LAUNCH CONJUNCTION ASSESSMENT HANDBOOK

VERSION 1.0 ◆ DECEMBER 2018

18 SPCS Process for Launch Conjunction Assessment

Contents

TABLE OF CONTENTS

Revision History

Version	Description of Changes	Date

Important Definitions

18TH SPACE CONTROL SQUADRON

18th Space Control Squadron (18 SPCS) performs the space surveillance mission for the U.S. Air Force and provides foundational space situational awareness (SSA) for the U.S. Department of Defense (DoD) and U.S. interagency partners, as well as global space entities. This role was performed by the Joint Space Operations Center (JSpOC) until July 2016, at which time 18 SPCS was activated and assumed all space surveillance functions, including detecting, tracking and identifying man-made objects in Earth orbit and maintaining the DoD space catalog, which is make available to the public on www.space-track.org. 18 SPCS is part of the 21st Space Wing and is currently co-located with the Combined Space Operations Center (CSpOC, previously the JSpOC) at Vandenberg Air Force Base in California.

LAUNCH CONJUNCTION ASSESSMENT

Launch conjunction assessment (CA) is the process of identifying close approaches between the planned trajectory(s) of a launch vehicle and other man-made objects on orbit, to include active and inactive satellites, rocket bodies, debris, and analyst objects that are not in the public catalog, as well as the International Space Station (ISS) and vehicles transiting to and from it. Trajectories should be provided for all objects associated with the launch vehicle, such as booster segments, payloads, jettisoned components, and debris. Launch CA may be performed for space launches and ballistic missile launches.

LAUNCH COLLISION AVOIDANCE

Launch collision avoidance is the decision to mitigate the risk of predicted conjunctions by altering planned launch times to avoid or resolve the close approaches. The decision is the responsibility of the launch entity, but may be directed by agencies, such as the U.S. Air Force, who have been given the authority to do so.

GENERAL PERTUBATIONS

Simplified General Perturbations model 4 (SGP4) is the general perturbation (GP) analytic algorithm used for integration of equations of motion and orbit propagation of satellites in the space catalog maintained by 18 SPCS.

SPECIAL PERTUBATIONS

Special Perturbations (SP) is the numerical method used in 18 SPCS' mission software for integration of the equations of motion and orbit propagation of satellites in the space catalog. This technique accomplishes direct numerical integration of the equations of motion including all necessary perturbing accelerations.

Launch Conjunction Assessment Authorities

AIR FORCE INSTRUCTION 91-217 SPACE SAFETY AND MISHAP PREVENTION PROGRAM

This document provides overarching guidance on space safety for acquisition, testing, and life cycle operations of terrestrial, launch, and orbital space systems, and includes specific direction on the acceptable risk thresholds for launches executed from Air Force launch ranges. It is applicable to all Air Force organizations that develop, test, or operate any space system, or who provide launch/range services for space systems, and requires that any entity launching an object to exceed 150km altitude from an Air Force range receive launch conjunction assessment from the 18th Space Control Squadron. Launch entities must submit their launch plans and data through the 30th Space Wing Safety Office (30 SW/SE) at Vandenberg Air Force Base or the 45th Space Wing Safety Office (45 SW/SE) at Cape Canaveral Air Force Station, who will be the direct interface with 18 SPCS for launch CA services.

The full instruction is available online at http://static.e-publishing.af.mil/production/1/af_se/publication/afi91-217/afi91-217.pdf

As of December 27, 2018, AFI 91-217 is being revised and incorporated into AFI 91-202.

TITLE 14 CODE OF FEDERAL REGULATIONS (14 CFR)

14 CFR sets forth the procedures and requirements applicable to commercial space transportation activities conducted in the United States or by a U.S. citizen or by a U.S.-licensed launch entity outside the U.S. In accordance with 14 CFR, the U.S. Federal Aviation Administration (FAA) requires that all launch entities receive launch CA from the U.S. Department of Defense. The full 14 CFR is available online at https://www.ecfr.gov/cgi-bin/text-idx?gp=&SID=ccae461521090c137b5134f855ad02bc&mc=true&tpl=/ecfrbrowse/Title14/14tab_02.tpl

USSTRATCOM SSA SHARING PROGRAM

Unites States Strategic Command (USSTRATCOM), as the U.S. government entity responsible for space situational awareness (SSA), is committed to promoting a safe, stable, sustainable and secure space environment through the sharing of SSA information. In 2009, USSTRATCOM initiated the SSA Sharing Program to provide no-cost basic, emergency, and advanced SSA data and services that cover the full scope of support needed through the lifetime of a satellite from pre-launch preparation to end-of-life disposal. Services include launch conjunction assessment (CA), launch support and early orbit determination, on-orbit CA and collision avoidance (COLA), anomaly support, end-of-life and disposal support, deorbit support, and reentry assessment. The SSA Sharing Program allows any launch entity or satellite operator in the world to request launch CA from USSTRATCOM by submitting an Orbital Data Request (ODR) and associated forms and data to 18 SPCS. Entities who have signed SSA Sharing Agreements with USSTRATCOM will receive expedited review of their request.

LAUNCH CONJUNCTION ASSESSMENT AUTHORITIES

USSTRATCOM has delegated management of the SSA Sharing Program to the Joint Functional Space Component Command (JFSCC), formerly Joint Functional Component Command for Space (JFCC SPACE). While JFSCC oversees the SSA Sharing program, they have directed 18 SPCS to execute day-to-day SSA data sharing and support. 18 SPCS performs the space surveillance mission for the U.S. Air Force, and provides foundational SSA for the U.S. government, as well as global space entities through the SSA Sharing Program. This role was performed by the Joint Space Operations Center (JSpOC) until July 2016, at which time 18 SPCS was activated and assumed all space surveillance functions. 18 SPCS is currently co-located with the Combined Space Operations Center (CSpOC, previously the JSpOC) at Vandenberg Air Force Base, but now has the separate and distinct mission of performing space surveillance, maintaining the space catalog, and providing foundational SSA to U.S. and global partners.

SPACE-TRACK.ORG

Space-Track.org (www.space-track.org) is a public website owned by USSTRATCOM, managed by JFSCC, and populated by 18 SPCS. It is the primary method of sharing SSA information with the global space community. All launch providers and satellite operators should register for a user account in order to access the full scope of SSA data and services available through the SSA Sharing Program.

Launch Conjunction Assessment Process

SCREENING PROCESS

The JFSCC Launch Conjunction Assessment (CA) process, executed by 18 SPCS, identifies close approaches between launch objects which exceed 150km in altitude and other cataloged space objects. It begins with satellite observations from the U.S. Space Surveillance Network (SSN), which includes a variety of sensors throughout the world that detect, track, catalog and identify man-made objects orbiting Earth. SSN observations are input into the 18 SPCS mission system, which implements GP and SP orbit propagation theory. Orbit determination (OD) is performed automatically multiple times per day to determine the position and velocity of every object in the catalog, which is then updated in the 18 SPCS space catalog. The 18 SPCS Orbital Safety Team screens the launch trajectories provided by launch entities against the rest of the space catalog, which includes active and inactive satellites, rocket bodies, debris, and analyst objects that are not in the public catalog, as well as the International Space Station (ISS) and vehicles transiting to and from it. Currently, 18 SPCS launch CA does not include screenings against other launch trajectories occurring at the same time. Results are provided based on miss distance or probability of collision and identify launch times that could result in a collision with an on-orbit space object.

18 SPCS will advise customers on whether GP or SP will be used for screenings. Due to customer data and mission prioritization, 18 SPCS may adjust screening requests accordingly due to mission needs.

Launch minus 15 days
18 SPCS receives initial Launch CA Request (Form 22)

Upon receipt of Form 22
18 SPCS reviews form and acknowledges receipt with Launch Entity (L/E) POCs

Launch minus 1 week
L/E provides initial trajectory files to 18 SPCS. 18 SPCS Launch CA SMEs complete preliminary screening check. No feedback is provided to L/E unless there are problems with files.

18 SPCS Mission Planning
18 SPCS determines manning requirements and schedule based on all launch CA requests/deadlines

Frequency IAW Form 22
18 SPCS Launch CA personnel complete screenings and provide results to those identified on Form 22 via Space-Track.org or SIPR.

Update Form 22
If launch is delayed, L/E submits new Form 22 to 18 SPCS.

IAW AFI 91-217
18 SPCS Launch CA personnel complete Mission Day screening and provide results via Space-Track.org or SIPR

Figure 1: Launch Conjunction Assessment Cycle

HOW TO REQUEST LAUNCH CONJUNCTION ASSESSMENT SUPPORT

All entities launching from an Air Force launch range are required to receive launch CA in accordance with AFI 91-217. All US-licensed launch providers are required by the Federal Aviation Authority (FAA) to receive launch CA directly from 18 SPCS. All other entities may request it through the Orbital Data Request (ODR) process. (Reference Launch Conjunction Assessment Authorities for more information.) All the forms referenced below are available on Space-Track.org at: https://www.space-track.org/documentation#/odr

1. Launch entities at Air Force ranges should consult with the 30 SW or 45 SW Safety Offices to determine requirements, which typically include submitting the following to 18 SPCS no later than 15 days in advance of launch:
    a. Launch plan and orbital parameters (R-15 form)
    b. Launch Conjunction Assessment Request (Form 22)
    c. Launch trajectories for each associated object (may be submitted within 7 days of launch)
2. U.S.-licensed launch entities launching from a non-Air Force range should submit the following to 18 SPCS no later than 15 days in advance of launch:
    a. Launch plan and orbital parameters (R-15 form)
    b. Launch Conjunction Assessment Request (Form 22)
    c. Launch trajectories for each associated object (may be submitted within 7 days of launch)
3. Non-U.S. launch entities should submit the following to 18 SPCS no later than 30 days in advance of launch:
    a. Orbital Data Request (submit according to instructions on the form)
    b. Launch plan and orbital parameters (R-15 form)
    c. Launch Conjunction Assessment Request (Form 22)
    d. Launch trajectories for each associated object (may be submitted within 7 days of launch)

If a launch entity has never received launch CA from 18 SPCS, forms and trajectories must be submitted 30 days in advance. All requests and associated forms should be submitted to 18 SPCS through Space-Track.org. Please register for a user account on Space-Track.org and contact 18SPCS.doo.launch@us.af.mil to set up a permissions-based folder (that will only be accessible by the launch entity and 18 SPCS), which will be used to submit files, as well as receive screening results.

SCREENING SCHEDULE

18 SPCS performs launch CA screenings according to the timing requested on the Form 22 submitted by the Air Force launch wing or launch entity. 18 SPCS will perform at minimum a screening the day of the launch with up to two additional screenings, as early as 7 days before mission day (e.g. L-7; L-4; and mission day), with the option of three backup days (listed as secondary launch dates within the Form 22). The initial backup screening will be first secondary launch date provided on the Form 22. If the launch is delayed one day, the secondary 2 date will be used as backup, with secondary 3 being used as the backup for secondary 2 if the launch continues to push. If launch delays exceed the last backup date, a new Form 22 must be

submitted to 18 SPCS. **New Form 22s must be received 24 hours prior to first requested screening delivery and include new trajectory files, if applicable.**

18 SPCS will make every attempt to perform the launch CA as close as possible to the requested delivery time but may need to complete the screenings earlier due to manning and resource constraints. Launch mission day screenings always take precedence over screenings days prior to launch (e.g. L-4, L-7).

Suborbital launches may list a date range as discussed in the Form 22. This information can be identified in Item 2 B) "Secondary launch date(s) & launch window(s)" and listed in Item 7 "Additional Information" on the Form 22 for clarification. If a date range is used for a suborbital launch, delivery times must also be noted within the Item 7. If they match the previous delivery times, just a statement in Item 7 noting that they match Item 3 delivery times will suffice.

SCREENING TIMESTEPS

Launch entities or Air Force launch ranges may request the frequency within the launch window the trajectories are screened:

- Top of every minute, +/- seconds
- Every 30 Seconds
- Every 10 Seconds
- Every 5 Seconds
- Every Second

18 SPCS will advise customers if limitations arise due to customer data or mission prioritization and may adjust screening parameters accordingly.

LAUNCH CONJUNCTION ASSESSMENT PROCESS

SCREENING TYPES

18 SPCS provides two types of screenings: stand-off radius and probability of collision (Pc). Pc screenings can be limited based on the data provided by the launching entity and customer, as well as mission prioritization and screening capability. Minimum screening volumes are based on the secondary object type according to the following table. Manned objects will only be screened using stand-off radius. In order to receive Pc, covariance information and size (in meters) of the launch vehicle, and any other launched objects for which screening is desired, must be provided in the trajectory files by the launch entity. 18 SPCS computes covariance for secondary objects. Launch entities may request larger screening volumes than those listed in the following table, which will be approved by 18 SPCS on a case-by-case basis. All trajectory files will be screened to the same value per category.

TABLE 1: SCREENING VOLUMES				
Object Type	**Definition**	**Propagation**	**Stand-off Radius**	**Probability of Collision**
Manned	Manned space stations, visiting vehicles	Duration of trajectory	200 km	Not an option
Active satellites	Satellites performing operational mission (may or may not be maneuverable)	Duration of trajectory	25 km	1x10E-5 (0.00001)
All others	Debris, rocket bodies, inactive satellites	Duration of trajectory	2.5 km	1x10E-5 (0.00001)

REPORTING CRITERIA

Launch CA customers will receive all close approaches identified within the screening volumes in Table 1 or as requested on the Form 22 approved by 18 SPCS.

RESULTS

Results will be provided in a single text file that includes screening results for all the trajectories provided, sorted by trajectory, referred to as the "All Sorted" file. Files known as ".res files" can be sent via SIPR in lieu of an All Sorted file if required. Under each trajectory file name there will be list of close approaches with information for the following fields:

- Year
- Day of year
- Launch time
- Satellite catalog number of the secondary object
- Common name of the secondary object
- Mission elapsed time (MET) in seconds
- Miss distance in km
- Probability of collision (if applicable)
- Screening volume

If there is no data listed under the trajectory file name it indicates that there are zero results within the requested screening volume for that file.

If .res files are required, this should be included in Item 7 of the Form 22 "Additional Details".

TRANSITION FROM LAUNCH TO ON-ORBIT CONJUNCTION ASSESSMENT

Once a spacecraft separates from the rocket, it enters the early orbit phase of operations which lasts from separation until it has reached its final orbit. During this time, it is imperative that the satellite operator provide predictive ephemeris to 18 SPCS for conjunction assessment screening to address the gap between launch trajectories and when 18 SPCS can consistently track the separated spacecraft. Once 18 SPCS consistently tracks the spacecraft they will be integrated into the daily on-orbit CA screening process. For more information on early orbit and on-orbit CA, please reference the Spaceflight Safety Handbook for Operators, which is available on Space-Track.org.

CONJUNCTION ASSESSMENT OF REENTERING OBJECTS

If a trajectory is provided for a reentering rocket body or other associated launch object, 18 SPCS will screen it and report results in accordance with launch CA parameters.

Screening Limitations

GENERAL

Trajectory files that are submitted for a launch conjunction assessment screening are grouped into a mission and screened together in a daisy-chain process. All associated trajectory files should be grouped into missions on a Form 22 that require the same launch window, time step, and screening criteria per category.

If a trajectory file requires a different launch window, time step, or screening criteria per category, it should be grouped into a separate Form 22 with any other files that may require those same criteria. Essentially, a copy of the Form 22 should be created with just the specific trajectory files listed for that different launch window/time step/screening criteria and all the respective data should remain the same.

The additional Form 22s should add a designator of some sort to the mission name to differentiate between the different screenings. (i.e. LAUNCH MISSION NAME-A, and the next followed by LAUNCH MISSION NAME-B)

LAUNCH WINDOWS

Trajectory files should be grouped into a mission and Form 22 based on their respective launch window that they will belong under. A Form 22 could be submitted with all the associated trajectory files for the same launch window as one mission.

If there were a set of additional trajectory files that were only viable for another launch window (i.e. trajectories that are only valid for a portion of the launch window for an interplanetary mission), they should then be submitted on another Form 22. Essentially, a copy of the Form 22 should be created with just the specific trajectory files listed for that different launch window and all the respective data should remain the same.

RCS VALUES

Only one RCS value can be used per each trajectory file. If there are multiple RCS values or another RCS value after a certain time in the file, those trajectory files should be provided by the launch entity as separate trajectory files for screening. If the launch entity cannot provide separate files, then the largest RCS value listed for that file within the Form 22 will be used.

ALL SORTED RESULTS

The single text file that is used to provide results known as the "All Sorted" file limits the reported conjunctions based on the parameters listed in the Form 22 request in Item 6 "Screening Type and Criteria". All trajectory files within a respective mission screening will be screened to the same value per category. For example, if a probability of collision (PoC) Criteria 1x10E-5 (0.00001) for active satellites is

being requested for particular screening request that criteria will be applied to all covariance trajectories within the same mission screening for active payloads.

Trajectory Formats

OVERVIEW

In order to perform launch CA, 18 SPCS must receive correctly formatted launch trajectories from the launch entity for all objects that require screening. All launch trajectories should be listed on the Form 22 in accordance with "How to Name Trajectory Files." Launch CA requires separate trajectory files per launch stage or RCS value. Multiple RCS values for one trajectory file cannot be accommodated and will result in 18 SPCS using the larger RCS value indicated on the Form 22. All trajectory files must be formatted in kilometers; any other unit will compromise the accuracy of the results.

Trajectories should be provided a minimum of 7 days in advance of mission day and at least 30 days in advance of mission day for launch entities who are receiving this service from 18 SPCS for the first time.

SYSTEM

SuperCOMBO/CALIPER is the launch CA software used by 18 SPCS. It accepts three input file formats: CALIPER Trajectory, Free-Format Ephemeris, and CALIPER Trajectory Covariance V2.0. The CALIPER Trajectory and Free-Format variations are used to input only ephemeris data (position and velocity), whereas the CALIPER Trajectory Covariance V2.0 input file includes both ephemeris and position covariance. The CALIPER Trajectory Covariance V2.0 file format is required for users who request a probability of collision (Pc) metric in addition to a miss distance.

The following sections provide guidance on input file coordinate systems and characteristics that apply to all formats, followed by descriptions of each specific format.

INPUT FILES - COORDINATE SYSTEMS AND CHARACTERISTICS

SuperCOMBO/CALIPER accepts launch vehicle position and velocity in rotating Earth-Fixed Greenwich (EFG) coordinates. In this system, E is along the line of intersection of the true equator of date and the Greenwich meridian, G is through the true North Pole (normal to the true equatorial plane) and F completes the right-handed coordinate system. SuperCOMBO/CALIPER converts the EFG ephemeris to Earth-Centered Inertial coordinates of date, a frame referred to as "ECI" in the 18 SPCS community. In the conversion from EFG to ECI, SuperCOMBO/CALIPER incorporates UT1-UTC corrections through a timing constants file populated with values from the International Earth Rotation and Reference Systems Service (IERS) Bulletin A.

EFG differs from the crust-fixed Earth-Centered Rotating (ECR) frame in that EFG does not incorporate polar motion. Differences between the EFG and ECR frames are small, on the order of 15 meters or less. Note that EFG is used interchangeably with the NASA "TDR" coordinate system. ECR is terminology used within 18 SPCS; it is equivalent to the Earth-Centered Earth-Fixed (ECEF) and Earth-Centered Fixed (ECF) frames.

Position covariance is entered in a launch vehicle-centered frame, in either UVW or PTW coordinates. In the UVW frame, U ("radial") is the unit vector in the radial direction, W ("cross-track") is the unit vector normal to the launch vehicle's inertial orbit plane, and V ("in-track") is the unit vector which completes the right-handed coordinate system. (Despite the "in-track" descriptor, V is only coincident with the velocity when the launch trajectory is circular.)

In the PTW covariance frame, T is the unit vector along the launch vehicle's velocity vector, W is again the unit vector normal to the launch vehicle's inertial orbit plane, and P is the unit vector that completes the right-handed coordinate system. PTW is the most easily visualized covariance frame for elliptical launch vehicle trajectories because the T direction is aligned with the launch vehicle's velocity.

The SuperCOMBO/CALIPER launch trajectory input file should have ephemeris/covariance points provided at sufficiently frequent time points that interpolation may be used with negligible error. For boosting launch trajectories, an ephemeris/covariance point spacing of 10 seconds is recommended – although less than 10 second spacing could be needed if the trajectory contains large maneuvers. For non-boosting, non-maneuvering phases of a launch trajectory profile, larger ephemeris/covariance point spacing can be used. Note that SuperCOMBO/CALIPER can accept launch trajectory files with variable ephemeris/covariance point spacing.

Because launch vehicle velocity is used for both interpolation and for identifying potential conjunctions, SuperCOMBO/CALIPER requires that the launch vehicle velocity be realistic such that the EFG velocity represents the derivative of the EFG position. Also, the position and velocity ephemeris points should be relatively smooth and continuous (e.g., real world delta-Vs for maneuvers are acceptable but large deviations particularly those that are discontinuous step functions are not).

For meaningful Pc calculations, the launching entity must provide realistic launch trajectory covariance. For responsible decision making based on Pc, the launching authority must be knowledgeable on the Pc metric and its use/limitations.

CALIPER

In the CALIPER trajectory file, one or more launch times/trajectories can be represented in a single file. In the previous version of CALIPER, all launch times in a launch window had to be represented in a single file.

Now, a single trajectory can be input and either run as SuperCOMBO/CALIPER or it can override the launch time and input launch window start/stop/time steps. Since most launch profiles maintain the same earth-fixed trajectory throughout the launch window, this approach is desirable as it requires less processing time. However, if the earth-fixed trajectories do differ with each new launch time (e.g., launch azimuth varies for interplanetary launch opportunities), then all launch times/trajectories will have to be submitted within a single file.

Note that each trajectory file is not screened for its own window if it is grouped into a mission with one overarching launch window (The launch window that is submitted on the Form 22 is used as an override for all trajectory files submitted for that launch screening).

TRAJECTORY FORMATS

There are several reasons for this, but it comes to system processes and procedures and mission growth. As launch CA has grown and launch screenings have become more system intensive, the trajectory files for missions are screened in a daisy-chain process with their screenings set up to a launch window (that would override a window listed within the trajectory file itself).

This can become an issue with some of the deep space/interplanetary missions if the trajectory files are only viable during a certain limited time within the launch window (i.e. a trajectory file is only valid from 0450-0455 of a launch window/won't be used after this time, but the file is six hours long and included within the overarching launch window on the Form 22).

Trajectory files must be grouped into a mission and Form 22 based on their respective launch window that they will belong under. A Form 22 could be submitted with all the associated trajectory files for the same launch window as one mission.

If there were a set of additional trajectory files that were only viable for another launch window, they must then be submitted on another Form 22.

Essentially a copy of the Form 22 should be created with just the specific trajectory files listed for that different launch window and all the respective data could remain the same. The additional Form 22s should add a designator of some sort to the mission name to differentiate between the different screenings (i.e. LAUNCH MISSION NAME-A, and the next followed by LAUNCH MISSION NAME-B)

In the example below, two launch times are represented.

```
LAUNCH TIME: 2019   1 1520  3.000  LAUNCH AZIMUTH:   0.000  DISPERSION FILE:
    0.000   -3048.065   -1597.441    5352.179
             0.000000    0.000000    0.000000
         0.000000000 0.000000000 0.000000000
   10.000   -3048.246   -1597.518    5352.450
            -0.053000   -0.018000    0.067000
         0.000000000 0.000000000 0.000000000
   20.000   -3049.416   -1597.747    5353.492
            -0.196000   -0.026000    0.141000
         0.000000000 0.000000000 0.000000000
   30.000   -3052.425   -1598.001    5355.278
            -0.417000   -0.023000    0.217000
         0.000000000 0.000000000 0.000000000
   40.000   -3057.928   -1598.172    5357.776
            -0.690000   -0.009000    0.280000
         0.000000000 0.000000000 0.000000000
LAUNCH TIME: 2019   1 1521  3.000  LAUNCH AZIMUTH:   0.000  DISPERSION FILE:
    0.000   -3048.065   -1597.441    5352.179
             0.000000    0.000000    0.000000
         0.000000000 0.000000000 0.000000000
   10.000   -3048.246   -1597.518    5352.450
            -0.053000   -0.018000    0.067000
         0.000000000 0.000000000 0.000000000
   20.000   -3049.416   -1597.747    5353.492
            -0.196000   -0.026000    0.141000
         0.000000000 0.000000000 0.000000000
```

```
30.000    -3052.425    -1598.001     5355.278
          -0.417000    -0.023000     0.217000
       0.000000000 0.000000000 0.000000000
40.000    -3057.928    -1598.172     5357.776
          -0.690000    -0.009000     0.280000
       0.000000000 0.000000000 0.000000000
```

A line with the launch time separates each EFG trajectory. Launch azimuth and the dispersion file are not used. The first line of each ephemeris point record contains time since launch in seconds followed by the XYZ components of EFG position in km. The second line contains the XYZ components of EFG velocity in km/s. The third line is a placeholder for acceleration of the asset, but acceleration is not currently used.

Any single CALIPER trajectory for a given launch time must contain a minimum of 5 points and a maximum of 25000 points. The maximum number of seconds since epoch is 999999.999 seconds, equivalent to 11.574 days.

FREE-FORMAT

The second format is a concise, space-delimited, free-format. An example is provided below.

```
3896.280    13660.571    2408.228    0.000    2.374    5.095    0.020
3900.000    13669.394    2427.179    0.000    2.369    5.093    0.020
3930.000    13739.930    2579.652    0.003    2.333    5.072    0.030
3960.000    13809.394    2731.493    0.006    2.298    5.051    0.030
3990.000    13877.810    2882.693    0.009    2.263    5.029    0.030
4020.000    13945.204    3033.248    0.012    2.230    5.008    0.040
4050.000    14011.600    3183.149    0.015    2.197    4.986    0.040
4080.000    14077.022    3332.393    0.018    2.165    4.964    0.040
4110.000    14141.495    3480.973    0.021    2.134    4.942    0.050
4140.000    14205.041    3628.885    0.024    2.103    4.919    0.050
4170.000    14267.683    3776.126    0.027    2.073    4.897    0.050
4200.000    14329.444    3922.691    0.030    2.044    4.874    0.050
```

This EFG file of positions and velocities is independent of launch time. Launch window start/stop/spans are entered within the SuperCOMBO/CALIPER program by 18 SPCS. Numbers are in standard double precision format (not scientific/exponential format).

The first column is time since launch in seconds. The next three columns are the XYZ components of EFG position in km. The last three columns are the XYZ components of EFG velocity in km/s.

CALIPER TRAJECTORY COVARIANCE V2.0

The elements of the CALIPER Trajectory Covariance V2.0 format are shown below:

```
CALIPER EPHEMERIS V2.0 COVARIANCE UVW (or PTW)
LAUNCH TIME:  yyyy ddd hhmm ss.sss…
TimeSinceLaunchInSeconds X  Y  Z  Vx  Vy  Vz
PosCov(1,1) PosCov(2,1)  PosCov(2,2)
PosCov(3,1) PosCov(3,2)  PosCov(3,3)
```

A sample CALIPER Trajectory Covariance V2.0 file is shown next:

```
CALIPER EPHEMERIS V2.0 COVARIANCE PTW
LAUNCH TIME: 2019  20 1105 35.986inidef
    0.000  -15614.190    9512.504   27201.506   -0.031674   -0.511889   -2.511603
             0.033489         -0.042779          0.112008
            -0.000589          0.000675          0.005907
  258.619  -15621.660    9378.301   26541.559   -0.025764   -0.526209   -2.592410
             0.033953         -0.045187          0.121013
            -0.000573          0.000669          0.006007
  510.329  -15627.212    9243.933   25878.882   -0.018003   -0.541701   -2.673392
             0.034352         -0.047596          0.130522
            -0.000543          0.000660          0.006000
```

A CALIPER Trajectory Covariance V2.0 file begins with 2 header lines.

Header line 1:

```
        1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
"CALIPER EPHEMERIS V2.0 COVARIANCE ccc"
```

ccc = covariance coordinate system in a launch vehicle-centered frame, specified as either "PTW" or "UVW".

- In PTW, T is along the velocity vector of the launch trajectory with W out-of plane and P completing the triad.
- In UVW, U is radial with W out-of-plane and V completing the triad.

Header line 2:

```
        1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
"LAUNCH TIME: yyyy ddd hhmm ss.sss…"
```

Launch time formats are self-explanatory. Note that the decimal seconds are actually double precision free-format and thus can contain more than 3 decimals.

Data Record Lines:

Although the ephemeris and covariance data records appear column specific and formatted, they are actually flexible, free-format. Numbers are space delimited and are entered as standard double precision notation (not scientific/exponential notation). The column alignment in the example was added only to aid readability. A data record consists of 3 lines.

The first line consists of both the timestamp and ephemeris data in EFG coordinates. EFG is an Earth-fixed rotating coordinate system related to the true equator/mean equinox of date Earth-Centered Inertial system by a simple rotation about the Z axis (normal to the true equator of date). The second and third lines contain the 6 elements of the lower triangular of the position covariance matrix. Again, despite the appearance of a strict format in the example above, all numbers are free-format double precision, space delimited values, in standard notation (not scientific/exponential notation).

Data record 1:

TimeSinceLaunchInSeconds = time since launch, in seconds

X   = X-component of EFG position in km
Y   = Y-component of EFG position in km
Z   = Z-component of EFG position in km
Vx   = X-component of EFG velocity in km/s
Vy   = Y-component of EFG velocity in km/s
Vz   = Z-component of EFG velocity in km/s

Data Record 2:

The second data record contains 3 of 6 elements of the lower triangular of the position covariance matrix.

PosCov(1,1) = position covariance element in km^2

PosCov(2,1) = position covariance element in km^2

PosCov(2,2) = position covariance element in km^2

Data Record 3:

The third data record contains 3 of 6 elements of the lower triangular of the position covariance matrix.

PosCov(3,1) = position covariance element in km^2

PosCov(3,2) = position covariance element in km^2

PosCov(3,3) = position covariance element in km^2

The CALIPER Trajectory Covariance Format V2.0 can be used to generate Pc and miss distance results, or only miss distance via stand-off radius mode. In this case, SuperCOMBO/CALIPER would use only the ephemeris data. This file could also be used to generate elliptical screening. In this case, SuperCOMBO/CALIPER would again ignore covariance data, using only the ephemeris data in the file.

How to Name Trajectory Files

OVERVIEW

18 SPCS requires that launch agencies name their files following a specific format, which dictates how the ephemeris file will be processed. The file name format is:

<Year>_<Mission>_<LaunchObject>_<MetaData>_<FileFormat>.<FileExtension>

Table 2: Trajectory File Name Convention			
Data Field	*Description*	*Normative Value (N) or Example (E)*	*Obligatory*
Year	The two-digit year of launch.	(E) 18 for 2019 (E) 19 for 2020	Yes
Mission	Typically, the primary payload for the launch. Will be designated by 18 SPCS.	(E) Telstar-18V (E) Iridium-6 (E) ICON (E) NROL-71	Yes
LaunchObject	The launch object or segment that the trajectory represents.	(E) PAYLOAD (E) STAGE2 (E) FAIRING (E) SKIRT-RING	Yes
MetaData	Optional additional information provided at the discretion of the launch. Often used to indicate deployment status or additional details on the variation of the file	(E) Pre-Deploy (E) Post-Deploy (E) NoBurns (E) Powered	No
FileFormat	Format of trajectory file. Must be one of three formats included in "Trajectory Formats" section: Caliper, Free-Format, or Covariance	(N) CAL (N) FF (N) COV	
File Extension	Indicates the type of file	(N) .txt (unless otherwise directed by 18 SPCS)	Yes

FILE NAME EXAMPLES

- 19_TELSTAR-18V_PAYLOAD_COV.txt

- 19_CRS-16_STAGE2_UNPOWERED_CAL.txt

- 19_Iridium-8_STAGE2_NoBurn_FF.txt

How to Submit Forms and Trajectory Files

Launch forms (R-15s, Form-22s and trajectory files) should be submitted through the website Space-Track.org, or, if Space-Track access is not possible, by email to the 18 SPCS Orbital Safety Crew at 18SPCS.doo.launch@us.af.mil.

Space-Track.org is the most efficient and secure method of submitting files on a recurring basis. To set up access, contact the 18 SPCS Launch CA Team at 18SPCS.doo.launch@us.af.mil or +1-805-605-3536. The Launch CA Team will request the following information:

1. The title of your launch organization
2. The Space-Track user names of the personnel who will upload trajectories/forms and download results

The Launch CA Team will create a permissions-based launch CA (LCA) folder for your organization that will only be accessed by 18 SPCS and the personnel you authorize. You will have upload, download, and delete permissions to the folder, which you will access through the Files Panel:
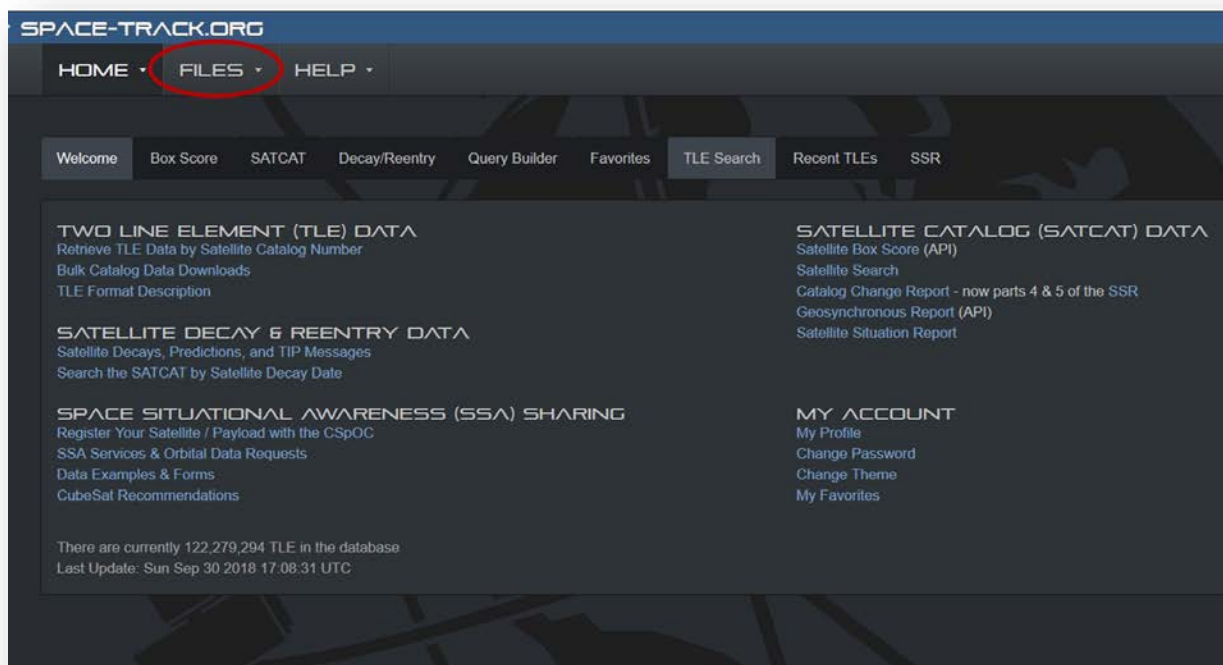

Figure 2: Files Panel on Space-Track.org

SUBMITTING FILES THROUGH SPACE-TRACK.ORG

Once you have an LCA folder on the Files Panel, you will also have access to the 'Download' and 'Upload' tabs. On the 'Upload' tab you can upload a variety of files to the folders you have permissions to. All of these folders will display in the 'Destination' dropdown menu:
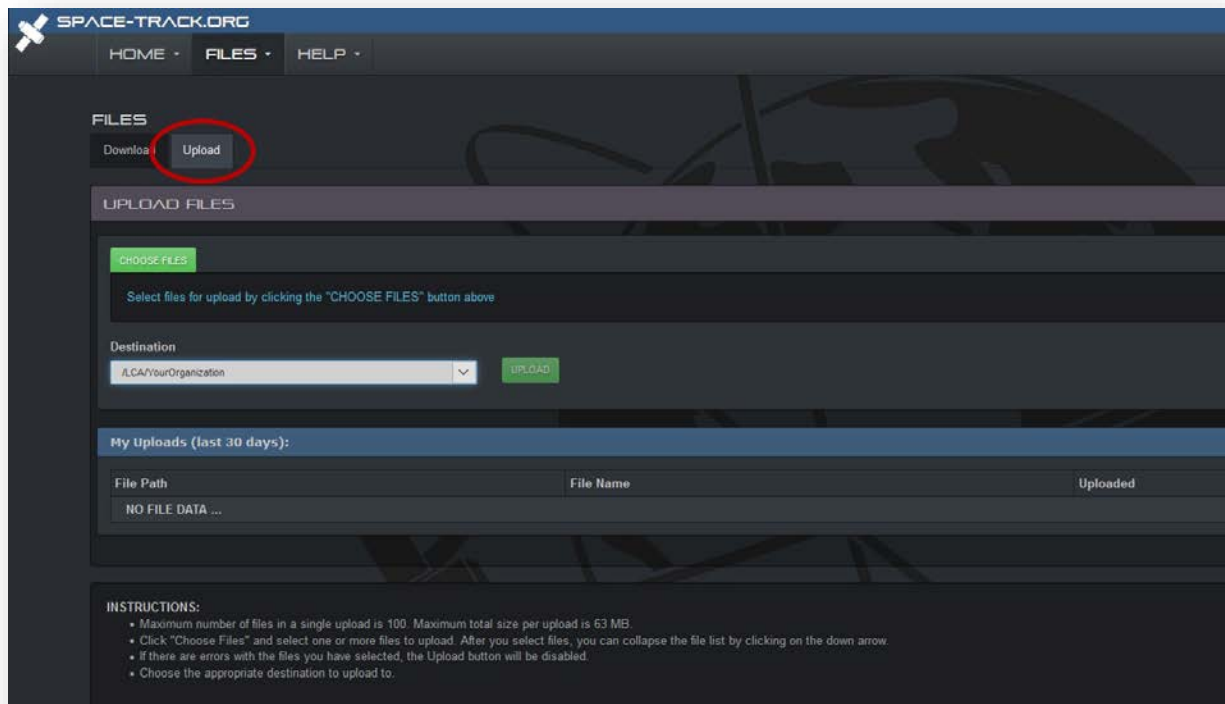

Figure 3: Files Panel Upload Tab - Ephemeris

MANUAL UPLOAD OF TRAJECTORY FILES AND FORMS

1. Log in to Space-Track.org, click on 'Files' at the top of the page, and then click on the 'Upload' tab
2. Click 'Choose Files' and select your files

   2.1 Maximum number of files in a single upload is 100
   2.2 Maximum total size per upload is 60 MB

3. Using the 'Destination' dropdown menu, select the '/LCA/' folder for your organization
4. Click 'Upload' to upload the files
5. After a successful upload, the files will display in 'My Uploads (Last 30 Days)' Table
6. The 18 SPCS Orbital Safety Crew will receive a notification that you have uploaded new forms or files for screening. However, if the screening request is within 24 hours, please phone or email the Orbital

Safety Crew to notify them that you need an immediate response: +1-805-605-3536 or 18SPCS.doo.launch@us.af.mil.

EMAIL

If your organization does not have an LCA folder on the Files Panel, you may send your files by email to the 18 SPCS Orbital Safety Crew at 18SPCS.doo.launch@us.af.mil. Please:

1. Name files in accordance with guidelines in 'How to Name Trajectory Files'
2. Send only .txt files - **.zip files cannot be accepted**

GUIDANCE FOR REQUESTS WITHIN 24 HOURS

After you submit your trajectories and updated Form 22, please phone the 18 SPCS Orbital Safety Crew at +1-805-605-3536 to provide the following information regarding the short notice request:

1. The launch mission name
2. The time the results are needed by
3. The Space-Track folder to which the updated files were uploaded
4. Reference your approved Orbital Data Request, if applicable

How to Receive Screening Results

OVERVIEW

18 SPCS will post results to the launch entity's folder on Space-Track.org as soon as they are completed and as close to the requested screening time as possible. The results will be posted to the same folder that the launch entity posted the Form 22 and launch trajectories to, as seen in Figure X below:
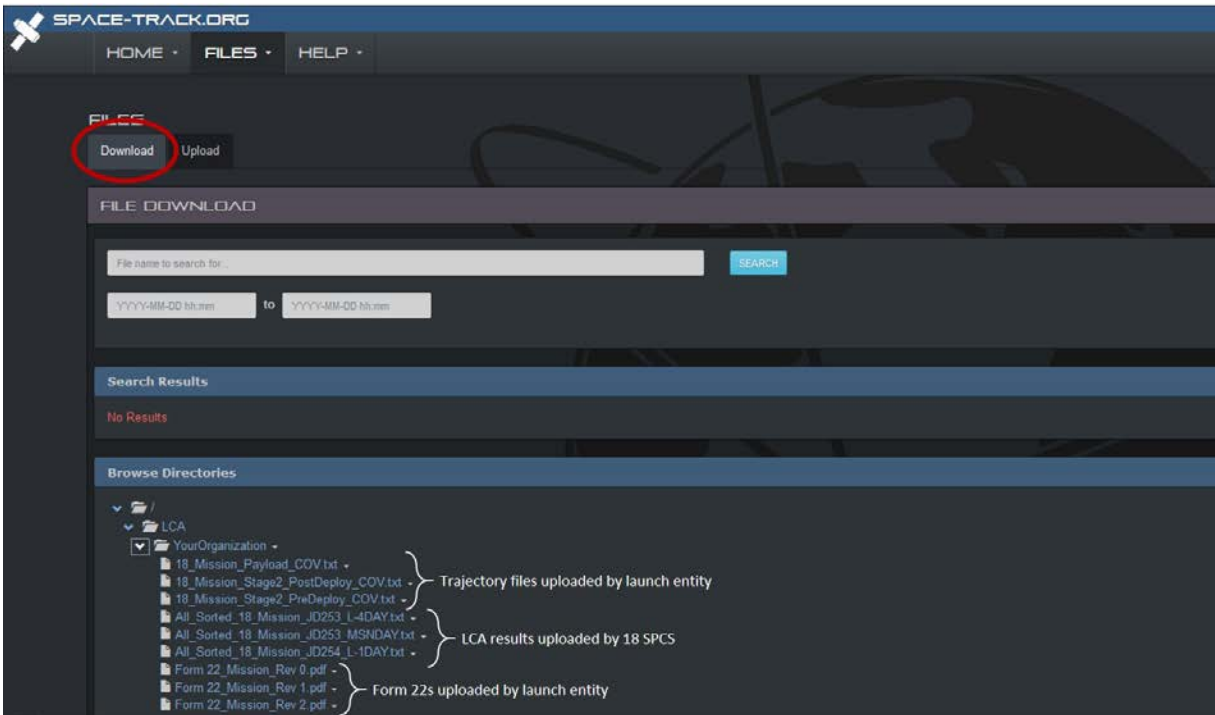

Figure 4: Download Tab - Launch CA Results

HOW TO RECEIVE SCREENING RESULTS

HOW TO SUBSCRIBE FOR AUTOMATED NOTIFICATIONS

Launch entities should subscribe for automated notifications from Space-Track to be immediately notified of new uploads to their respective LCA folder.
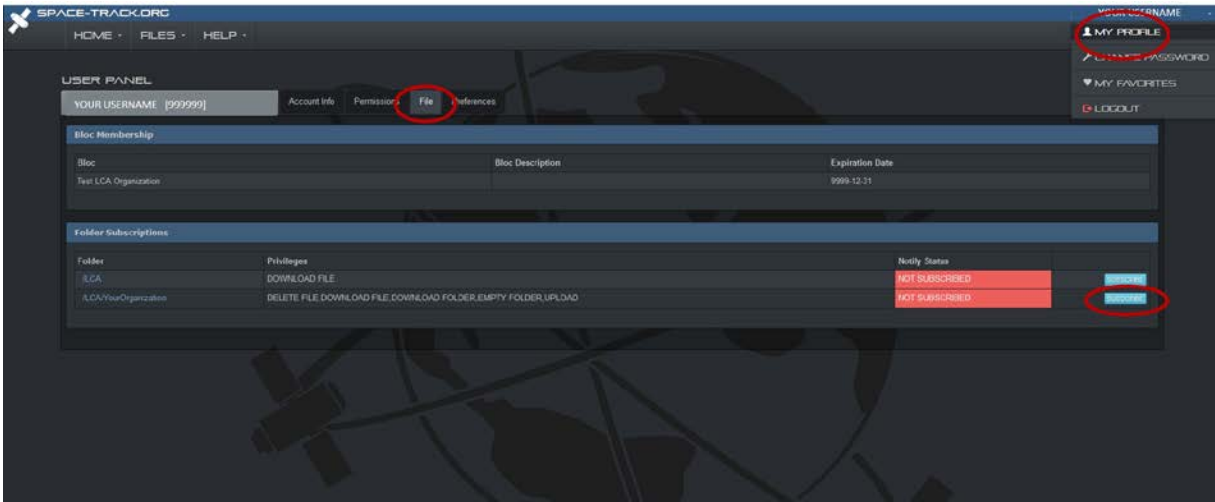

Figure 5: Folder Subscriptions

1. Login to Space-Track.org and click on your username in the top right corner. Select "My Profile" from the drop-down menu.
2. Select the "File" tab
3. In the "Folder Subscriptions" table select "Subscribe" for the "/LCA/YourOrganization/" folder

Contact Us

18 SPCS LAUNCH CONJUNCTION ASSESSMENT TEAM

For questions on launch conjunction assessment, please contact:

- Monday – Friday, 1600 UTC – 0000 UTC:
  - 18SPCS.doo.launch@us.af.mil, +1-805-605-3536
- Monday – Friday, 0000 UTC – 1600 UTC, and Saturday and Sunday:
  - 18SPCS.doo.orbitalsafety@us.af.mil, +1-805-605-3533

18 SPCS ORBITAL SAFETY CREW

For questions on on-orbit conjunction assessment and collision avoidance support, please contact the 18 SPCS Orbital Safety Crew by email at 18SPCS.doo.orbitalsafety@us.af.mil or by phone at +1-805-605-3533. Examples of support include:

- Questions about screening results
- Screenings for high-interest events
- Missing CDMs

18 SPCS SSA SHARING TEAM

For questions about specialized SSA support or data products, please contact the 18 SPCS SSA Sharing Team by email at 18SPCS.doo.ssasharing@us.af.mil or by phone at +1-805-606-2675. Examples include:

- Submitting an Orbital Data Request for advanced services or support
- Questions about data formats
- Space-Track access and permissions
- Registering your satellite to receive spaceflight safety support

SPACE-TRACK.ORG ADMINISTRATION TEAM

For questions about the Space-Track.org website, please contact admin@space-track.org. Examples include:

- API queries
- Automation
- Website performance