18th Space Control Squadron

This Briefing is UNCLASSIFIED

18 SPCS Methods of Processing Reentries of Space Objects

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Overview

- Definitions
- Background
- Reentry Processing
- Reentry Processing Tools
- Breakups
- Reentry Confirmation
- Messaging
- Difficult orbits for reentries
- Space-track.org products

18th Space Control Squadron

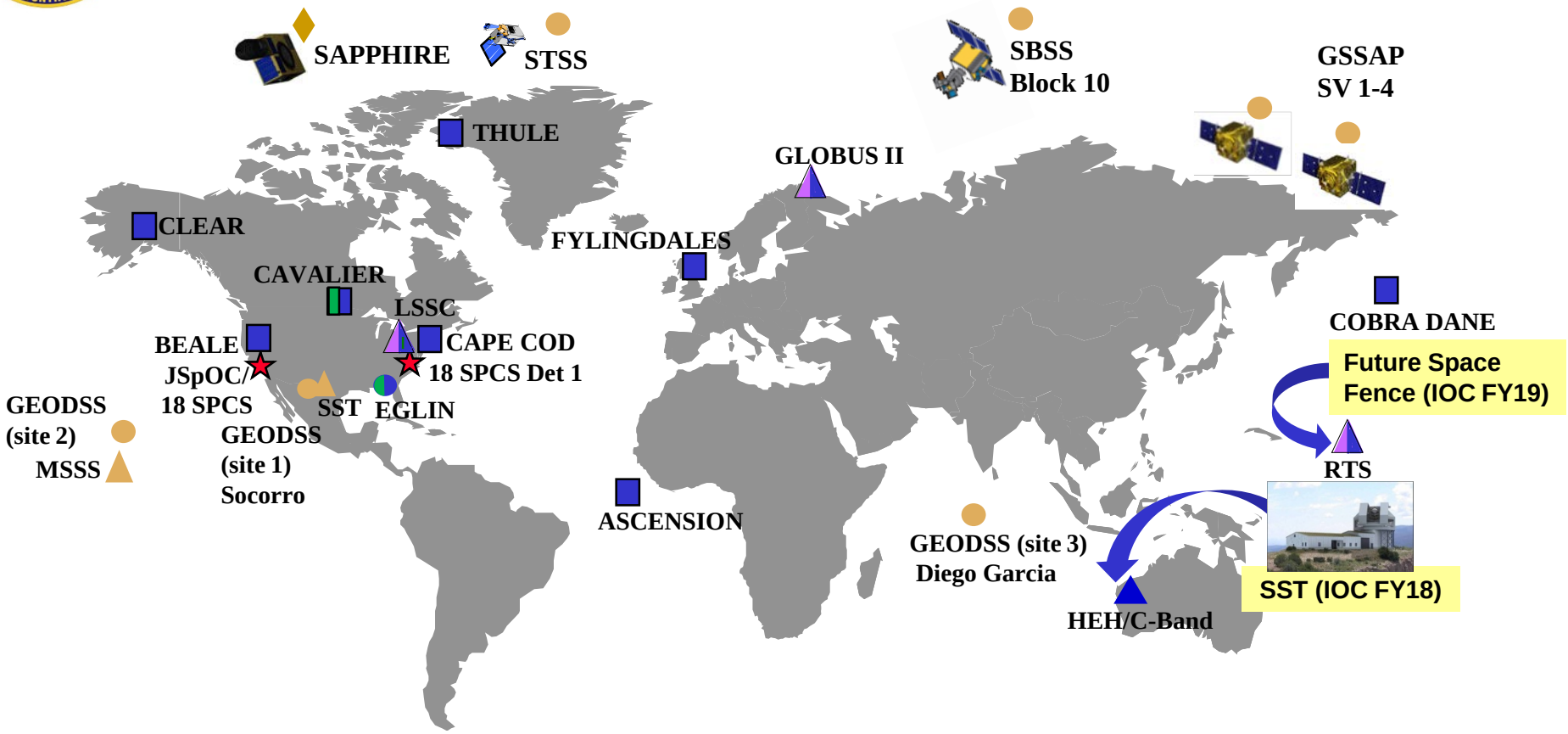
MISSION

Deliver foundational Space Situational Awareness to assure global freedom of action in space.

VISION

Global innovator and leader providing unrivaled SSA through operational excellence.

Space Surveillance Network



Tracking Radar	Optical Telescope	● Dedicated	★ SSN C2
Detection Radar	SSN C2	■ Collateral	◆ Dedicated Int'l
Imaging Radar		▲ Contributing	

18 SPCS Definitions

REENTRY:

Man-made object that reenters the Earth's atmosphere and no longer remains in orbit

3 Types of Reentries

Deorbit

Controlled reentry of an object, usually at a known time to a planned location; not possible to process as RA object

Normal Decay

Uncontrolled, gradual reduction of an object's orbit; not expected to survive reentry; typically RCS < $1m^2$

Reentry Assessment (RA) Objects

Portions of large or dense objects that may survive reentry through the atmosphere and impact the Earth; Payload, R/B's or Debris > $1m^2$ or historically expected to survive

18 SPCS Definitions, cont.

- **Reentry Assessment (RA)** - the process of maintaining the TLEs of reentering objects, predicting the point and time of reentry, and notifying the appropriate international agencies and the public of the predictions
- RA objects can:
  - Damage people or property
  - Trigger missile warnings
- RA objects categorized as **High Interest** if:
  - Historically significant
  - Deemed significant by a higher authority
  - Historically survivable or RCS > $10m^2$
  - Garners significant media interest
  - Has a radioactive/nuclear payload or power source
  - Contains human remains

Background

Article 3 of the 1971 “Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War between the United States of America and the Union of Soviet Socialist Republics” states that “The Parties undertake to notify each other immediately in the event of detection by missile warning systems of unidentified objects.”

18 SPCS Reentry Processing Tools

- SPADOC SP
  - Used for real-time event processing
  - State vector built off of SGP4 TLEs when RA is initialized and maintained until final prediction run is complete
  - Reentry prediction based off of a propagation to altitude of 10 km above Earth's surface
  - Can be extremely slow and difficult to get states to converge
- ASW SP
  - Used for analysis and determining when an RA should be initialized
  - More up-to-date force models
    - » Earth Models
    - » Dynamic Calibration Atmosphere (DCA)
  - Higher accuracy
  - Faster and states converge easier

Reentry Processing Tools (cont.)

- SGPE
  - Program written by AFSPC
  - Semi-analytic
  - Does a least-squares fit to TLEs to determine average Ballistic Coefficient
  - Used with dynamic atmosphere model to propagate to decay
  - Can be more accurate and timely than SP for near-earth circular
  - Used for normal decays

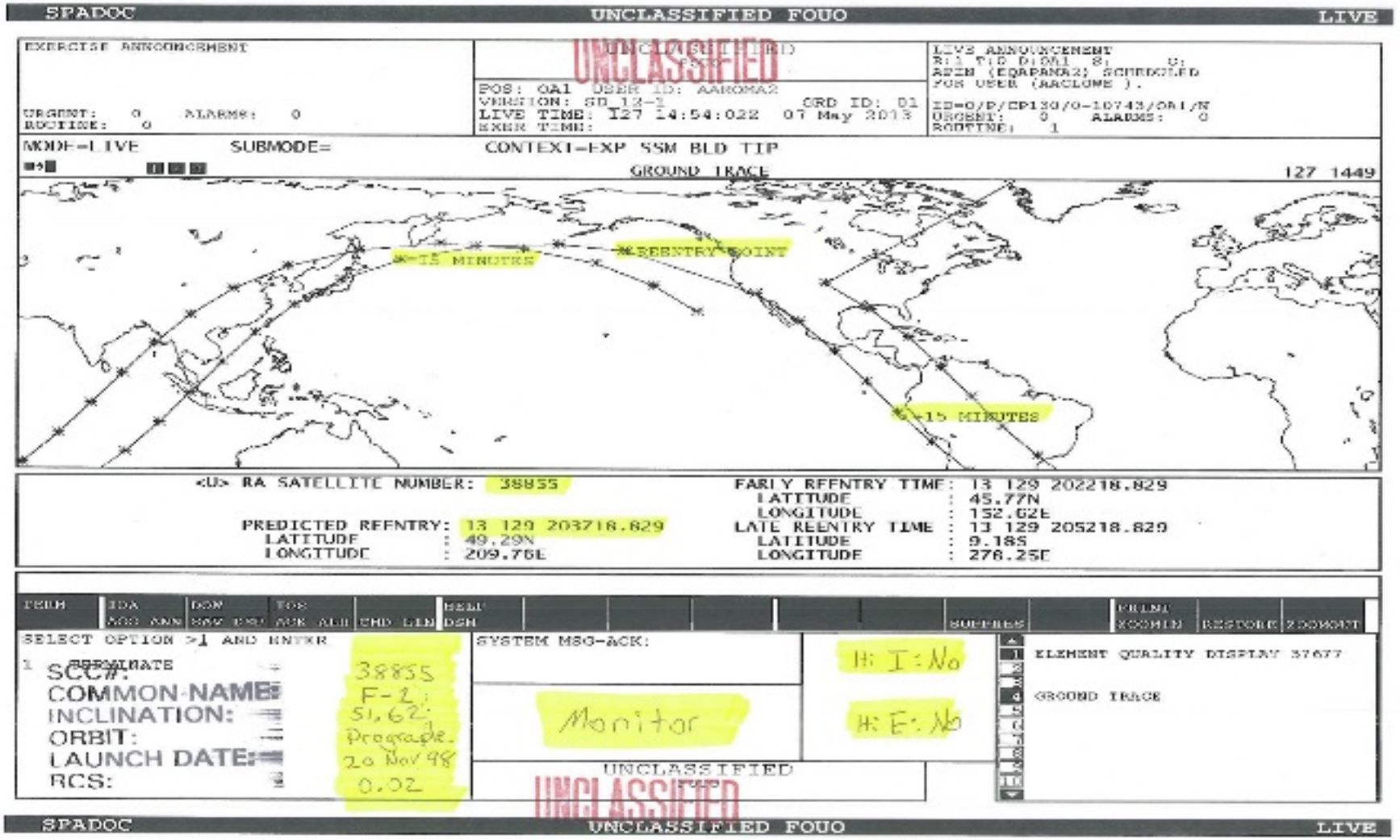
Reentry Processing

- All objects are screened Mon-Fri for decay status
- Near-earth circular orbits:
  - SGP4 propagations for 60 days
- Highly eccentric orbits:
  - Database query
  - Perigee height less than 250 km for near earth
  - Perigee height less than 200 km for deep space
  - Analyst determine likelihood of decay and adds to list for initialization

Reentry Processing (cont.)

- Reentering objects that qualify for RA are **initialized** 7 to 14 days before predicted reentry
  - Six part folder created, includes: All ground traces, run logs, messages, and state vectors
  - Sensor tasking upgraded
  - SPADOC SP state vector created
- Required runs
  - **Required runs** entail updating the state, running decay prediction, and transmitting appropriate messages
  - Done at 4, 3, 2, 1-day, and 12, 6, 2-hour points and post decay (Final)
- Monitor runs
  - Done when new sensor observations acquired
  - Keeps the state up-to-date
  - Updates prediction time; **no message transmitted**

Ground Trace of F-1, 38855



Reentry Breakups

- Objects may fragment before reentry
- RA Officer creates whatever pieces possible
- Many times pieces will reenter before they can be created
- Pieces tasked for radar cross section (RCS)
  - Used to determine if still large enough to be considered RA
- Objects may fragment multiple times
- Objects that fragment within 6 hours of predicted reentry time and cross CIS or Southwest Asia are reported to higher headquarters

Reentry Confirmation

- Sensors tasked to perform POS/NEG reporting after predicted reentry time
- Confirmation done with visual information (when available)
  - Correlated with ephemeris
  - Reported as official time of reentry
- 1 no-show required from sensors if visual information is received
- 3 no-shows required from sensors if no visual information is received
- Alternatively, RA Officer may deem an object reentered
- After reentry is confirmed, sensors de-tasked via Decay Message

18 SPCS Reentry Process

General Perturbation

Special Perturbation

DAY 60→7

18 SPCS generates weekly reentry and decay predictions using GP data.

DAY 7→5

- Sensor tasking increased
- Reentry assessment run once per day

DAY 4→1

- Sensor tasking increased
- Reentry assessment run once every 8 hours

HOUR 12, 6, 2

Reentry assessments run at 12, 6, and 2 hour points

HOUR 0

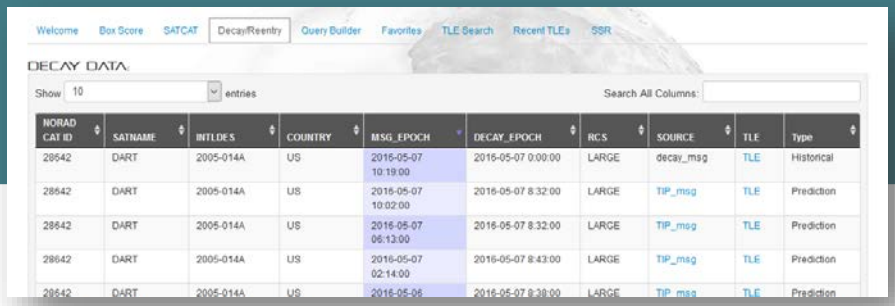
- Sensors tasked to search +/- 2 mins of tasking criteria
- Sensors reports no-show to 18 SPCS

60 Day Reentry/Decay

TIP: 1/day

TIP at each RA update

Final TIP after 3 no-shows



Messaging

- Tracking and Impact Prediction (TIP) Tasking
  - Sent to SSN as a direction to increase tasking
  - 2-day and 1-day point
- TIP Alert (available on Space-Track.org)
  - Contains Time, Latitude, and longitude of reentry
  - Sent after every required update
- OPREP-3 advance notification
  - Sent to state department and disseminated appropriately
  - Sent at the six hour, two hours, and final runs
- Two hour Missile Warning Message
  - Tips Missile Warning agencies
  - Sent at the 2-hour point

Required Runs and Messages

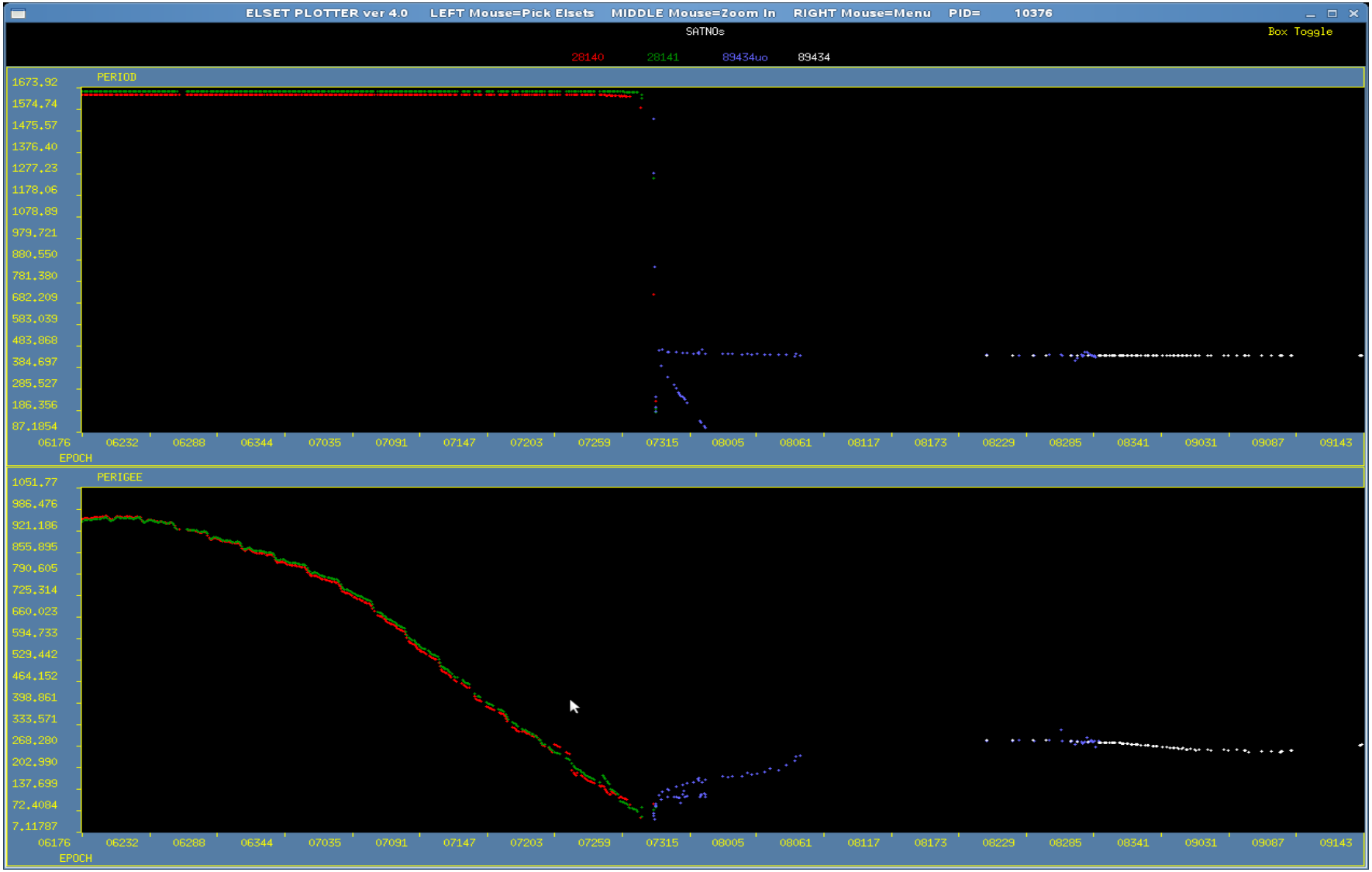
Required Run	Additional Actions	Messages Sent
4 Day	Initialize Reentry	TIP Alert
3 Day	N/A	TIP Alert
2 Day	ASW Crosscheck*, Upgrade Tasking	TIP Alert, TIP Tasking
1 Day	ASW Crosscheck*, Upgrade Tasking, Geocentric crossing analysis (GCA)	TIP Alert, TIP Tasking
12 Hour	ASW Crosscheck*, GCA*, Voice task sensors	TIP Alert
6 Hour	ASW Crosscheck*, GCA*	TIP Alert, OPREP-3*
2 Hour	ASW Crosscheck*, GCA*, print no-show reports, Voice Task sensors	TIP Alert, OPREP-3*, 2-hr Missile Warning

* If required

Difficult Orbits for Reentry

- High-eccentricity
  - Sensors use SGP4 TLEs
  - Uncorrelated observations
  - More likely to break up due to higher drag forces
  - Perigee skip
    - » Can push out reentry time for weeks or years
- Catastrophic decay
  - Extremely high eccentricity
  - Period can decrease over 20+ mins/day
- Low Inclination
  - Poor sensor coverage
  - Can also be high eccentricity

Perigee "Skip" of DOUBLESTAR piece



Difficult Orbits for Reentry (cont.)

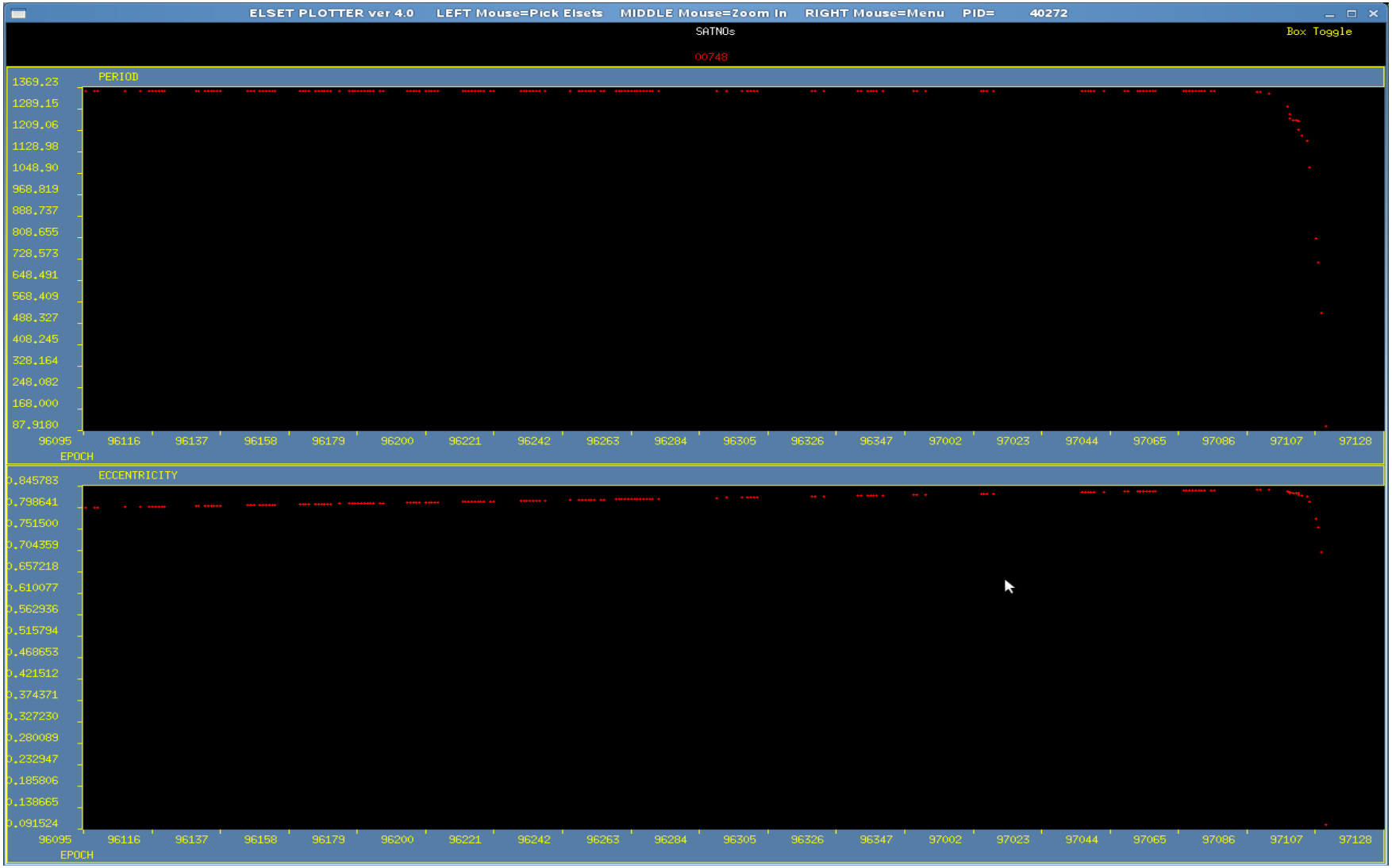
- Objects with extremely high periods (multi-days)
  - Highly inclined
  - Period > 2 days
  - Lunar perturbations cause eccentricity to change
  - Objects do not decay, they run into the earth
  - Highly accurate reentry predictions
  - GRANAT and rocket body (20352 and 20354)
  - INTERBOL 1 and rocket body (23632 and 23635)
  - WT1190F
    - » Likely leftover from a translunar mission
    - » Prediction off by < 15 secs
    - » Used a network of asteroid tracking telescopes to track

Reentry of WT1190F

Difficult Orbits for Reentry (cont.)

- Catastrophic Decays: inclined geosynchronous orbits/Tundra orbits
  - Geosynchronous orbits with much shorter lifetimes than equatorial orbits
  - Inclination in the 55 to 65 degree range
  - Lunar perturbations cause eccentricity to change
    - » Causes perigee to dip extremely low into atmosphere
  - Period can decay hundreds of minutes per day
  - Can cause perigee skip
    - » Might push decay out by years
  - ELEKTRON 2 and rocket body (00748, 00751)

Catastrophic Decay of ELEKTRON 2, 00748



Catastrophic Decay of SL-3 R/B, 00751

Space-Track.org Reentry Products

- Reentries are a basic service provided to registered users
- 60-Day Decay message
  - Posted once a week on Wednesdays
  - First done with SGP4 prediction
  - May be overwritten with SP prediction if one has been done
- TIP Alert
  - Posted after the required runs
  - SP prediction
  - Only done for objects that meet RA criteria
- Decay Message
  - Posted when object is decayed
  - For an RA, done after the final run

Space-Track.org Reentry Tab

Welcome | Box Score | SATCAT | Decay/Reentry | Query Builder | Favorites | TLE Search | Recent TLEs | SSR

DECAY DATA:

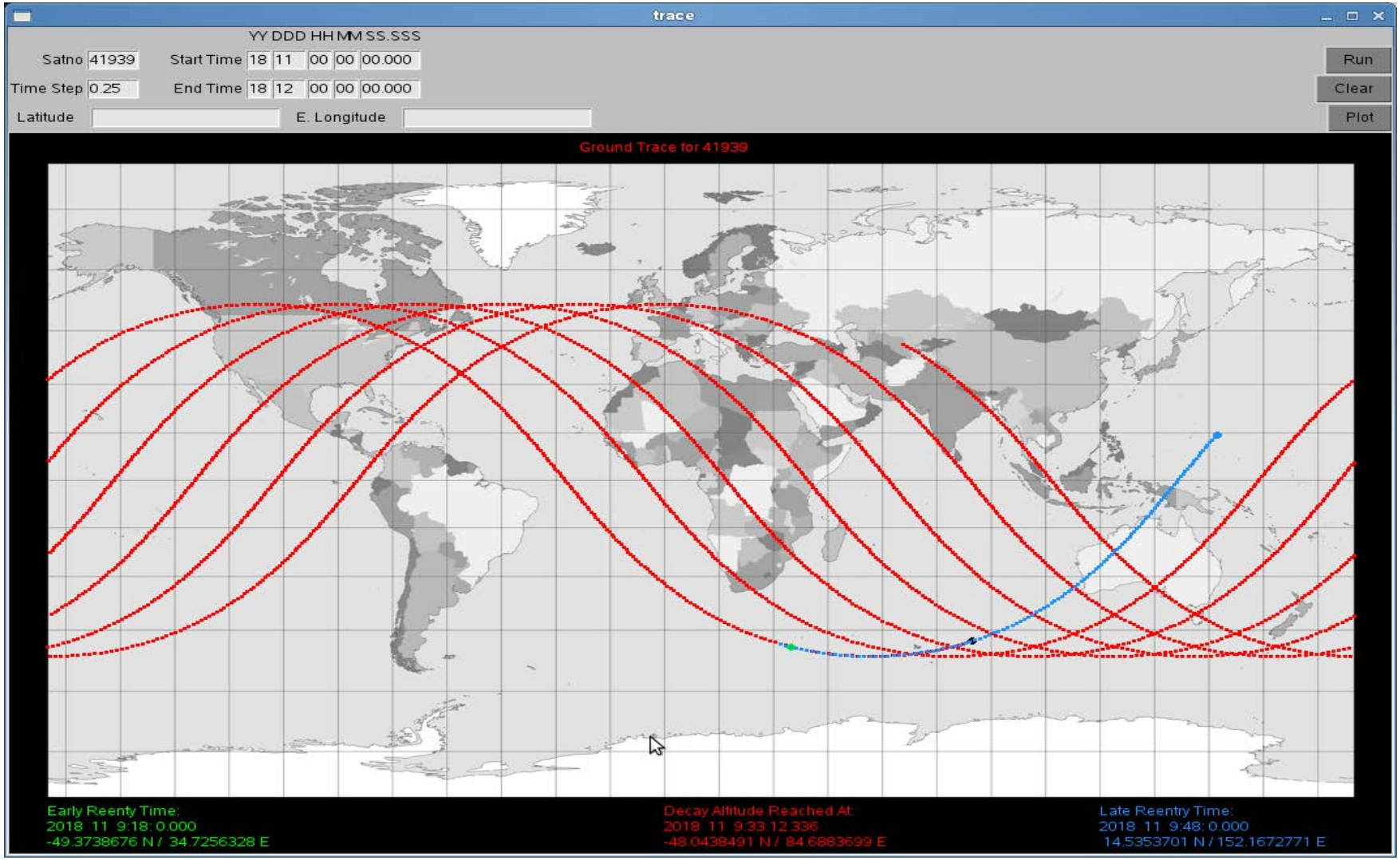
Show 10 entries Search All Columns:

NORAD CAT ID	SATNAME	INTLDES	COUNTRY	MSG_EPOCH	DECAY_EPOCH	RCS	SOURCE	TLE	Type
36536	COSMOS 2251 DEB	1993-036BCW	CIS	2018-01-02 18:52:00	2014-10-21 0:00:00	SMALL	decay_msg	TLE	Historical
40304	SL-24 PLAT	2014-070G	CIS	2017-12-29 03:36:00	2017-12-29 0:00:00	LARGE	decay_msg	TLE	Historical
40304	SL-24 PLAT	2014-070G	CIS	2017-12-29 02:28:00	2017-12-29 0:07:00	LARGE	TIP_msg	TLE	Prediction
40304	SL-24 PLAT	2014-070G	CIS	2017-12-28 21:29:00	2017-12-28 23:55:00	LARGE	TIP_msg	TLE	Prediction
40304	SL-24 PLAT	2014-070G	CIS	2017-12-28 16:53:00	2017-12-28 23:18:00	LARGE	TIP_msg	TLE	Prediction
40304	SL-24 PLAT	2014-070G	CIS	2017-12-28 10:48:00	2017-12-28 23:06:00	LARGE	TIP_msg	TLE	Prediction
40304	SL-24 PLAT	2014-070G	CIS	2017-12-27 23:30:00	2017-12-28 22:53:00	LARGE	TIP_msg	TLE	Prediction
40304	SL-24 PLAT	2014-070G	CIS	2017-12-27 23:21:00	2017-12-28 22:53:00	LARGE	TIP_msg	TLE	Prediction
41563	FLOCK 2E 6	1998-067JM	US	2017-12-27 16:48:42	2017-01-31 0:00:00	SMALL	60day_msg	TLE	Prediction

TIP Alert Message

NORAD_CAT_ID	MSG_EPOCH	INSERT_EPOCH	DECAY_EPOCH	WINDOW	REV	DIRECTION	LAT	LON	INCL	NEXT_REPORT	ID	HIGH_IN
40304	2017-12-29 02:28:00	2017-12-29 03:11:33	2017-12-29 00:07:00	5	17798	descending	-60	208.5	97.4	0	6787	N
40304	2017-12-28 21:29:00	2017-12-28 21:44:16	2017-12-28 23:55:00	38	17799	descending	-11.2	222.9	97.4	0	6786	Y
40304	2017-12-28 16:53:00	2017-12-28 17:11:09	2017-12-28 23:18:00	60	17799	ascending	35.9	48.5	97.4	2	6785	Y
40304	2017-12-28 10:48:00	2017-12-28 10:52:09	2017-12-28 23:06:00	180	17797	ascending	-12.6	58.5	97.4	6	6784	Y
40304	2017-12-27 23:30:00	2017-12-27 23:35:48	2017-12-28 22:53:00	300	17797	ascending	-62.5	74.3	97.4	12	6783	Y
40304	2017-12-27 23:21:00	2017-12-27 23:28:37	2017-12-28 22:53:00	300	17797	ascending	-62.5	74.3	97.4	12	6782	N
40304	2017-12-26 21:52:00	2017-12-26 21:56:56	2017-12-28 22:10:00	600	17797	descending	59.4	263.4	97.4	24	6781	Y
40304	2017-12-26 00:38:00	2017-12-26 00:46:47	2017-12-29 00:22:00	900	17798	ascending	-62.2	52	97.4	48	6780	Y
40304	2017-12-25 09:38:00	2017-12-25 09:43:22	2017-12-28 20:59:00	1020	17797	descending	-14.7	266.5	97.5	72	6779	Y

ASW Ground Trace of OSNSAT, 41939



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