IDSat 2.1

Contents

1. Introduction

IDSat assists in the identification of observed satellites, by computing and tabulating close appulses of known satellites relative to the observed time and position. The user provides a file of orbital data in TLE (2-line element) format, creates an observation file with the time and position of the object to be identified, and specifies the maximum difference in time and position between it and any candidate objects to be reported by IDSat.

In addition to reporting appulse time and position difference, IDSat provides the direction of travel, angular velocity and estimated prediction time uncertainty. Subject to the availability of data, it can also provide the predicted visual magnitude and report the radar cross-section area (RCS).

IDSat automatically detects and decodes observations input in the IOD and U.K. formats, including the abbreviated form of the latter used by Russell Eberst. It also reads the 4-line *.ctl input files used with early versions of Mike McCants' Findsat program.

IDSat obtains satellite size and magnitude data from a file derived from my database. Mike McCants' qs.mag file may be used as an alternative.

IDSat is a Windows 32-bit console program, developed and tested under Windows 7. It is believed to be compatible with all 32-bit and 64-bit versions of Windows. The source code is not available.

IDSat.exe may be used free of charge.

IDSat.exe may be shared with others, as long as at it is distributed in the original IDsat.zip distribution file, without any alterations.

Please address questions, problems or comments to Ted Molczan via admin@satobs.org.

2. Program installation

The IDSat.zip distribution file contains the following files, which should be copied to a single folder.

File	Description
IDSat.exe	Executable program.
IDSat.ini	Initialization file used to customize the program's operation.
IDinput.txt	Default observation data file for use with observations in IOD or UK format. As distributed, it contains the sample observation referred to in this document.
IDout.txt	Output file. Initially contains result of running a search against the sample observation in IDinput.txt.
2018 06 23.ctl	Sample Findsat ctl file, with the equivalent sample observation of IDinput.txt.
2018 06 23.unk	Sample unk variant of Findsat file, with the equivalent sample observation of IDinput.txt.
COSPAR.txt	Co-ordinates of sites with Cospar identification numbers.
classfd.tle	Sample text file containing TLEs of objects in secret orbits, updated on 2018 Jun 23. Used for the search example in this document.
Objects.txt	Default file with satellite name, size and magnitude data.
readme.pdf	The file you are reading now.

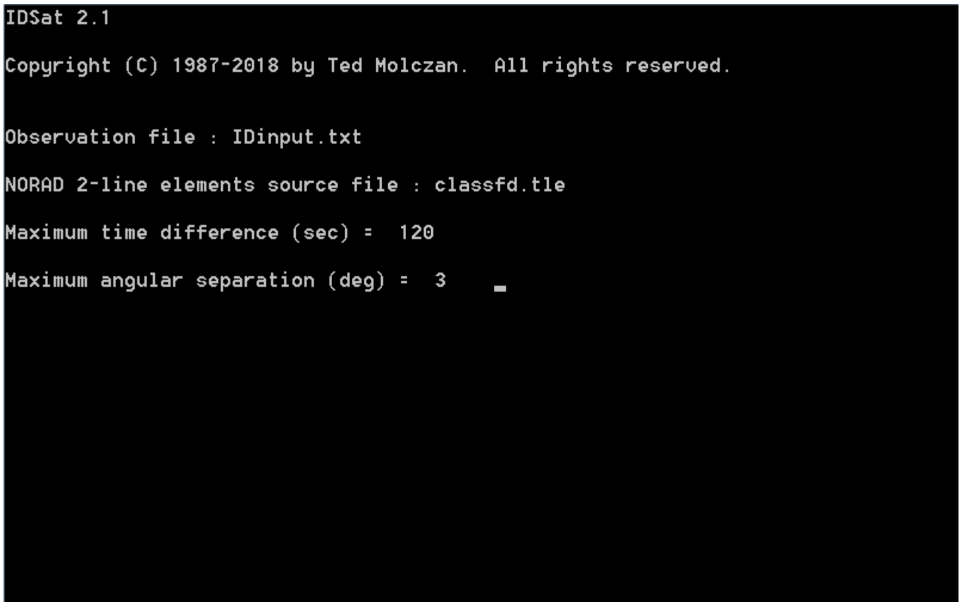
IMPORTANT

The user must provide a file of 2-line orbital elements, named in accordance with Windows conventions, and then enter its path and name at line 2 of IDSat.ini. For additional information on orbital elements, including sources, please see Section 3.5.

3. Running IDSat

3.1 General operation

IDSat.exe begins execution by prompting for an `observation file`, `NORAD 2-line elements source file`, `the maximum time difference` and `the maximum angular separation.` To accept the default values, hit the enter key after each prompt. As distributed, IDSat's screen looks as follows at the fourth prompt. Hitting enter after the fourth prompt begins the search.



IDSat does not display search results; instead it writes them to file IDout.txt. When the search has concluded, IDSat displays the number of objects that met the search criteria and prompts to perform another search.

The search results may be viewed by opening file IDout.txt using a text editor.

IDSat always over-writes IDout.txt. To save the search results, rename the file before performing another search.

It is not necessary to exit the program to view the output file.

To perform another search type y and hit enter; to exit hit enter.

3.2 Output file

IDsat writes search results to a file named IDout.txt. Below is the result of running the sample search found in the input file IDput.txt as distributed. The purpose of the search was to verify the observation of an object in a low Earth orbit, believed to be the OTV 5 space plane.

The first several lines echo the input data and key search settings, which are described in the following sections. Four objects met the search criteria, but OTV 5 was by far the closest. The table shows that the observation was just 5.64 s later than predicted (tdiff column), and within 0.02 deg of prediction (Sep column). OTV 5 makes frequent small manoeuvres to maintain its orbit against drag; therefore, prediction time errors of at least several seconds are normal. The predicted magnitude of 2.3 (Mv column) was close to the observed mag 2.8.

The information under all 13 column headings is described below the table.

```
42932 17 052A   2420 G 2018062323424049  27 14 151823 +005100 90 S+028

Observation: 2018 06 23  23 42 40.49   15 18 23.  +00 51 00  1950  Mv = +2.8

Site 2420 co-ordinates:  55.9486 N  3.1386 W  43 m

NORAD 2-line elements source file: classfd.tle

Maximum time difference = 120 s
Maximum angular separation = 3 deg
Elset age to trigger Earth rotation allowance = 30 days
Prediction time uncertainty to trigger Earth rotation allowance = 20 s

                                     tdiff     Sep      Mv     RCS  Range Trk  FE  Vang  Age    Unc
     Name        Desig   NORAD         s       deg     pred    m^2   km   deg hour deg/s days    s
-------------- -------- ----- ---------- ----- ------- ---- ----- --- ---- ----- ---- -------
NOSS 3-1 r     01040B   26906      95.32  1.05    5.7 v ????  2233 142  2.5  0.17    4     0.0
OTV 5          17052A   42932       5.64  0.02    2.3 v ????   633 109  3.3  0.66    3     0.0
06521A         06521A   90047   -7845.94  1.16    7.9 v ????  9204 101  2.7  0.03   64     0.0
11670A         11670A   90086  -15763.77  1.13  ????    ????  8424  96  2.8  0.03  697 26573.6

NOTE: tdiff < 0 means observation was earlier than prediction.


NOSS 3-1 r
1 26906U 01040B   18170.86841488 0.00000000  00000-0  00000-0 0    05
2 26906  63.4567 110.5880 0387756 341.2323  18.7676 13.44029231    07

OTV 5
1 42932U 17052A   18172.00549212 0.00000000  00000-0  00000-0 0    00
2 42932  54.5145 160.0567 0004791  29.0251 330.9748 15.84843887    01

Unknown 060121
1 90047U 06521A   18111.06360688 0.00000000  00000-0  00000-0 0    06
2 90047  25.2019 145.1469 7162347 174.5894 202.5006  2.28673341    00

Unknown 110619
1 90086U 11670A   16209.17686950 0.00024428  00000-0  17579-2 0    02
2 90086  26.0874 213.5918 6574248 239.7058  40.1327  3.25134116    04


No elements were rejected.
```

Description of tabulated search results:

Name: if IDSat can not find a name in its data base, it uses the International Designation

Desig: International Designation

NORAD: satellite catalogue number issued by U.S. Space Command, aka NORAD number

tdiff: the difference between the observed time and the predicted time of the appulse of the observed position by the listed satellite. Negative values denote early observations.

Sep: appulse distance of listed satellite relative to observed position

mv: predicted magnitude. IDSat predicts the magnitude using standard magnitudes derived using any of three methods, denoted by a letter after the magnitude. The letter "v" denotes standard magnitude determined from visual observations. The letter "d" denotes standard magnitude determined from the satellite's dimensions. The letter "r" denotes standard magnitude determined from the satellite's radar cross-section.

If no standard magnitude data is available to IDSat, it reports predicted magnitude as “????”.

If the object is in the umbra of Earth's shadow, then "shadow" appears in place of magnitude. I decided to list objects that were in shadow for two reasons. First, the boundary of the shadow can not be determined with great precision, so an object computed to be in shadow, may still be in the penumbra. Second, self-illuminated objects cannot be ruled out. A number of observers have reported observing the space shuttle deep in shadow, illuminated by the flood-lights in its cargo bay. In 1996, an observer reported seeing a satellite in shadow, which turned out to be glowing as it passed through its very low perigee.

RCS: radar cross-section area

Range: distance between observer and listed satellite, km

Trk: satellite's track relative to Earth, i.e. direction of travel, expressed as degrees azimuth, measured clock-wise from North

FE: field-entry angle. Indicates the position angle at which the listed satellite would have entered the observer's field of view using non-inverting optics, such as binoculars. Expressed as the hours on the face of a clock. For example, FE = 3 means that the satellite moved from right to left; FE = 12 means the satellite moved from top to bottom.

Vang: listed satellite's angular velocity at the point of appulse in deg/s

Age: age of the listed satellite's orbital elements, in days

Unc: prediction time uncertainty, assuming 10 percent uncertainty in the rate of decay. Expressed in seconds. The time uncertainty varies in direct proportion to the uncertainty of the rate of decay.

The 2-line elements of each object in the table are listed immediately below the table.

3.3 Initialization file

The behaviour of IDSat is controlled by editing the ten default settings in the text file IDSat.ini.

Line	Description	Default
1	Name and path to observation file. (Section 3.4)	IDSat.in
2	Name and path to orbital elements file. (Section 3.5)	
3	Maximum time difference between observation and predicted passage of candidate object (s). (Section 3.7)	120
4	Maximum positional difference between observation and predicted passage of candidate object, (deg). (Section 3.7)	3
5	Prompt for the above items at run-time? (yes/no)	yes
6	Elset age to trigger Earth rotation allowance (days) (Section 3.7)	30
7	Prediction time uncertainty to trigger Earth rotation allowance (s) (Section 3.7)	20
8	Object characteristics file (objects.txt or qs.mag) (Section 4)	objects.txt
9	Check elements for non-numeric characters (yes/no)	yes
10	Type of prompt after execution (resume, exit, none)	exit

Notes

Search time may be reduced by about 20 percent by disabling the checking of elements for non-numeric characters at line 9.

The prompt that occurs at the conclusion of a search may be altered or disabled by editing line 10. The string "resume" tells IDSat to ask whether or not to perform another search; "exit" tells IDSat to ask whether or not to exit; "none" tells IDSat to exit after each search, without any prompt.

3.4 Observation data files

Observations are input to IDSat by means of text files.

The next two sections discuss the observation and file formats read by IDSat.

3.4.1 Standard IOD and U.K. format

IDSat automatically detects and decodes observations in the IOD and U.K. formats, including the abbreviated form of the latter used by Russell Eberst.

Below is the observation from the example search of Section 3.2, in the three standard formats:

IOD	`42932 17 052A   2420 G 20180623234240 49  27 14 151823 +005100 90 S+028`
U.K.	`17052012420180623234240 49  020  11151823  +005100 120 4            +28+28  S`

RDE	`2420 1806 0.211 1204`
	`23`
	`1705201 234240.49 151823+005100 2.8 2.8 0 S`

The above formats are described here.

Marco Langbroek has written IOD Entry for reporting observations in IOD format.

As distributed, IDSat's default file name for IOD and U.K. formatted observations is IDinput.txt. Users may specify an alternative file name, in response to a prompt at run-time. To change the default file name, edit the name that appears on line 1 of file IDSat.ini.

IDSat processes one observation per session and expects the observation to begin on the first line of the observation data file.

IDSat supports only the R.A. and Dec of the IOD and U.K. formats; altitude/azimuth observations may be entered via the Findsat format *.ctl file, described in Section 3.4.2.

PLEASE NOTE: in order to process observations in the IOD, U.K. or Eberst formats, IDSat requires that the observation site's Cospar number, latitude, longitude and height above sea level appear in file Cospar.txt. Please see Section 5 for more information.

3.4.2 Findsat's *.ctl format

IDSat processes files ending with the extension “ctl” as Findsat input files. This feature will be of interest to those who:

- make R.A. and Dec observations, but do not use the IOD, U.K. or Eberst reporting formats
- make altitude/azimuth observations
- are familiar with Findsat and prefer its input data format

IDSat recognizes the 4-line observation input files used with early versions of Findsat. Below is the example observation from the search in Section 3.2, in Findsat format.

```
55.9486  3.1386  141. Eberst
18 06 23  23 42 40.49  15 18.3833  0.85  1950 comments
120 3
classfd.tle
```

Each line is described below:

Line One

55.9486 is degrees north latitude (enter south latitudes as negative values)

3.1386 is degrees west longitude (enter east longitudes as negative values)

141. is feet above sea level

"Eberst" is an optional description of the site.

Note: IDSat can read an alternate format of line one, in which the latitude, longitude and height are replaced by the observer's COSPAR number. IDSat accepts this variant of the Findsat format only via files named with the extension "unk". The above site has the Cospar ID 2420; therefore, line one of the unk file variant would read:

2420 Eberst

Please note that when using the unk variant, IDSat requires that the observer's Cospar number, latitude, longitude and height above sea level appear in file Cospar.txt. Please see Section 5 for more information.

Line Two

18 06 23 is the date of the observation, 2018 Jun 23

23 42 40.49 is the time of the observation, 23:42:40.49 UTC

15 18.3833 is the right-ascension of the observation, in hh dd.dd format

0.85 is the declination of the observation, in decimal degrees. Enter southern declinations as negative numbers.

1950 is the epoch of the observation

"comments" is an optional comment text

Note: observers who prefer to use altitude and azimuth instead of R.A. and Dec should use the following alternate format, in which R.A. and Dec are replaced by the letters "AA", which indicate that the position is altitude and azimuth, followed by those two values. The following example is a close approximation of the sample observation of the search in Section 3.2:

```
18 06 23  23 42 40.49  AA 28.29 219.89 comments
```

Line Three

120 seconds maximum time difference between observation and appulse by satellites found by IDSat

3 degrees maximum position difference between observation and appulse by satellites found by IDSat

Line Four

Line four states the path and name of the file containing the orbital elements of the satellites which IDSat will attempt to match to the observation.

3.5 Orbital elements files

To maximize the probability of identifying observed satellites, it is necessary to provide IDSat with as complete a collection of orbital elements as possible, with epochs as close to the date of the observation as possible.

IDSat processes only NORAD 2-line elements (TLE) format. Space-Track.org is the primary distributor of U.S. Department of Defense (DoD) 2-line orbital elements and related data.

Mike McCants provides orbital elements of hundreds of objects for which elements are not available from official sources. The elements are derived from observations made by amateur satellite observers.

For the most thorough searches, combine the official elements with those of Mike McCants and any other sources in a single file.

Elements files need not contain only elements. IDSat will skip over blank lines or lines containing other text. It does so by looking for the distinctive format of the 2-line elements. IDSat will make use of satellite name lines in the event that the information is not available in its satellite information file.

IMPORTANT

The 2-line orbital elements file must be named in accordance with Windows conventions. Edit line 2 of IDSat.ini to show the path and name of the file. If the file is located in the same folder as IDSat.exe, then the path is not required, e.g. *tle.txt*. If the file is located in a different folder, then the path is required, e.g. *c:\My tledata\tle file.txt*.

3.6 Rejection of bad elements

Rejected elements are listed in the output file, immediately following the elements of the objects that met the search criteria.

As distributed, IDSat checks each orbital element set to ensure that it has the correct structure and has not been corrupted with non-numeric characters. If an element is found to have been corrupted, then the entire element set is rejected. This check can be disabled by editing line 9 of the IDSat.ini file. The only advantage to doing so, is an approximately 20 percent reduction in execution time.

To protect against crashes and promote accurate results, IDSat's implementation of the SGP4/SDP4 orbit propagators rejects elements that propagate to unrealistic values of eccentricity and semi-major axis.

Despite my best efforts, there likely are element sets that can bring down IDSat. To help cope with this eventuality, IDSat lists each NORAD number it has processed to a text file named progress.txt.

If all goes well, the user will never see this file, because it is erased upon the completion of each search run. However, if IDSat crashes during a search, the file will remain on disk. If there is reason to suspect a bad element set, the one that was being processed at the time of the crash may be determined by opening file progress.txt and noting the NORAD number on the final line.

3.7 Coping with outdated elements

The accuracy of IDSat`s results depends on the accuracy of the orbital elements. In principle, the older the elements, the less accurate. Elements of objects in orbits with small perturbations may be fairly accurate for several weeks. Those with large perturbations, e.g. objects near decay, may lose significant accuracy within a day of their epoch. The orbits of manoeuvrable objects become less accurate after each manoeuvre.

One way to cope with inaccurate elements is to allow a reasonably large time and position window for the IDSat search. Even if the observation is believed to be accurate to small fractions of one second of time and one degree of arc, allow a couple of minutes for prediction time uncertainty, and 2 or 3 degrees of position uncertainty, by editing lines 3 and 4 of the IDSat.ini file, respectively:

Line	Description	Default
3	Maximum time difference between observation and predicted passage of candidate object (s).	120
4	Maximum positional difference between observation and predicted passage of candidate object, (deg).	3

The wider these limits, the more candidates IDSat will find. Those that most closely match the observed time, position, magnitude, track and angular velocity are the most likely candidates. Usually, it is not difficult to quickly narrow down to the correct match.

3.7.1 When all else fails

To cope with elements that may be inaccurate due to extreme age and/or high rate of decay, IDSat can be instructed to compute the time of closest approach with allowance for Earth's rotation. This measure is triggered based on the settings of lines 6 and 7 of IDSat.ini:

Line	Description	Default
6	Elset age to trigger Earth rotation allowance (days)	30
7	Prediction time uncertainty to trigger Earth rotation allowance (s)	20

When the Earth rotation allowance is triggered, IDSat adjusts the time of passage to force the object to pass at the time that minimizes its angular distance at closest approach to the observed position, regardless of the maximum time difference specified in line 3 of IDSat.ini. This technique tends to generate many false positives; therefore, great care is required in interpreting the results.

Objects that most closely match the observed time, position, magnitude, track and angular velocity are worthy of further consideration. Look for more current elements and repeat the search. Has the match improved?

Are any of the candidates manoeuvrable? Could any of them have manoeuvred in the interim between the epoch of their elements and the time of the observation? If so, watch for updated elements that may reveal a manoeuvre and yield a match to the observation. If elements are not available from official sources, then consider making a planar search.

4. Satellite information files

IDSat is distributed with file objects.txt, which it uses by default to provide the name, dimensions and standard magnitude of thousands of orbiting objects, that I have compiled from various sources. IDSat will look for objects.txt only in the same folder as IDSat.exe.

An excellent alternative is Mike McCants' qs.mag file, available here in the qsmag.zip archive file. To use qs.mag, unzip it into the same folder as IDSat.exe, and edit line 8 of the IDSat.ini file to replace objects.txt with qs.mag.

It should be noted that IDSat uses standard magnitudes based on 1000 km and a phase angle of 90 deg. The standard magnitudes in qs.mag are based on 1000 km and zero phase angle (i.e. full illumination), IDSat adjusts for the different phases angles by adding 1.243 to qs.mag standard magnitudes.

If IDSat does not find a record for a satellite in the specified file, then it looks for it in two other places.

Certain orbital element files include the name of each satellite on a third line. Others add dimensions, standard magnitude and RCS value to the name line:

ISS 20.0 10.0 0.0 -2.0 d 103

IDSat automatically detects and uses this data if it does not appear in the standard files.

Finally, if IDSat does not find standard magnitude, dimensions or RCS values in any of the aforementioned sources, then it looks for a file of RCS values, named "rcs". RCS values are less reliable for estimating visual magnitude than standard magnitudes derived from observations or satellite dimensions, but they are better than nothing.

File "rcs" must be a standard Windows or MS-DOS text file. Each line contains data for a single satellite, except for the final line, which should contain only "99999". The satellite data must be formatted as follows:

```
sssss rrrr nn
    5 0.12 35
```

where:

sssss =	catalogue number
rrrr =	RCS values (a decimal point may appear at any position within this field
nn =	number of RCS values evaluated to obtain the listed value. This field may be left blank.

Although objects.txt (or qs.mag) and file "rcs" provide important information, IDSat will operate even if each one is missing. IDSat does not report the absence of any of these three files, so it is up to users to ensure that they are in the same folder as IDSat.exe.

5. COSPAR site co-ordinate file

In order to process observations in the IOD, U.K. formats, IDSat requires that the observer's Cospar number, latitude, longitude and height above sea level appear in the file Cospar.txt. The *.unk variant of Findsat's .ctl file also requires this file.

Additional sites may be added by editing Cospar.txt using a text editor.

Here is a sample entry:

```
2701  43.68764   79.39243   230
```

Interpretation:

2701 = COSPAR number

43.68764 deg north latitude (enter south latitudes as negative values)

79.39243 deg west longitude (enter east longitudes as negative values)

230 metres above sea level

PLEASE NOTE: IDSat expects to find the above values in specific fields:

COSPAR: columns 1 to 4 (If the site does not have an official COSPAR ID, use 9999 or another similarly high value as a placeholder.)

latitude: columns 6 to 14

longitude: columns 16 to 25

hasl: columns 27 to 33