34 | 23.3 | 1255.9 | 2.641 | -23.453 | 884.2 | 81.3 | 0.003 | 0.053 |
| 395 | 322 | 6 | 34 | 57.3 | 2099.8 | -2.652 | -18.787 | 1702.5 | 82.5 | 0.019 | 0.101 |
| 396 | 322 | 6 | 36 | 51.3 | 646.9 | 0.854 | -21.316 | 333.1 | 65.0 | 0.002 | 0.063 |
| 397 | 322 | 6 | 38 | 9.3 | 628.9 | 0.887 | -25.681 | 359.8 | 64.9 | 0.003 | 0.047 |
| 398 | 322 | 6 | 38 | 22.3 | 1400.8 | 5.659 | -22.289 | 622.5 | 98.7 | 0.025 | 0.057 |
| 399 | 322 | 6 | 39 | 19.3 | 2274.0 | 5.030 | -17.950 | 867.3 | 99.1 | 0.002 | 0.117 |
| 400 | 322 | 6 | 39 | 53.3 | 1240.2 | 4.513 | -18.911 | 870.5 | 99.2 | 0.003 | 0.099 |
| 401 | 322 | 6 | 40 | 50.0 | 2178.8 | 5.028 | -19.37 | 903.2 | 99.0 | 0.013 | 0.089 |
| 402 | 322 | 6 | 40 | 58.3 | 1383.7 | 4.821 | -19.434 | 862.5 | 98.9 | 0.010 | 0.086 |
| 403 | 322 | 6 | 41 | 23.3 | 1212.7 | 6.063 | -24.320 | 467.0 | 98.4 | 0.025 | 0.050 |
| 404 | 322 | 6 | 42 | 6.3 | 701.9 | 0.576 | -25.812 | 302.1 | 65.1 | 0.001 | 0.047 |
| 405 | 322 | 6 | 42 | 32.3 | 859.1 | -3.635 | -32.719 | 724.2 | 70.9 | 0.002 | 0.036 |
| 406 | 322 | 6 | 42 | 46.3 | 605.7 | 1.010 | -23.127 | 380.3 | 65.1 | 0.001 | 0.054 |
| 407 | 322 | 6 | 42 | 55.3 | 626.2 | 0.940 | -35.911 | 374.5 | 65.0 | 0.002 | 0.032 |
| 408 | 322 | 6 | 43 | 30.3 | 881.0 | -0.499 | -25.886 | 262.2 | 65.0 | 0.002 | 0.047 |
| 409 | 322 | 6 | 43 | 51.3 | 1075.8 | 4.201 | -28.729 | 814.9 | 99.1 | 0.009 | 0.043 |
| 410 | 322 | 6 | 45 | 25.3 | 1464.0 | 4.950 | -19.333 | 868.6 | 99.3 | 0.009 | 0.091 |
| 411 | 322 | 6 | 46 | 48.3 | 1314.9 | 4.706 | -20.424 | 855.2 | 99.0 | 0.011 | 0.071 |
| 412 | 322 | 6 | 47 | 48.3 | 812.4 | -0.053 | -28.933 | 269.2 | 65.0 | 0.001 | 0.042 |
| 413 | 322 | 6 | 48 | 10.3 | 1797.6 | 3.564 | -19.144 | 1449.9 | 101.3 | 0.004 | 0.096 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 414 | 322 | 6 | 48 | 22.3 | 1806.1 | 5.320 | -21.879 | 776.9 | 98.7 | 0.005 | 0.060 |
| 415 | 322 | 6 | 48 | 50.0 | 1315.4 | 4.997 | -20.991 | 783.0 | 98.2 | 0.001 | 0.066 |
| 416 | 322 | 6 | 48 | 58.3 | 1238.6 | 2.609 | -21.187 | 975.0 | 83.0 | 0.003 | 0.064 |
| 417 | 322 | 6 | 50 | 11.3 | 740.8 | 0.407 | -22.026 | 386.6 | 65.1 | 0.004 | 0.059 |
| 418 | 322 | 6 | 50 | 28.3 | 1700.8 | 5.147 | -20.032 | 858.0 | 99.2 | 0.007 | 0.076 |
| 419 | 322 | 6 | 51 | 1.3 | 588.8 | 1.146 | -15.722 | 425.0 | 65.0 | 0.003 | 0.165 |
| 420 | 322 | 6 | 51 | 7.0 | 1464.4 | 4.865 | -18.433 | 874.2 | 99.1 | 0.012 | 0.108 |
| 421 | 322 | 6 | 51 | 31.3 | 2379.8 | 5.076 | -18.452 | 962.3 | 99.3 | 0.060 | 0.107 |
| 422 | 322 | 6 | 51 | 47.3 | 2419.0 | 4.859 | -18.569 | 890.3 | 98.9 | 0.009 | 0.105 |
| 423 | 322 | 6 | 52 | 8.5 | 1614.7 | 5.098 | -19.072 | 869.5 | 99.3 | 0.007 | 0.097 |
| 424 | 322 | 6 | 52 | 12.3 | 1270.1 | 4.830 | -19.195 | 806.5 | 99.0 | 0.013 | 0.094 |
| 425 | 322 | 6 | 53 | 28.0 | 1812.3 | 4.816 | -19.209 | 1010.2 | 99.1 | 0.024 | 0.094 |
| 426 | 322 | 6 | 54 | 37.3 | 1255.5 | 4.566 | -22.546 | 865.4 | 99.2 | 0.010 | 0.056 |
| 427 | 322 | 6 | 56 | 25.3 | 2042.1 | 5.245 | -18.058 | 778.5 | 99.1 | 0.019 | 0.115 |
| 428 | 322 | 6 | 56 | 29.2 | 1385.7 | 4.803 | -21.980 | 877.9 | 99.1 | 0.008 | 0.059 |
| 429 | 322 | 6 | 57 | 22.3 | 1313.6 | 4.684 | -23.736 | 864.8 | 99.1 | 0.009 | 0.052 |
| 430 | 322 | 6 | 57 | 50.0 | 1259.7 | 4.560 | -20.825 | 867.0 | 99.1 | 0.010 | 0.067 |
| 431 | 322 | 6 | 58 | 17.3 | 1841.9 | 4.742 | -14.553 | 976.9 | 98.4 | 0.017 | 0.197 |
| 432 | 322 | 6 | 58 | 35.3 | 905.2 | -0.367 | -25.174 | 338.2 | 65.1 | 0.001 | 0.048 |
| 433 | 322 | 7 | 0 | 2.3 | 814.8 | 0.034 | -49.242 | 326.0 | 65.1 | 0.008 | 0.019 |
| 434 | 322 | 7 | 0 | 56.3 | 875.4 | -0.208 | -19.923 | 341.9 | 65.0 | 0.001 | 0.078 |
| 435 | 322 | 7 | 1 | 15.3 | 872.4 | -0.233 | -23.859 | 345.9 | 65.0 | 0.003 | 0.052 |
| 436 | 322 | 7 | 1 | 47.2 | 1875.5 | 5.105 | -23.141 | 905.0 | 99.2 | 0.009 | 0.054 |
| 437 | 322 | 7 | 1 | 55.3 | 837.6 | -0.027 | -23.637 | 345.3 | 65.0 | 0.006 | 0.052 |
| 438 | 322 | 7 | 2 | 46.3 | 901.6 | 4.530 | -20.368 | 687.1 | 98.6 | 0.042 | 0.072 |
| 439 | 322 | 7 | 3 | 6.3 | 858.4 | -0.183 | -20.384 | 356.1 | 65.1 | 0.006 | 0.072 |
| 440 | 322 | 7 | 3 | 9.3 | 815.5 | 0.121 | -22.160 | 404.9 | 65.0 | 0.005 | 0.058 |
| 441 | 322 | 7 | 3 | 13.3 | 972.6 | -0.724 | -18.229 | 312.3 | 65.0 | 0.002 | 0.113 |
| 442 | 322 | 7 | 3 | 34.5 | 1767.4 | 5.112 | -18.09 | 864.1 | 98.9 | 0.009 | 0.115 |
| 443 | 322 | 7 | 3 | 35.3 | 970.7 | 4.137 | -19.825 | 752.0 | 98.3 | 0.001 | 0.079 |
| 444 | 322 | 7 | 4 | 45.3 | 1016.6 | 5.622 | -19.386 | 592.2 | 99.5 | 0.047 | 0.088 |
| 445 | 322 | 7 | 5 | 2.3 | 2272.6 | 4.998 | -19.106 | 861.7 | 99.1 | 0.004 | 0.097 |
| 446 | 322 | 7 | 6 | 10.3 | 974.7 | -0.681 | -17.66 | 334.7 | 65.1 | 0.001 | 0.122 |
| 447 | 322 | 7 | 6 | 16.5 | 1238.6 | -3.508 | -23.869 | 908.8 | 83.1 | 0.002 | 0.052 |
| 448 | 322 | 7 | 6 | 25.3 | 1575.8 | 4.847 | -22.417 | 948.7 | 99.2 | 0.018 | 0.057 |
| 449 | 322 | 7 | 6 | 41.3 | 1402.7 | 5.237 | -19.398 | 745.8 | 98.8 | 0.012 | 0.087 |
| 450 | 322 | 7 | 6 | 55.3 | 992.1 | 5.765 | -25.299 | 472.8 | 98.6 | 0.040 | 0.048 |
| 451 | 322 | 7 | 6 | 57.3 | 1295.4 | -1.595 | -18.985 | 898.5 | 98.6 | 0.079 | 0.099 |
| 452 | 322 | 7 | 7 | 11.3 | 2213.0 | 2.798 | -18.155 | 1738.9 | 96.3 | 0.082 | 0.114 |
| 453 | 322 | 7 | 7 | 43.3 | 806.8 | 0.020 | -20.466 | 338.1 | 65.1 | 0.005 | 0.071 |
| 454 | 322 | 7 | 7 | 47.3 | 978.6 | -0.792 | -21.790 | 290.3 | 65.0 | 0.003 | 0.060 |
| 455 | 322 | 7 | 8 | 3.3 | 1993.0 | 5.223 | -19.525 | 799.7 | 98.9 | 0.005 | 0.084 |
| 456 | 322 | 7 | 8 | 23.5 | 1576.4 | -1.356 | -22.057 | 1217.7 | 99.1 | 0.062 | 0.059 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 457 | 322 | 7 | 9 | 4.3 | 1391.3 | 4.940 | -20.318 | 850.0 | 99.2 | 0.006 | 0.072 |
| 458 | 322 | 7 | 9 | 20.5 | 1690.2 | -0.586 | -19.161 | 561.4 | 100.1 | 0.031 | 0.095 |
| 459 | 322 | 7 | 9 | 27.3 | 1464.7 | 5.023 | -21.239 | 858.9 | 99.3 | 0.003 | 0.064 |
| 460 | 322 | 7 | 9 | 37.3 | 1732.2 | -0.945 | -20.105 | 727.3 | 99.0 | 0.006 | 0.075 |
| 461 | 322 | 7 | 9 | 54.5 | 2489.0 | -0.340 | -19.155 | 1687.5 | 101.4 | 0.043 | 0.095 |
| 462 | 322 | 7 | 10 | 18.3 | 1694.0 | 4.643 | -23.885 | 1010.9 | 99.9 | 0.037 | 0.052 |
| 463 | 322 | 7 | 10 | 35.1 | 1747.3 | 5.298 | -21.734 | 847.7 | | | 0.061 |
| 464 | 322 | 7 | 10 | 29.3 | 895.7 | -0.329 | -25.156 | 382.4 | 65.0 | 0.003 | 0.048 |
| 465 | 322 | 7 | 10 | 36.3 | 2349.9 | -4.255 | -18.877 | 1673.2 | 64.5 | 0.080 | 0.100 |
| 466 | 322 | 7 | 12 | 14.3 | 1822.8 | 5.182 | -18.524 | 783.7 | 98.1 | 0.005 | 0.106 |
| 467 | 322 | 7 | 13 | 12.3 | 1434.8 | 5.048 | -24.190 | 821.6 | 99.2 | 0.011 | 0.051 |
| 468 | 322 | 7 | 13 | 25.3 | 1369.9 | 4.813 | -27.093 | 875.1 | 99.2 | 0.006 | 0.045 |
| 469 | 322 | 7 | 14 | 30.3 | 1038.8 | -1.018 | -18.674 | 320.9 | 65.1 | 0.003 | 0.103 |
| 470 | 322 | 7 | 14 | 42.5 | 845.4 | -0.059 | -28.085 | 355.5 | 65.1 | 0.003 | 0.043 |
| 471 | 322 | 7 | 14 | 44.3 | 646.1 | 0.686 | -26.717 | 396.1 | 64.6 | 0.004 | 0.045 |
| 472 | 322 | 7 | 16 | 22.0 | 1078.0 | -1.118 | -28.363 | 327.1 | 65.1 | 0.002 | 0.043 |
| 473 | 322 | 7 | 17 | 13.3 | 1050.7 | -1.113 | -37.255 | 315.7 | 65.0 | 0.002 | 0.030 |
| 474 | 322 | 7 | 17 | 24.0 | 1679.5 | 3.776 | -19.393 | 1084.3 | 94.4 | 0.047 | 0.088 |
| 475 | 322 | 7 | 19 | 57.3 | 1156.6 | -1.363 | -22.909 | 359.0 | 65.0 | 0.002 | 0.055 |
| 476 | 322 | 7 | 20 | 26.3 | 982.0 | -0.679 | -29.759 | 346.3 | 65.0 | 0.001 | 0.040 |
| 477 | 322 | 7 | 21 | 51.3 | 1318.2 | 5.342 | -20.658 | 697.8 | 98.8 | 0.015 | 0.069 |
| 478 | 322 | 7 | 21 | 56.3 | 1293.6 | 4.855 | -32.026 | 813.8 | 98.9 | 0.010 | 0.037 |
| 479 | 322 | 7 | 21 | 58.3 | 2279.9 | 4.636 | -18.985 | 988.0 | 98.3 | 0.017 | 0.099 |
| 480 | 322 | 7 | 22 | 11.3 | 1012.3 | -0.914 | -19.614 | 327.4 | 65.0 | 0.003 | 0.082 |
| 481 | 322 | 7 | 22 | 32.3 | 1774.1 | 5.225 | -25.346 | 813.9 | 98.9 | 0.009 | 0.048 |
| 482 | 322 | 7 | 22 | 50.3 | 1847.9 | 5.080 | -22.287 | 814.6 | 98.8 | 0.026 | 0.057 |
| 483 | 322 | 7 | 23 | 36.3 | 1044.0 | -1.003 | -23.330 | 315.3 | 64.9 | 0.005 | 0.053 |
| 484 | 322 | 7 | 25 | 32.0 | 1237.1 | 5.750 | -33.791 | 583.2 | 98.7 | 0.024 | 0.035 |
| 485 | 322 | 7 | 26 | 0.3 | 966.5 | -0.571 | -25.968 | 395.2 | 65.0 | 0.005 | 0.047 |
| 486 | 322 | 7 | 27 | 8.3 | 1070.1 | -1.007 | -22.950 | 355.7 | 65.0 | 0.006 | 0.055 |
| 487 | 322 | 7 | 27 | 28.3 | 1151.1 | -1.397 | -22.467 | 356.1 | 65.0 | 0.003 | 0.057 |
| 488 | 322 | 7 | 29 | 29.3 | 950.6 | 5.781 | -30.646 | 499.1 | 98.4 | 0.024 | 0.039 |
| 489 | 322 | 7 | 30 | 1.3 | 1005.2 | -0.829 | -22.915 | 292.1 | 65.1 | 0.003 | 0.055 |
| 490 | 322 | 7 | 31 | 7.4 | 2413.8 | 4.613 | -18.535 | 963.3 | 98.5 | 0.017 | 0.105 |
| 491 | 322 | 7 | 31 | 7.0 | 2098.4 | 5.394 | -19.939 | 668.3 | 99.1 | 0.013 | 0.077 |
| 492 | 322 | 7 | 31 | 15.3 | 1115.7 | -1.192 | -16.067 | 386.5 | 65.0 | 0.004 | 0.159 |
| 493 | 322 | 7 | 31 | 20.3 | 769.5 | 4.788 | -38.717 | 564.5 | 99.7 | 0.051 | 0.029 |
| 494 | 322 | 7 | 31 | 51.5 | 1249.6 | 4.563 | -25.630 | 866.0 | 99.2 | 0.007 | 0.047 |
| 495 | 322 | 7 | 31 | 52.3 | 918.6 | -0.308 | -19.691 | 368.7 | 65.1 | 0.004 | 0.081 |
| 496 | 322 | 7 | 32 | 1.3 | 984.8 | -0.643 | -23.812 | 392.1 | 65.0 | 0.001 | 0.052 |
| 497 | 322 | 7 | 32 | 8.3 | 1088.6 | -1.126 | -19.409 | 367.0 | 65.0 | 0.005 | 0.087 |
| 498 | 322 | 7 | 33 | 41.3 | 995.7 | -0.636 | -20.032 | 388.7 | 65.0 | 0.002 | 0.076 |
| 499 | 322 | 7 | 35 | 10.1 | 2296.8 | -2.408 | -17.023 | 1893.5 | 86.4 | 0.170 | 0.139 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 500 | 322 | 7 | 35 | 12.5 | 1597.1 | 5.849 | -19.356 | 508.0 | 98.4 | 0.033 | 0.090 |
| 501 | 322 | 7 | 35 | 16.3 | 1061.2 | -0.966 | -20.435 | 368.8 | 65.0 | 0.004 | 0.071 |
| 502 | 322 | 7 | 36 | 7.0 | 1057.2 | -0.986 | -21.244 | 345.5 | 65.1 | 0.002 | 0.064 |
| 503 | 322 | 7 | 36 | 39.3 | 1406.6 | 5.155 | -24.147 | 767.5 | 98.3 | 0.005 | 0.051 |
| 504 | 322 | 7 | 37 | 4.0 | 1569.4 | -3.303 | -21.957 | 1305.4 | 75.3 | 0.010 | 0.059 |
| 505 | 322 | 7 | 37 | 33.3 | 1023.2 | -1.654 | -26.375 | 640.1 | 98.7 | 0.001 | 0.046 |
| 506 | 322 | 7 | 37 | 58.3 | 1007.5 | -0.645 | -14.763 | 427.5 | 65.0 | 0.005 | 0.189 |
| 507 | 322 | 7 | 38 | 12.3 | 1150.4 | 3.948 | -19.254 | 899.2 | 99.1 | 0.018 | 0.093 |
| 508 | 322 | 7 | 38 | 41.3 | 1810.6 | 5.190 | -22.177 | 867.4 | 99.5 | 0.004 | 0.058 |
| 509 | 322 | 7 | 39 | 24.5 | 1200.4 | 4.270 | -24.194 | 876.1 | 99.2 | 0.018 | 0.051 |
| 510 | 322 | 7 | 39 | 26.3 | 1212.1 | -1.764 | -23.580 | 300.0 | 65.0 | 0.003 | 0.053 |
| 511 | 322 | 7 | 39 | 57.3 | 1152.7 | -1.428 | -22.702 | 353.6 | 65.0 | 0.003 | 0.056 |
| 512 | 322 | 7 | 39 | 59.3 | 1140.3 | -1.332 | -28.292 | 356.4 | 65.0 | 0.002 | 0.043 |
| 513 | 322 | 7 | 42 | 5.3 | 1284.1 | -2.071 | -29.253 | 300.0 | 65.0 | 0.005 | 0.041 |
| 514 | 322 | 7 | 42 | 22.3 | 1243.4 | 5.002 | -27.195 | 755.3 | 98.9 | 0.013 | 0.045 |
| 515 | 322 | 7 | 42 | 56.3 | 1834.4 | 5.555 | -18.146 | 668.2 | 98.6 | 0.033 | 0.114 |
| 516 | 322 | 7 | 43 | 14.9 | 1264.7 | -3.081 | -26.679 | 1009.6 | 83.0 | 0.004 | 0.046 |
| 517 | 322 | 7 | 43 | 17.5 | 1918.6 | 4.136 | -19.562 | 1403.0 | 101.9 | 0.009 | 0.083 |
| 518 | 322 | 7 | 43 | 19.3 | 1376.0 | 4.832 | -27.117 | 846.2 | 99.0 | 0.014 | 0.045 |
| 519 | 322 | 7 | 43 | 46.3 | 1190.7 | -1.710 | -22.308 | 277.7 | 65.1 | 0.009 | 0.057 |
| 520 | 322 | 7 | 44 | 16.4 | 1189.9 | -3.166 | -28.176 | 939.6 | 82.8 | 0.002 | 0.043 |
| 521 | 322 | 7 | 44 | 17.5 | 2336.3 | 4.914 | -19.368 | 825.9 | | | 0.089 |
| 522 | 322 | 7 | 44 | 20.3 | 1262.6 | -1.950 | -23.170 | 324.4 | 65.0 | 0.007 | 0.054 |
| 523 | 322 | 7 | 45 | 10.2 | 2088.5 | -4.445 | -18.872 | 1523.6 | 69.2 | 0.057 | 0.100 |
| 524 | 322 | 7 | 45 | 16.3 | 1250.9 | 5.300 | -29.457 | 692.2 | 99.0 | 0.010 | 0.041 |
| 525 | 322 | 7 | 46 | 16.3 | 1226.4 | -1.876 | -24.158 | 273.5 | 65.1 | 0.001 | 0.051 |
| 526 | 322 | 7 | 46 | 35.3 | 1236.6 | -1.842 | -21.139 | 319.1 | 65.0 | 0.001 | 0.065 |
| 527 | 322 | 7 | 46 | 39.3 | 1337.6 | -2.264 | -23.029 | 336.2 | 65.0 | 0.013 | 0.055 |
| 528 | 322 | 7 | 47 | 49.3 | 1106.5 | -1.122 | -19.669 | 386.7 | 65.1 | 0.006 | 0.081 |
| 529 | 322 | 7 | 48 | 20.0 | 1028.3 | 5.459 | -25.827 | 588.3 | 98.9 | 0.020 | 0.047 |
| 530 | 322 | 7 | 48 | 48.3 | 1167.4 | -1.372 | -20.259 | 385.8 | 65.1 | 0.003 | 0.073 |
| 531 | 322 | 7 | 48 | 54.3 | 1108.3 | -1.121 | -23.242 | 370.5 | 65.1 | 0.004 | 0.054 |
| 532 | 322 | 7 | 49 | 2.3 | 1179.1 | -1.500 | -23.107 | 354.0 | 65.1 | 0.012 | 0.054 |
| 533 | 322 | 7 | 49 | 6.3 | 1253.8 | -1.917 | -22.912 | 327.0 | 65.0 | 0.004 | 0.055 |
| 534 | 322 | 7 | 49 | 30.3 | 1118.6 | -1.182 | -19.376 | 374.4 | 65.1 | 0.007 | 0.089 |
| 535 | 322 | 7 | 49 | 41.3 | 1209.6 | -1.516 | -24.978 | 395.2 | 65.0 | 0.002 | 0.049 |
| 536 | 322 | 7 | 49 | 56.3 | 1324.9 | -2.181 | -17.465 | 329.6 | 65.1 | 0.009 | 0.126 |
| 537 | 322 | 7 | 50 | 3.3 | 1306.1 | -2.180 | -22.405 | 304.6 | 65.0 | 0.002 | 0.057 |
| 538 | 322 | 7 | 50 | 17.3 | 1684.0 | 2.631 | -23.207 | 911.1 | 83.0 | 0.018 | 0.054 |
| 539 | 322 | 7 | 50 | 18.3 | 1231.0 | 4.687 | -28.501 | 790.3 | 98.8 | 0.030 | 0.043 |
| 540 | 322 | 7 | 51 | 50.3 | 1351.1 | -2.475 | -21.971 | 255.6 | 65.0 | 0.004 | 0.059 |
| 541 | 322 | 7 | 51 | 51.5 | 995.9 | 4.583 | -22.741 | 704.7 | 99.0 | 0.016 | 0.056 |
| 542 | 322 | 7 | 52 | 11.3 | 1330.0 | -0.544 | -26.514 | 921.7 | 65.0 | 0.003 | 0.046 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 543 | 322 | 7 | 52 | 14.3 | 1596.5 | 5.007 | -23.717 | 873.1 | 99.2 | 0.017 | 0.052 |
| 544 | 322 | 7 | 52 | 21.3 | 1309.8 | 4.971 | -27.960 | 789.2 | 98.9 | 0.011 | 0.044 |
| 545 | 322 | 7 | 52 | 43.3 | 1185.7 | -1.498 | -19.248 | 375.7 | 65.1 | 0.005 | 0.093 |
| 546 | 322 | 7 | 52 | 54.3 | 1419.0 | 5.819 | -27.427 | 575.7 | 98.7 | 0.024 | 0.044 |
| 547 | 322 | 7 | 53 | 15.3 | 2417.8 | 4.920 | -19.342 | 804.2 | 99.1 | 0.009 | 0.090 |
| 548 | 322 | 7 | 53 | 58.5 | 2009.4 | 5.164 | -19.220 | 793.2 | 98.9 | 0.009 | 0.094 |
| 549 | 322 | 7 | 54 | 4.3 | 1101.6 | 4.935 | -29.082 | 710.5 | 99.0 | 0.016 | 0.041 |
| 550 | 322 | 7 | 54 | 35.3 | 1272.4 | -1.890 | -20.188 | 372.2 | 65.0 | 0.005 | 0.074 |
| 551 | 322 | 7 | 56 | 0.3 | 1208.0 | 4.998 | -19.364 | 740.6 | 98.9 | 0.017 | 0.089 |
| 552 | 322 | 7 | 56 | 28.3 | 2095.1 | 4.741 | -20.024 | 1007.3 | 99.1 | 0.033 | 0.076 |
| 553 | 322 | 7 | 58 | 50.3 | 1170.3 | 5.060 | -21.203 | 721.2 | 99.1 | 0.007 | 0.064 |
| 554 | 322 | 8 | 0 | 19.5 | 1222.2 | -1.113 | -29.133 | 836.3 | 100.9 | 0.012 | 0.041 |
| 555 | 322 | 8 | 0 | 19.3 | 1288.3 | -2.021 | -23.259 | 345.2 | 65.0 | 0.005 | 0.054 |
| 556 | 322 | 8 | 1 | 26.0 | 1411.2 | 5.899 | -20.610 | 540.6 | 98.6 | 0.023 | 0.069 |
| 557 | 322 | 8 | 2 | 54.0 | 1677.7 | 5.149 | -24.679 | 838.0 | 99.2 | 0.012 | 0.050 |
| 558 | 322 | 8 | 3 | 7.3 | 874.8 | 4.840 | -24.879 | 599.0 | 98.9 | 0.022 | 0.049 |
| 559 | 322 | 8 | 3 | 23.3 | 1357.4 | -2.160 | -15.876 | 399.2 | 65.0 | 0.002 | 0.162 |
| 560 | 322 | 8 | 3 | 35.3 | 1237.1 | -1.728 | -20.209 | 364.8 | 65.1 | 0.005 | 0.074 |
| 561 | 322 | 8 | 4 | 10.3 | 1510.5 | 5.776 | -23.324 | 590.6 | 98.8 | 0.019 | 0.053 |
| 562 | 322 | 8 | 4 | 27.5 | 1711.2 | 5.052 | -23.740 | 874.6 | 99.3 | 0.021 | 0.052 |
| 563 | 322 | 8 | 4 | 30.3 | 1216.3 | -1.490 | -19.149 | 428.4 | 65.0 | 0.005 | 0.096 |
| 564 | 322 | 8 | 5 | 20.3 | 1349.7 | -2.215 | -21.300 | 357.1 | 65.0 | 0.003 | 0.063 |
| 565 | 322 | 8 | 6 | 39.3 | 1263.5 | -1.787 | -22.269 | 376.7 | 65.0 | 0.004 | 0.058 |
| 566 | 322 | 8 | 7 | 8.3 | 1371.6 | -2.434 | -22.733 | 305.4 | 65.0 | 0.003 | 0.056 |
| 567 | 322 | 8 | 7 | 28.3 | 1183.9 | -1.224 | -21.934 | 884.3 | 98.7 | 0.075 | 0.059 |
| 568 | 322 | 8 | 7 | 52.3 | 1311.6 | -1.996 | -21.023 | 388.5 | 65.1 | 0.006 | 0.065 |
| 569 | 322 | 8 | 7 | 53.3 | 1258.5 | -1.339 | -22.748 | 445.7 | 99.7 | 0.008 | 0.056 |
| 570 | 322 | 8 | 8 | 26.3 | 1656.2 | 3.710 | -18.771 | 1327.2 | 102.0 | 0.006 | 0.101 |
| 571 | 322 | 8 | 9 | 13.3 | 1363.1 | -2.294 | -20.169 | 331.2 | 65.0 | 0.003 | 0.074 |
| 572 | 322 | 8 | 9 | 52.3 | 1387.1 | -2.431 | -19.994 | 333.8 | 65.0 | 0.003 | 0.077 |
| 573 | 322 | 8 | 10 | 29.3 | 1135.0 | 4.920 | -30.619 | 730.8 | 99.2 | 0.009 | 0.039 |
| 574 | 322 | 8 | 10 | 41.3 | 1284.6 | -1.843 | -16.593 | 409.7 | 65.1 | 0.004 | 0.149 |
| 575 | 322 | 8 | 10 | 57.3 | 1293.1 | -1.919 | -22.006 | 378.6 | 65.1 | 0.005 | 0.059 |
| 576 | 322 | 8 | 10 | 59.3 | 1307.7 | -1.869 | -25.849 | 423.4 | 65.1 | 0.014 | 0.047 |
| 577 | 322 | 8 | 12 | 13.0 | 1155.6 | 5.005 | -21.193 | 718.1 | 99.1 | 0.020 | 0.064 |
| 578 | 322 | 8 | 13 | 33.0 | 2262.6 | -3.475 | -19.334 | 1894.4 | 63.8 | 0.091 | 0.091 |
| 579 | 322 | 8 | 13 | 54.3 | 1152.5 | 4.253 | -19.642 | 861.7 | 99.4 | 0.006 | 0.082 |
| 580 | 322 | 8 | 14 | 51.3 | 2394.1 | -4.350 | -17.283 | 1191.0 | 64.6 | 0.079 | 0.133 |
| 581 | 322 | 8 | 15 | 14.0 | 2229.5 | 5.048 | -17.393 | 808.3 | 99.2 | 0.018 | 0.130 |
| 582 | 322 | 8 | 16 | 41.3 | 1361.0 | -2.206 | -21.199 | 380.5 | 65.1 | 0.005 | 0.064 |
| 583 | 322 | 8 | 17 | 8.3 | 806.0 | 4.733 | -23.896 | 574.9 | 98.8 | 0.023 | 0.052 |
| 584 | 322 | 8 | 17 | 32.3 | 1425.5 | -2.509 | -20.892 | 356.2 | 65.1 | 0.004 | 0.067 |
| 585 | 322 | 8 | 18 | 15.0 | 1642.0 | 5.139 | -19.971 | 868.3 | 99.4 | 0.004 | 0.077 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 586 | 322 | 8 | 18 | 17.3 | 2219.9 | 4.272 | -19.077 | 1539.9 | 99.3 | 0.063 | 0.097 |
| 587 | 322 | 8 | 18 | 30.3 | 1482.4 | 5.497 | -18.649 | 674.5 | 99.0 | 0.016 | 0.103 |
| 588 | 322 | 8 | 18 | 56.0 | 1204.3 | 5.918 | -26.952 | 530.4 | 98.7 | 0.023 | 0.045 |
| 589 | 322 | 8 | 19 | 49.3 | 2264.9 | 5.193 | -16.888 | 645.1 | 98.6 | 0.026 | 0.142 |
| 590 | 322 | 8 | 20 | 56.3 | 913.2 | 4.868 | -19.263 | 615.2 | 97.7 | 0.002 | 0.093 |
| 591 | 322 | 8 | 21 | 10.3 | 1491.9 | -2.897 | -21.754 | 320.5 | 65.1 | 0.003 | 0.060 |
| 592 | 322 | 8 | 22 | 47.5 | 2096.6 | 5.206 | -18.276 | 759.9 | 99.1 | 0.018 | 0.111 |
| 593 | 322 | 8 | 22 | 55.3 | 1086.5 | -0.912 | -19.671 | 438.7 | 65.1 | 0.005 | 0.081 |
| 594 | 322 | 8 | 25 | 13.3 | 1560.4 | -3.090 | -20.477 | 361.7 | 65.0 | 0.001 | 0.071 |
| 595 | 322 | 8 | 26 | 21.3 | 1413.7 | -2.416 | -19.235 | 388.0 | 65.0 | 0.004 | 0.093 |
| 596 | 322 | 8 | 28 | 21.0 | 1535.6 | -2.964 | -22.265 | 359.8 | 65.1 | 0.002 | 0.058 |
| 597 | 322 | 8 | 28 | 34.3 | 1381.7 | -6.498 | -26.706 | 499.5 | 62.2 | 0.069 | 0.046 |
| 598 | 322 | 8 | 28 | 52.0 | 2001.2 | 5.108 | -18.136 | 870.5 | 99.3 | 0.013 | 0.114 |
| 599 | 322 | 8 | 29 | 45.3 | 2415.6 | 4.312 | -20.767 | 1545.8 | 102.5 | 0.016 | 0.068 |
| 600 | 322 | 8 | 30 | 27.3 | 1445.3 | -1.688 | -19.493 | 783.3 | 97.5 | 0.043 | 0.084 |
| 601 | 322 | 8 | 31 | 1.3 | 1601.7 | -3.283 | -20.860 | 362.5 | 65.1 | 0.003 | 0.067 |
| 602 | 322 | 8 | 31 | 33.3 | 1174.5 | 5.151 | -17.613 | 656.7 | 97.7 | 0.014 | 0.123 |
| 603 | 322 | 8 | 33 | 55.3 | 1363.4 | -2.419 | -19.248 | 369.6 | 64.7 | 0.002 | 0.093 |
| 604 | 322 | 8 | 33 | 59.3 | 1578.3 | -3.248 | -21.412 | 342.2 | 65.0 | 0.005 | 0.063 |
| 605 | 322 | 8 | 34 | 36.3 | 1496.6 | 5.767 | -20.074 | 577.6 | 98.8 | 0.025 | 0.076 |
| 606 | 322 | 8 | 35 | 4.3 | 1681.7 | 5.534 | -23.727 | 661.4 | 98.9 | 0.000 | 0.052 |
| 607 | 322 | 8 | 35 | 36.3 | 1648.3 | -3.585 | -17.689 | 313.4 | 65.1 | 0.002 | 0.121 |
| 608 | 322 | 8 | 35 | 38.3 | 1603.2 | -1.241 | -21.199 | 606.9 | 98.3 | 0.005 | 0.064 |
| 609 | 322 | 8 | 37 | 0.5 | 1070.8 | -1.700 | -19.939 | 755.2 | 97.6 | 0.045 | 0.077 |
| 610 | 322 | 8 | 37 | 6.3 | 1515.5 | -2.835 | -19.363 | 393.1 | 65.0 | 0.005 | 0.089 |
| 611 | 322 | 8 | 38 | 2.3 | 1579.1 | -3.220 | -19.666 | 347.2 | 65.1 | 0.001 | 0.081 |
| 612 | 322 | 8 | 38 | 14.3 | 1459.5 | -2.597 | -20.840 | 377.9 | 65.1 | 0.002 | 0.067 |
| 613 | 322 | 8 | 38 | 37.3 | 1674.4 | -3.692 | -19.263 | 307.4 | 65.0 | 0.006 | 0.093 |
| 614 | 322 | 8 | 38 | 47.3 | 1496.6 | 4.982 | -19.658 | 858.3 | 99.3 | 0.012 | 0.081 |
| 615 | 322 | 8 | 40 | 25.3 | 1509.6 | -2.838 | -22.155 | 386.3 | 65.0 | 0.007 | 0.058 |
| 616 | 322 | 8 | 40 | 25.5 | 2410.8 | 4.446 | -18.559 | 1484.8 | 101.6 | 0.006 | 0.105 |
| 617 | 322 | 8 | 41 | 55.0 | 1881.4 | 5.214 | -19.219 | 847.9 | 99.5 | 0.008 | 0.094 |
| 618 | 322 | 8 | 42 | 41.3 | 1613.3 | -3.372 | -19.611 | 362.4 | 65.0 | 0.001 | 0.082 |
| 619 | 322 | 8 | 43 | 18.3 | 1590.8 | -3.227 | -21.243 | 365.1 | 65.0 | 0.002 | 0.064 |
| 620 | 322 | 8 | 44 | 18.3 | 1640.0 | -3.490 | -19.110 | 342.8 | 65.0 | 0.004 | 0.097 |
| 621 | 322 | 8 | 44 | 49.2 | 1144.3 | -1.251 | -21.117 | 933.7 | 97.4 | 0.023 | 0.065 |
| 622 | 322 | 8 | 47 | 9.0 | 2173.0 | 5.242 | -18.805 | 686.0 | | | 0.101 |
| 623 | 322 | 8 | 50 | 45.3 | 1302.4 | 5.999 | -19.376 | 515.7 | 98.8 | 0.023 | 0.089 |
| 624 | 322 | 8 | 50 | 45.5 | 2167.4 | 4.996 | -18.557 | 880.8 | 99.2 | 0.020 | 0.105 |
| 625 | 322 | 8 | 51 | 34.3 | 1665.6 | -3.584 | -21.713 | 348.7 | 65.0 | 0.006 | 0.061 |
| 626 | 322 | 8 | 52 | 32.3 | 1666.1 | -3.587 | -20.860 | 353.3 | 64.9 | 0.011 | 0.067 |
| 627 | 322 | 8 | 52 | 44.3 | 1588.9 | 5.451 | -19.637 | 707.4 | 99.1 | 0.017 | 0.082 |
| 628 | 322 | 8 | 53 | 22.0 | 1603.7 | 5.514 | -18.431 | 614.7 | 97.7 | 0.003 | 0.108 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 629 | 322 | 8 | 53 | 39.3 | 2051.7 | 4.183 | -20.585 | 1459.1 | 101.7 | 0.011 | 0.069 |
| 630 | 322 | 8 | 55 | 1.3 | 1736.6 | -5.971 | -24.606 | 806.5 | 65.1 | 0.002 | 0.050 |
| 631 | 322 | 8 | 56 | 4.3 | 1704.3 | -3.861 | -20.886 | 316.2 | 64.9 | 0.007 | 0.067 |
| 632 | 322 | 8 | 56 | 51.5 | 1658.4 | -1.462 | -19.015 | 780.7 | 97.5 | 0.041 | 0.098 |
| 633 | 322 | 8 | 57 | 7.3 | 1349.4 | -1.530 | -19.966 | 1026.0 | 97.1 | 0.018 | 0.077 |
| 634 | 322 | 8 | 58 | 4.3 | 1599.1 | -5.843 | -26.609 | 805.5 | 65.0 | 0.002 | 0.046 |
| 635 | 322 | 8 | 58 | 34.3 | 1556.0 | 5.323 | -19.371 | 751.8 | 98.5 | 0.037 | 0.089 |
| 636 | 322 | 8 | 58 | 46.3 | 2123.5 | 0.054 | -18.185 | 1614.3 | 64.6 | 0.269 | 0.114 |
| 637 | 322 | 8 | 58 | 51.3 | 1782.9 | 5.669 | -19.421 | 720.6 | 99.7 | 0.033 | 0.086 |
| 638 | 322 | 8 | 58 | 51.2 | 2379.3 | -3.939 | -18.536 | 631.1 | 82.3 | 0.013 | 0.105 |
| 639 | 322 | 8 | 59 | 3.3 | 1580.0 | -5.823 | -25.013 | 805.4 | 64.9 | 0.002 | 0.049 |
| 640 | 322 | 8 | 59 | 17.3 | 1657.0 | 5.620 | -18.556 | 622.8 | 99.0 | 0.017 | 0.105 |
| 641 | 322 | 8 | 59 | 43.3 | 1558.7 | -5.797 | -26.411 | 805.6 | 65.0 | 0.003 | 0.046 |
| 642 | 322 | 8 | 59 | 49.3 | 1684.1 | -5.922 | -25.749 | 810.6 | 65.0 | 0.001 | 0.047 |
| 643 | 322 | 9 | 0 | 18.3 | 1732.8 | -3.846 | -19.822 | 356.4 | 65.0 | 0.006 | 0.079 |
| 644 | 322 | 9 | 0 | 57.3 | 1513.2 | 5.947 | -23.164 | 510.6 | 98.8 | 0.025 | 0.054 |
| 645 | 322 | 9 | 1 | 2.3 | 1645.2 | -5.895 | -25.812 | 807.6 | 65.0 | 0.001 | 0.047 |
| 646 | 322 | 9 | 3 | 21.3 | 1266.2 | 4.680 | -22.947 | 852.3 | 99.4 | 0.007 | 0.055 |
| 647 | 322 | 9 | 3 | 44.3 | 2006.8 | 0.342 | -21.383 | 1249.6 | 72.4 | 0.078 | 0.063 |
| 648 | 322 | 9 | 3 | 50.5 | 1230.3 | -5.138 | -25.035 | 805.8 | 65.0 | 0.002 | 0.049 |
| 649 | 322 | 9 | 3 | 51.4 | 2046.4 | -3.767 | -19.022 | 1061.8 | 82.6 | 0.027 | 0.098 |
| 650 | 322 | 9 | 3 | 55.3 | 1346.1 | 5.381 | -20.536 | 737.9 | 98.8 | 0.042 | 0.070 |
| 651 | 322 | 9 | 4 | 20.5 | 1256.6 | -5.220 | -26.315 | 805.4 | 65.0 | 0.000 | 0.046 |
| 652 | 322 | 9 | 4 | 49.5 | 1192.7 | -5.023 | -26.641 | 804.9 | 65.1 | 0.002 | 0.046 |
| 653 | 322 | 9 | 5 | 13.3 | 1769.0 | -3.928 | -17.456 | 389.4 | 65.0 | 0.006 | 0.126 |
| 654 | 322 | 9 | 5 | 25.3 | 1616.7 | -3.278 | -19.390 | 369.3 | 65.1 | 0.001 | 0.088 |
| 655 | 322 | 9 | 5 | 34.3 | 1739.9 | -3.853 | -18.594 | 367.7 | 65.0 | 0.001 | 0.104 |
| 656 | 322 | 9 | 5 | 45.4 | 1089.1 | -4.596 | -26.999 | 804.5 | | | 0.045 |
| 657 | 322 | 9 | 5 | 45.4 | 1089.6 | -4.602 | -25.211 | 804.2 | 64.9 | 0.002 | 0.048 |
| 658 | 322 | 9 | 6 | 1.5 | 1034.5 | -4.287 | -26.146 | 804.7 | 65.0 | 0.002 | 0.047 |
| 659 | 322 | 9 | 6 | 16.5 | 958.9 | -3.722 | -26.711 | 804.0 | 65.0 | 0.002 | 0.045 |
| 660 | 322 | 9 | 6 | 24.3 | 722.0 | -4.604 | -18.479 | 394.6 | 56.9 | 0.251 | 0.107 |
| 661 | 322 | 9 | 6 | 51.3 | 1977.4 | 5.215 | -12.568 | 647.1 | 97.8 | 0.023 | 0.246 |
| 662 | 322 | 9 | 8 | 34.3 | 1618.5 | -3.304 | -20.769 | 395.4 | 64.9 | 0.005 | 0.068 |
| 663 | 322 | 9 | 9 | 35.5 | 1531.8 | -3.774 | -25.428 | 995.2 | 83.1 | 0.008 | 0.048 |
| 664 | 322 | 9 | 9 | 50.0 | 1909.9 | 5.331 | -21.080 | 614.5 | 97.6 | 0.002 | 0.065 |
| 665 | 322 | 9 | 10 | 46.3 | 834.9 | 5.040 | -22.942 | 559.3 | 99.0 | 0.021 | 0.055 |
| 666 | 322 | 9 | 12 | 9.3 | 1635.4 | -2.397 | -22.926 | 1190.7 | 90.3 | 0.016 | 0.055 |
| 667 | 322 | 9 | 14 | 21.3 | 1762.8 | -3.946 | -23.521 | 371.9 | 65.0 | 0.001 | 0.053 |
| 668 | 322 | 9 | 14 | 22.3 | 1352.7 | 5.412 | -20.318 | 682.9 | 99.1 | 0.019 | 0.072 |
| 669 | 322 | 9 | 14 | 33.3 | 2354.5 | 5.226 | -17.603 | 599.0 | | | 0.123 |
| 670 | 322 | 9 | 16 | 25.5 | 1636.1 | 5.228 | -19.604 | 798.6 | 98.5 | 0.035 | 0.082 |
| 671 | 322 | 9 | 18 | 7.0 | 1460.4 | 5.867 | -25.442 | 549.8 | 99.0 | 0.022 | 0.048 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 672 | 322 | 9 | 19 | 24.3 | 1396.4 | 5.839 | -21.309 | 565.8 | 99.0 | 0.021 | 0.063 |
| 673 | 322 | 9 | 20 | 5.3 | 925.6 | -3.969 | -25.600 | 753.0 | 70.7 | 0.007 | 0.048 |
| 674 | 322 | 9 | 21 | 37.0 | 1757.8 | -3.850 | -21.042 | 386.8 | 65.1 | 0.002 | 0.065 |
| 675 | 322 | 9 | 22 | 36.3 | 2212.5 | -2.752 | -16.614 | 1784.4 | 82.1 | 0.032 | 0.149 |
| 676 | 322 | 9 | 23 | 3.0 | 1777.2 | -3.950 | -19.524 | 374.5 | 65.1 | 0.001 | 0.084 |
| 677 | 322 | 9 | 24 | 7.3 | 1835.4 | -4.195 | -18.444 | 391.7 | 65.1 | 0.005 | 0.108 |
| 678 | 322 | 9 | 24 | 27.3 | 2226.8 | 5.126 | -19.131 | 756.4 | 98.9 | 0.010 | 0.096 |
| 679 | 322 | 9 | 25 | 3.3 | 2176.0 | 5.339 | -18.463 | 614.4 | 98.7 | 0.021 | 0.107 |
| 680 | 322 | 9 | 29 | 38.0 | 1145.7 | 4.254 | -26.772 | 861.7 | 99.7 | 0.005 | 0.045 |
| 681 | 322 | 9 | 31 | 20.0 | 1450.2 | 5.602 | -18.941 | 627.4 | 99.5 | 0.043 | 0.099 |
| 682 | 322 | 9 | 33 | 12.0 | 1375.9 | 5.799 | -24.054 | 568.3 | 98.8 | 0.025 | 0.051 |
| 683 | 322 | 9 | 33 | 23.3 | 1157.7 | 2.560 | -16.893 | 878.6 | 81.2 | 0.002 | 0.142 |
| 684 | 322 | 9 | 34 | 45.3 | 1763.5 | 5.788 | -20.119 | 554.9 | 98.7 | 0.023 | 0.075 |
| 685 | 322 | 9 | 35 | 50.0 | 2262.5 | 5.153 | -19.950 | 766.5 | 99.5 | 0.008 | 0.077 |
| 686 | 322 | 9 | 36 | 51.3 | 1407.5 | 5.891 | -17.458 | 557.2 | 99.1 | 0.022 | 0.126 |
| 687 | 322 | 9 | 37 | 16.3 | 1954.1 | -4.667 | -15.984 | 400.9 | 65.0 | 0.006 | 0.160 |
| 688 | 322 | 9 | 37 | 42.3 | 1209.7 | 2.636 | -23.471 | 882.8 | 81.2 | 0.001 | 0.053 |
| 689 | 322 | 9 | 37 | 47.3 | 1823.9 | 5.844 | -18.755 | 484.3 | 98.7 | 0.032 | 0.101 |
| 690 | 322 | 9 | 38 | 39.3 | 1577.7 | 5.317 | -19.969 | 752.6 | 98.9 | 0.008 | 0.077 |
| 691 | 322 | 9 | 38 | 54.3 | 1845.8 | -4.138 | -17.475 | 428.9 | 65.0 | 0.002 | 0.125 |
| 692 | 322 | 9 | 40 | 12.2 | 1382.5 | -3.153 | -22.113 | 768.2 | 89.4 | 0.018 | 0.058 |
| 693 | 322 | 9 | 40 | 17.3 | 1879.8 | -4.449 | -20.609 | 378.7 | 65.0 | 0.010 | 0.069 |
| 694 | 322 | 9 | 40 | 49.3 | 1279.3 | 5.427 | -18.697 | 665.9 | 99.3 | 0.017 | 0.102 |
| 695 | 322 | 9 | 42 | 32.0 | 1423.3 | 5.368 | -24.122 | 719.9 | 99.3 | 0.018 | 0.051 |
| 696 | 322 | 9 | 43 | 10.0 | 1422.4 | 5.678 | -25.775 | 617.0 | 99.1 | 0.019 | 0.047 |
| 697 | 322 | 9 | 44 | 17.3 | 1429.7 | 5.017 | -27.294 | 861.6 | 99.7 | 0.005 | 0.044 |
| 698 | 322 | 9 | 44 | 59.3 | 1218.4 | 4.534 | -20.464 | 858.3 | 99.7 | 0.007 | 0.071 |
| 699 | 322 | 9 | 45 | 0.5 | 1899.6 | -4.412 | -17.138 | 411.0 | 65.0 | 0.002 | 0.137 |
| 700 | 322 | 9 | 45 | 53.3 | 1672.5 | -3.318 | -19.399 | 446.4 | 65.1 | 0.008 | 0.087 |
| 701 | 322 | 9 | 46 | 24.0 | 1359.0 | 4.840 | -20.104 | 858.2 | 99.6 | 0.014 | 0.075 |
| 702 | 322 | 9 | 47 | 34.3 | 1925.7 | -2.647 | -21.34 | 1075.0 | 90.4 | 0.022 | 0.063 |
| 703 | 322 | 9 | 48 | 46.3 | 2012.5 | -1.153 | -19.266 | 1506.8 | 97.9 | 0.049 | 0.093 |
| 704 | 322 | 9 | 49 | 34.3 | 1700.8 | -2.922 | -20.438 | 1341.8 | 82.6 | 0.030 | 0.071 |
| 705 | 322 | 9 | 51 | 6.0 | 1627.3 | 5.931 | -22.733 | 521.6 | | | 0.056 |
| 706 | 322 | 9 | 51 | 8.3 | 967.7 | -3.842 | -25.106 | 702.3 | 81.3 | 0.002 | 0.049 |
| 707 | 322 | 9 | 51 | 42.0 | 1925.8 | 5.499 | -20.191 | 678.4 | 99.4 | 0.010 | 0.074 |
| 708 | 322 | 9 | 52 | 10.3 | 2034.1 | 1.740 | -19.851 | 600.9 | 82.1 | 0.008 | 0.078 |
| 709 | 322 | 9 | 54 | 50.3 | 1455.3 | 4.777 | -21.955 | 910.5 | 99.7 | 0.032 | 0.059 |
| 710 | 322 | 10 | 0 | 18.3 | 1939.6 | -4.548 | -16.647 | 425.6 | 65.0 | 0.003 | 0.148 |
| 711 | 322 | 10 | 0 | 31.3 | 861.1 | 5.185 | -32.160 | 556.2 | 99.1 | 0.020 | 0.037 |
| 712 | 322 | 10 | 1 | 54.3 | 1945.5 | 5.617 | -17.638 | 556.8 | 99.2 | 0.022 | 0.122 |
| 713 | 322 | 10 | 2 | 40.3 | 1504.5 | 5.419 | -22.039 | 745.8 | 99.1 | 0.009 | 0.059 |
| 714 | 322 | 10 | 3 | 45.3 | 1749.6 | -5.225 | -19.513 | 1131.4 | 62.3 | 0.366 | 0.084 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 715 | 322 | 10 | 4 | 4.3 | 1870.9 | 2.212 | -19.351 | 974.2 | 82.4 | 0.006 | 0.090 |
| 716 | 322 | 10 | 4 | 34.5 | 974.8 | -2.248 | -20.210 | 489.1 | 96.9 | 0.041 | 0.074 |
| 717 | 322 | 10 | 5 | 30.0 | 1779.1 | -2.335 | -22.477 | 958.7 | 64.9 | 0.024 | 0.057 |
| 718 | 322 | 10 | 6 | 26.3 | 2073.8 | 5.205 | -17.989 | 868.0 | 99.8 | 0.006 | 0.116 |
| 719 | 322 | 10 | 7 | 53.3 | 1402.4 | 5.951 | -27.022 | 521.5 | | | 0.045 |
| 720 | 322 | 10 | 9 | 20.3 | 1838.0 | 5.241 | -21.780 | 860.0 | 99.7 | 0.008 | 0.060 |
| 721 | 322 | 10 | 10 | 38.5 | 1846.4 | 5.519 | -21.366 | 664.2 | 99.0 | 0.024 | 0.063 |
| 722 | 322 | 10 | 10 | 40.3 | 1524.3 | 5.945 | -22.707 | 523.4 | 99.1 | 0.023 | 0.056 |
| 723 | 322 | 10 | 10 | 59.3 | 2088.3 | -0.066 | -16.406 | 1534.6 | 102.8 | 0.059 | 0.153 |
| 724 | 322 | 10 | 14 | 44.3 | 1193.8 | 6.049 | -27.803 | 492.2 | 98.8 | 0.025 | 0.044 |
| 725 | 322 | 10 | 15 | 54.3 | 935.3 | 5.704 | -25.681 | 527.6 | 99.1 | 0.027 | 0.047 |
| 726 | 322 | 10 | 16 | 6.3 | 1818.9 | 5.547 | -19.603 | 685.4 | 99.3 | 0.012 | 0.082 |
| 727 | 322 | 10 | 16 | 27.0 | 1113.1 | 4.335 | -23.869 | 816.7 | 99.6 | 0.012 | 0.052 |
| 728 | 322 | 10 | 18 | 12.3 | 1690.5 | -1.545 | -22.168 | 1026.7 | 97.3 | 0.026 | 0.058 |
| 729 | 322 | 10 | 19 | 15.3 | 2075.1 | 4.982 | -14.083 | 776.2 | 98.4 | 0.034 | 0.207 |
| 730 | 322 | 10 | 19 | 56.3 | 1348.1 | 6.166 | -19.77 | 443.5 | 98.5 | 0.033 | 0.080 |
| 731 | 322 | 10 | 20 | 20.0 | 2006.6 | 5.603 | -21.391 | 516.3 | 98.5 | 0.024 | 0.063 |
| 732 | 322 | 10 | 21 | 34.3 | 1347.9 | -1.518 | -26.050 | 628.9 | 98.6 | 0.003 | 0.047 |
| 733 | 322 | 10 | 23 | 48.3 | 815.6 | 5.060 | -19.998 | 561.0 | 98.8 | 0.022 | 0.077 |
| 734 | 322 | 10 | 25 | 6.3 | 1343.4 | 6.065 | -25.365 | 475.0 | 98.9 | 0.022 | 0.048 |
| 735 | 322 | 10 | 26 | 17.3 | 1656.1 | 5.208 | -22.790 | 849.4 | 99.8 | 0.011 | 0.055 |
| 736 | 322 | 10 | 28 | 7.0 | 1706.3 | 5.224 | -21.899 | 852.2 | 99.7 | 0.007 | 0.060 |
| 737 | 322 | 10 | 28 | 33.3 | 1344.7 | 6.041 | -23.363 | 507.4 | 99.1 | 0.020 | 0.053 |
| 738 | 322 | 10 | 28 | 35.3 | 1700.4 | -2.554 | -19.804 | 1307.2 | 88.2 | 0.005 | 0.079 |
| 739 | 322 | 10 | 29 | 57.0 | 1677.8 | 4.213 | -19.585 | 1093.4 | 98.7 | 0.154 | 0.083 |
| 740 | 322 | 10 | 30 | 15.3 | 1844.9 | 5.796 | -19.749 | 526.5 | 99.1 | 0.021 | 0.080 |
| 741 | 322 | 10 | 31 | 58.3 | 1031.5 | 4.840 | -18.690 | 685.3 | 98.1 | 0.000 | 0.102 |
| 742 | 322 | 10 | 32 | 9.3 | 1531.2 | 5.126 | -19.127 | 830.5 | 99.6 | 0.010 | 0.096 |
| 743 | 322 | 10 | 36 | 10.3 | 1793.9 | 0.582 | -19.384 | 593.2 | 75.7 | 0.009 | 0.088 |
| 744 | 322 | 10 | 41 | 10.3 | 1466.8 | -1.520 | -21.056 | 794.4 | 97.9 | 0.037 | 0.065 |
| 745 | 322 | 10 | 43 | 3.0 | 1109.1 | -1.828 | -27.466 | 741.0 | 97.2 | 0.016 | 0.044 |
| 746 | 322 | 10 | 43 | 32.3 | 1134.8 | 5.858 | -21.603 | 565.2 | 99.1 | 0.032 | 0.061 |
| 747 | 322 | 10 | 44 | 27.3 | 1777.7 | -4.675 | -18.126 | 524.8 | 83.7 | 0.299 | 0.114 |
| 748 | 322 | 10 | 45 | 49.0 | 2172.7 | 5.141 | -21.262 | 854.7 | | | 0.064 |
| 749 | 322 | 10 | 50 | 46.3 | 1951.1 | 1.757 | -18.809 | 1544.6 | 82.0 | 0.021 | 0.101 |
| 750 | 322 | 10 | 50 | 57.3 | 1105.2 | 4.479 | -22.923 | 719.1 | 95.1 | 0.024 | 0.055 |
| 751 | 322 | 10 | 53 | 30.3 | 1520.0 | 5.367 | -19.378 | 743.7 | 99.5 | 0.018 | 0.089 |
| 752 | 322 | 10 | 53 | 40.3 | 1182.7 | 5.595 | -21.282 | 537.2 | 97.3 | 0.025 | 0.063 |
| 753 | 322 | 10 | 58 | 12.0 | 1485.6 | 0.394 | -19.313 | 464.5 | 104.8 | 0.027 | 0.092 |
| 754 | 322 | 11 | 2 | 28.3 | 1182.7 | 0.479 | -22.926 | 958.6 | 67.0 | 0.008 | 0.055 |
| 755 | 322 | 11 | 3 | 58.3 | 685.3 | 5.178 | -32.974 | 468.5 | | | 0.036 |
| 756 | 322 | 11 | 4 | 30.3 | 1034.2 | 5.466 | -20.208 | 590.8 | 98.9 | 0.016 | 0.074 |
| 757 | 322 | 11 | 4 | 57.3 | 824.9 | 5.320 | -18.822 | 502.4 | 98.0 | 0.018 | 0.101 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 758 | 322 | 11 | 8 | 4.3 | 1434.7 | -2.909 | -24.065 | 839.5 | 90.3 | 0.004 | 0.051 |
| 759 | 322 | 11 | 8 | 31.3 | 1118.6 | 5.935 | -18.818 | 536.0 | 99.2 | 0.029 | 0.101 |
| 760 | 322 | 11 | 8 | 45.3 | 1407.2 | 6.057 | -25.881 | 498.3 | 99.1 | 0.023 | 0.047 |
| 761 | 322 | 11 | 8 | 50.3 | 2163.7 | 5.599 | -18.233 | 525.1 | 98.9 | 0.032 | 0.112 |
| 762 | 322 | 11 | 10 | 58.0 | 1558.4 | -1.983 | -19.392 | 1303.3 | 90.0 | 0.005 | 0.088 |
| 763 | 322 | 11 | 11 | 52.3 | 2053.0 | -2.908 | -19.382 | 1641.0 | 82.6 | 0.027 | 0.088 |
| 764 | 322 | 11 | 12 | 7.3 | 1222.6 | 6.035 | -20.778 | 494.8 | 99.2 | 0.026 | 0.067 |
| 765 | 322 | 11 | 12 | 25.3 | 1915.8 | -2.578 | -23.082 | 1354.0 | 88.4 | 0.006 | 0.054 |
| 766 | 322 | 11 | 13 | 11.3 | 1959.8 | 1.897 | -17.588 | 1482.8 | 82.2 | 0.014 | 0.123 |
| 767 | 322 | 11 | 14 | 7.3 | 1567.9 | -2.101 | -23.318 | 1284.5 | 90.0 | 0.006 | 0.054 |
| 768 | 322 | 11 | 14 | 52.0 | 2258.4 | 5.152 | -17.724 | 752.1 | 100.0 | 0.038 | 0.120 |
| 769 | 322 | 11 | 18 | 50.3 | 1988.1 | 0.640 | -19.305 | 1500.5 | 73.7 | 0.003 | 0.092 |
| 770 | 322 | 11 | 19 | 24.3 | 1501.0 | 5.808 | -26.901 | 586.3 | 99.2 | 0.014 | 0.045 |
| 771 | 322 | 11 | 19 | 52.0 | 1648.0 | 5.442 | -22.312 | 633.9 | 97.7 | 0.022 | 0.057 |
| 772 | 322 | 11 | 20 | 0.3 | 1300.1 | 5.837 | -19.826 | 576.8 | 98.9 | 0.021 | 0.079 |
| 773 | 322 | 11 | 22 | 2.3 | 1261.8 | -1.506 | -19.282 | 459.1 | 65.5 | 0.018 | 0.092 |
| 774 | 322 | 11 | 24 | 27.3 | 1254.7 | -1.587 | -19.933 | 842.5 | 97.9 | 0.020 | 0.077 |
| 775 | 322 | 11 | 24 | 41.3 | 912.6 | -0.130 | -19.869 | 397.2 | 65.4 | 0.016 | 0.078 |
| 776 | 322 | 11 | 25 | 12.3 | 1612.7 | -5.958 | -21.288 | 678.4 | 62.2 | 0.445 | 0.063 |
| 777 | 322 | 11 | 28 | 41.3 | 1931.1 | 5.434 | | 708.0 | 99.6 | 0.016 | |
| 778 | 322 | 11 | 30 | 12.3 | 1221.3 | 4.689 | | 824.4 | 99.9 | 0.014 | |
| 779 | 322 | 11 | 30 | 48.3 | 1859.9 | -2.434 | | 1302.5 | 99.1 | 0.031 | |
| 780 | -8000 | 11 | 31 | 5.3 | 1103.5 | 5.569 | | 619.2 | | | |
| 781 | 322 | 11 | 33 | 28.3 | 1558.7 | -1.740 | | 818.9 | 65.1 | 0.005 | |
| 782 | 322 | 11 | 36 | 42.3 | 1515.7 | -2.539 | | 893.6 | 62.3 | 0.272 | |
| 783 | 322 | 11 | 37 | 51.3 | 1887.6 | 5.279 | | 621.4 | 97.8 | 0.028 | |
| 784 | 322 | 11 | 39 | 26.3 | 1627.4 | 6.072 | | 440.9 | 99.5 | 0.033 | |
| 785 | 322 | 11 | 39 | 49.3 | 1018.0 | -1.502 | | 697.7 | 98.1 | 0.049 | |
| 786 | 322 | 11 | 40 | 17.3 | 1916.2 | -2.428 | | 1281.9 | 90.1 | 0.005 | |
| 787 | 322 | 11 | 40 | 55.3 | 1452.0 | -0.785 | | 1153.8 | 99.4 | 0.068 | |
| 788 | 322 | 11 | 42 | 8.0 | 1285.4 | 6.156 | | 473.8 | 99.1 | 0.024 | |
| 789 | 322 | 11 | 43 | 4.3 | 665.6 | -0.922 | | 536.2 | 99.6 | 0.003 | |
| 790 | 322 | 11 | 44 | 55.3 | 1889.5 | 5.599 | | 604.8 | 98.9 | 0.024 | |
| 791 | 322 | 11 | 45 | 37.3 | 1757.5 | -2.347 | | 1289.9 | 90.2 | 0.004 | |
| 792 | 322 | 11 | 48 | 52.0 | 1209.2 | -1.858 | | 622.8 | 97.1 | 0.030 | |
| 793 | 322 | 11 | 49 | 18.3 | 921.6 | 5.607 | | 520.8 | 98.9 | 0.018 | |
| 794 | 322 | 11 | 49 | 51.5 | 2460.5 | -0.321 | | 1510.3 | 98.5 | 0.054 | |
| 795 | -8000 | 11 | 49 | 56.3 | 2152.6 | 5.230 | | 744.1 | | | |
| 796 | 322 | 11 | 53 | 27.3 | 980.3 | 5.790 | | 517.6 | 99.0 | 0.023 | |
| 797 | 322 | 11 | 56 | 46.3 | 1614.6 | 5.631 | | 620.0 | 99.4 | 0.026 | |
| 798 | 322 | 11 | 57 | 4.3 | 1362.5 | 5.944 | | 511.5 | 98.9 | 0.015 | |
| 799 | 322 | 12 | 2 | 49.0 | 1506.4 | -1.491 | | 834.1 | 98.1 | 0.029 | |
| 800 | 322 | 12 | 3 | 32.3 | 1426.2 | 5.731 | | 708.1 | 102.4 | 0.008 | |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 801 | 322 | 12 | 3 | 38.3 | 1304.2 | -1.565 | | 841.8 | 98.0 | 0.029 | |
| 802 | 322 | 12 | 6 | 46.0 | 1624.2 | 5.218 | | 817.9 | 99.0 | 0.001 | |
| 803 | 322 | 12 | 7 | 44.3 | 1571.2 | 5.353 | | 747.6 | 99.7 | 0.022 | |
| 804 | 322 | 12 | 11 | 48.3 | 1047.3 | -7.097 | | 277.2 | 65.0 | 0.001 | |
| 805 | 322 | 12 | 20 | 34.3 | 2402.8 | 2.953 | | 1130.7 | 90.0 | 0.013 | |
| 806 | 322 | 12 | 20 | 53.3 | 1798.9 | -7.076 | | 331.9 | 65.0 | 0.004 | |
| 807 | 322 | 12 | 21 | 40.2 | 1052.4 | -7.034 | | 295.9 | 100.0 | 0.016 | |
| 808 | -8000 | 12 | 21 | 28.3 | 1293.3 | 4.987 | | 797.9 | | | |
| 809 | 322 | 12 | 22 | 42.3 | 1549.7 | -7.085 | | 329.8 | 65.0 | 0.002 | |
| 810 | 322 | 12 | 23 | 1.5 | 1754.9 | -7.057 | | 345.7 | 65.0 | 0.004 | |
| 811 | 322 | 12 | 23 | 3.3 | 1334.1 | 0.704 | | 842.2 | 71.0 | 0.002 | |
| 812 | 322 | 12 | 24 | 35.3 | 1396.5 | -7.080 | | 322.6 | 65.0 | 0.004 | |
| 813 | 322 | 12 | 24 | 56.3 | 686.7 | -6.833 | | 262.1 | 65.1 | 0.003 | |
| 814 | 322 | 12 | 25 | 32.3 | 1340.7 | -7.192 | | 268.2 | 64.9 | 0.003 | |
| 815 | 322 | 12 | 25 | 52.0 | 1678.1 | -7.121 | | 316.9 | 65.0 | 0.001 | |
| 816 | 322 | 12 | 25 | 52.5 | 1137.2 | -1.520 | | 868.4 | 98.3 | 0.028 | |
| 817 | 322 | 12 | 26 | 5.5 | 1359.4 | -1.858 | | 530.9 | 97.2 | 0.005 | |
| 818 | 322 | 12 | 27 | 10.3 | 1749.4 | -0.996 | | 1124.0 | 99.7 | 0.030 | |
| 819 | 322 | 12 | 27 | 27.0 | 1844.6 | -1.131 | | 551.4 | 97.1 | 0.033 | |
| 820 | 322 | 12 | 27 | 46.3 | 1548.8 | -7.209 | | 271.6 | 65.1 | 0.001 | |
| 821 | 322 | 12 | 27 | 49.3 | 2254.8 | -3.994 | | 1622.5 | 74.5 | 0.025 | |
| 822 | 322 | 12 | 29 | 24.3 | 851.1 | -1.434 | | 609.2 | 65.0 | 0.003 | |
| 823 | 322 | 12 | 29 | 55.3 | 1753.7 | -7.075 | | 342.6 | 65.1 | 0.001 | |
| 824 | 322 | 12 | 30 | 24.3 | 825.0 | -6.851 | | 298.6 | 99.4 | 0.061 | |
| 825 | -8000 | 12 | 30 | 48.3 | 1429.6 | -1.053 | | 973.3 | | | |
| 826 | 322 | 12 | 36 | 9.3 | 776.7 | -3.628 | | 507.0 | 56.8 | 0.173 | |
| 827 | 322 | 12 | 36 | 10.3 | 1773.0 | -7.003 | | 374.2 | 65.1 | 0.003 | |
| 828 | 322 | 12 | 36 | 59.3 | 1251.4 | -1.539 | | 934.5 | 98.3 | 0.027 | |
| 829 | 322 | 12 | 38 | 29.3 | 1122.1 | -6.841 | | 370.1 | 65.0 | 0.002 | |
| 830 | 322 | 12 | 38 | 53.3 | 681.9 | -6.098 | | 371.4 | 65.0 | 0.001 | |
| 831 | 322 | 12 | 39 | 0.3 | 1303.6 | -4.918 | | 585.0 | 81.2 | 0.002 | |
| 832 | 322 | 12 | 39 | 42.5 | 1386.6 | -7.019 | | 347.7 | 65.1 | 0.003 | |
| 833 | 322 | 12 | 39 | 48.3 | 792.2 | 5.937 | | 417.3 | 99.2 | 0.022 | |
| 834 | 322 | 12 | 40 | 7.3 | 874.5 | -6.732 | | 337.8 | 65.0 | 0.001 | |
| 835 | 322 | 12 | 41 | 0.0 | 656.7 | -2.382 | | 403.7 | 56.9 | 0.250 | |
| 836 | 322 | 12 | 41 | 22.3 | 1289.2 | -1.536 | | 871.0 | 98.1 | 0.016 | |
| 837 | 322 | 12 | 42 | 40.0 | 1595.4 | -6.936 | | 400.0 | 65.1 | 0.003 | |
| 838 | 322 | 12 | 42 | 59.5 | 1337.3 | -6.939 | | 373.9 | 65.0 | 0.002 | |
| 839 | 322 | 12 | 43 | 19.3 | 849.1 | -6.664 | | 343.2 | 64.9 | 0.000 | |
| 840 | 322 | 12 | 43 | 20.3 | 1226.8 | -1.545 | | 868.8 | 98.4 | 0.027 | |
| 841 | 322 | 12 | 45 | 13.3 | 1853.5 | -7.043 | | 362.1 | 65.1 | 0.001 | |
| 842 | -8000 | 12 | 45 | 21.2 | 1261.2 | -2.000 | | 541.9 | | | |
| 843 | -8000 | 12 | 45 | 23.0 | 1451.5 | -4.715 | | 1010.5 | | | |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 844 | 322 | 12 | 46 | 38.9 | 1583.2 | -4.026 | | 910.5 | 83.0 | 0.002 | |
| 845 | 322 | 12 | 46 | 48.3 | 1389.5 | 5.929 | | 521.4 | 99.0 | 0.016 | |
| 846 | 322 | 12 | 47 | 5.3 | 1582.2 | 0.894 | | 1312.9 | 62.6 | 0.355 | |
| 847 | 322 | 12 | 47 | 41.3 | 1146.4 | -3.602 | | 945.4 | 57.0 | 0.308 | |
| 848 | 322 | 12 | 48 | 40.3 | 1407.8 | 5.206 | | 782.8 | 99.9 | 0.013 | |
| 849 | 322 | 12 | 49 | 1.3 | 1127.2 | -6.898 | | 355.8 | 65.1 | 0.002 | |
| 850 | 322 | 12 | 49 | 14.3 | 986.7 | 5.350 | | 563.2 | 98.8 | 0.020 | |
| 851 | 322 | 12 | 50 | 6.0 | 1593.4 | -0.802 | | 1308.6 | 101.5 | 0.001 | |
| 852 | 322 | 12 | 50 | 38.2 | 2467.6 | -1.068 | | 2092.4 | 64.8 | 0.042 | |
| 853 | 322 | 12 | 50 | 39.6 | 1644.9 | -1.307 | | 833.7 | 98.3 | 0.031 | |
| 854 | 322 | 12 | 50 | 44.3 | 753.8 | -2.632 | | 500.1 | 57.0 | 0.257 | |
| 855 | 322 | 12 | 50 | 48.3 | 1257.0 | -6.904 | | 375.1 | 65.0 | 0.001 | |
| 856 | 322 | 12 | 51 | 38.3 | 1468.5 | -1.363 | | 842.0 | 98.1 | 0.030 | |
| 857 | 322 | 12 | 52 | 45.5 | 1220.1 | -1.524 | | 868.5 | 98.5 | 0.035 | |
| 858 | 322 | 12 | 53 | 48.3 | 1875.8 | -1.261 | | 460.3 | 96.6 | 0.014 | |
| 859 | 322 | 12 | 54 | 18.3 | 546.3 | -5.125 | | 386.9 | 65.0 | 0.003 | |
| 860 | 322 | 12 | 54 | 35.4 | 1355.9 | -1.549 | | 872.0 | 98.3 | 0.020 | |
| 861 | 322 | 12 | 54 | 40.3 | 1283.7 | 6.088 | | 439.0 | 98.8 | 0.005 | |
| 862 | 322 | 12 | 54 | 41.0 | 860.9 | -1.674 | | 589.2 | 97.3 | 0.033 | |
| 863 | 322 | 12 | 55 | 0.0 | 735.4 | -6.189 | | 384.3 | 65.0 | 0.000 | |
| 864 | 322 | 12 | 55 | 9.0 | 1143.8 | -6.836 | | 373.9 | 65.3 | 0.003 | |
| 865 | 322 | 12 | 56 | 56.3 | 1507.2 | -1.694 | | 455.9 | 97.2 | 0.045 | |
| 866 | 322 | 12 | 58 | 51.3 | 1306.7 | -1.332 | | 915.8 | 98.2 | 0.023 | |
| 867 | 322 | 13 | 0 | 59.3 | 1512.2 | -1.537 | | 939.8 | 98.4 | 0.029 | |
| 868 | 322 | 13 | 1 | 14.3 | 1641.2 | -3.183 | | 395.6 | 65.4 | 0.016 | |
| 869 | -8000 | 13 | 4 | 44.3 | 1273.4 | 5.180 | | 741.0 | | | |
| 870 | -8000 | 13 | 5 | 6.3 | 1465.1 | -1.539 | | 1006.3 | | | |
| 871 | 322 | 13 | 6 | 18.3 | 1251.8 | -1.556 | | 872.9 | 98.4 | 0.025 | |
| 872 | 322 | 13 | 7 | 30.3 | 1121.1 | 5.640 | | 579.9 | 99.7 | 0.023 | |
| 873 | 322 | 13 | 8 | 2.3 | 1454.7 | -1.552 | | 804.5 | 97.8 | 0.018 | |
| 874 | 322 | 13 | 14 | 5.5 | 1147.1 | -2.048 | | 498.2 | 97.4 | 0.042 | |
| 875 | 322 | 13 | 14 | 13.3 | 1238.9 | -2.012 | | 500.9 | 97.4 | 0.041 | |
| 876 | 322 | 13 | 14 | 56.0 | 1672.6 | -1.223 | | 809.7 | 98.3 | 0.032 | |
| 877 | 322 | 13 | 16 | 47.0 | 1492.8 | 5.291 | | 778.7 | 99.1 | 0.003 | |
| 878 | 322 | 13 | 17 | 8.3 | 1824.9 | -1.040 | | 871.8 | 98.2 | 0.023 | |
| 879 | 322 | 13 | 22 | 48.5 | 1685.6 | -1.146 | | 912.8 | 98.2 | 0.025 | |
| 880 | 322 | 13 | 22 | 52.3 | 1496.2 | 3.801 | | 1119.2 | 95.6 | 0.029 | |
| 881 | 322 | 13 | 23 | 18.3 | 1758.9 | 2.478 | | 983.6 | 83.1 | 0.006 | |
| 882 | 322 | 13 | 25 | 26.0 | 1620.4 | 5.683 | | 609.3 | 99.0 | 0.017 | |
| 883 | 322 | 13 | 26 | 18.0 | 1338.7 | -1.285 | | 968.7 | 98.1 | 0.023 | |
| 884 | 322 | 13 | 28 | 17.3 | 1530.7 | -1.367 | | 665.5 | 98.4 | 0.055 | |
| 885 | 322 | 13 | 28 | 36.3 | 2499.6 | 4.553 | | 1467.9 | 101.7 | 0.023 | |
| 886 | 322 | 13 | 28 | 39.3 | 1355.0 | -1.522 | -29.999 | 884.0 | 98.2 | 0.014 | 0.040 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 887 | 322 | 13 | 30 | 1.3 | 1462.2 | -5.346 | -21.846 | 883.8 | 66.7 | 0.004 | 0.060 |
| 888 | 322 | 13 | 35 | 47.3 | 1952.4 | 5.834 | -19.700 | 497.8 | 99.1 | 0.039 | 0.081 |
| 889 | 322 | 13 | 36 | 14.3 | 620.4 | -1.449 | -19.819 | 434.6 | 56.8 | 0.223 | 0.079 |
| 890 | 322 | 13 | 37 | 19.3 | 1551.8 | -1.378 | -21.371 | 891.3 | 98.1 | 0.010 | 0.063 |
| 891 | 322 | 13 | 37 | 41.3 | 1277.0 | -1.330 | -19.783 | 765.1 | 98.4 | 0.062 | 0.079 |
| 892 | 322 | 13 | 39 | 50.3 | 903.0 | 6.116 | -22.133 | 423.6 | 99.3 | 0.022 | 0.058 |
| 893 | 322 | 13 | 40 | 33.3 | 1507.6 | -2.980 | -19.630 | 1209.0 | 82.5 | 0.002 | 0.082 |
| 894 | 322 | 13 | 41 | 55.3 | 2090.8 | -0.627 | -18.060 | 833.2 | 98.3 | 0.028 | 0.115 |
| 895 | 322 | 13 | 42 | 10.3 | 1662.6 | -1.058 | -19.537 | 888.0 | 99.8 | 0.070 | 0.084 |
| 896 | 322 | 13 | 43 | 40.3 | 1296.1 | -1.781 | -19.453 | 660.5 | 97.1 | 0.026 | 0.085 |
| 897 | 322 | 13 | 46 | 31.0 | 1607.8 | -1.498 | -19.720 | 494.5 | 97.4 | 0.038 | 0.080 |
| 898 | 322 | 13 | 51 | 6.0 | 1474.3 | 0.190 | -25.491 | 734.3 | 70.9 | 0.004 | 0.048 |
| 899 | 322 | 13 | 51 | 19.3 | 1438.7 | -1.570 | -19.937 | 791.3 | 98.3 | 0.038 | 0.077 |
| 900 | 322 | 13 | 57 | 24.0 | 1424.9 | 5.482 | -20.950 | 709.5 | 100.2 | 0.018 | 0.066 |
| 901 | 322 | 13 | 58 | 48.3 | 1508.0 | -0.892 | -20.267 | 712.0 | 99.8 | 0.057 | 0.073 |
| 902 | 322 | 13 | 59 | 17.3 | 1106.6 | -6.662 | -32.944 | 428.6 | 65.2 | 0.005 | 0.036 |
| 903 | 322 | 13 | 59 | 45.3 | 1090.2 | -1.209 | -29.559 | 888.3 | 98.3 | 0.009 | 0.041 |
| 904 | 322 | 14 | 1 | 39.3 | 1788.7 | 5.657 | -21.505 | 606.8 | 99.6 | 0.030 | 0.062 |
| 905 | 322 | 14 | 2 | 57.3 | 1612.9 | -1.303 | -19.761 | 706.5 | 98.6 | 0.055 | 0.080 |
| 906 | 322 | 14 | 3 | 24.3 | 1806.2 | -0.841 | -19.609 | 1052.0 | 99.6 | 0.007 | 0.082 |
| 907 | 322 | 14 | 8 | 42.3 | 1842.8 | -6.990 | -20.062 | 410.0 | 65.1 | 0.006 | 0.076 |
| 908 | 322 | 14 | 8 | 46.3 | 1836.6 | -3.281 | -18.252 | 1340.1 | 82.5 | 0.003 | 0.112 |
| 909 | 322 | 14 | 9 | 2.3 | 1422.0 | -2.827 | -17.442 | 472.6 | 63.9 | 0.103 | 0.127 |
| 910 | 322 | 14 | 11 | 12.0 | 1382.1 | -1.410 | -21.836 | 859.2 | 98.4 | 0.023 | 0.060 |
| 911 | 322 | 14 | 18 | 14.3 | 2040.0 | 4.374 | -21.872 | 1364.0 | 100.8 | 0.035 | 0.060 |
| 912 | 322 | 14 | 18 | 56.3 | 1918.3 | 5.795 | -22.327 | 538.5 | 99.2 | 0.037 | 0.057 |
| 913 | 322 | 14 | 19 | 7.3 | 1744.8 | -1.354 | -18.728 | 1288.3 | 98.8 | 0.049 | 0.102 |
| 914 | 322 | 14 | 19 | 33.3 | 1185.7 | -1.397 | -22.942 | 916.3 | 98.7 | 0.021 | 0.055 |
| 915 | 322 | 14 | 22 | 24.5 | 1167.3 | -1.064 | -20.246 | 900.9 | 99.9 | 0.061 | 0.073 |
| 916 | 322 | 14 | 22 | 29.3 | 2202.9 | -4.097 | -17.220 | 1530.0 | 73.4 | 0.005 | 0.135 |
| 917 | 322 | 14 | 22 | 45.2 | 2034.9 | -0.848 | -19.249 | 1599.9 | 101.3 | 0.029 | 0.093 |
| 918 | 322 | 14 | 22 | 52.3 | 1353.9 | 5.788 | -20.963 | 550.8 | 99.1 | 0.018 | 0.066 |
| 919 | 322 | 14 | 23 | 13.3 | 1533.8 | -1.356 | -23.002 | 902.2 | 98.2 | 0.010 | 0.055 |
| 920 | 322 | 14 | 24 | 32.0 | 1868.7 | 5.962 | -20.770 | 437.7 | 99.5 | 0.023 | 0.068 |
| 921 | 322 | 14 | 24 | 50.3 | 1197.8 | -1.452 | -22.808 | 945.3 | 98.7 | 0.022 | 0.055 |
| 922 | 322 | 14 | 25 | 40.3 | 1511.1 | -3.644 | -25.913 | 1028.5 | 82.7 | 0.008 | 0.047 |
| 923 | 322 | 14 | 26 | 14.3 | 1072.6 | -1.015 | -38.553 | 770.7 | 62.3 | 0.089 | 0.029 |
| 924 | 322 | 14 | 27 | 19.3 | 1001.3 | 0.070 | -22.669 | 627.0 | 65.7 | 0.002 | 0.056 |
| 925 | 322 | 14 | 27 | 42.3 | 1156.5 | -1.352 | -21.085 | 893.4 | 98.3 | 0.009 | 0.065 |
| 926 | 322 | 14 | 29 | 49.3 | 1325.2 | 6.086 | -20.412 | 505.5 | 99.8 | 0.024 | 0.071 |
| 927 | 322 | 14 | 31 | 5.3 | 1534.2 | -2.071 | -22.040 | 1295.2 | 83.1 | 0.107 | 0.059 |
| 928 | 322 | 14 | 34 | 57.3 | 1138.9 | 6.028 | -22.730 | 500.1 | 99.7 | 0.022 | 0.056 |
| 929 | 322 | 14 | 36 | 21.3 | 690.5 | -4.845 | -19.349 | 252.8 | 57.2 | 0.020 | 0.090 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 930 | 322 | 14 | 38 | 59.0 | 1354.7 | 4.435 | -25.676 | 969.1 | 102.7 | 0.046 | 0.047 |
| 931 | 322 | 14 | 39 | 37.3 | 1226.3 | 5.779 | -18.462 | 539.9 | 98.2 | 0.004 | 0.107 |
| 932 | 322 | 14 | 41 | 54.3 | 1266.1 | 5.864 | -19.363 | 486.7 | 97.7 | 0.002 | 0.089 |
| 933 | 322 | 14 | 44 | 24.0 | 1794.6 | 5.139 | -22.343 | 638.8 | 95.5 | 0.028 | 0.057 |
| 934 | 322 | 14 | 44 | 26.3 | 1723.5 | 5.940 | -21.253 | 377.6 | 98.6 | 0.004 | 0.064 |
| 935 | 322 | 14 | 47 | 10.5 | 1402.9 | -6.949 | -21.078 | 388.0 | 65.2 | 0.005 | 0.065 |
| 936 | 322 | 14 | 52 | 1.3 | 1184.5 | -1.411 | -19.425 | 893.9 | 98.3 | 0.007 | 0.086 |
| 937 | 322 | 14 | 53 | 48.3 | 1234.3 | 3.058 | -19.35 | 613.8 | 81.2 | 0.004 | 0.090 |
| 938 | 322 | 14 | 58 | 55.3 | 1917.7 | 5.768 | -21.256 | 401.3 | 98.8 | 0.010 | 0.064 |
| 939 | 322 | 14 | 58 | 56.3 | 2084.5 | 5.618 | -19.960 | 545.8 | 99.2 | 0.028 | 0.077 |
| 940 | 322 | 15 | 0 | 58.3 | 1853.7 | 3.736 | -21.905 | 776.9 | 89.4 | 0.006 | 0.060 |
| 941 | 322 | 15 | 1 | 25.3 | 720.2 | -1.395 | -28.435 | 563.3 | 97.9 | 0.028 | 0.043 |
| 942 | 322 | 15 | 5 | 16.3 | 1522.9 | -1.434 | -20.483 | 736.5 | 98.1 | 0.023 | 0.070 |
| 943 | 322 | 15 | 8 | 6.5 | 1138.1 | -1.134 | -19.487 | 943.5 | 98.4 | 0.008 | 0.085 |
| 944 | 322 | 15 | 8 | 11.3 | 1904.0 | -0.530 | -19.222 | 1457.6 | 102.0 | 0.005 | 0.094 |
| 945 | 322 | 15 | 9 | 33.5 | 1783.4 | -0.809 | -20.429 | 1049.3 | 100.0 | 0.001 | 0.071 |
| 946 | 322 | 15 | 9 | 39.3 | 1520.7 | 4.765 | -20.010 | 1032.8 | 102.1 | 0.017 | 0.076 |
| 947 | 322 | 15 | 9 | 54.3 | 1320.7 | -1.343 | -17.715 | 942.0 | 98.4 | 0.018 | 0.121 |
| 948 | 322 | 15 | 12 | 6.3 | 1603.4 | -4.732 | -24.973 | 688.3 | 81.2 | 0.001 | 0.049 |
| 949 | 322 | 15 | 12 | 38.3 | 1675.2 | -0.962 | -18.836 | 1045.3 | 100.4 | 0.019 | 0.100 |
| 950 | 322 | 15 | 13 | 1.3 | 862.9 | -1.720 | -26.129 | 567.9 | 97.7 | 0.031 | 0.047 |
| 951 | 322 | 15 | 15 | 0.3 | 1580.2 | -1.443 | -18.645 | 633.4 | 97.7 | 0.022 | 0.103 |
| 952 | 322 | 15 | 15 | 31.3 | 2076.5 | -0.893 | -18.238 | 1034.9 | 99.0 | 0.065 | 0.112 |
| 953 | 322 | 15 | 16 | 18.0 | 2117.6 | 0.097 | -18.288 | 1040.7 | 101.3 | 0.021 | 0.111 |
| 954 | 322 | 15 | 17 | 46.3 | 896.5 | -4.401 | -24.622 | 640.1 | 57.0 | 0.313 | 0.050 |
| 955 | 322 | 15 | 18 | 17.3 | 1182.1 | 0.556 | -26.309 | 571.0 | 70.0 | 0.002 | 0.046 |
| 956 | 322 | 15 | 19 | 6.0 | 1151.1 | -3.487 | -28.048 | 977.7 | 64.6 | 0.006 | 0.043 |
| 957 | 322 | 15 | 20 | 20.0 | 1025.6 | -1.214 | -22.042 | 827.6 | 98.3 | 0.011 | 0.059 |
| 958 | 322 | 15 | 26 | 36.0 | 1946.0 | -0.924 | -17.945 | 973.7 | 98.7 | 0.025 | 0.117 |
| 959 | 322 | 15 | 26 | 57.3 | 1505.6 | -1.315 | -19.518 | 957.0 | 98.5 | 0.015 | 0.084 |
| 960 | 322 | 15 | 29 | 40.3 | 1479.4 | 2.805 | -23.119 | 876.9 | 82.8 | 0.007 | 0.054 |
| 961 | 322 | 15 | 31 | 26.0 | 881.4 | -1.600 | -19.584 | 652.3 | 98.0 | 0.024 | 0.083 |
| 962 | 322 | 15 | 33 | 20.3 | 1507.2 | -1.345 | -19.345 | 711.8 | 98.1 | 0.028 | 0.090 |
| 963 | 322 | 15 | 33 | 54.3 | 1541.0 | -1.290 | -22.421 | 927.5 | 98.5 | 0.016 | 0.057 |
| 964 | 322 | 15 | 35 | 33.3 | 1821.4 | 5.360 | -22.075 | 778.0 | 99.1 | 0.005 | 0.059 |
| 965 | 322 | 15 | 35 | 46.0 | 1330.3 | -1.474 | -20.486 | 866.0 | 98.7 | 0.015 | 0.070 |
| 966 | 322 | 15 | 35 | 58.3 | 1602.6 | -1.319 | -19.124 | 611.0 | 97.6 | 0.029 | 0.096 |
| 967 | 322 | 15 | 36 | 34.5 | 1412.1 | -1.660 | -24.320 | 633.6 | 97.9 | 0.026 | 0.050 |
| 968 | 322 | 15 | 36 | 41.3 | 1503.9 | -1.585 | -18.869 | 844.1 | 97.5 | 0.018 | 0.100 |
| 969 | 322 | 15 | 37 | 41.3 | 1193.8 | 3.113 | -26.630 | 767.0 | 83.0 | 0.003 | 0.046 |
| 970 | 322 | 15 | 38 | 54.3 | 1740.2 | -1.171 | -17.414 | 660.4 | 97.5 | 0.031 | 0.129 |
| 971 | 322 | 15 | 39 | 26.3 | 721.6 | -1.471 | -20.328 | 539.8 | 97.9 | 0.034 | 0.072 |
| 972 | 322 | 15 | 41 | 38.3 | 1776.4 | 4.220 | -18.353 | 1321.3 | 102.0 | 0.019 | 0.110 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 973 | 322 | 15 | 42 | 36.3 | 913.7 | 0.767 | -20.832 | 478.7 | 68.1 | 0.005 | 0.067 |
| 974 | 322 | 15 | 43 | 3.5 | 1365.4 | -1.755 | -21.714 | 542.8 | 97.8 | 0.025 | 0.061 |
| 975 | 322 | 15 | 45 | 35.3 | 1923.6 | -3.457 | -19.233 | 790.7 | 65.0 | 0.019 | 0.094 |
| 976 | 322 | 15 | 48 | 51.0 | 1925.3 | -0.508 | -17.799 | 1335.5 | 101.7 | 0.010 | 0.119 |
| 977 | 322 | 15 | 52 | 38.0 | 1664.2 | 5.296 | -20.403 | 1059.2 | 99.9 | 0.123 | 0.071 |
| 978 | 322 | 15 | 52 | 55.0 | 961.7 | 5.868 | -23.640 | 472.0 | 99.3 | 0.016 | 0.052 |
| 979 | 322 | 15 | 53 | 10.3 | 1257.4 | -1.343 | -24.161 | 916.7 | 97.9 | 0.037 | 0.051 |
| 980 | 322 | 15 | 53 | 36.3 | 1102.6 | -1.329 | -18.739 | 850.6 | 98.9 | 0.020 | 0.102 |
| 981 | 322 | 15 | 56 | 4.3 | 1196.7 | -1.414 | -23.698 | 861.5 | 98.7 | 0.013 | 0.052 |
| 982 | 322 | 15 | 58 | 3.3 | 1987.4 | -0.987 | -19.650 | 1031.5 | 98.5 | 0.029 | 0.082 |
| 983 | 322 | 15 | 58 | 27.3 | 1287.3 | 2.928 | -26.462 | 692.7 | 81.3 | 0.004 | 0.046 |
| 984 | 322 | 15 | 58 | 38.4 | 1819.1 | -0.981 | -20.208 | 956.0 | 98.6 | 0.011 | 0.074 |
| 985 | 322 | 15 | 58 | 47.0 | 1804.6 | 2.021 | -20.832 | 1455.5 | 82.6 | 0.003 | 0.067 |
| 986 | 322 | 15 | 58 | 55.0 | 1773.7 | -1.058 | -20.217 | 811.2 | 98.4 | 0.015 | 0.074 |
| 987 | 322 | 15 | 59 | 9.3 | 1177.0 | 4.238 | -22.477 | 864.2 | 96.7 | 0.020 | 0.057 |
| 988 | 322 | 16 | 0 | 37.3 | 1659.1 | -0.303 | -18.230 | 417.8 | 101.1 | 0.012 | 0.112 |
| 989 | 322 | 16 | 1 | 20.3 | 1148.3 | -1.151 | -20.665 | 925.7 | 98.6 | 0.013 | 0.068 |
| 990 | 322 | 16 | 3 | 58.3 | 2021.6 | 3.151 | -18.262 | 1478.0 | 85.8 | 0.220 | 0.112 |
| 991 | 322 | 16 | 4 | 45.0 | 1900.0 | 3.978 | -19.941 | 1197.3 | 97.1 | 0.048 | 0.077 |
| 992 | 322 | 16 | 13 | 48.3 | 1724.3 | -1.320 | -17.159 | 1043.0 | 98.2 | 0.028 | 0.136 |
| 993 | 322 | 16 | 14 | 57.0 | 1408.7 | -1.443 | -27.719 | 875.2 | 98.5 | 0.013 | 0.044 |
| 994 | 322 | 16 | 17 | 19.3 | 1842.3 | -0.918 | -17.980 | 938.6 | 98.5 | 0.015 | 0.116 |
| 995 | 322 | 16 | 17 | 50.3 | 1129.5 | -1.691 | -17.874 | 649.0 | 97.7 | 0.030 | 0.118 |
| 996 | 322 | 16 | 20 | 7.3 | 1187.1 | -1.834 | -18.479 | 601.3 | 97.5 | 0.000 | 0.107 |
| 997 | 322 | 16 | 21 | 25.3 | 2205.3 | -0.327 | -18.09 | 925.1 | 98.4 | 0.017 | 0.115 |
| 998 | 322 | 16 | 23 | 32.3 | 1171.5 | -1.299 | -23.583 | 844.6 | 98.8 | 0.021 | 0.053 |
| 999 | 322 | 16 | 27 | 23.3 | 1291.0 | 2.914 | -29.791 | 886.9 | 83.1 | 0.003 | 0.040 |
| 1000 | 322 | 16 | 29 | 44.5 | 1181.8 | -1.391 | -25.935 | 716.9 | 98.9 | 0.052 | 0.047 |
| 1001 | 322 | 16 | 30 | 42.3 | 1359.5 | -1.106 | -23.487 | 846.3 | 98.8 | 0.059 | 0.053 |
| 1002 | 322 | 16 | 33 | 2.3 | 1636.5 | -1.119 | -20.159 | 916.3 | 98.6 | 0.013 | 0.074 |
| 1003 | 322 | 16 | 34 | 26.0 | 1266.7 | 0.210 | -22.405 | 1002.6 | 65.8 | 0.011 | 0.057 |
| 1004 | 322 | 16 | 36 | 36.5 | 978.0 | -1.752 | -19.772 | 682.3 | 98.2 | 0.025 | 0.080 |
| 1005 | 322 | 16 | 36 | 51.0 | 2191.5 | -0.438 | -16.857 | 945.3 | 98.5 | 0.015 | 0.143 |
| 1006 | 322 | 16 | 37 | 22.5 | 1366.4 | -1.417 | -21.046 | 785.1 | 99.2 | 0.015 | 0.065 |
| 1007 | 322 | 16 | 37 | 26.3 | 2227.6 | -0.314 | -17.601 | 938.0 | 98.6 | 0.013 | 0.123 |
| 1008 | 322 | 16 | 37 | 41.3 | 1152.8 | -1.722 | -20.887 | 693.4 | 98.1 | 0.002 | 0.067 |
| 1009 | 322 | 16 | 39 | 20.3 | 1822.8 | 6.170 | -20.953 | 434.2 | 100.0 | 0.029 | 0.066 |
| 1010 | 322 | 16 | 39 | 27.0 | 1429.2 | -1.306 | -19.606 | 950.1 | 98.6 | 0.016 | 0.082 |
| 1011 | 322 | 16 | 40 | 39.5 | 1758.4 | -1.049 | -19.937 | 900.2 | 98.9 | 0.020 | 0.077 |
| 1012 | 322 | 16 | 42 | 21.0 | 1609.6 | 4.314 | -25.428 | 1156.8 | 100.7 | 0.003 | 0.048 |
| 1013 | 322 | 16 | 43 | 47.3 | 1282.4 | -1.525 | -24.209 | 818.3 | 98.6 | 0.011 | 0.051 |
| 1014 | 322 | 16 | 44 | 43.0 | 1400.9 | -1.319 | -21.516 | 991.6 | 98.7 | 0.015 | 0.062 |
| 1015 | 322 | 16 | 48 | 11.3 | 1095.0 | -1.837 | -31.427 | 661.9 | 98.3 | 0.027 | 0.038 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 1016 | 322 | 16 | 52 | 38.3 | 1291.7 | -1.484 | -18.523 | 837.7 | 98.5 | 0.013 | 0.106 |
| 1017 | 322 | 16 | 52 | 58.3 | 1935.0 | 5.620 | -21.769 | 520.1 | 99.4 | 0.023 | 0.060 |
| 1018 | 322 | 16 | 53 | 57.3 | 1782.8 | 4.422 | -20.376 | 1076.7 | 98.7 | 0.083 | 0.072 |
| 1019 | 322 | 16 | 55 | 3.3 | 1684.8 | 0.917 | -20.501 | 755.1 | 75.8 | 0.008 | 0.070 |
| 1020 | 322 | 17 | 0 | 36.3 | 1126.1 | -1.740 | -22.618 | 708.4 | 97.6 | 0.022 | 0.056 |
| 1021 | 322 | 17 | 2 | 47.3 | 1444.2 | -1.524 | -19.704 | 712.4 | 98.0 | 0.007 | 0.081 |
| 1022 | 322 | 17 | 6 | 36.0 | 1858.4 | -1.070 | -19.990 | 1317.0 | 99.5 | 0.034 | 0.077 |
| 1023 | 322 | 17 | 6 | 56.3 | 1310.1 | -2.094 | -23.567 | 668.6 | 62.4 | 0.085 | 0.053 |
| 1024 | 322 | 17 | 12 | 2.5 | 1475.5 | -1.367 | -20.126 | 1039.3 | 99.1 | 0.018 | 0.075 |
| 1025 | 322 | 17 | 12 | 9.3 | 1856.3 | 5.606 | -19.136 | 901.6 | 102.4 | 0.024 | 0.096 |
| 1026 | 322 | 17 | 12 | 44.0 | 1354.4 | 4.072 | -23.164 | 1038.0 | 100.7 | 0.006 | 0.054 |
| 1027 | 322 | 17 | 13 | 46.3 | 2418.2 | -3.417 | -18.798 | 1353.2 | 82.9 | 0.009 | 0.101 |
| 1028 | 322 | 17 | 15 | 36.0 | 1313.9 | -1.484 | -24.523 | 763.4 | 98.3 | 0.013 | 0.050 |
| 1029 | 322 | 17 | 17 | 51.3 | 2130.1 | -0.443 | -19.423 | 856.6 | 98.7 | 0.012 | 0.086 |
| 1030 | 322 | 17 | 20 | 37.0 | 1225.7 | -1.441 | -19.158 | 848.6 | 98.8 | 0.013 | 0.095 |
| 1031 | 322 | 17 | 22 | 38.0 | 1170.4 | -1.306 | -29.992 | 882.3 | 99.0 | 0.007 | 0.040 |
| 1032 | 322 | 17 | 23 | 57.3 | 1330.8 | -1.727 | -17.166 | 853.8 | 98.4 | 0.050 | 0.136 |
| 1033 | 322 | 17 | 25 | 5.3 | 1432.3 | -1.100 | -19.347 | 1032.8 | 100.0 | 0.000 | 0.090 |
| 1034 | 322 | 17 | 28 | 20.3 | 1562.9 | -1.304 | -21.403 | 843.7 | 98.5 | 0.009 | 0.063 |
| 1035 | 322 | 17 | 29 | 45.3 | 914.1 | -1.154 | -21.048 | 758.5 | 98.5 | 0.011 | 0.065 |
| 1036 | 322 | 17 | 31 | 9.3 | 1331.4 | -1.377 | -26.620 | 860.5 | 99.0 | 0.013 | 0.046 |
| 1037 | 322 | 17 | 31 | 41.3 | 1206.5 | -1.392 | -20.349 | 850.5 | 98.7 | 0.009 | 0.072 |
| 1038 | 322 | 17 | 32 | 58.2 | 1260.6 | -1.737 | -30.215 | 648.7 | 97.7 | 0.024 | 0.040 |
| 1039 | 322 | 17 | 33 | 25.3 | 1390.4 | 2.884 | -20.681 | 872.1 | 83.0 | 0.005 | 0.068 |
| 1040 | 322 | 17 | 36 | 7.3 | 1527.5 | -5.663 | -23.065 | 794.2 | 70.9 | 0.016 | 0.054 |
| 1041 | 322 | 17 | 36 | 12.3 | 1495.9 | -3.703 | -16.335 | 997.8 | 82.9 | 0.004 | 0.154 |
| 1042 | 322 | 17 | 36 | 35.0 | 1213.8 | -1.350 | -22.149 | 859.6 | 99.1 | 0.015 | 0.058 |
| 1043 | 322 | 17 | 39 | 32.3 | 1822.5 | 3.485 | -19.885 | 1464.2 | 102.4 | 0.074 | 0.078 |
| 1044 | 322 | 17 | 39 | 37.3 | 1916.2 | -0.835 | -19.293 | 847.1 | 98.6 | 0.011 | 0.092 |
| 1045 | 322 | 17 | 40 | 13.3 | 1333.9 | 2.729 | -21.959 | 947.1 | 82.5 | 0.001 | 0.059 |
| 1046 | 322 | 17 | 41 | 3.3 | 1263.6 | 6.002 | -21.554 | 611.1 | 101.1 | 0.156 | 0.062 |
| 1047 | 322 | 17 | 42 | 30.5 | 1209.8 | -1.349 | -19.664 | 873.6 | 98.9 | 0.007 | 0.081 |
| 1048 | 322 | 17 | 42 | 32.0 | 1251.0 | -1.293 | -26.478 | 1020.1 | 98.6 | 0.023 | 0.046 |
| 1049 | 322 | 17 | 43 | 39.0 | 1702.2 | -5.189 | -23.256 | 927.9 | 63.4 | 0.058 | 0.054 |
| 1050 | 322 | 17 | 44 | 15.2 | 1415.7 | -1.337 | -19.890 | 864.2 | 99.0 | 0.012 | 0.078 |
| 1051 | 322 | 17 | 47 | 14.5 | 2136.8 | 5.102 | -21.769 | 824.9 | 99.0 | 0.003 | 0.060 |
| 1052 | 322 | 17 | 48 | 58.0 | 1502.9 | -1.073 | -24.634 | 750.7 | 99.1 | 0.047 | 0.050 |
| 1053 | 322 | 17 | 50 | 47.3 | 1153.7 | -1.290 | -27.665 | 878.9 | 98.8 | 0.008 | 0.044 |
| 1054 | 322 | 17 | 51 | 40.3 | 1396.6 | 5.614 | -23.253 | 510.2 | 96.1 | 0.046 | 0.054 |
| 1055 | 322 | 17 | 54 | 41.3 | 869.9 | -1.895 | -31.634 | 437.8 | 98.4 | 0.006 | 0.038 |
| 1056 | 322 | 17 | 55 | 56.0 | 1546.3 | -6.266 | -18.585 | 622.8 | 63.9 | 0.104 | 0.104 |
| 1057 | 322 | 17 | 56 | 7.4 | 1200.3 | -1.537 | -27.214 | 742.8 | 98.5 | 0.011 | 0.045 |
| 1058 | 322 | 17 | 56 | 9.3 | 1229.1 | 2.770 | -22.261 | 893.2 | 82.6 | 0.003 | 0.058 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 1059 | 322 | 17 | 56 | 44.3 | 1199.9 | -1.385 | -23.586 | 856.2 | 99.1 | 0.016 | 0.053 |
| 1060 | 322 | 18 | 0 | 33.0 | 1117.8 | -1.390 | -18.113 | 846.3 | 98.8 | 0.003 | 0.115 |
| 1061 | 322 | 18 | 0 | 59.3 | 1424.7 | -1.425 | -20.501 | 737.0 | 98.6 | 0.015 | 0.070 |
| 1062 | 322 | 18 | 2 | 5.0 | 979.7 | -1.105 | -19.443 | 815.9 | 98.7 | 0.005 | 0.085 |
| 1063 | 322 | 18 | 2 | 31.3 | 1715.2 | -1.075 | -21.031 | 865.5 | 99.0 | 0.013 | 0.065 |
| 1064 | 322 | 18 | 5 | 18.0 | 1195.8 | -1.457 | -18.543 | 836.7 | 98.8 | 0.003 | 0.105 |
| 1065 | 322 | 18 | 7 | 7.4 | 1133.1 | -1.264 | -29.830 | 865.0 | 99.1 | 0.007 | 0.040 |
| 1066 | 322 | 18 | 7 | 7.5 | 1111.0 | -1.284 | -21.948 | 866.5 | 99.3 | 0.017 | 0.059 |
| 1067 | 322 | 18 | 7 | 8.3 | 1623.7 | -1.216 | -19.850 | 856.7 | 98.8 | 0.011 | 0.078 |
| 1068 | 322 | 18 | 9 | 55.4 | 1110.2 | -1.191 | -24.346 | 898.3 | 98.9 | 0.008 | 0.050 |
| 1069 | 322 | 18 | 9 | 58.0 | 2260.8 | 1.701 | -18.558 | 1369.1 | 82.2 | 0.012 | 0.105 |
| 1070 | 322 | 18 | 10 | 7.3 | 1233.8 | -1.395 | -25.707 | 871.8 | 98.9 | 0.007 | 0.047 |
| 1071 | 322 | 18 | 12 | 26.3 | 1264.9 | -1.479 | -19.254 | 760.7 | 98.7 | 0.014 | 0.093 |
| 1072 | 322 | 18 | 12 | 57.5 | 1255.0 | -1.346 | -19.898 | 875.2 | 99.0 | 0.012 | 0.078 |
| 1073 | 322 | 18 | 12 | 59.3 | 1088.3 | -1.261 | -24.566 | 861.1 | 99.1 | 0.010 | 0.050 |
| 1074 | 322 | 18 | 13 | 54.3 | 1946.9 | -3.633 | -19.875 | 1515.2 | 73.8 | 0.005 | 0.078 |
| 1075 | 322 | 18 | 15 | 48.3 | 1757.7 | -1.050 | -19.244 | 838.2 | 98.7 | 0.010 | 0.093 |
| 1076 | 322 | 18 | 16 | 7.2 | 1869.4 | -3.609 | -18.447 | 1253.5 | 82.3 | 0.012 | 0.108 |
| 1077 | 322 | 18 | 16 | 11.3 | 1262.0 | 4.353 | -28.387 | 911.0 | 99.0 | 0.004 | 0.043 |
| 1078 | 322 | 18 | 16 | 38.0 | 1661.6 | -1.048 | -19.451 | 890.0 | 98.9 | 0.015 | 0.085 |
| 1079 | 322 | 18 | 18 | 34.2 | 1984.4 | -0.787 | -19.318 | 790.6 | 98.4 | 0.025 | 0.091 |
| 1080 | 322 | 18 | 18 | 45.3 | 1580.2 | -1.225 | -20.015 | 878.9 | 98.9 | 0.007 | 0.076 |
| 1081 | 322 | 18 | 20 | 12.3 | 1150.3 | -1.321 | -27.796 | 862.7 | 98.9 | 0.007 | 0.044 |
| 1082 | 322 | 18 | 20 | 30.3 | 1382.5 | -1.334 | -24.441 | 865.7 | 99.2 | 0.012 | 0.050 |
| 1083 | 322 | 18 | 24 | 13.0 | 1146.5 | -1.303 | -20.984 | 866.6 | 99.1 | 0.007 | 0.066 |
| 1084 | 322 | 18 | 26 | 22.5 | 1291.5 | -1.513 | -20.245 | 772.3 | 98.8 | 0.012 | 0.073 |
| 1085 | 322 | 18 | 26 | 51.3 | 1009.6 | -1.768 | -19.974 | 653.9 | 98.5 | 0.027 | 0.077 |
| 1086 | 322 | 18 | 28 | 11.3 | 1776.1 | -0.929 | -19.130 | 862.6 | 99.1 | 0.016 | 0.096 |
| 1087 | 322 | 18 | 28 | 23.3 | 1128.9 | 2.795 | -22.912 | 865.7 | 83.0 | 0.001 | 0.055 |
| 1088 | 322 | 18 | 28 | 44.3 | 1403.8 | -1.473 | -18.780 | 962.8 | 98.7 | 0.025 | 0.101 |
| 1089 | 322 | 18 | 32 | 8.3 | 1385.8 | -1.379 | -18.879 | 813.1 | 98.9 | 0.008 | 0.100 |
| 1090 | 322 | 18 | 32 | 51.3 | 1543.3 | -1.224 | -19.698 | 895.5 | 98.9 | 0.007 | 0.081 |
| 1091 | 322 | 18 | 35 | 15.5 | 1811.9 | -0.920 | -19.143 | 876.7 | 99.2 | 0.017 | 0.096 |
| 1092 | 322 | 18 | 35 | 36.5 | 1711.5 | -1.081 | -20.129 | 865.0 | 99.1 | 0.012 | 0.075 |
| 1093 | 322 | 18 | 35 | 45.5 | 1756.3 | -1.085 | -18.840 | 1181.4 | 99.6 | 0.027 | 0.100 |
| 1094 | 322 | 18 | 35 | 55.3 | 1837.8 | -0.906 | -19.011 | 856.0 | 98.9 | 0.010 | 0.098 |
| 1095 | 322 | 18 | 36 | 46.3 | 1374.3 | -1.370 | -18.037 | 864.0 | 99.0 | 0.008 | 0.116 |
| 1096 | 322 | 18 | 37 | 35.0 | 1835.7 | -0.873 | -19.103 | 885.1 | 98.8 | 0.016 | 0.097 |
| 1097 | 322 | 18 | 38 | 18.5 | 965.6 | -1.328 | -19.726 | 723.8 | 98.7 | 0.013 | 0.080 |
| 1098 | 322 | 18 | 38 | 29.3 | 1129.7 | -1.637 | -25.211 | 814.6 | 98.6 | 0.032 | 0.048 |
| 1099 | 322 | 18 | 39 | 17.3 | 1824.6 | -0.882 | -19.994 | 888.7 | 98.8 | 0.006 | 0.077 |
| 1100 | 322 | 18 | 40 | 17.3 | 1597.2 | -1.190 | -22.969 | 775.8 | 98.6 | 0.010 | 0.055 |
| 1101 | 322 | 18 | 40 | 57.3 | 1408.9 | 4.179 | -21.465 | 971.5 | 97.5 | 0.043 | 0.062 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 1102 | 322 | 18 | 41 | 14.3 | 1304.2 | -1.645 | -24.61 | 745.2 | 98.3 | 0.012 | 0.050 |
| 1103 | 322 | 18 | 43 | 11.3 | 1428.2 | -1.285 | -20.516 | 878.4 | 98.9 | 0.004 | 0.070 |
| 1104 | 322 | 18 | 43 | 25.3 | 786.6 | -3.426 | -18.311 | 506.2 | 57.0 | 0.318 | 0.111 |
| 1105 | 322 | 18 | 46 | 2.5 | 1978.0 | 0.149 | -17.421 | 904.1 | 102.4 | 0.003 | 0.129 |
| 1106 | 322 | 18 | 46 | 29.3 | 1391.3 | -1.408 | -14.125 | 867.5 | 98.9 | 0.000 | 0.206 |
| 1107 | 322 | 18 | 47 | 14.3 | 1914.4 | -1.127 | -19.367 | 1015.7 | 98.5 | 0.043 | 0.089 |
| 1108 | 322 | 18 | 47 | 37.3 | 1623.0 | -1.211 | -20.812 | 813.4 | 98.8 | 0.010 | 0.067 |
| 1109 | 322 | 18 | 49 | 34.3 | 1779.4 | -0.980 | -19.358 | 875.4 | 98.8 | 0.006 | 0.090 |
| 1110 | 322 | 18 | 50 | 11.5 | 923.5 | -1.128 | -26.519 | 746.6 | 98.8 | 0.013 | 0.046 |
| 1111 | 322 | 18 | 50 | 39.3 | 1871.5 | -1.069 | -19.075 | 711.9 | 97.6 | 0.027 | 0.097 |
| 1112 | 322 | 18 | 51 | 2.3 | 1096.6 | -1.031 | -19.325 | 915.6 | 99.1 | 0.010 | 0.091 |
| 1113 | 322 | 18 | 51 | 22.3 | 1179.5 | -1.531 | -25.133 | 713.2 | 98.6 | 0.016 | 0.049 |
| 1114 | 322 | 18 | 53 | 37.3 | 1010.7 | -1.314 | -21.280 | 772.6 | 98.8 | 0.009 | 0.063 |
| 1115 | 322 | 18 | 54 | 22.5 | 997.5 | -1.188 | -25.346 | 798.2 | 98.8 | 0.005 | 0.048 |
| 1116 | 322 | 18 | 54 | 33.4 | 1150.2 | -1.338 | -25.070 | 863.3 | 99.3 | 0.010 | 0.049 |
| 1117 | 322 | 18 | 55 | 3.3 | 1576.8 | -1.297 | -19.354 | 557.0 | 98.3 | 0.027 | 0.090 |
| 1118 | 322 | 18 | 55 | 6.3 | 931.6 | -1.172 | -26.441 | 773.4 | 98.9 | 0.009 | 0.046 |
| 1119 | 322 | 18 | 56 | 25.1 | 1754.0 | -0.228 | -20.590 | 880.3 | | | 0.069 |
| 1120 | 322 | 18 | 57 | 12.3 | 1349.1 | -1.322 | -26.970 | 854.0 | 98.8 | 0.005 | 0.045 |
| 1121 | 322 | 18 | 58 | 40.5 | 1310.1 | -1.641 | -20.976 | 639.0 | 97.6 | 0.013 | 0.066 |
| 1122 | 322 | 18 | 59 | 9.3 | 1513.7 | -1.255 | -18.354 | 876.1 | 99.0 | 0.005 | 0.110 |
| 1123 | 322 | 19 | 0 | 42.2 | 1347.8 | -1.027 | -19.743 | 1063.7 | 100.2 | 0.004 | 0.080 |
| 1124 | 322 | 19 | 0 | 53.3 | 1471.3 | -1.256 | -21.903 | 902.4 | 99.1 | 0.007 | 0.060 |
| 1125 | 322 | 19 | 2 | 26.3 | 1284.4 | -1.392 | -23.505 | 852.9 | 99.1 | 0.007 | 0.053 |
| 1126 | 322 | 19 | 5 | 22.3 | 1241.3 | -1.578 | -20.084 | 595.9 | 98.8 | 0.036 | 0.075 |
| 1127 | 322 | 19 | 7 | 51.3 | 1760.3 | -1.145 | -19.279 | 1042.3 | 98.8 | 0.029 | 0.092 |
| 1128 | 322 | 19 | 8 | 23.3 | 1329.1 | 4.399 | -28.746 | 958.9 | 100.2 | 0.004 | 0.043 |
| 1129 | 322 | 19 | 10 | 14.2 | 2014.2 | -0.692 | -17.592 | 961.4 | 98.7 | 0.017 | 0.123 |
| 1130 | 322 | 19 | 10 | 20.3 | 726.4 | -1.496 | -32.996 | 538.6 | 57.0 | 0.269 | 0.036 |
| 1131 | 322 | 19 | 13 | 0.0 | 1177.7 | 0.237 | -30.606 | 919.2 | 65.8 | 0.010 | 0.039 |
| 1132 | 322 | 19 | 14 | 23.3 | 1291.9 | -1.623 | -27.665 | 705.6 | 98.7 | 0.028 | 0.044 |
| 1133 | 322 | 19 | 15 | 11.3 | 1279.4 | -1.288 | -22.144 | 902.3 | | | 0.058 |
| 1134 | 322 | 19 | 15 | 46.3 | 2218.3 | 4.481 | -19.357 | 983.7 | 97.5 | 0.047 | 0.090 |
| 1135 | 322 | 19 | 15 | 53.3 | 1266.0 | -1.340 | -27.338 | 864.9 | 99.3 | 0.006 | 0.044 |
| 1136 | 322 | 19 | 16 | 22.5 | 1468.8 | -1.331 | -19.225 | 844.7 | 99.0 | 0.007 | 0.094 |
| 1137 | 322 | 19 | 17 | 43.3 | 1955.6 | -0.708 | -19.701 | 860.5 | 98.8 | 0.007 | 0.081 |
| 1138 | 322 | 19 | 17 | 48.3 | 927.8 | -1.398 | -29.013 | 723.5 | 99.0 | 0.020 | 0.041 |
| 1139 | 322 | 19 | 18 | 39.0 | 1612.9 | -6.064 | -17.659 | 766.4 | 65.0 | 0.018 | 0.122 |
| 1140 | 322 | 19 | 19 | 18.3 | 1380.4 | -5.744 | -17.880 | 765.0 | 65.0 | 0.019 | 0.118 |
| 1141 | 322 | 19 | 20 | 21.3 | 1072.4 | -1.231 | -29.875 | 857.3 | 99.0 | 0.002 | 0.040 |
| 1142 | 322 | 19 | 21 | 24.3 | 2472.2 | 3.395 | -18.784 | 1713.0 | 98.8 | 0.060 | 0.101 |
| 1143 | 322 | 19 | 21 | 49.3 | 1706.9 | 5.231 | -22.899 | 783.7 | 98.6 | 0.002 | 0.055 |
| 1144 | 322 | 19 | 22 | 27.3 | 1744.0 | -1.013 | -17.697 | 892.3 | 98.9 | 0.008 | 0.121 |
| 1145 | 322 | 19 | 23 | 7.3 | 1807.3 | 4.022 | -21.513 | 1187.2 | 98.1 | 0.049 | 0.062 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 1146 | 322 | 19 | 23 | 40.0 | 2130.9 | 4.685 | -18.782 | 908.3 | 97.4 | 0.038 | 0.101 |
| 1147 | 322 | 19 | 24 | 36.0 | 1737.3 | -1.001 | -19.636 | 716.7 | 98.7 | 0.016 | 0.082 |
| 1148 | 322 | 19 | 25 | 1.5 | 2026.0 | -0.585 | -18.141 | 909.9 | 99.0 | 0.005 | 0.114 |
| 1149 | 322 | 19 | 25 | 7.5 | 1836.1 | -0.914 | -18.390 | 905.4 | 98.8 | 0.010 | 0.109 |
| 1150 | 322 | 19 | 25 | 16.3 | 1342.5 | -1.328 | -18.961 | 887.4 | 99.2 | 0.009 | 0.099 |
| 1151 | 322 | 19 | 25 | 48.3 | 920.1 | -1.241 | -23.929 | 741.8 | 98.8 | 0.009 | 0.052 |
| 1152 | 322 | 19 | 26 | 6.3 | 1167.5 | -1.270 | -22.131 | 906.6 | 99.1 | 0.009 | 0.058 |
| 1153 | 322 | 19 | 33 | 9.0 | 1979.5 | -3.347 | -21.241 | 898.3 | 64.8 | 0.005 | 0.064 |
| 1154 | 322 | 19 | 34 | 48.3 | 1291.7 | 2.599 | -25.179 | 1004.1 | 83.0 | 0.004 | 0.048 |
| 1155 | 322 | 19 | 34 | 57.3 | 1322.5 | -1.463 | -19.383 | 721.5 | 98.8 | 0.013 | 0.088 |
| 1156 | 322 | 19 | 38 | 58.2 | 2010.7 | -0.522 | -18.564 | 555.5 | 98.4 | 0.028 | 0.105 |
| 1157 | 322 | 19 | 40 | 36.1 | 1578.5 | 4.429 | -21.047 | 612.4 | | | 0.065 |
| 1158 | 322 | 19 | 42 | 31.3 | 1232.6 | 4.840 | -24.331 | 783.3 | 97.6 | 0.037 | 0.050 |
| 1159 | 322 | 19 | 42 | 55.3 | 2149.7 | -0.315 | -19.505 | 890.8 | 99.0 | 0.003 | 0.084 |
| 1160 | 322 | 19 | 43 | 34.3 | 835.3 | -3.767 | -25.004 | 541.7 | 57.0 | 0.317 | 0.049 |
| 1161 | 322 | 19 | 43 | 42.0 | 1775.4 | -0.562 | -20.258 | 1105.1 | 100.3 | 0.050 | 0.073 |
| 1162 | 322 | 19 | 45 | 2.3 | 1268.8 | -1.469 | -20.367 | 869.9 | 99.0 | 0.002 | 0.072 |
| 1163 | 322 | 19 | 46 | 2.3 | 1678.7 | -1.145 | -18.868 | 778.3 | 98.9 | 0.009 | 0.100 |
| 1164 | 322 | 19 | 48 | 3.2 | 1471.8 | -1.235 | -20.153 | 924.7 | 98.9 | 0.012 | 0.075 |
| 1165 | 322 | 19 | 48 | 8.3 | 1200.7 | -1.666 | -25.039 | 555.4 | 98.4 | 0.024 | 0.049 |
| 1166 | 322 | 19 | 48 | 47.3 | 1136.3 | 5.245 | -21.524 | 663.5 | 98.7 | 0.002 | 0.062 |
| 1167 | 322 | 19 | 49 | 21.3 | 2015.5 | -0.656 | -17.913 | 882.6 | 98.8 | 0.004 | 0.117 |
| 1168 | 322 | 19 | 50 | 5.0 | 1227.4 | -1.344 | -21.228 | 834.8 | 99.2 | 0.007 | 0.064 |
| 1169 | 322 | 19 | 52 | 1.2 | 1427.1 | -1.397 | -24.407 | 813.2 | 98.7 | 0.003 | 0.050 |
| 1170 | 322 | 19 | 52 | 9.3 | 1089.5 | -1.201 | -21.380 | 879.1 | 99.1 | 0.002 | 0.063 |
| 1171 | 322 | 19 | 53 | 43.3 | 1882.1 | 2.230 | -20.512 | 916.3 | 82.4 | 0.005 | 0.070 |
| 1172 | 322 | 19 | 57 | 5.0 | 1798.6 | -0.908 | -17.315 | 913.8 | 99.1 | 0.010 | 0.133 |
| 1173 | 322 | 19 | 57 | 55.3 | 1066.9 | -4.118 | -14.701 | 765.2 | 81.7 | 0.069 | 0.192 |
| 1174 | 322 | 19 | 57 | 54.5 | 1300.7 | -1.540 | -30.117 | 764.2 | 98.6 | 0.003 | 0.040 |
| 1175 | 322 | 19 | 59 | 36.2 | 1062.0 | -1.112 | -27.719 | 807.3 | 98.6 | 0.040 | 0.044 |
| 1176 | 322 | 20 | 3 | 6.3 | 1971.8 | -0.549 | -15.939 | 1547.8 | 101.5 | 0.020 | 0.161 |
| 1177 | 322 | 20 | 3 | 47.5 | 1649.8 | -1.104 | -19.981 | 922.6 | | | 0.077 |
| 1178 | 322 | 20 | 3 | 47.0 | 1396.1 | -0.707 | -24.245 | 971.8 | 65.0 | 0.002 | 0.051 |
| 1179 | 322 | 20 | 4 | 22.3 | 945.9 | -1.251 | -19.532 | 768.0 | 98.8 | 0.011 | 0.084 |
| 1180 | 322 | 20 | 5 | 48.3 | 1575.4 | -4.287 | -19.977 | 886.8 | 81.2 | 0.001 | 0.077 |
| 1181 | 322 | 20 | 7 | 18.3 | 1781.0 | -0.936 | -18.587 | 914.1 | 99.0 | 0.008 | 0.104 |
| 1182 | 322 | 20 | 8 | 10.3 | 806.2 | -4.371 | -20.051 | 529.7 | 56.9 | 0.317 | 0.076 |
| 1183 | 322 | 20 | 11 | 8.3 | 1774.1 | -0.953 | -17.815 | 885.8 | 99.1 | 0.003 | 0.119 |
| 1184 | 322 | 20 | 12 | 21.4 | 1851.4 | -0.832 | -19.665 | 921.2 | 99.2 | 0.006 | 0.081 |
| 1185 | 322 | 20 | 12 | 27.2 | 1182.9 | -1.297 | -21.223 | 863.6 | 99.3 | 0.005 | 0.064 |
| 1186 | 322 | 20 | 12 | 33.3 | 803.7 | -4.439 | -26.924 | 532.0 | 56.9 | 0.315 | 0.045 |
| 1187 | 322 | 20 | 12 | 53.3 | 1972.6 | -0.535 | -17.801 | 865.1 | 99.4 | 0.010 | 0.119 |
| 1188 | 322 | 20 | 14 | 36.5 | 1420.3 | -1.184 | -21.323 | 936.8 | 99.0 | 0.015 | 0.063 |
| 1189 | 322 | 20 | 15 | 11.1 | 1126.3 | -1.439 | -21.703 | 819.9 | 99.1 | 0.003 | 0.061 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 1190 | 322 | 20 | 15 | 18.3 | 1447.7 | -1.267 | -18.621 | 871.3 | 99.6 | 0.012 | 0.103 |
| 1191 | 322 | 20 | 15 | 18.5 | 1097.1 | -1.372 | -30.334 | 821.7 | 99.0 | 0.008 | 0.039 |
| 1192 | 322 | 20 | 15 | 52.3 | 1552.1 | 5.502 | -20.858 | 725.1 | 98.9 | 0.024 | 0.067 |
| 1193 | 322 | 20 | 15 | 59.3 | 1212.1 | 4.501 | -31.766 | 848.5 | 97.6 | 0.019 | 0.037 |
| 1194 | 322 | 20 | 16 | 45.0 | 2093.2 | -0.400 | -18.478 | 894.6 | 99.2 | 0.006 | 0.107 |
| 1195 | 322 | 20 | 17 | 41.3 | 1082.8 | -1.443 | -18.435 | 838.5 | 98.7 | 0.017 | 0.108 |
| 1196 | 322 | 20 | 19 | 18.3 | 1266.3 | -1.414 | -21.481 | 858.0 | 99.0 | 0.007 | 0.062 |
| 1197 | 322 | 20 | 20 | 16.3 | 1934.2 | -0.781 | -19.564 | 1147.5 | 99.1 | 0.041 | 0.083 |
| 1198 | 322 | 20 | 21 | 34.0 | 1642.9 | -3.796 | -23.490 | 1061.0 | 82.9 | 0.014 | 0.053 |
| 1199 | 322 | 20 | 22 | 45.0 | 1469.9 | -1.141 | -21.116 | 908.1 | 99.3 | 0.012 | 0.065 |
| 1200 | 322 | 20 | 23 | 17.3 | 2165.9 | 5.007 | -18.699 | 1002.2 | 100.0 | 0.003 | 0.102 |
| 1201 | 322 | 20 | 23 | 22.3 | 1192.4 | -1.437 | -21.567 | 642.5 | 98.8 | 0.043 | 0.062 |
| 1202 | 322 | 20 | 25 | 1.3 | 1054.7 | -1.493 | -19.210 | 780.0 | 98.2 | 0.000 | 0.094 |
| 1203 | 322 | 20 | 25 | 31.3 | 2039.3 | -3.859 | -17.397 | 1512.4 | 73.6 | 0.005 | 0.130 |
| 1204 | 322 | 20 | 26 | 31.0 | 1197.2 | -1.691 | -23.819 | 701.6 | 98.4 | 0.021 | 0.052 |
| 1205 | 322 | 20 | 28 | 22.3 | 1567.9 | -3.075 | -24.227 | 776.4 | 64.0 | 0.182 | 0.051 |
| 1206 | 322 | 20 | 28 | 38.5 | 986.8 | -1.431 | -24.480 | 738.8 | 98.8 | 0.002 | 0.050 |
| 1207 | 322 | 20 | 28 | 42.0 | 1683.9 | 5.236 | -20.185 | 777.4 | 97.7 | 0.036 | 0.074 |
| 1208 | 322 | 20 | 30 | 0.2 | 1680.7 | -1.073 | -22.608 | 909.4 | 99.1 | 0.007 | 0.056 |
| 1209 | 322 | 20 | 30 | 12.5 | 1307.0 | -1.436 | -20.001 | 820.9 | 99.0 | 0.008 | 0.076 |
| 1210 | 322 | 20 | 30 | 36.2 | 2054.5 | -0.525 | -19.030 | 833.7 | 99.1 | 0.010 | 0.098 |
| 1211 | 322 | 20 | 32 | 31.5 | 1152.3 | -1.382 | -20.246 | 836.6 | 99.1 | 0.006 | 0.073 |
| 1212 | 322 | 20 | 32 | 47.3 | 1412.5 | 2.648 | -23.815 | 806.6 | 81.3 | 0.005 | 0.052 |
| 1213 | 322 | 20 | 33 | 11.0 | 1267.2 | -1.641 | -26.417 | 800.9 | 98.1 | 0.003 | 0.046 |
| 1214 | 322 | 20 | 33 | 24.3 | 1604.7 | -1.108 | -23.835 | 678.7 | 98.8 | 0.019 | 0.052 |
| 1215 | 322 | 20 | 33 | 53.3 | 942.3 | -1.352 | -20.403 | 726.5 | 98.9 | 0.011 | 0.071 |
| 1216 | 322 | 20 | 34 | 16.0 | 1552.5 | -1.237 | -19.602 | 748.4 | 99.1 | 0.018 | 0.082 |
| 1217 | 322 | 20 | 34 | 51.3 | 1485.3 | -1.435 | -20.732 | 764.7 | 98.8 | 0.009 | 0.068 |
| 1218 | 322 | 20 | 35 | 20.5 | 1113.1 | -1.463 | -17.507 | 805.0 | 99.0 | 0.010 | 0.125 |
| 1219 | 322 | 20 | 37 | 12.3 | 1260.3 | -1.570 | -23.315 | 785.4 | 98.2 | 0.002 | 0.054 |
| 1220 | 322 | 20 | 39 | 30.3 | 1282.4 | -4.413 | -19.964 | 689.3 | 81.8 | 0.033 | 0.077 |
| 1221 | 322 | 20 | 40 | 45.3 | 2000.2 | -3.347 | -13.754 | 1345.1 | 82.4 | 0.022 | 0.214 |
| 1222 | 322 | 20 | 41 | 7.3 | 1461.8 | -1.345 | -17.409 | 735.2 | 98.9 | 0.012 | 0.129 |
| 1223 | 322 | 20 | 41 | 42.3 | 1758.8 | -0.963 | -20.053 | 862.0 | 99.4 | 0.013 | 0.076 |
| 1224 | 322 | 20 | 43 | 6.3 | 1045.6 | -1.325 | -19.857 | 815.0 | 99.1 | 0.008 | 0.078 |
| 1225 | 322 | 20 | 43 | 49.3 | 2033.5 | -0.674 | -16.168 | 994.9 | 99.0 | 0.020 | 0.157 |
| 1226 | 322 | 20 | 44 | 11.5 | 960.8 | -1.488 | -19.645 | 681.0 | 98.9 | 0.012 | 0.082 |
| 1227 | 322 | 20 | 44 | 16.3 | 1017.3 | -1.258 | -22.329 | 812.7 | 99.1 | 0.008 | 0.057 |
| 1228 | 322 | 20 | 46 | 40.0 | 1610.1 | -6.579 | -24.264 | 612.9 | 63.0 | 0.096 | 0.051 |
| 1229 | 322 | 20 | 47 | 30.3 | 1755.4 | -0.912 | -19.755 | 864.9 | 99.4 | 0.007 | 0.080 |
| 1230 | 322 | 20 | 48 | 40.2 | 1796.4 | -0.984 | -21.060 | 818.3 | 98.9 | 0.007 | 0.065 |
| 1231 | 322 | 20 | 48 | 51.3 | 1278.9 | -1.292 | -21.733 | 869.9 | 99.5 | 0.005 | 0.061 |
| 1232 | 322 | 20 | 49 | 8.2 | 1504.4 | -1.139 | -18.213 | 922.1 | 99.4 | 0.015 | 0.113 |
| 1233 | 322 | 20 | 49 | 17.3 | 1442.1 | -5.595 | -21.788 | 641.7 | 75.7 | 0.010 | 0.060 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 1234 | 322 | 20 | 50 | 54.5 | 1848.1 | -0.883 | -18.975 | 952.0 | 99.1 | 0.013 | 0.099 |
| 1235 | 322 | 20 | 51 | 1.0 | 1433.0 | -1.523 | -19.791 | 786.4 | 98.2 | 0.001 | 0.079 |
| 1236 | 322 | 20 | 51 | 20.4 | 1208.8 | -1.369 | -29.843 | 720.4 | 98.8 | 0.041 | 0.040 |
| 1237 | 322 | 20 | 51 | 22.5 | 1747.1 | -1.008 | -20.502 | 822.7 | 99.2 | 0.006 | 0.070 |
| 1238 | 322 | 20 | 51 | 36.3 | 2156.1 | 4.832 | -18.530 | 1186.1 | 98.7 | 0.061 | 0.106 |
| 1239 | 322 | 20 | 52 | 52.0 | 1385.9 | 0.993 | -21.372 | 1091.8 | 64.9 | 0.249 | 0.063 |
| 1240 | 322 | 20 | 53 | 2.3 | 1175.1 | -1.447 | -18.801 | 773.2 | 99.0 | 0.006 | 0.101 |
| 1241 | 322 | 20 | 53 | 30.1 | 1028.3 | -1.316 | -23.153 | 782.7 | 99.2 | 0.007 | 0.054 |
| 1242 | 322 | 20 | 53 | 33.2 | 1495.1 | -1.317 | -19.898 | 681.4 | 98.9 | 0.018 | 0.078 |
| 1243 | 322 | 20 | 53 | 41.3 | 1328.9 | -1.722 | -15.649 | 697.6 | 98.3 | 0.033 | 0.166 |
| 1244 | 322 | 20 | 54 | 33.3 | 2345.6 | 1.310 | -16.958 | 925.9 | 82.6 | 0.009 | 0.141 |
| 1245 | 322 | 20 | 56 | 40.3 | 1427.8 | -1.344 | -22.928 | 795.8 | 99.0 | 0.009 | 0.055 |
| 1246 | 322 | 20 | 57 | 47.3 | 1354.3 | -1.371 | -18.981 | 630.3 | 98.9 | 0.028 | 0.099 |
| 1247 | 322 | 20 | 58 | 1.3 | 1090.4 | -7.923 | -30.713 | 322.9 | 62.3 | 0.323 | 0.039 |
| 1248 | 322 | 21 | 0 | 26.3 | 1453.0 | -1.306 | -22.717 | 674.3 | 98.8 | 0.019 | 0.056 |
| 1249 | 322 | 21 | 1 | 14.3 | 1092.1 | -1.336 | -26.546 | 765.1 | 99.2 | 0.010 | 0.046 |
| 1250 | 322 | 21 | 1 | 32.0 | 1214.5 | -1.358 | -20.533 | 880.3 | 98.6 | 0.036 | 0.070 |
| 1251 | 322 | 21 | 2 | 31.5 | 1283.9 | -1.416 | -22.504 | 831.5 | 99.1 | 0.005 | 0.057 |
| 1252 | 322 | 21 | 2 | 41.5 | 1069.3 | -1.541 | -22.999 | 717.4 | 99.0 | 0.011 | 0.055 |
| 1253 | 322 | 21 | 3 | 6.3 | 2356.0 | 4.958 | -18.257 | 1027.5 | 98.4 | 0.066 | 0.112 |
| 1254 | 322 | 21 | 4 | 15.3 | 1586.6 | -1.200 | -20.856 | 689.2 | 99.0 | 0.015 | 0.067 |
| 1255 | 322 | 21 | 4 | 35.3 | 2013.7 | -0.676 | -18.058 | 965.2 | 99.1 | 0.016 | 0.115 |
| 1256 | 322 | 21 | 5 | 55.5 | 1668.1 | -2.611 | -20.738 | 1406.6 | 83.4 | 0.009 | 0.068 |
| 1257 | 322 | 21 | 6 | 2.3 | 1931.6 | -1.035 | -18.764 | 1132.6 | 98.9 | 0.055 | 0.101 |
| 1258 | 322 | 21 | 7 | 6.3 | 1062.1 | -1.474 | -23.119 | 739.3 | 99.0 | 0.010 | 0.054 |
| 1259 | 322 | 21 | 8 | 5.3 | 1422.6 | -1.331 | -25.630 | 671.6 | 98.9 | 0.018 | 0.047 |
| 1260 | 322 | 21 | 8 | 5.5 | 1148.1 | -0.944 | -19.638 | 868.9 | 99.6 | 0.047 | 0.082 |
| 1261 | 322 | 21 | 8 | 22.3 | 1396.7 | 2.738 | -26.315 | 974.4 | 82.9 | 0.004 | 0.046 |
| 1262 | 322 | 21 | 9 | 19.5 | 1139.5 | -1.798 | -20.986 | 505.9 | | | 0.066 |
| 1263 | 322 | 21 | 9 | 24.3 | 1365.4 | -1.374 | -19.228 | 871.5 | 99.4 | 0.003 | 0.094 |
| 1264 | 322 | 21 | 12 | 11.3 | 1041.3 | -1.218 | -32.217 | 831.7 | 99.5 | 0.010 | 0.037 |
| 1265 | 322 | 21 | 12 | 53.3 | 1551.0 | 3.681 | -22.848 | 1167.3 | 99.4 | 0.071 | 0.055 |
| 1266 | 322 | 21 | 15 | 15.4 | 1430.6 | -1.391 | -19.683 | 1123.1 | 99.0 | 0.061 | 0.081 |
| 1267 | 322 | 21 | 16 | 25.3 | 1733.4 | 2.523 | -24.535 | 939.1 | 82.9 | 0.004 | 0.050 |
| 1268 | 322 | 21 | 17 | 42.3 | 1994.2 | 4.594 | -21.305 | 1337.2 | 99.0 | 0.088 | 0.063 |
| 1269 | 322 | 21 | 18 | 8.3 | 1205.1 | -1.488 | -22.393 | 766.7 | 99.2 | 0.008 | 0.057 |
| 1270 | 322 | 21 | 18 | 27.5 | 1019.1 | -1.467 | -34.440 | 726.8 | | | 0.034 |
| 1271 | 322 | 21 | 18 | 57.3 | 1798.0 | -0.885 | -16.802 | 848.9 | 99.2 | 0.003 | 0.144 |
| 1272 | 322 | 21 | 19 | 14.3 | 1863.1 | 3.891 | -21.635 | 1396.1 | | | 0.061 |
| 1273 | 322 | 21 | 19 | 46.3 | 847.7 | -1.260 | -28.559 | 674.0 | 99.0 | 0.013 | 0.043 |
| 1274 | 322 | 21 | 23 | 1.3 | 1385.6 | -0.837 | -24.353 | 762.8 | 66.0 | 0.023 | 0.050 |
| 1275 | 322 | 21 | 23 | 12.0 | 1422.3 | -1.380 | -21.535 | 779.8 | 99.0 | 0.008 | 0.062 |
| 1276 | 322 | 21 | 23 | 29.0 | 1629.8 | 1.198 | -19.760 | 875.6 | 75.8 | 0.014 | 0.080 |
| 1277 | 322 | 21 | 24 | 40.5 | 724.5 | -1.336 | -20.492 | 566.8 | 98.9 | 0.031 | 0.070 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 1278 | 322 | 21 | 24 | 46.2 | 857.9 | -1.313 | -21.335 | 645.1 | 98.7 | 0.022 | 0.063 |
| 1279 | 322 | 21 | 24 | 58.3 | 2006.7 | 3.967 | -19.850 | 1389.6 | 98.3 | 0.044 | 0.078 |
| 1280 | 322 | 21 | 25 | 2.0 | 2250.7 | -0.149 | -18.561 | 935.3 | 99.2 | 0.013 | 0.105 |
| 1281 | 322 | 21 | 25 | 24.3 | 833.6 | -3.105 | -28.577 | 580.8 | 56.8 | 0.263 | 0.042 |
| 1282 | 322 | 21 | 25 | 35.3 | 1932.0 | -0.865 | -17.244 | 838.6 | 98.5 | 0.017 | 0.134 |
| 1283 | 322 | 21 | 25 | 56.3 | 1991.4 | -0.835 | -18.228 | 853.2 | 98.4 | 0.017 | 0.113 |
| 1284 | 322 | 21 | 28 | 44.3 | 1600.2 | -1.200 | -21.405 | 836.8 | 99.1 | 0.007 | 0.063 |
| 1285 | 322 | 21 | 30 | 23.3 | 2019.6 | -0.752 | -19.036 | 847.3 | 98.5 | 0.014 | 0.098 |
| 1286 | 322 | 21 | 30 | 48.5 | 1139.9 | -1.558 | -30.156 | 651.0 | 98.6 | 0.023 | 0.040 |
| 1287 | 322 | 21 | 30 | 51.3 | 897.9 | -1.382 | -20.351 | 700.7 | 99.0 | 0.012 | 0.072 |
| 1288 | 322 | 21 | 31 | 40.3 | 1403.7 | -1.292 | -22.405 | 869.6 | 99.4 | 0.002 | 0.057 |
| 1289 | 322 | 21 | 32 | 11.3 | 1269.1 | -1.441 | -26.783 | 916.6 | 98.5 | 0.037 | 0.045 |
| 1290 | 322 | 21 | 32 | 51.3 | 2201.7 | -0.898 | -17.867 | 1761.1 | 100.8 | 0.051 | 0.118 |
| 1291 | 322 | 21 | 33 | 42.3 | 1076.7 | 5.519 | -21.431 | 587.4 | 96.7 | 0.041 | 0.062 |
| 1292 | 322 | 21 | 36 | 31.3 | 1320.4 | -1.203 | -22.455 | 1074.6 | 99.2 | 0.036 | 0.057 |
| 1293 | 322 | 21 | 36 | 52.7 | 1723.6 | -0.980 | -19.486 | 760.8 | 99.1 | 0.009 | 0.085 |
| 1294 | 322 | 21 | 36 | 59.3 | 1423.2 | -1.534 | -21.684 | 826.3 | 99.1 | 0.035 | 0.061 |
| 1295 | 322 | 21 | 39 | 7.3 | 952.4 | 5.049 | -44.082 | 618.2 | 96.7 | 0.032 | 0.023 |
| 1296 | 322 | 21 | 39 | 15.5 | 1348.7 | -1.225 | -18.458 | 987.9 | 99.4 | 0.020 | 0.107 |
| 1297 | 322 | 21 | 39 | 43.0 | 966.5 | -1.184 | -30.935 | 790.8 | 99.2 | 0.007 | 0.039 |
| 1298 | 322 | 21 | 42 | 49.0 | 2118.1 | -0.520 | -17.188 | 853.7 | 98.7 | 0.020 | 0.136 |
| 1299 | 322 | 21 | 44 | 9.3 | 1507.7 | -1.278 | -19.350 | 576.3 | 99.3 | 0.048 | 0.090 |
| 1300 | 322 | 21 | 45 | 15.1 | 670.1 | -1.261 | -18.117 | 556.0 | 97.7 | 0.013 | 0.115 |
| 1301 | 322 | 21 | 45 | 47.3 | 1493.4 | -0.848 | -19.091 | 919.5 | 99.4 | 0.070 | 0.097 |
| 1302 | 322 | 21 | 48 | 15.0 | 1034.0 | 0.614 | -29.888 | 822.2 | 63.0 | 0.133 | 0.040 |
| 1303 | 322 | 21 | 48 | 40.3 | 1454.3 | -1.347 | -17.486 | 629.1 | 98.8 | 0.016 | 0.125 |
| 1304 | 322 | 21 | 48 | 45.3 | 808.2 | -1.309 | -19.461 | 624.2 | 99.0 | 0.016 | 0.085 |
| 1305 | 322 | 21 | 51 | 36.5 | 1244.5 | -1.597 | -21.966 | 669.6 | 98.5 | 0.020 | 0.059 |
| 1306 | 322 | 21 | 51 | 44.3 | 885.8 | -1.524 | -19.216 | 615.6 | 98.9 | 0.017 | 0.094 |
| 1307 | 322 | 21 | 53 | 18.3 | 1174.3 | 5.347 | -28.115 | 609.8 | 97.0 | 0.034 | 0.043 |
| 1308 | 322 | 21 | 53 | 24.3 | 1332.1 | 5.044 | -19.735 | 839.3 | 99.4 | 0.067 | 0.080 |
| 1309 | 322 | 21 | 56 | 40.3 | 1055.5 | -1.191 | -27.511 | 820.9 | 99.9 | 0.016 | 0.044 |
| 1310 | 322 | 21 | 57 | 8.3 | 1688.1 | -1.038 | -18.444 | 743.5 | 99.1 | 0.010 | 0.108 |
| 1311 | 322 | 21 | 58 | 30.3 | 1361.0 | -1.412 | -18.993 | 687.5 | 99.0 | 0.013 | 0.098 |
| 1312 | 322 | 21 | 59 | 3.5 | 1771.4 | -0.930 | -19.995 | 606.1 | 98.8 | 0.027 | 0.077 |
| 1313 | 322 | 21 | 59 | 43.3 | 1894.0 | -0.701 | -18.254 | 805.8 | 99.3 | 0.010 | 0.112 |
| 1314 | 322 | 22 | 0 | 9.3 | 1918.4 | -0.791 | -18.237 | 936.9 | 98.5 | 0.044 | 0.112 |
| 1315 | 322 | 22 | 1 | 36.3 | 1350.9 | -1.247 | -25.057 | 902.0 | 99.6 | 0.009 | 0.049 |
| 1316 | 322 | 22 | 1 | 52.5 | 895.3 | -1.818 | -19.564 | 600.8 | 97.8 | 0.002 | 0.083 |
| 1317 | 322 | 22 | 2 | 4.3 | 1338.4 | 2.812 | -24.934 | 704.0 | 81.2 | 0.004 | 0.049 |
| 1318 | 322 | 22 | 2 | 9.3 | 1716.8 | -0.961 | -23.786 | 671.9 | 98.8 | 0.022 | 0.052 |
| 1319 | 322 | 22 | 3 | 5.2 | 1688.3 | -1.006 | -19.342 | 722.1 | 99.0 | 0.011 | 0.090 |
| 1320 | 322 | 22 | 5 | 14.5 | 1250.3 | -1.514 | -24.111 | 729.9 | 99.1 | 0.016 | 0.051 |
| 1321 | 322 | 22 | 6 | 3.3 | 1584.8 | -1.192 | -24.484 | 760.6 | 98.8 | 0.008 | 0.050 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 1322 | 322 | 22 | 7 | 54.0 | 1770.8 | 2.401 | -20.236 | 962.9 | 82.6 | 0.004 | 0.073 |
| 1323 | 322 | 22 | 9 | 9.5 | 1587.1 | -4.693 | -17.869 | 699.8 | 81.2 | 0.004 | 0.118 |
| 1324 | 322 | 22 | 9 | 9.1 | 1978.6 | -0.681 | -17.772 | 854.8 | 99.1 | 0.014 | 0.120 |
| 1325 | 322 | 22 | 9 | 19.5 | 1517.7 | -4.064 | -24.926 | 886.9 | 82.8 | 0.003 | 0.049 |
| 1326 | 322 | 22 | 9 | 27.5 | 1152.6 | -1.565 | -19.441 | 635.8 | 99.0 | 0.015 | 0.085 |
| 1327 | 322 | 22 | 9 | 32.0 | 973.3 | -1.233 | -27.967 | 774.9 | 99.3 | 0.007 | 0.043 |
| 1328 | 322 | 22 | 10 | 3.5 | 1231.9 | -1.337 | -18.664 | 828.9 | 99.6 | 0.007 | 0.103 |
| 1329 | 322 | 22 | 10 | 37.5 | 1934.6 | -0.658 | -19.130 | 703.4 | 99.0 | 0.012 | 0.096 |
| 1330 | 322 | 22 | 10 | 45.0 | 2426.7 | 0.257 | -18.250 | 774.6 | 99.0 | 0.016 | 0.112 |
| 1331 | 322 | 22 | 11 | 26.3 | 1578.1 | -1.062 | -19.345 | 669.4 | 98.9 | 0.022 | 0.090 |
| 1332 | 322 | 22 | 13 | 32.0 | 1492.8 | 2.634 | -25.817 | 845.7 | 81.7 | 0.020 | 0.047 |
| 1333 | 322 | 22 | 14 | 54.3 | 1247.6 | -1.462 | -19.954 | 744.5 | 99.1 | 0.004 | 0.077 |
| 1334 | 322 | 22 | 15 | 27.3 | 1713.6 | 2.238 | -20.927 | 1271.6 | 82.5 | 0.008 | 0.066 |
| 1335 | 322 | 22 | 16 | 57.3 | 2251.8 | 0.040 | -17.476 | 943.7 | 99.5 | 0.028 | 0.125 |
| 1336 | 322 | 22 | 18 | 6.0 | 1388.6 | -1.441 | -26.146 | 488.1 | 98.8 | 0.033 | 0.047 |
| 1337 | 322 | 22 | 19 | 5.3 | 1495.8 | -1.106 | -19.333 | 888.8 | 99.6 | 0.008 | 0.091 |
| 1338 | 322 | 22 | 19 | 52.0 | 1494.3 | 4.905 | -23.872 | 857.9 | 98.2 | 0.027 | 0.052 |
| 1339 | 322 | 22 | 21 | 44.0 | 1404.3 | -1.424 | -25.403 | 529.3 | 98.6 | 0.028 | 0.048 |
| 1340 | 322 | 22 | 23 | 15.3 | 1676.3 | -1.000 | -19.369 | 659.0 | 98.9 | 0.014 | 0.089 |
| 1341 | 322 | 22 | 24 | 36.5 | 1419.6 | -1.369 | -25.147 | 717.4 | 99.0 | 0.012 | 0.048 |
| 1342 | 322 | 22 | 24 | 52.0 | 1910.6 | 4.041 | -18.978 | 1258.6 | 98.5 | 0.040 | 0.099 |
| 1343 | 322 | 22 | 29 | 15.3 | 1108.0 | 4.153 | -26.135 | 836.3 | 98.2 | 0.030 | 0.047 |
| 1344 | 322 | 22 | 31 | 25.3 | 1659.9 | -1.090 | -20.577 | 776.1 | 99.1 | 0.018 | 0.069 |
| 1345 | 322 | 22 | 33 | 25.3 | 1597.2 | 5.625 | -23.981 | 620.0 | 97.5 | 0.033 | 0.051 |
| 1346 | 322 | 22 | 34 | 27.3 | 1680.0 | 3.912 | -19.319 | 1184.9 | 98.3 | 0.038 | 0.091 |
| 1347 | 322 | 22 | 35 | 8.0 | 1600.7 | 2.678 | -21.133 | 984.9 | 83.0 | 0.003 | 0.065 |
| 1348 | 322 | 22 | 38 | 6.3 | 1462.9 | -1.244 | -23.074 | 811.4 | 99.2 | 0.008 | 0.054 |
| 1349 | 322 | 22 | 39 | 14.3 | 1495.0 | -1.501 | -19.882 | 604.9 | 97.8 | 0.021 | 0.078 |
| 1350 | 322 | 22 | 40 | 2.3 | 1785.4 | 4.640 | -18.355 | 1006.3 | 98.0 | 0.016 | 0.110 |
| 1351 | 322 | 22 | 40 | 15.3 | 1886.5 | 2.366 | -17.763 | 919.8 | 82.9 | 0.015 | 0.120 |
| 1352 | 322 | 22 | 41 | 48.5 | 1824.1 | -0.835 | -16.968 | 753.2 | 99.1 | 0.019 | 0.141 |
| 1353 | 322 | 22 | 41 | 50.0 | 1675.4 | -0.995 | -17.064 | 644.3 | 99.0 | 0.022 | 0.138 |
| 1354 | 322 | 22 | 42 | 46.3 | 1162.3 | 4.850 | -25.285 | 723.6 | 97.8 | 0.040 | 0.048 |
| 1355 | 322 | 22 | 43 | 0.3 | 1311.0 | 0.040 | -23.842 | 1024.0 | 66.3 | 0.006 | 0.052 |
| 1356 | 322 | 22 | 44 | 7.3 | 1359.0 | -1.499 | -23.493 | 696.1 | 99.1 | 0.026 | 0.053 |
| 1357 | 322 | 22 | 44 | 35.3 | 1309.9 | 5.084 | -24.507 | 744.7 | 97.5 | 0.006 | 0.050 |
| 1358 | 322 | 22 | 44 | 48.0 | 1507.4 | -1.245 | -22.017 | 748.9 | 99.3 | 0.012 | 0.059 |
| 1359 | 322 | 22 | 45 | 23.0 | 1118.3 | 4.221 | -30.559 | 830.6 | 98.3 | 0.032 | 0.039 |
| 1360 | 322 | 22 | 45 | 32.3 | 2103.2 | 4.077 | -18.249 | 1410.8 | 98.6 | 0.035 | 0.112 |
| 1361 | 322 | 22 | 45 | 34.3 | 1125.9 | -1.559 | -24.744 | 682.7 | 99.2 | 0.018 | 0.049 |
| 1362 | 322 | 22 | 45 | 48.3 | 1709.2 | 4.819 | -20.318 | 1022.2 | 99.9 | 0.006 | 0.072 |
| 1363 | 322 | 22 | 46 | 58.3 | 1991.6 | 4.023 | -19.331 | 1421.2 | 98.8 | 0.042 | 0.091 |
| 1364 | 322 | 22 | 48 | 20.3 | 1564.3 | -1.188 | -17.561 | 809.8 | 99.2 | 0.006 | 0.124 |
| 1365 | 322 | 22 | 48 | 46.3 | 2192.1 | -0.309 | -20.514 | 1553.2 | 101.9 | 0.005 | 0.070 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 1366 | 322 | 22 | 51 | 21.0 | 1007.3 | -1.267 | -25.327 | 788.6 | 99.4 | 0.010 | 0.048 |
| 1367 | 322 | 22 | 51 | 47.3 | 1439.5 | -3.860 | -17.430 | 943.4 | 82.5 | 0.001 | 0.128 |
| 1368 | 322 | 22 | 52 | 2.5 | 1648.7 | -1.003 | -19.738 | 837.6 | 99.7 | 0.010 | 0.080 |
| 1369 | 322 | 22 | 52 | 13.3 | 1398.2 | -1.400 | -27.331 | 722.7 | 99.3 | 0.021 | 0.044 |
| 1370 | 322 | 22 | 52 | 49.3 | 2262.4 | 4.933 | -19.222 | 825.0 | 97.8 | 0.025 | 0.094 |
| 1371 | 322 | 22 | 53 | 7.5 | 1834.8 | -4.100 | -20.602 | 937.9 | 82.5 | 0.002 | 0.069 |
| 1372 | 322 | 22 | 53 | 9.3 | 1768.9 | 5.006 | -23.280 | 868.8 | 98.0 | 0.013 | 0.054 |
| 1373 | 322 | 22 | 54 | 16.3 | 2099.6 | -0.323 | -17.358 | 713.6 | 99.0 | 0.011 | 0.132 |
| 1374 | 322 | 22 | 55 | 41.0 | 1972.5 | 5.035 | -18.252 | 711.3 | 97.4 | 0.024 | 0.112 |
| 1375 | 322 | 22 | 58 | 19.3 | 1280.3 | 4.563 | -29.145 | 877.6 | 97.8 | 0.008 | 0.041 |
| 1376 | 322 | 22 | 58 | 32.3 | 1738.4 | -0.950 | -18.449 | 828.1 | 99.4 | 0.007 | 0.107 |
| 1377 | 322 | 23 | 1 | 58.0 | 1567.0 | 4.364 | -23.399 | 1023.0 | 98.2 | 0.025 | 0.053 |
| 1378 | 322 | 23 | 2 | 32.3 | 1451.6 | -1.358 | -25.389 | 604.0 | 99.0 | 0.022 | 0.048 |
| 1379 | 322 | 23 | 2 | 46.3 | 1620.5 | 3.054 | -23.233 | 1270.6 | 89.9 | 0.007 | 0.054 |
| 1380 | 322 | 23 | 3 | 36.3 | 1327.0 | -1.316 | -24.342 | 743.6 | 99.5 | 0.005 | 0.050 |
| 1381 | 322 | 23 | 4 | 16.3 | 2044.3 | -0.522 | -19.665 | 894.4 | 98.7 | 0.035 | 0.081 |
| 1382 | 322 | 23 | 5 | 30.3 | 1883.4 | 5.144 | -23.749 | 822.9 | 98.1 | 0.030 | 0.052 |
| 1383 | 322 | 23 | 5 | 31.5 | 1066.5 | -1.564 | -28.924 | 594.0 | 99.1 | 0.018 | 0.042 |
| 1384 | 322 | 23 | 5 | 32.3 | 1048.0 | -5.551 | -31.461 | 627.7 | 71.0 | 0.016 | 0.038 |
| 1385 | 322 | 23 | 5 | 46.6 | 1291.3 | 4.949 | -29.089 | 770.4 | 98.3 | 0.050 | 0.041 |
| 1386 | 322 | 23 | 6 | 3.0 | 1507.6 | -1.342 | -19.868 | 620.9 | 98.4 | 0.022 | 0.078 |
| 1387 | 322 | 23 | 7 | 54.5 | 1309.6 | 4.303 | -26.429 | 929.6 | 98.2 | 0.017 | 0.046 |
| 1388 | 322 | 23 | 8 | 8.3 | 1557.4 | -1.162 | -21.938 | 595.3 | 98.9 | 0.020 | 0.059 |
| 1389 | 322 | 23 | 9 | 47.5 | 2037.6 | -0.361 | -17.949 | 660.8 | 99.0 | 0.015 | 0.117 |
| 1390 | 322 | 23 | 9 | 55.3 | 2115.2 | -0.231 | -18.715 | 767.8 | 99.5 | 0.025 | 0.102 |
| 1391 | 322 | 23 | 10 | 55.0 | 1510.2 | -3.887 | -21.458 | 940.8 | 82.6 | 0.002 | 0.062 |
| 1392 | 322 | 23 | 11 | 25.3 | 788.3 | -1.299 | -25.179 | 591.7 | 99.1 | 0.019 | 0.048 |
| 1393 | 322 | 23 | 11 | 44.3 | 1600.8 | 3.000 | -24.715 | 1269.2 | 89.9 | 0.007 | 0.049 |
| 1394 | 322 | 23 | 11 | 51.3 | 2017.1 | 4.046 | -19.134 | 1388.4 | 98.8 | 0.035 | 0.096 |
| 1395 | 322 | 23 | 14 | 50.3 | 1785.2 | 5.077 | -22.824 | 849.6 | 98.2 | 0.024 | 0.055 |
| 1396 | 322 | 23 | 15 | 4.5 | 1975.3 | -0.781 | -15.623 | 611.4 | 97.7 | 0.022 | 0.167 |
| 1397 | 322 | 23 | 15 | 11.0 | 1565.5 | 4.843 | -25.360 | 897.3 | 98.1 | 0.017 | 0.048 |
| 1398 | 322 | 23 | 15 | 38.3 | 1862.6 | -0.546 | -18.558 | 1322.2 | 102.3 | 0.011 | 0.105 |
| 1399 | 322 | 23 | 16 | 6.3 | 1454.7 | -1.253 | -18.879 | 649.3 | 98.9 | 0.023 | 0.100 |
| 1400 | 322 | 23 | 16 | 32.5 | 1322.1 | -1.301 | -21.817 | 817.8 | 100.0 | 0.050 | 0.060 |
| 1401 | 322 | 23 | 18 | 34.5 | 1738.5 | -3.029 | -22.487 | 1488.7 | 73.7 | 0.003 | 0.057 |
| 1402 | 322 | 23 | 18 | 34.3 | 1837.6 | 3.260 | -17.455 | 1275.7 | 90.2 | 0.003 | 0.127 |
| 1403 | 322 | 23 | 18 | 49.3 | 1105.5 | 4.597 | -29.999 | 786.8 | 98.2 | 0.026 | 0.040 |
| 1404 | 322 | 23 | 18 | 50.3 | 1381.7 | -1.419 | -27.902 | 570.5 | 99.1 | 0.006 | 0.044 |
| 1405 | 322 | 23 | 19 | 8.3 | 2008.3 | 4.663 | -21.472 | 1012.2 | 98.3 | 0.032 | 0.062 |
| 1406 | 322 | 23 | 19 | 39.3 | 1849.5 | 3.675 | -19.185 | 1348.6 | 98.9 | 0.049 | 0.095 |
| 1407 | 322 | 23 | 20 | 25.3 | 1136.7 | -1.384 | -26.514 | 849.0 | 98.6 | 0.035 | 0.046 |
| 1408 | 322 | 23 | 21 | 34.3 | 1518.7 | -2.079 | -15.570 | 688.4 | 65.0 | 0.013 | 0.169 |
| 1409 | 322 | 23 | 21 | 55.2 | 971.4 | -1.600 | -18.863 | 561.5 | 99.0 | 0.022 | 0.100 |

**Table D-3. Detection list Cobra Dane radar observed during the 2008 campaign - cont.**

| | Epoch | | | | Slant Range | Range Rate | Radar Cross Section | Altitude | Inclination | Eccentricity | Characteristic Length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | doy | hr | min | sec | (km) | (km/sec) | (dBsm) | (km) | (deg) | | (m) |
| 1410 | 322 | 23 | 23 | 15.3 | 1905.5 | 4.205 | -19.739 | 1204.7 | 98.6 | 0.033 | 0.080 |
| 1411 | 322 | 23 | 23 | 43.5 | 1367.8 | -1.312 | -19.520 | 573.8 | 99.3 | 0.032 | 0.084 |
| 1412 | 322 | 23 | 23 | 52.0 | 1722.6 | 3.648 | -19.999 | 1362.9 | 98.6 | 0.037 | 0.077 |
| 1413 | 322 | 23 | 24 | 8.3 | 1660.0 | 3.098 | -21.978 | 1272.9 | 89.9 | 0.007 | 0.059 |
| 1414 | 322 | 23 | 24 | 32.0 | 1590.2 | 4.843 | -23.558 | 905.4 | 98.0 | 0.014 | 0.053 |
| 1415 | 322 | 23 | 24 | 34.3 | 1611.9 | 4.438 | -20.648 | 1022.7 | 98.3 | 0.024 | 0.069 |
| 1416 | 322 | 23 | 26 | 3.0 | 1802.2 | -0.809 | -19.654 | 843.4 | 99.7 | 0.012 | 0.082 |
| 1417 | 322 | 23 | 26 | 29.3 | 1913.3 | 5.372 | -19.126 | 873.5 | 99.4 | 0.056 | 0.096 |
| 1418 | 322 | 23 | 26 | 50.3 | 1411.1 | -1.273 | -19.558 | 827.7 | 99.6 | 0.004 | 0.083 |
| 1419 | 322 | 23 | 28 | 58.0 | 1876.3 | 5.027 | -19.314 | 873.7 | 98.1 | 0.013 | 0.092 |
| 1420 | 322 | 23 | 29 | 51.3 | 1110.6 | -1.341 | -34.471 | 776.7 | 99.7 | 0.007 | 0.034 |
| 1421 | 322 | 23 | 31 | 51.5 | 704.2 | -1.097 | -29.999 | 546.3 | 99.1 | 0.020 | 0.040 |
| 1422 | 322 | 23 | 33 | 22.0 | 1184.6 | 4.345 | -28.284 | 863.6 | 98.1 | 0.009 | 0.043 |
| 1423 | 322 | 23 | 36 | 25.5 | 2393.0 | -0.486 | -17.493 | 1885.4 | 103.6 | 0.061 | 0.125 |
| 1424 | 322 | 23 | 36 | 48.3 | 1901.3 | 3.789 | -23.029 | 619.9 | 89.3 | 0.015 | 0.055 |
| 1425 | 322 | 23 | 37 | 34.0 | 1901.2 | -0.580 | -18.674 | 1240.4 | 100.7 | 0.058 | 0.103 |
| 1426 | 322 | 23 | 39 | 5.5 | 1219.9 | -1.488 | -22.098 | 623.1 | 99.0 | 0.021 | 0.059 |
| 1427 | 322 | 23 | 40 | 48.0 | 1241.4 | 5.195 | -19.401 | 693.3 | 97.9 | 0.035 | 0.087 |
| 1428 | 322 | 23 | 42 | 5.0 | 1462.3 | -1.335 | -18.273 | 537.7 | 99.0 | 0.022 | 0.112 |
| 1429 | 322 | 23 | 42 | 37.3 | 1371.9 | -1.353 | -20.290 | 773.9 | 99.5 | 0.013 | 0.073 |
| 1430 | 322 | 23 | 43 | 0.3 | 1200.4 | 2.904 | -21.616 | 738.3 | 81.2 | 0.006 | 0.061 |
| 1431 | 322 | 23 | 43 | 24.3 | 1385.4 | -5.367 | -20.229 | 819.1 | 70.0 | 0.006 | 0.074 |
| 1432 | 322 | 23 | 43 | 37.3 | 1947.5 | 3.256 | -22.840 | 1271.4 | 90.1 | 0.003 | 0.055 |
| 1433 | 322 | 23 | 43 | 39.9 | 1417.0 | -1.155 | -19.325 | 691.4 | 100.0 | 0.022 | 0.091 |
| 1434 | 322 | 23 | 43 | 44.4 | 1141.3 | -1.264 | -24.777 | 828.2 | 99.0 | 0.013 | 0.049 |
| 1435 | 322 | 23 | 43 | 46.3 | 1295.7 | 2.795 | -27.069 | 758.9 | 81.3 | 0.004 | 0.045 |
| 1436 | 322 | 23 | 43 | 50.3 | 1559.9 | 5.068 | -22.885 | 821.5 | 98.0 | 0.019 | 0.055 |
| 1437 | 322 | 23 | 44 | 6.0 | 2237.4 | 4.393 | -19.525 | 1161.0 | 98.1 | 0.027 | 0.084 |
| 1438 | 322 | 23 | 44 | 13.5 | 1751.2 | -0.710 | -16.715 | 1437.7 | 101.6 | 0.002 | 0.146 |
| 1439 | 322 | 23 | 44 | 25.3 | 1555.9 | 2.688 | -18.329 | 754.8 | 83.8 | 0.298 | 0.110 |
| 1440 | 322 | 23 | 46 | 9.3 | 2350.3 | 4.842 | -17.446 | 706.1 | 97.8 | 0.019 | 0.127 |
| 1441 | 322 | 23 | 47 | 41.3 | 1863.1 | 4.850 | -22.926 | 1057.2 | 100.0 | 0.003 | 0.055 |
| 1442 | 322 | 23 | 47 | 53.3 | 1359.6 | -1.364 | -20.296 | 663.0 | 98.9 | 0.020 | 0.073 |
| 1443 | 322 | 23 | 48 | 44.3 | 779.2 | -1.343 | -31.098 | 557.7 | 99.1 | 0.023 | 0.038 |
| 1444 | 322 | 23 | 49 | 41.5 | 1269.1 | -1.398 | -24.445 | 725.4 | 99.3 | 0.013 | 0.050 |
| 1445 | 322 | 23 | 49 | 46.0 | 1670.7 | 6.059 | -18.450 | 525.1 | 101.2 | 0.023 | 0.107 |
| 1446 | 322 | 23 | 52 | 37.3 | 1125.2 | -1.470 | -20.381 | 625.2 | 99.3 | 0.018 | 0.072 |
| 1447 | 322 | 23 | 53 | 12.3 | 1156.9 | -1.587 | -28.323 | 558.8 | 99.0 | 0.024 | 0.043 |
| 1448 | 322 | 23 | 56 | 10.3 | 1218.4 | 4.446 | -21.348 | 864.4 | 98.2 | 0.009 | 0.063 |
| 1449 | 322 | 23 | 56 | 25.3 | 1325.1 | -1.425 | -23.193 | 777.0 | 99.4 | 0.011 | 0.054 |
| 1450 | 322 | 23 | 57 | 7.3 | 1374.3 | 5.757 | -20.942 | 587.5 | 98.4 | 0.019 | 0.066 |
| 1451 | 322 | 23 | 58 | 39.3 | 1988.7 | 4.640 | -19.935 | 1245.6 | 99.3 | 0.044 | 0.077 |
| 1452 | 322 | 23 | 59 | 15.3 | 1937.2 | 5.996 | | 489.2 | 99.7 | 0.057 | |

## Appendix E

## NASA's Size Estimation Model

Physical size is estimated from radar cross section (RCS) using NASA's Size Estimation Model (SEM). Debris objects were selected from two hypervelocity impacts of simulated satellites. Some artificial debris-like objects were also included in the sample to better represent the postulated orbital debris environment. This included a printed circuit board and a piece of solid rocket motor aluminum oxide ($Al_2O_3$) slag. The RCS values of these 39 debris objects were measured at a controlled RCS radar range operated by the System Planning Corporation. The RCSs of these objects were measured over 4 radar frequency bands (2.5647-3.9111 GHz, 4.116-7.986 GHz, 8.1544-12.7684 GHz, and 12.924-17.538 GHz) with 8 steps in the band of the lowest frequency and 16 steps in the band for the other three, and with hundreds of source-object orientations. These frequencies, S-, C-, X-, and Ku-band, respectively, were chosen since they represent radar frequencies often used for orbital debris observations.

The characteristic length of an object is defined as the average of the largest dimensions for an object measured along three orthogonal axes. The first axis was chosen to coincide with the largest dimension, the second axis to coincide with the largest dimension in a plane orthogonal to the first axis, and the third axis to be orthogonal to the first two axes. In this report, the characteristic length of an object is often referred to as size or diameter.

Consistent with Maxwell's equations of electromagnetics, radar data from different wavelengths can be compared by normalizing the size by the wavelength of the measuring frequency and the RCS by the wavelength squared. This results in a size parameter x = size/wavelength and an RCS parameter z = RCS/wavelength$^2$. Figure E-1 shows the relationship between the measured RCS parameter and the object's physical size parameter. Each of the 2072 points on this plot is a weighted average for a single object over hundreds of different orientations at a single frequency. The data were weighted to account for nonuniform sampling of the object orientations as the data were collected.

From this plot, a scaling curve (smooth solid line) was developed, which represents the mean of the measured RCS for each size/wavelength. For debris sizes much smaller or larger than the radar wavelength, the scaling curve approaches the Rayleigh or optics region curves, as expected. Between the Rayleigh and optics region curves is the Mie resonance region that results in an enhanced RCS measurement, on average, for a given size. In the resonance region, the scaling curve deviates from the optical curve (not shown) such that for a given RCS, the object is smaller in characteristic length than it would have been

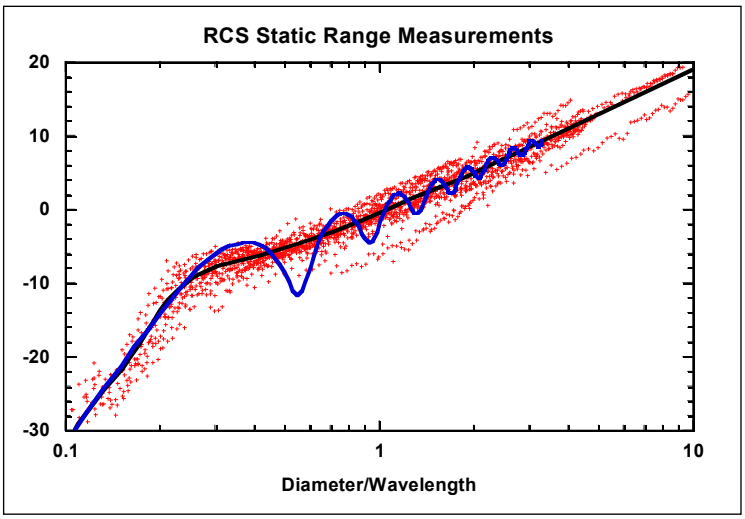


**Figure E-1. Results of RCS-to-Physical size measurements on 39 "representative" debris objects over the frequency range 2.0 - 18 GHz (15 - 1.67 cm wavelength). Each point represents an average RCS for a single object measured at a single frequency over many orientations. The oscillating line is the radar cross section for a spherical conductor while the smooth line is the polynomial fit to the data.**

interpreted to be by using the optical approximation. The scaling curve may be expressed as:

$x = \sqrt{\frac{4z}{\pi}}$ , for $z > 5$, Optical Regime

$x = \sqrt[6]{\frac{4z}{9\pi^5}}$ , for $z < 0.03$, Rayleigh Regime

$x = g(z)$ , in between, Mie Resonance Regime

where $z$ = RCS/λ, $x$ = diameter/λ, and λ is wavelength. In the above equations, the quantity z is assumed to not be expressed in dB. The smooth function g(z) is expressed by 23 points in Table E-1.

**Table E-1. The NASA SEM curve x=g(z) in the Mie resonance region.**

| x=diameter/λ | z=RCS/λ² |
|---|---|
| 0.10997 | 0.001220 |
| 0.11685 | 0.001735 |
| 0.12444 | 0.002468 |
| 0.13302 | 0.003511 |
| 0.14256 | 0.004993 |
| 0.15256 | 0.007102 |
| 0.16220 | 0.01010 |
| 0.17138 | 0.01437 |
| 0.18039 | 0.02044 |
| 0.18982 | 0.02907 |
| 0.20014 | 0.04135 |
| 0.21237 | 0.05881 |
| 0.22902 | 0.08365 |
| 0.25574 | 0.1190 |
| 0.30537 | 0.1692 |
| 0.42028 | 0.2407 |
| 0.56287 | 0.3424 |
| 0.71108 | 0.4870 |
| 0.86714 | 0.6927 |
| 1.0529 | 0.9852 |
| 1.2790 | 1.401 |
| 1.5661 | 1.993 |
| 1.8975 | 2.835 |

Note that most of the debris for Haystack is in the Rayleigh region, which allows size estimates that are relatively insensitive to errors in the RCS measurements.

For comparison, the oscillating RCS-to-size curve for a spherical conductor is shown in the figure. The NASA SEM is not applicable to estimate sizes of spherical conductors (such as NaK droplets) in the Mie Resonance region. The oscillations result from constructive and destructive interference of electromagnetically induced waves on the surface of the conducting sphere.

The size-to-RCS curve for a spherical conductor is expressed theoretically as:

$$z = \frac{1}{\pi}\left|\sum_{n=1}^{\infty}(-1)^n\left(n+\frac{1}{2}\right)(b_n - a_n)\right|^2$$

where the coefficients $a_n$ and $b_n$ are

$$a_n = \frac{j_n(2\pi x)}{h_n^{(2)}(2\pi x)}$$

$$b_n = \frac{2\pi x \cdot j_{n-1}(2\pi x) - n \cdot j_n(2\pi x)}{2\pi x \cdot h_{n-1}^{(2)}(2\pi x) - n \cdot h_n^{(2)}(2\pi x)}$$

where $h_n^{(2)}(x) = j_n(x) - i \cdot y_n(x)$, in which $j_n(x)$ and $y_n(x)$ are the spherical Bessel functions of the first and second kinds, respectively.