SATELLITE TRACKING with SMALL TELESCOPES

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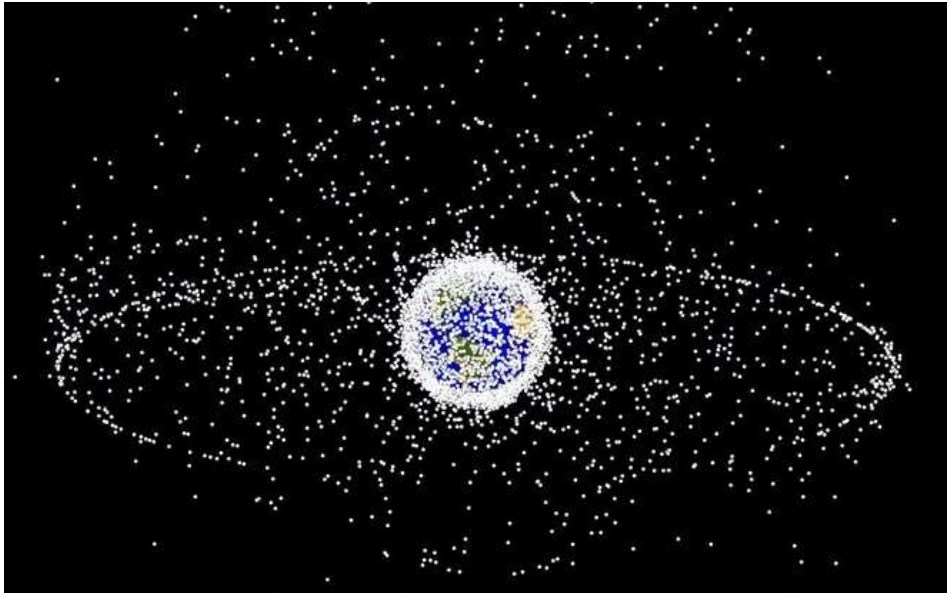
Satellite tracking

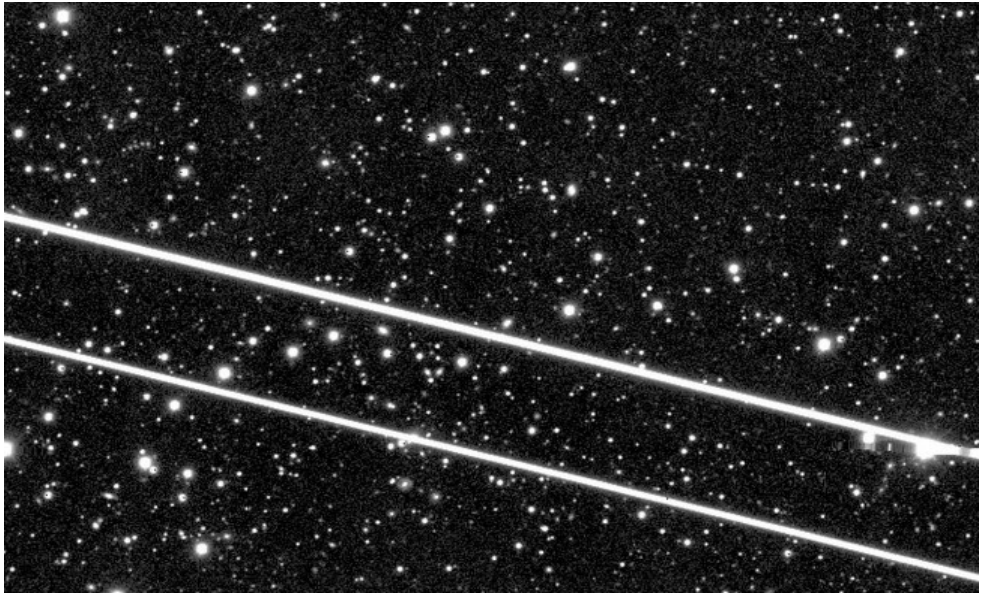
There are more and more satellites that orbit the Earth. Tracking satellites in realtime is important for defense and monitoring the sky, as well as to obtain good astronomical data.

In this lecture/project, we will learn:

- Search for the satellite's orbit in the database and their visibility.
- Take consecutive images of the satellite.
- Calculate the orbital elements.

Objects around the Earth



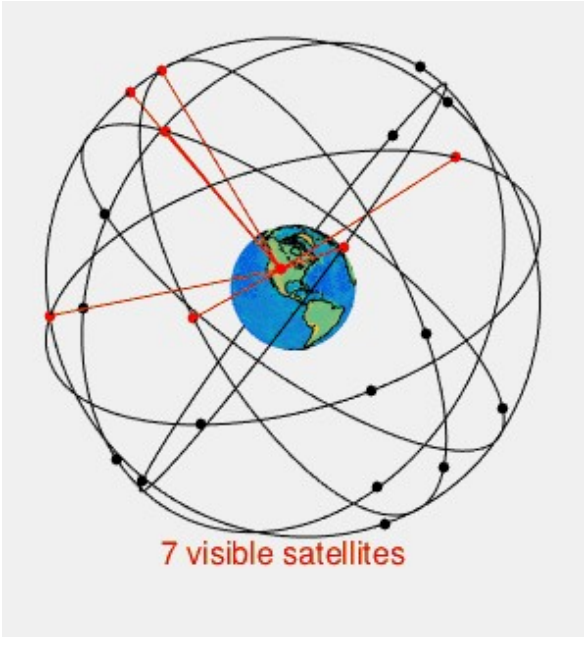


- Natural objects:
  - Asteroids, Comets …
- Artificial objects:
  - Active/Inactive satellites
  - Rocket booster
  - Debris from explosions/collisions in space

What is the satellite ?

Artificial satellite:

- Man-made.
- Reconnaissance, mapping, weather forecast, ocean/forest monitoring, communication, navigation…

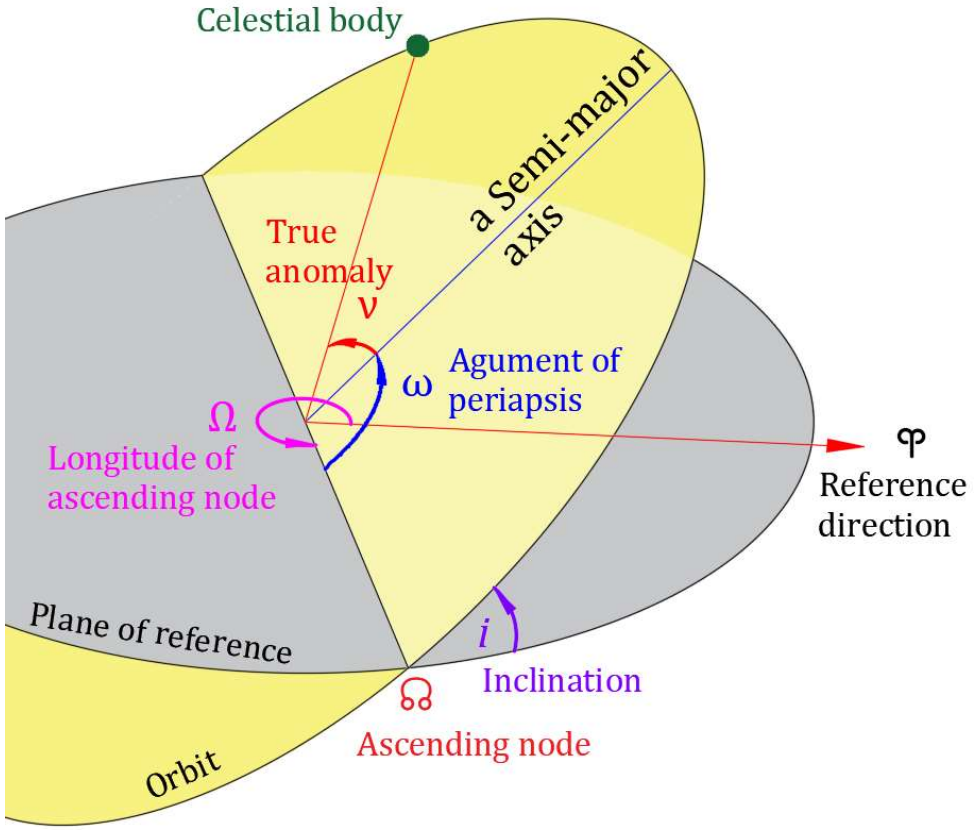


Orbital type:

- LEO/MEO/GEO/HEO
- Constellation

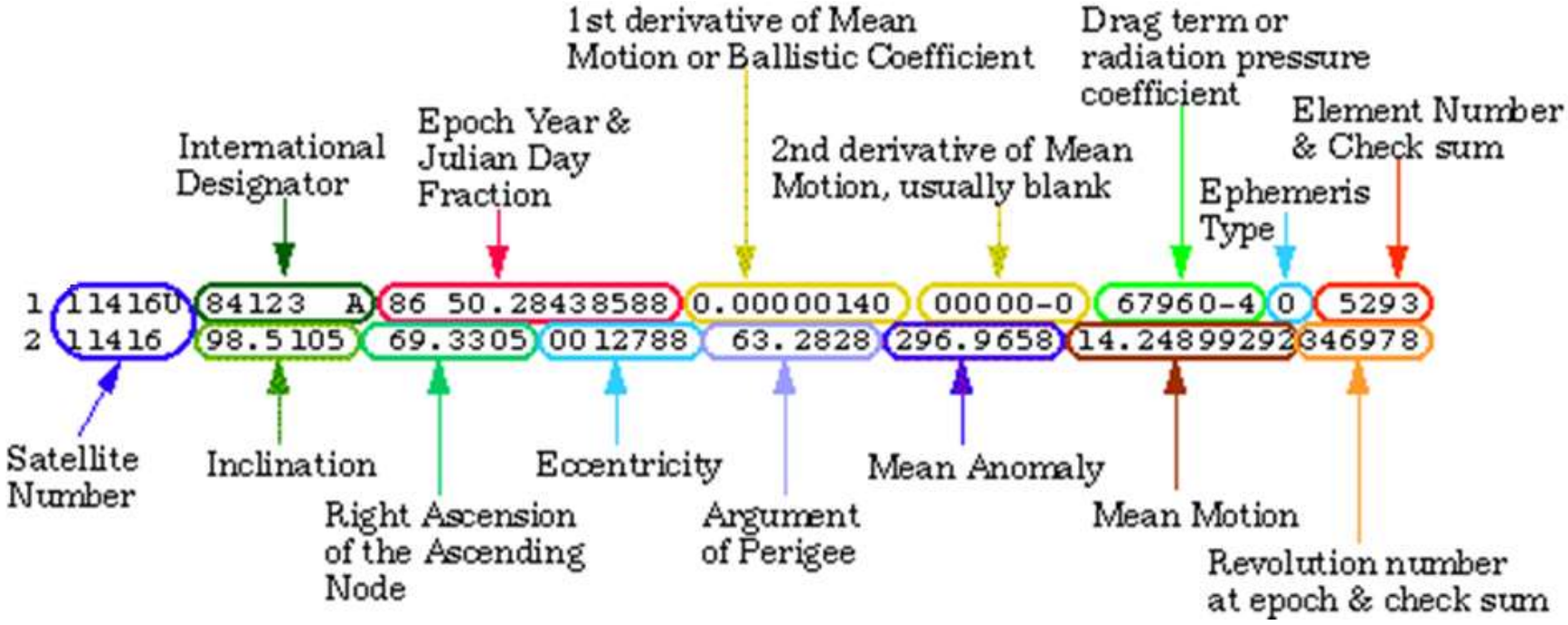
Orbital elements

Element	Sign	Definition
1. Inclination	i	Angle between the orbital plane and plane of reference
2. Longitude of ascending node	Ω	horizontally orients the ascending node of the ellipse with respect to the reference direction ♈
3. Argument of periapsis	ω	the orientation of the ellipse in the orbital plane
4. Semi-major axis	a	half the distance between the apoapsis and periapsis
5. Eccentricity	e	shape of the ellipse
6. True anomaly	ν	the position of the orbiting body along the ellipse at a specific time



Two-line element set

This is a data format encoding a list of orbital elements of an Earth-orbiting object for a given point in time.



www.celestrak.com, www.n2yo.com

Two-line element set

Line 1	
Column	**Description**
01	Line Number of Element Data
03-07	Satellite Number
08	Classification (U=Unclassified)
10-11	International Designator (Last two digits of launch year)
12-14	International Designator (Launch number of the year)
15-17	International Designator (Piece of the launch)
19-20	Epoch Year (Last two digits of year)
21-32	Epoch (Day of the year and fractional portion of the day)
34-43	First Time Derivative of the Mean Motion
45-52	Second Time Derivative of Mean Motion (Leading decimal point assumed)
54-61	BSTAR drag term (Leading decimal point assumed)
63	Ephemeris type
65-68	Element number
69	Checksum (Modulo 10) (Letters, blanks, periods, plus signs = 0; minus signs = 1)

Line 2	
Column	**Description**
01	Line Number of Element Data
03-07	Satellite Number
09-16	Inclination [Degrees]
18-25	Right Ascension of the Ascending Node [Degrees]
27-33	Eccentricity (Leading decimal point assumed)
35-42	Argument of Perigee [Degrees]
44-51	Mean Anomaly [Degrees]
53-63	Mean Motion [Revs per day]
64-68	Revolution number at epoch [Revs]
69	Checksum (Modulo 10)

How to observe ?

Information obtained:

- Azimuth, altitude

Observation conditions:

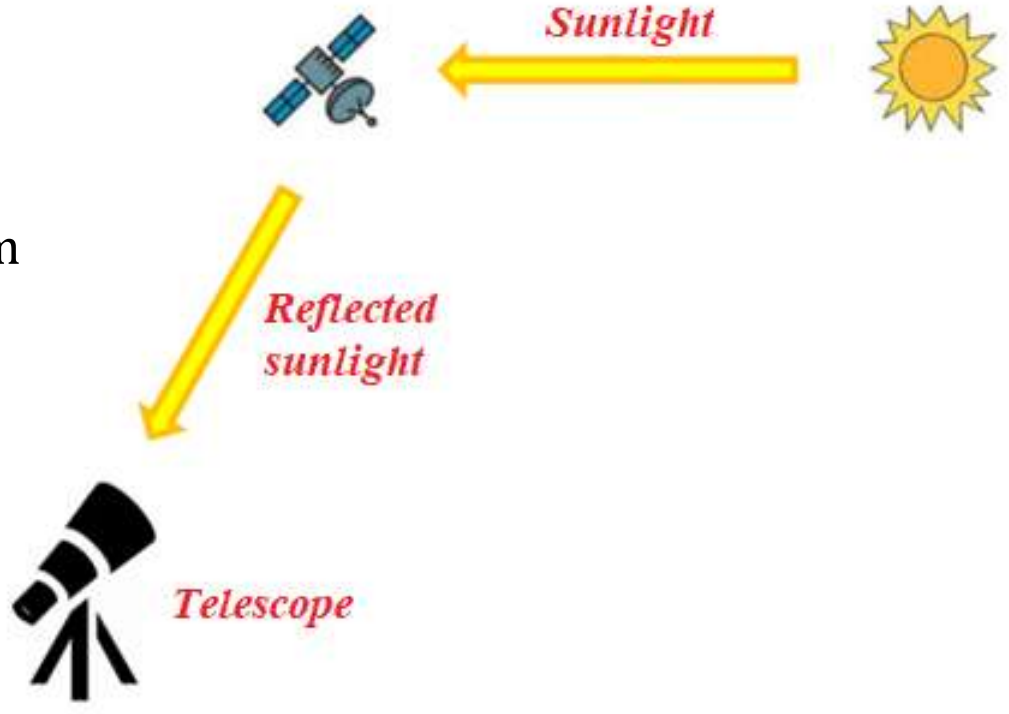
- At dusk, at a certain angle to the sun
- Obscured by clouds, interference from ambient light

Observation ability:

- Even distant orbits
- Small objects

Cost:

- Low



How to observe ?

Prediction of Space Station appearance in next few days.

Start		Max altitude			End		All passes	
Date, Local time	Az	Local time	Az	El	Local time	Az	Mag	Info
27-Jul 22:43	NW 307°	22:48	SW 237°	26°	22:53	SSE 164°	-	Map and details
28-Jul 10:26	S 179°	10:30	SE 125°	11°	10:34	ENE 71°	+0.2	Map and details
28-Jul 12:02	SW 238°	12:07	NW 309°	25°	12:11	NNE 20°	-0.8	Map and details
28-Jul 21:54	NW 319°	22:00	SW 225°	66°	22:05	SE 148°	-	Map and details
29-Jul 11:13	SW 223°	11:18	NW 312°	60°	11:23	NE 32°	-2.1	Map and details
29-Jul 21:06	NNW 331°	21:11	NE 47°	46°	21:16	SE 133°	+1.3	Map and details
30-Jul 10:24	SSW 208°	10:29	SE 132°	51°	10:34	NE 44°	-1.9	Map and details
30-Jul 20:17	NNW 343°	20:22	NE 51°	20°	20:27	ESE 117°	+0.7	Map and details
30-Jul 21:54	WNW 294°	21:59	SW 235°	14°	22:03	S 178°	-	Map and details

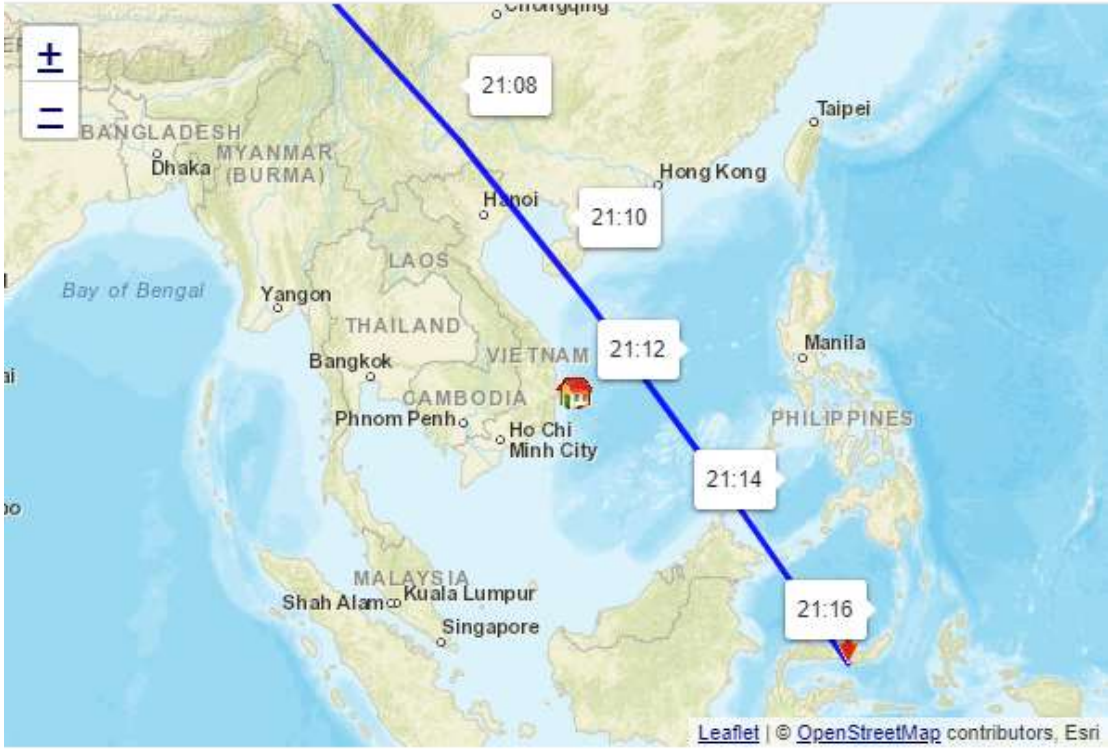
Legend:	Not visible	Marginal	Good	Excellent

https://www.n2yo.com/passes/?s=25544

How to observe ?

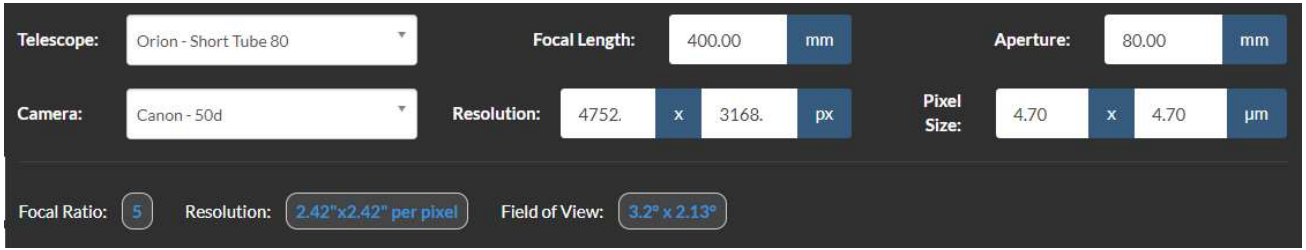
Pass beginning	Max altitude	Pass ending
Date: 29-Jul 21:06:10	Date: 29-Jul 21:11:20	Date: 29-Jul 21:16:30
Az: 330.63° (NNW)	Az: 46.78° (NE)	Az: 132.94° (SE)
El (alt): 0.18°	El (alt): 45.97°	El (alt): 0.83°
Mag: +1.3	Mag: -	Mag: -
Dist to sat: 2308.3 km	Dist to sat: 555.5 km	Dist to sat: 2230.3 km
Eclipsed?: NO	Eclipsed? YES	Eclipsed? YES

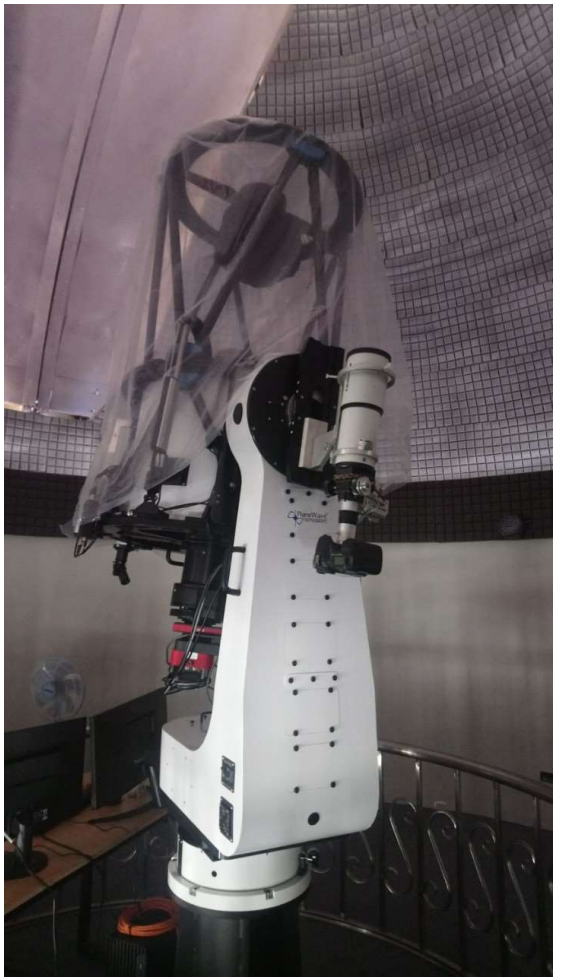
Barely visible pass | Add this pass on your notifications list



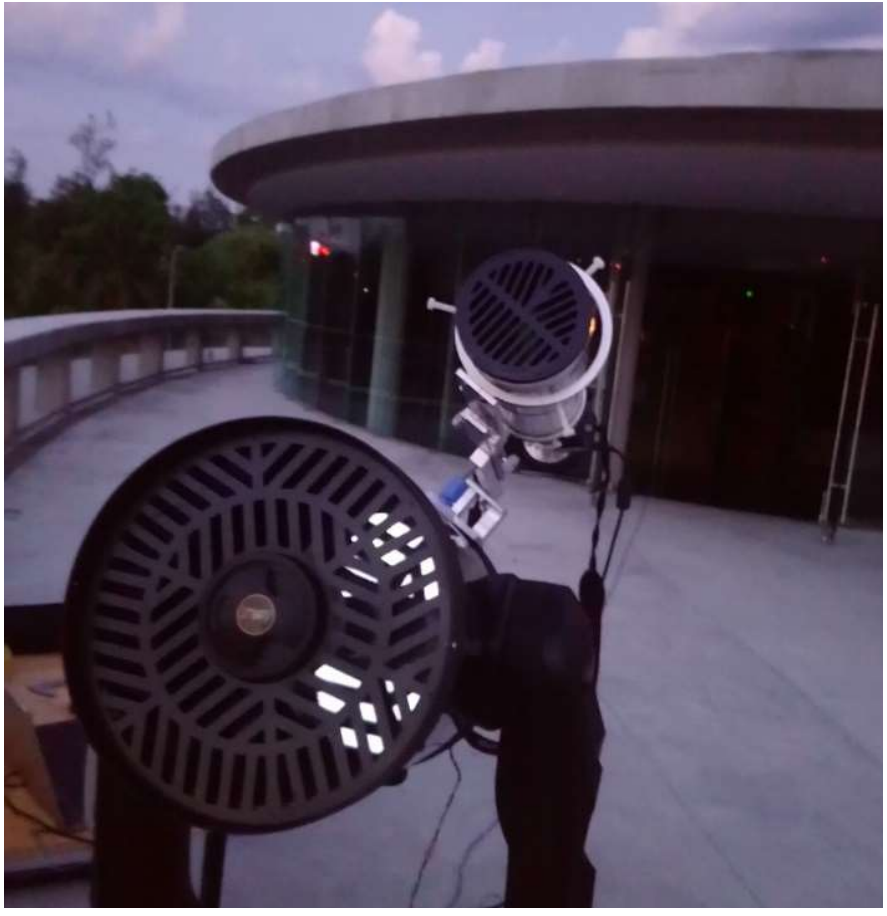
How to observe ?

- Wide field of view telescope with digital camera/CCD
- Digital camera with long focal length lens
- Computerized telescope mount





How to observe ?



Get the proper focus by using the Bahtinov mask with a bright star.

Standard interface with telescopes

The ASCOM standard interface is used to control multiple observatory devices simultaneously, such as telescopes, domes, focusers, CCDs, filters, etc.

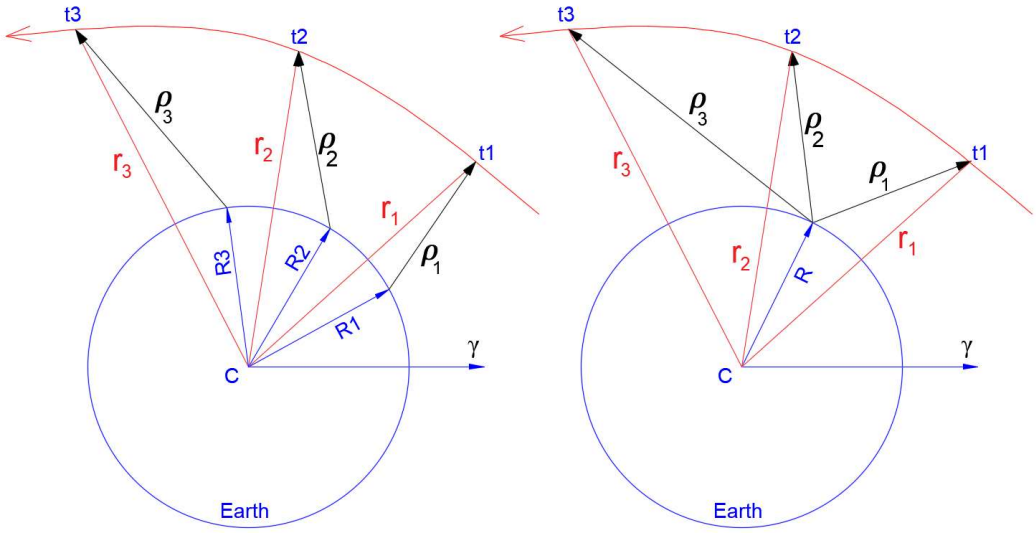
ASCOM is a widely used standard interface in both professional and amateur astronomy. With this standard interface, users can develop many more applications to expand the working capabilities of the observatory, telescopes, ... on many programming languages such as C++, C#, Java…

Method of calculating orbital elements

- To determine the orbit of a flying object, at least three observations are required, at times *t1*, *t2*, *t3*.

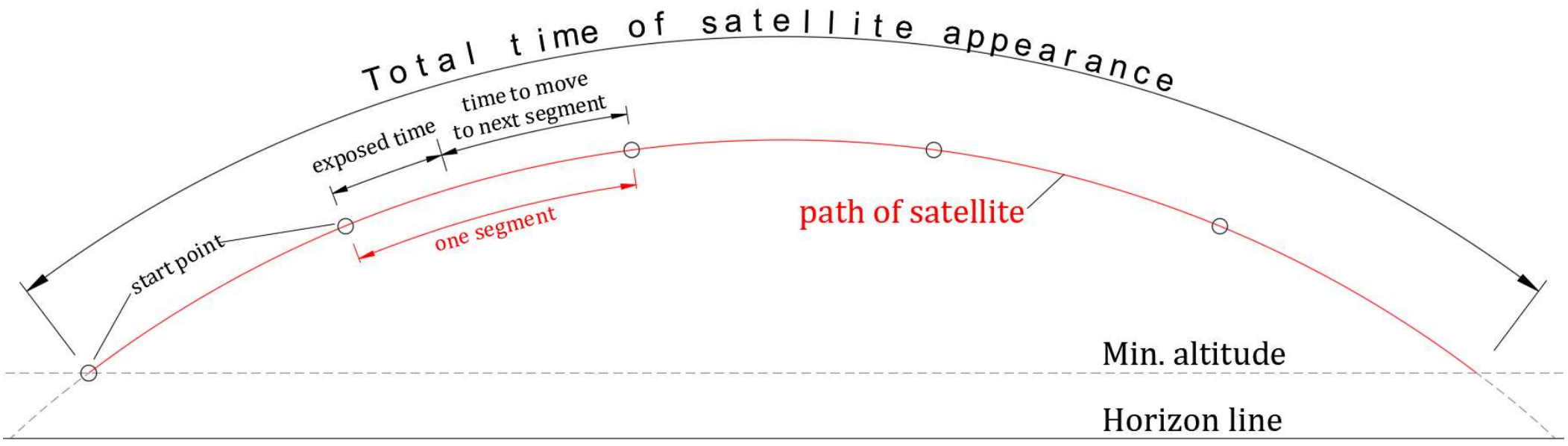
- The star coordinates determination algorithm analyzes the image and calculates the satellite coordinates (plate solving algorithm).

- Other algorithms are used to calculate the set of six orbit parameters of the object.



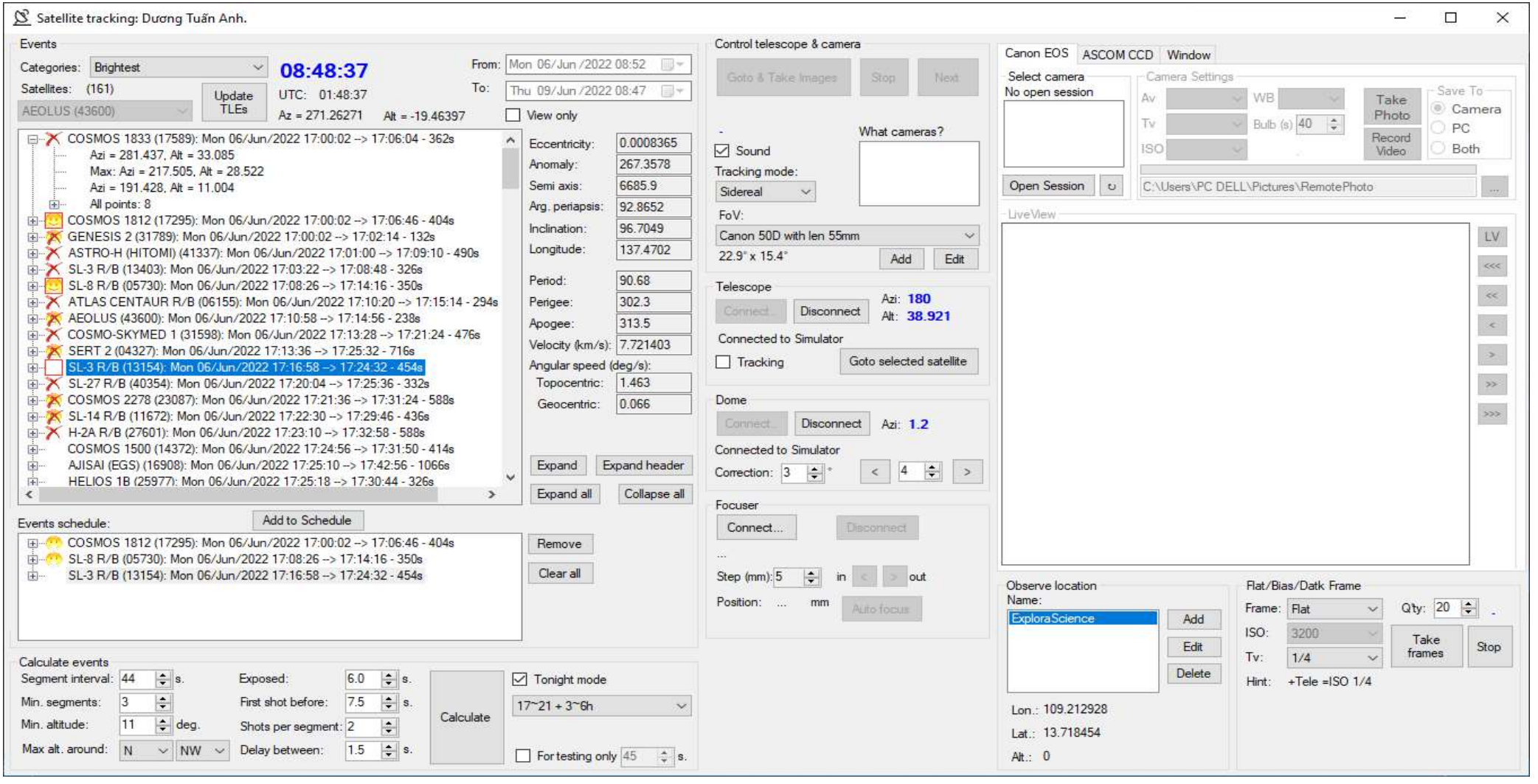
Three observations for one satellite.
Right: at different locations
Left: at different times

How to take consecutive images

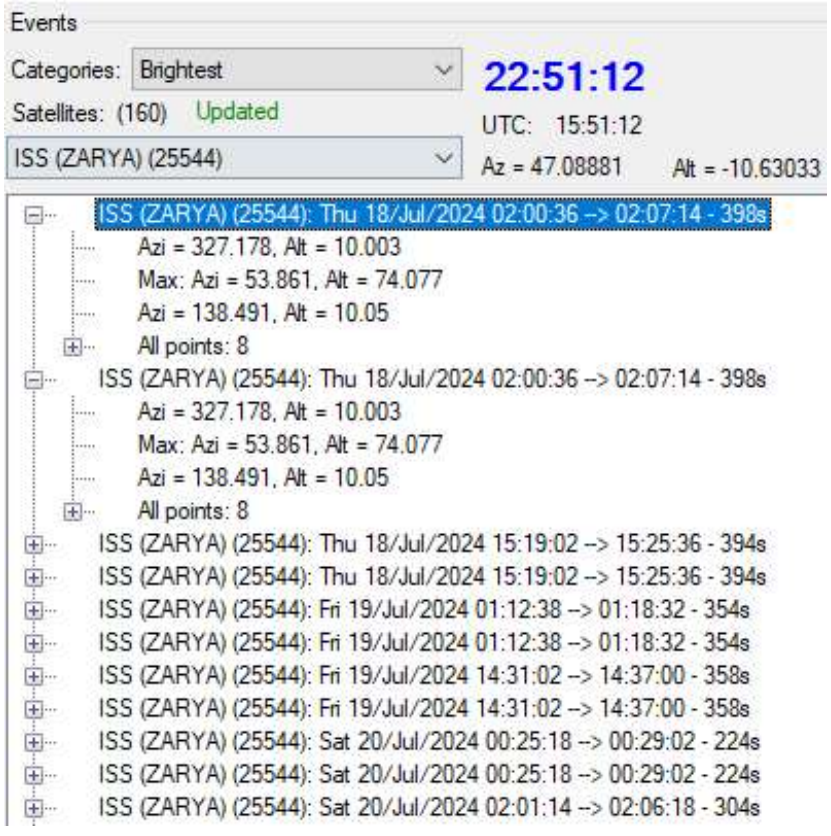


With the time of appearance in the sky at a specific time and location, we divide it into segments. Each segment will have coordinates and times corresponding to each starting point of that segment. This segment must be long enough so that after taking a long exposure photo, there is still time for the telescope (and dome, if there is one) to move to the new point and stabilize.

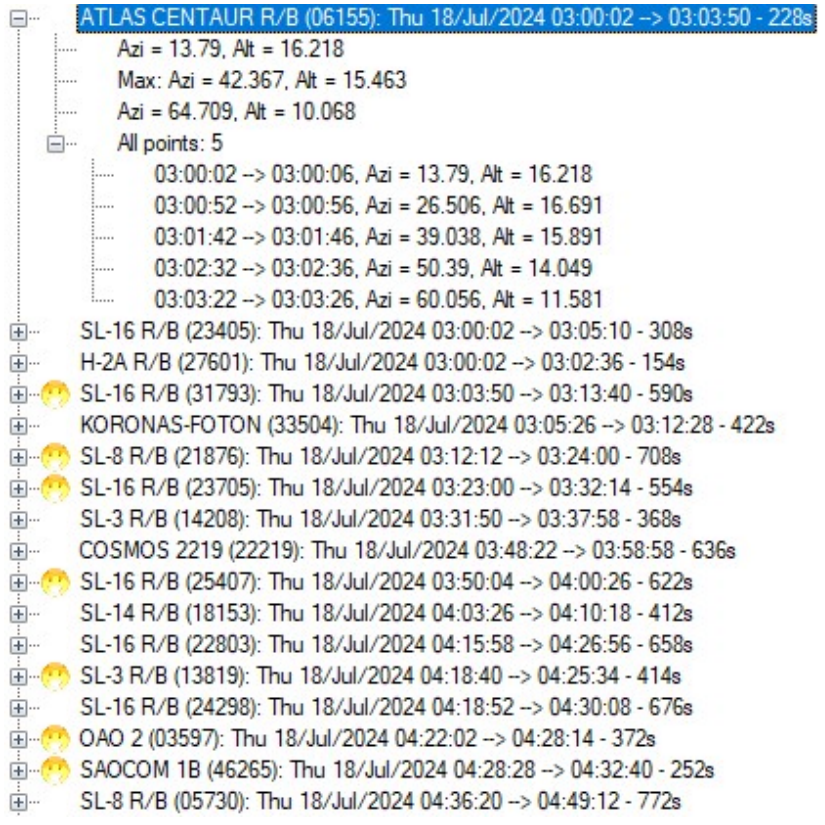
Support software



Satellite appearances



ISS appearance within the next three days



Tonight mode for all satellite in selected category

Observation log

Site: ExploraScience
Longitude: 109.212927798986, Latitude: 13.7184543262769, Altitude: 0
Telecsope: Celestron Nexstar+ SLT 5.31
Captured device: EOS1
FoV: 5.1° x 3.4°
Satellite name: H-2AR_B-27601
Satellite NORAD ID: 27601
Satellite TLE:
1 27601U 02056E 22128.82045977 .00000131 00000+0 61908-4 0 9998
2 27601 98.1778 137.7203 0072500 20.5947 152.0765 14.32060210 13483
Segments count: 4
Shot per segment: 2
Exposed: 4
Number of images: 8

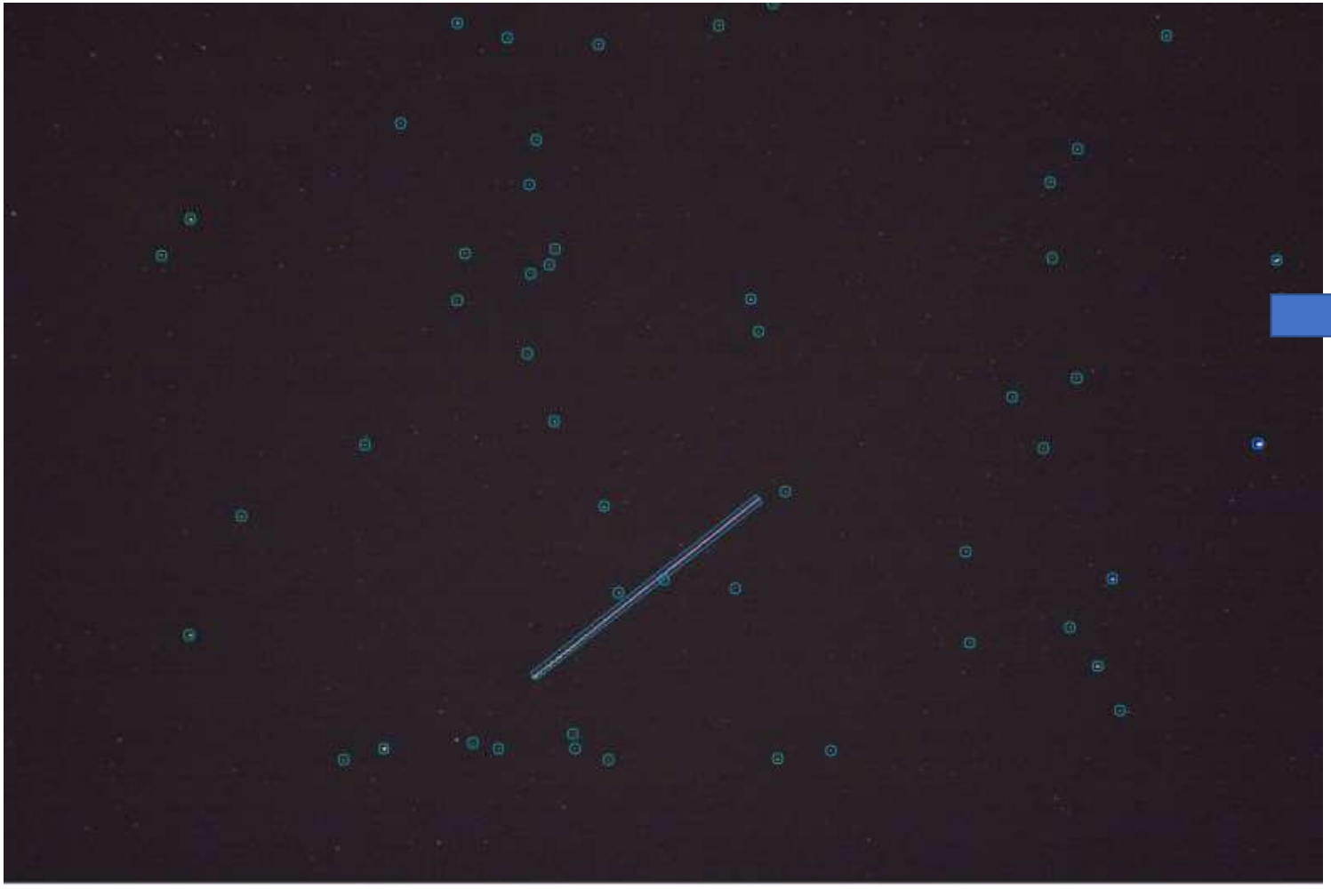
Saved directory: E:\0Satellite images\20220506\H-2AR_B-27601 09May20221840
Images info:

No	Name = Time	Alt	Azi
1	09May2022-184028	11.973	236.273
2	09May2022-184033	11.973	236.273
3	09May2022-184124	13.833	247.971
4	09May2022-184129	13.833	247.971
5	09May2022-184220	14.522	260.8
6	09May2022-184225	14.522	260.8
7	09May2022-184316	13.882	273.674
8	09May2022-184321	13.882	273.674

Satellite images

Satellite images

Stars and satellite track coordinates



(α_1, δ_1)

(α_2, δ_2)

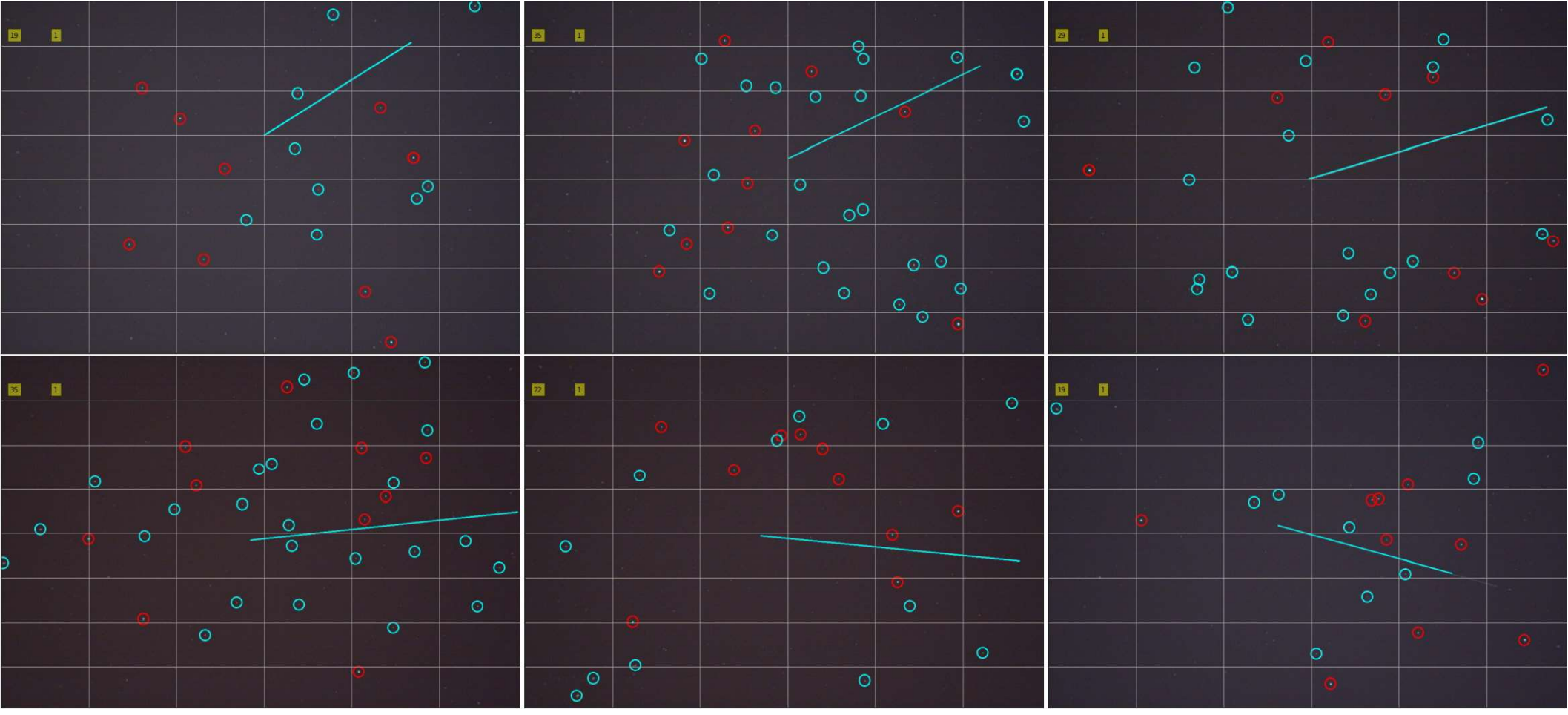
(α_3, δ_3)

(α_4, δ_4)

....

https://nova.astrometry.net/upload/

Stars and satellite track coordinates



Satellite observing network

- Current telescopes devoting time to LEOsat observations are located in Chile, Spain, Vietnam and South Korea.
- Measure any orbital-attitude aspect to satellite brightness for different geographical locations.
- Measure TLE accuracy as a function of longitude (time zone), to aid satellite visibility forecasting.