GOC Geomatics procedure for handling Space Debris re-entry events (SPADOCs)

Background

When space debris is re-entering the atmosphere, NORAD (North American Air Defense – Canada/US joint air force command centre located in Colorado) will notify DND CanSpOC (Canadian Space OpsCen) of the re-entry of the object. That notification is then sent to the GOC, who then sends it to GOC Geo for assessment. These are sometimes called 'TIP alerts'. TIP representing 'time to impact'.

The object of concern can be left-over remnants from a previous launch, like a rocket-body, or can be the payload of the launch (such as a satellite). When those objects enter the stratosphere, they are given an object ID number. Those ID numbers are publicly searchable and will usually identify what the object is and who it belonged to.

NORAD will only send a notification if the re-entering object is deemed 'high-interest'. That classification is assigned when any of the following criteria are met:

- The object has a radar cross-section of 10m2 or more
- It contains hazardous materials
- It contains human remains
- The re-entry may generate significant media interest
- The object has a high probability that significant components will survive the re-entry
- The object is deemed to be high interest by a competent authority
    - This last criteria is a way to assign the high-interest flag whenever an authority wants to, but the other criteria may not fit.

Regardless of the reason for the high-interest flag, when we are notified of the re-entry, we are NOT notified of the particular criteria that was met. We have to use our deductive skills to figure it out.

The responsibility of GOC Geo, once notified of the SPADOC, is to determine the risk to Canadian territory, and notify the GOC of our assessment. This is done by interpreting the coordinates and the trajectory and plotting it against Canadian territory.

Before you begin

1. GOC sends the SPADOC notification to GOC Geo, and often to others on the GOC duty team
    a. This may happen during business hours, or after-hours. Regardless of the time received, it needs to be assessed by Geo soon – within 1hr of receipt.
    b. If the notification is received late night – the GOC may call the Geo Duty officer to alert them to the message and request assessment.
2. Once received, GOC Geomatics Duty Officer needs to assess the threat to Canadian territory, with the information received. It is possible that the email from the GOC contains only a brief assessment from CanSpOC without any object details. We cannot do our assessment without the necessary info, so request the full Spadoc notification from the GOC (they will ask CanSpOC to supply it).
    a. Appendix 1 shows a Full SPADOC notification.
3. Once the full notification is received, GOC Geo will then interpret the various parts of the notification to do an assessment of risk.
    a. This assessment can be done at the office, or away from the office with a smart phone and access to the internet and a map application like Google maps.
    b. The assessment will also change based on where the re-entry is located (a location over Canada will require a map and more locational detail).
4. Ensure your assessment does not state 'place of impact'. That is not the info we are provided. We are provided the coordinates for the re-entry into the earth's atmosphere. The object my travel a great distance horizontally between that re-entry and impact on the surface, but we don't know where or how far. We only use the positional info provided.
5. Remember that you are not the source of the information, and that your assessment is derived from the data provided by others. Your assessment should state something to the effect of "Based on the information provided, the object……".

The assessment

1. Using the object ID, try to research what the object is on the internet. Often, the info is publicly available. This may help in knowing whether the object is an observation satellite, or a space probe with aliens. Knowing what the object is will let you state it in the assessment (eg. This object is an earth observation satellite). This will allow you to also make a better estimate on the survivability of the object on re-entry. GOC Geo techs are not expected to know the exact composition of space objects, but it is reasonable to assume something as fragile as a satellite would not survive an uncontrolled re-entry at 16,000 km/hr – while the reinforced hull of a large rocketbody may survive in some fashion.

2. The origin/owner of the object needs to be noted also. (eg. This object, a Russian earth observation satellite…) Sometimes the object can have hazardous materials on board, and if it impacts on land, it can be recovered by the originating nation. Include the nationality in your assessment.

3. The date and time of the re-entry is the next piece of info to be included in the assessment. Always state the event in EDT or EST (eg. This object, a Russian earth observation satellite, is expected to re-enter the atmosphere at 14:14 EDT on 16 of March)

4. The next portion of your assessment should be the predicted path the object will be following prior to re-entry and the expected re-entry location.
    a. Regardless of where you are doing your assessment, at the office or on a phone away from work, you should be able to use the coordinates on a map, and determine the approximate path the object will follow prior to decay. There is a reason the object was listed as high-interest, and the trajectory passing over North America may be the reason. The objects are uncontrolled, so they have the potential to re-enter along its path earlier or later than expected. That is why there are many coordinates provided prior to re-entry. Use a map, plot the coordinates and connect the dots (in your head if necessary).
    b. If the re-entry is occurring outside the vicinity of Canada, and the path prior to that re-entry also doesn't come close to Canada, then you will only need to state the general path and re-entry point in your assessment. (eg. Based on the information provided, the object's trajectory will bring it over the Arctic, southward toward Hawaii, passing over Alaska and near the Yukon border along the way. The predicted re-entry point is approx. 700km southwest of Hawaii, in the Pacific Ocean)

    c. If the re-entry is occurring outside the vicinity of Canada but the path prior passes over Canada, then the assessment will need a bit more precision. There should be a clear description of the P/Ts that it will pass over, and major towns that it would pass near. This is because the object my re-enter early along the path, or be seen in those areas as it streaks across the sky. The GOC could notify the authorities in those P/Ts, so they are aware in advance – in case something does happen. (eg. Based on the information provided, the object's trajectory will bring it over the Arctic, southward toward Hawaii, passing over Alaska and Yukon along the way. The path will bring it near Old Crow and Dawson City YT – within 100km of each. Sightings may be possible, however it is unlikely because of the time of day. An early re-entry along this path may result in the re-entry occurring over Yukon territory. The predicted re-entry point is approx. 700km southwest of Hawaii, in the Pacific Ocean)
        i. This type of assessment would also be applicable to a late re-entry. If the object continues travelling beyond the expected end point, and is heading toward Canada, you would provide a similar report. This late re-entry is very common, so if you can extrapolate the path beyond the end point, based on the previous points, and Canada is threatened, then be sure to mention it.

d. If the re-entry is predicted to occur over Canadian territory or in the vicinity of Canadian territory (land or sea), then your assessment will require more detail about the path and re-entry location. Towns in the area and distances will be required. (eg. Based on the information provided, the object's trajectory will bring it over the Canadian arctic, southward over the Beaufort Sea and then over Yukon territory. The predicted re-entry point is 60km east of Old Crow, YT.)

    i. If the assessment shows a potential threat to Canada, request guidance from the Duty SOO as to whether a map is required that could be sent to relevant partners. If the object is small and likely to burn-up on re-entry, they will probably not require one. If it is large and has the potential to survive, like a rocket-body, then a map may be required. That decision rests with the SOO.

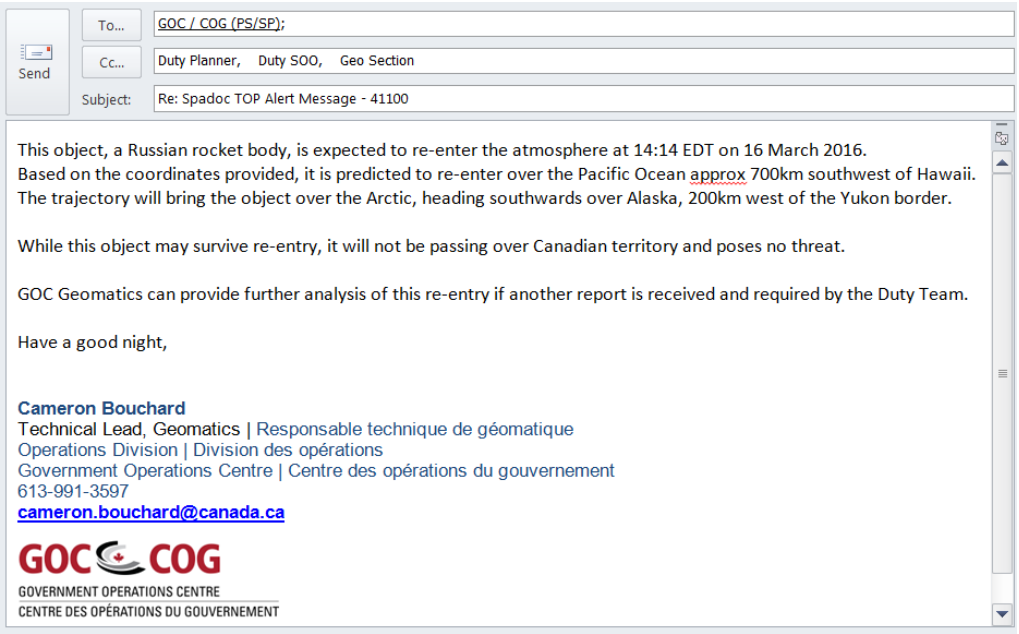
5. The last part of the assessment is the determination of risk. While this is not something that GOC Geo is trained in, it is nonetheless something we provide, to the best of our abilities. The location of the object re-entry and the trajectory are elements that can be used to determine risk to Canadian territory. The type of object, as identified earlier, is also an element that can impact the risk because it has a direct correlation to the ability of that object to survive re-entry.

    a. As a rule of thumb, satellites are not typically designed to survive re-entry, while rocket bodies may have sufficient mass and reinforced shielding to potentially survive.

    b. Make your best assessment of risk to Canadian territory based on the locations provided and the object type. (eg. Based on the information provided, this re-entry does not pose a threat to Canadian territory OR Based on the location of this re-entry, sightings may be possible and might draw media attention, however the object is not designed to survive re-entry and therefore should not pose a threat to Canadian territory OR Based on the location of the re-entry and the composition of this object, there is the possibility of it surviving re-entry over Canadian territory)

6. Put all of this together into a concise, well-crafted email to the whole Duty team (regardless of who was cc'd on the original email. GOC Geo will notify the whole Duty team – Duty Planner, Duty SOO, Geo section, GOC)

7. Example assessment



Appendix 1 – Structure of a SPADOC notification

From: GOC / COG (PS/SP)
Sent: March-16-16 1:18 PM
To: PS.O GOC Geomatics / Géomatique COG O.SP
Cc: PS.O GOC Planning / Planification COG O.SP
Subject: Spadoc TIP Alert Message - 41100 2015-071C SL-4 RB - Update 1

DL – 3 - Releasable to Authorized Organizations and Key Decision-Makers.

Please see attached SPADOC Tip update from CANSPOC for your assessment.

1. (U) MESSAGE TYPE: TIP ALERT MESSAGE 2. (U) PREPARATION DATE TIME: 161258ZMAR16
SUBJECT: PROJECT TIP.
1. 41100/2015-071C /SL-4 R/B /ROCKET BODY / CIS
2. 05 DEC 2015
3. REV 1604/DESCENDING/16 MAR 1814Z
4. 15.6 DEG N 198.6 DEG E
5. DECAY WINDOW IS PLUS OR MINUS 36 MINUTES.
6. INCLINATION 098.1 DEGREES.
TRAJECTORY PRIOR TO DECAY (DEG):

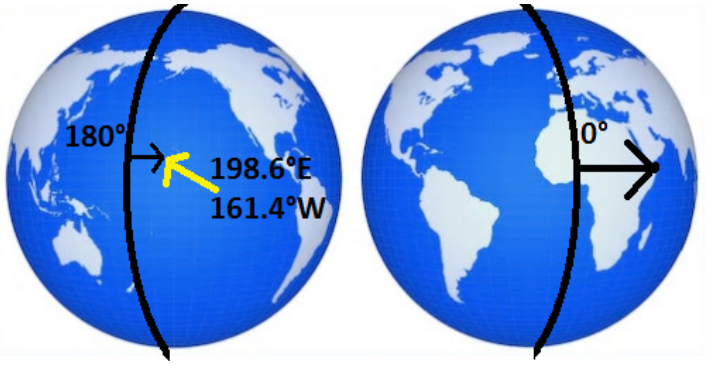
D/TIME	076/1659Z	0276/1714Z	0276/1729Z	076/1744Z	076/1759Z
LAT.	-50.6	-65.9	-5.1	56.4	59.7
E LONG	204.1	048.9	027.3	010.5	213.1

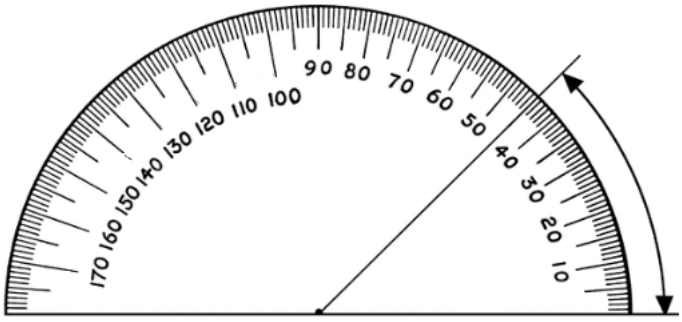
7. NEXT REPORT DUE AFTER DECAY.

Government Operations Centre
Centre des opérations du gouvernement
ps.goc-cog.sp@canada.ca

Definitions of each line in the notification:

1. Type of message and preparation time and date. Note the Z in the timestamp. It is Zulu/UTC time.
1. Object ID, object type and nationality
2. Original Launch date of the object into space
3. Orientation of trajectory (eg. descending = southward, ascending = northward) and the expected date/time of re-entry into the atmosphere – Zulu time. We report all events in Eastern time. Convert the time given to Eastern.
    a. EDT = UTC-4 (2^{nd} Sunday in March 2am ~ 1^{st} Sunday in November 2am)
    b. EST = UTC-5 (1^{st} Sunday in November 2am ~ 2^{nd} Sunday in March 2am)
4. Predicted location of re-entry
    a. The format of this coordinate can be confusing. The Northing is simple enough, 45°N is not confusing. The Easting is the confusing part. The example above shows 198.6°E. On a map, the Eastings typically go from 0 to 180 eastward (degrees east), and then negative 180 up to zero (degrees west). The coordinates provided in Spadocs continue from 0 to 360°. The example above shows 198.6° which is 18.6° past 180. Because it is above 180, the coordinate must be in the West, so to get that number, use this formula.
        i. If X is the given easting, and Y is the resulting coordinate in Degrees West, then:
        ii. $Y = 360 - X$
        iii. The example above would result in: $Y = 360 - 198.6$. Therefore $Y = 161.4°W$



5. Decay window essentially represents the accuracy of the prediction
6. Angle at which the object is crossing the equator (a) AND the trajectory prior to decay (b)
    a. This also indicates how far north and south the orbit is confined to
        i. If the inclination is below 90°, such as 65 degrees, then the orbit keeps the object between 65N and 65S. Nothing beyond that is threatened.
        ii. If the inclination is above 90°, then the object is actually passing over the poles (not an equatorial orbit).
        iii. 

    b. Trajectory prior to decay. This is the path the object is expected to follow before it reaches the final re-entry point (line 4).
        i. The locations are shown with a date/time above the coordinates. The date is actually the date on the Julian calendar (number of days in the year). The example above shows the 76th day of the year. The re-entry date on Line 4 shows that this is actually 16 March. The time is Zulu/UTC. We report all times Eastern