

SATELLITE TRACKING with SMALL TELESCOPES

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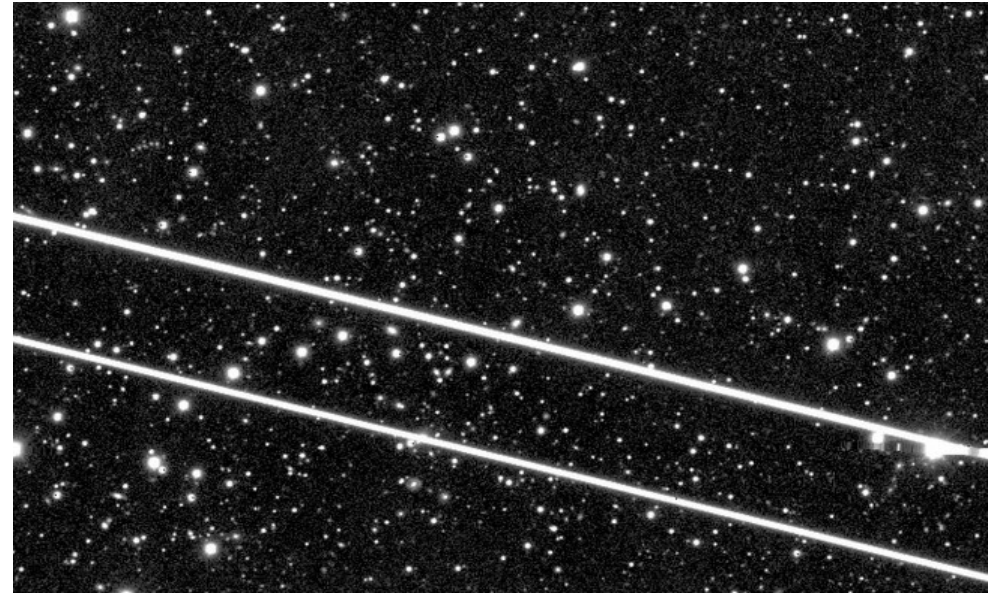
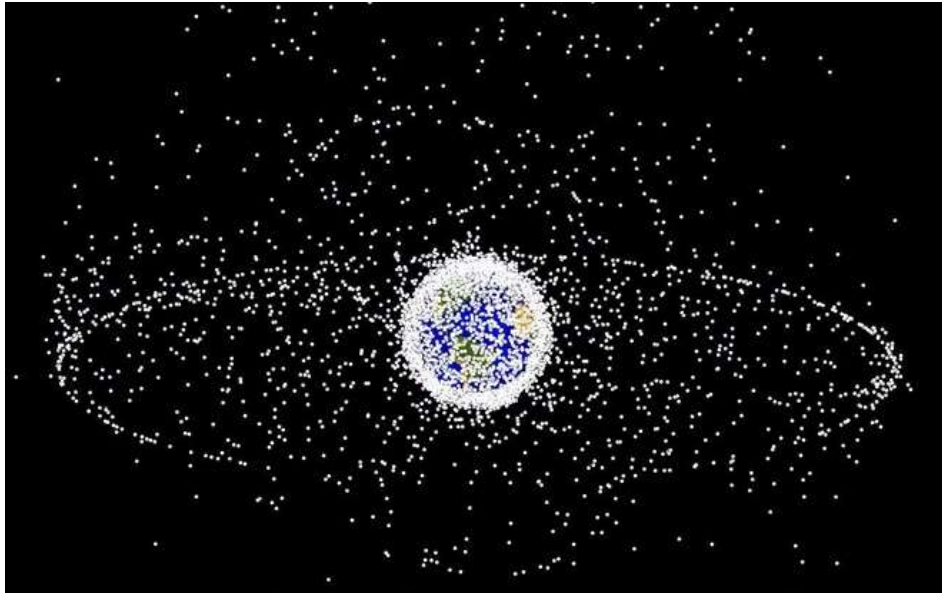
Satellite tracking

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

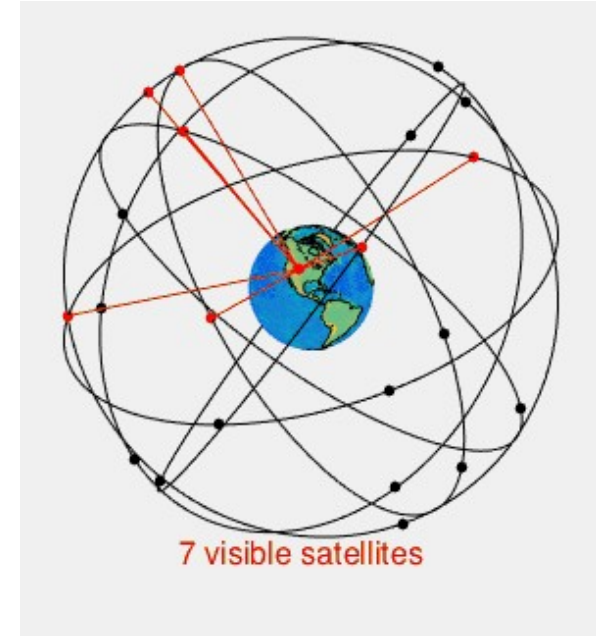
What is the satellite ?

Artificial satellite:

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

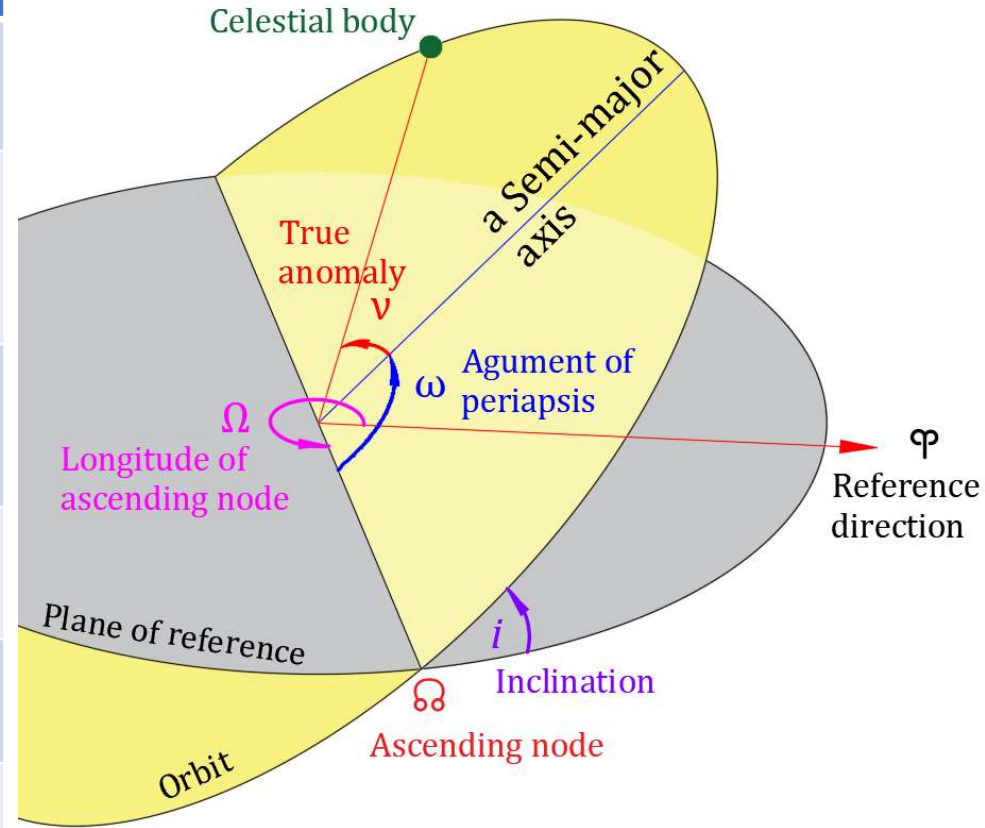
Orbital type:

- LEO/MEO/GEO/HEO
- Constellation



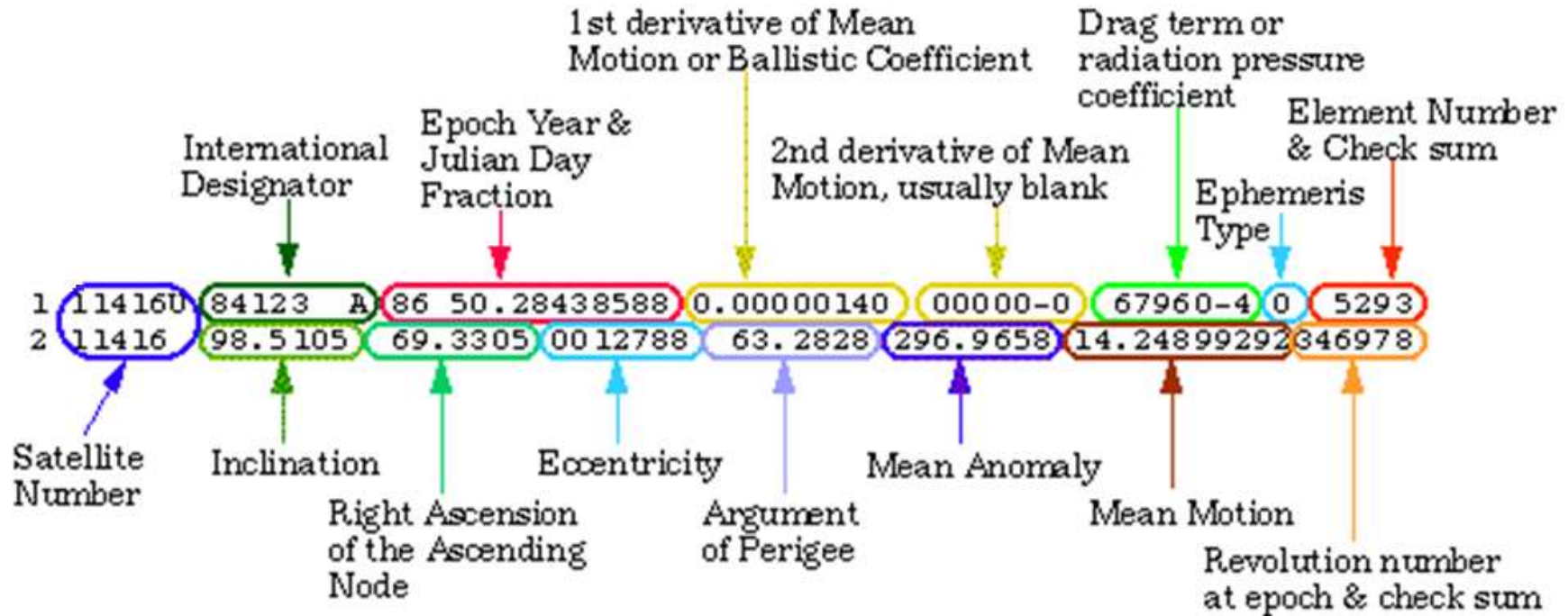
Orbital elements

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 φ
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	v	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.



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:

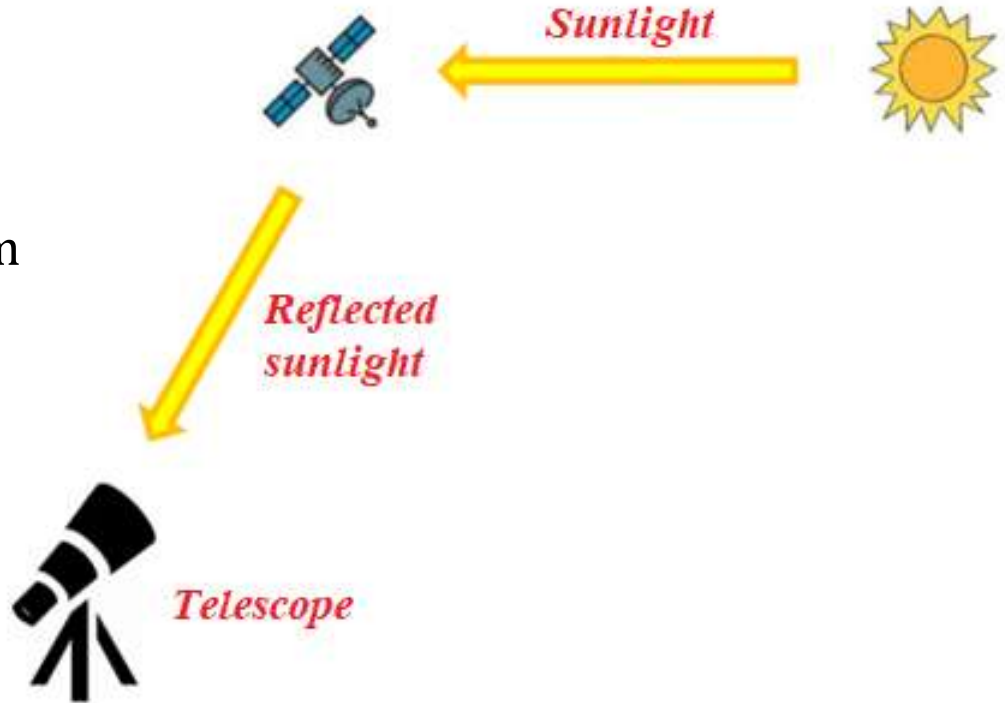
- At dusk, at a certain angle to the sun
- Obscured by clouds, interference from ambient light

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

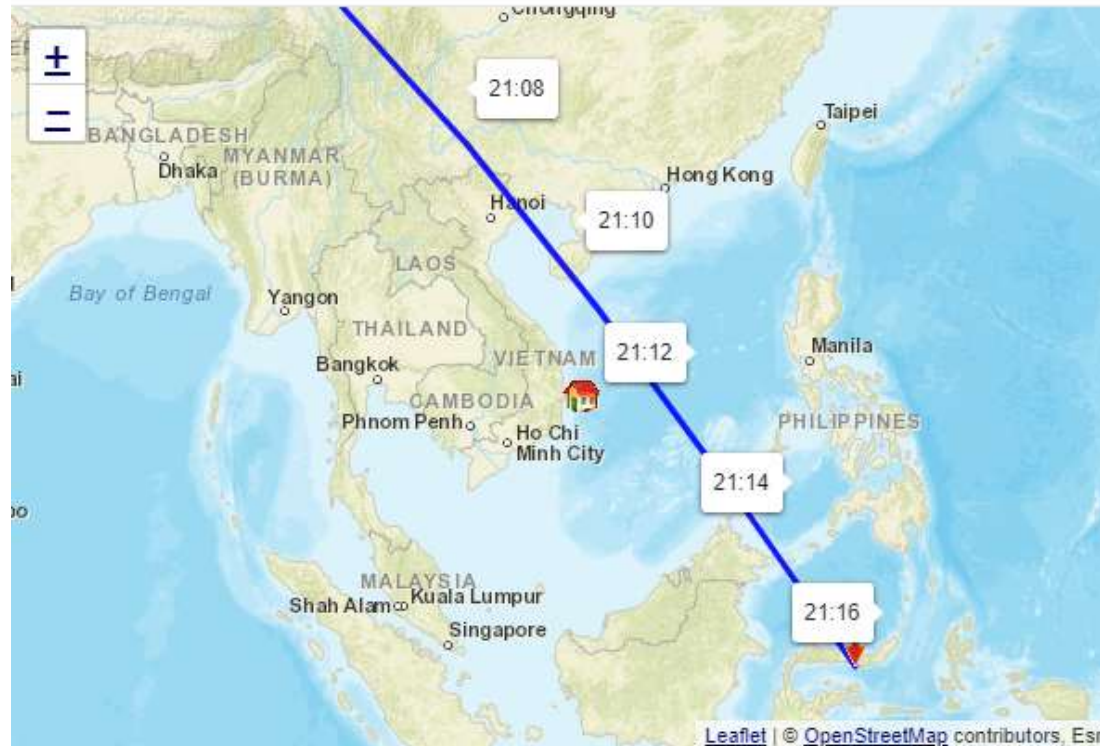
<https://www.n2yo.com/passes/?s=25544>

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

Telescope:	Orion - Short Tube 80	Focal Length:	400.00	mm	Aperture:	80.00	mm				
Camera:	Canon - 50d	Resolution:	4752	x	3168	px	Pixel Size:	4.70	x	4.70	μm
Focal Ratio:	5	Resolution:	2.42"x2.42" per pixel		Field of View:	3.2° x 2.13°					



How to observe ?



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



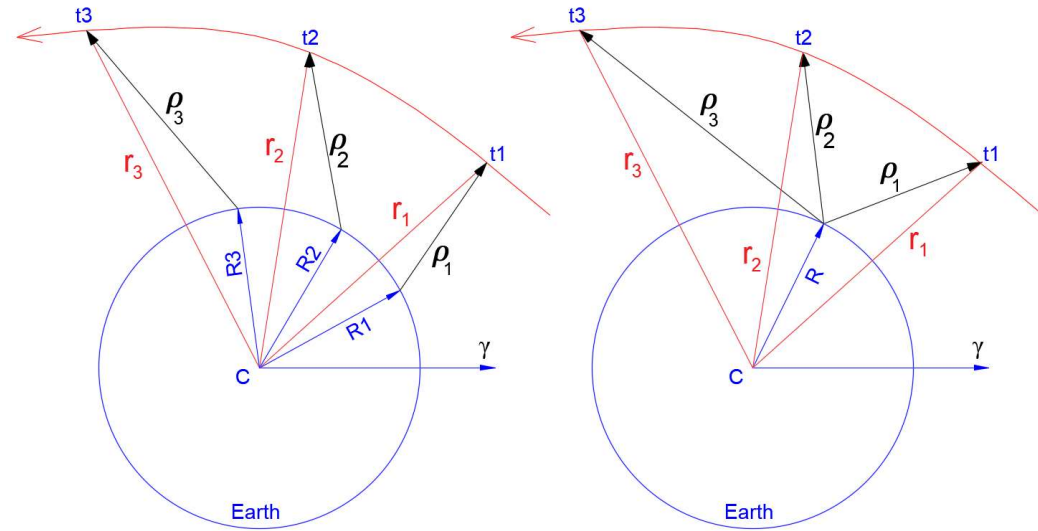
Standard interface with telescopes

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 t_1, t_2, t_3 .
- 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.

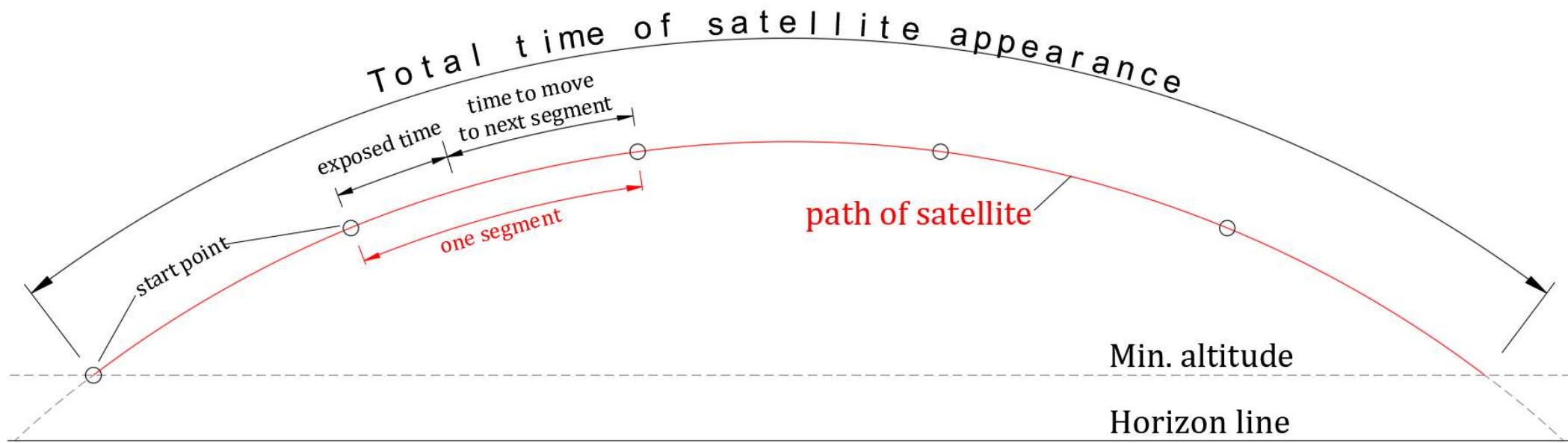


Three observations for one satellite.

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 tracking: Dương Tuấn Anh.

Events

Categories: **Brightest** **08:48:37** From: Mon 06/Jun/2022 08:52 To: Thu 09/Jun/2022 08:47

Satellites: (161) Update TLEs UTC: 01:48:37

AEOLUS (43600) Az = 271.26271 Alt = -19.46397 View only

☒ COSMOS 1833 (17589): Mon 06/Jun/2022 17:00:02 -> 17:06:04 - 362s
Azi = 281.437, Alt = 33.085
Max: Azi = 217.505, Alt = 28.522
Azi = 191.428, Alt = 11.004
All points: 8

☒ COSMOS 1812 (17295): Mon 06/Jun/2022 17:00:02 -> 17:06:46 - 404s

☒ GENESIS 2 (31789): Mon 06/Jun/2022 17:00:02 -> 17:02:14 - 132s

☒ ASTRO-H (HITOMI) (41337): Mon 06/Jun/2022 17:01:00 -> 17:09:10 - 490s

☒ SL-3 R/B (13403): Mon 06/Jun/2022 17:03:22 -> 17:08:48 - 326s

☒ SL-8 R/B (05730): Mon 06/Jun/2022 17:08:26 -> 17:14:16 - 350s

☒ ATLAS CENTAUR R/B (06155): Mon 06/Jun/2022 17:10:20 -> 17:15:14 - 294s

☒ AEOLUS (43600): Mon 06/Jun/2022 17:10:58 -> 17:14:56 - 238s

☒ COSMO-SKYMED 1 (31598): Mon 06/Jun/2022 17:13:28 -> 17:21:24 - 476s

☒ SERT 2 (04327): Mon 06/Jun/2022 17:13:36 -> 17:25:32 - 716s

☒ SL-3 R/B (13154): Mon 06/Jun/2022 17:16:58 -> 17:24:32 - 454s

☒ SL-27 R/B (40354): Mon 06/Jun/2022 17:20:04 -> 17:25:36 - 332s

☒ COSMOS 2278 (23087): Mon 06/Jun/2022 17:21:36 -> 17:31:24 - 588s

☒ SL-14 R/B (11672): Mon 06/Jun/2022 17:22:30 -> 17:29:46 - 436s

☒ H-2A R/B (27601): Mon 06/Jun/2022 17:23:10 -> 17:32:58 - 588s

☒ COSMOS 1500 (14372): Mon 06/Jun/2022 17:24:56 -> 17:31:50 - 414s

☒ AUSA (EGS) (16908): Mon 06/Jun/2022 17:25:10 -> 17:42:56 - 1066s

☒ HELIOS 1B (25977): Mon 06/Jun/2022 17:25:18 -> 17:30:44 - 326s

Eccentricity: 0.0008365
Anomaly: 267.3578
Semi axis: 6685.9
Arg. periapsis: 92.8652
Inclination: 96.7049
Longitude: 137.4702
Period: 90.68
Perigee: 302.3
Apogee: 313.5
Velocity (km/s): 7.721403
Angular speed (deg/s):
Topocentric: 1.463
Geocentric: 0.066

Expand Expand header
Expand all Collapse all

Events schedule: Add to Schedule

☒ COSMOS 1812 (17295): Mon 06/Jun/2022 17:00:02 -> 17:06:46 - 404s
☒ SL-8 R/B (05730): Mon 06/Jun/2022 17:08:26 -> 17:14:16 - 350s
☒ SL-3 R/B (13154): Mon 06/Jun/2022 17:16:58 -> 17:24:32 - 454s

Remove
Clear all

Calculate events
Segment interval: 44 s. Exposed: 6.0 s. ☒ Tonight mode
Min. segments: 3 First shot before: 7.5 s. 17~21 + 3~6h
Min. altitude: 11 deg. Shots per segment: 2
Max alt. around: N NW Delay between: 1.5 s. Calculate
☐ For testing only 45 s.

Control telescope & camera

Goto & Take Images Stop Next

What cameras?

☒ Sound
Tracking mode: Sidereal
FoV: Canon 50D with len 55mm
22.9° x 15.4° Add Edit

Telescope
Connect Disconnect Azi: 180 Alt: 38.921
Connected to Simulator
☐ Tracking Goto selected satellite

Dome
Connect Disconnect Azi: 1.2
Connected to Simulator
Correction: 3 4

Focuser
Connect... Disconnect
Step (mm): 5 in out
Position: mm Auto focus

Canon EOS ASCOM CCD Window

Select camera No open session

Camera Settings
Av WB Bulb (s) 40 Take Photo Record Video Save To Camera PC Both
C:\Users\PC DELL\Pictures\RemotePhoto

Open Session

LiveView
LV
<<< << < > >> >>>

Observe location
Name: ExploraScience Add Edit Delete
Lon.: 109.212928
Lat.: 13.718454
Alt.: 0

Flat/Bias/DatK Frame
Frame: Flat Qty: 20
ISO: 3200 Take frames Stop
Tv: 1/4
Hint: +Tele =ISO 1/4

Satellite appearances

Events

Categories: **Brightest** 22:51:12

Satellites: (160) Updated UTC: 15:51:12

ISS (ZARYA) (25544) Az = 47.08881 Alt = -10.63033

ISS (ZARYA) (25544): Thu 18/Jul/2024 02:00:36 -> 02:07:14 - 398s

- Azi = 327.178, Alt = 10.003
- Max: Azi = 53.861, Alt = 74.077
- Azi = 138.491, Alt = 10.05
- All points: 8

ISS (ZARYA) (25544): Thu 18/Jul/2024 02:00:36 -> 02:07:14 - 398s

- Azi = 327.178, Alt = 10.003
- Max: Azi = 53.861, Alt = 74.077
- Azi = 138.491, Alt = 10.05
- All points: 8

ISS (ZARYA) (25544): Thu 18/Jul/2024 15:19:02 -> 15:25:36 - 394s

ISS (ZARYA) (25544): Thu 18/Jul/2024 15:19:02 -> 15:25:36 - 394s

ISS (ZARYA) (25544): Fri 19/Jul/2024 01:12:38 -> 01:18:32 - 354s

ISS (ZARYA) (25544): Fri 19/Jul/2024 01:12:38 -> 01:18:32 - 354s

ISS (ZARYA) (25544): Fri 19/Jul/2024 14:31:02 -> 14:37:00 - 358s

ISS (ZARYA) (25544): Fri 19/Jul/2024 14:31:02 -> 14:37:00 - 358s

ISS (ZARYA) (25544): Sat 20/Jul/2024 00:25:18 -> 00:29:02 - 224s

ISS (ZARYA) (25544): Sat 20/Jul/2024 00:25:18 -> 00:29:02 - 224s

ISS (ZARYA) (25544): Sat 20/Jul/2024 02:01:14 -> 02:06:18 - 304s

ISS appearance within the next three days

ATLAS CENTAUR R/B (06155): Thu 18/Jul/2024 03:00:02 -> 03:03:50 - 228s

- Azi = 13.79, Alt = 16.218
- Max: Azi = 42.367, Alt = 15.463
- Azi = 64.709, Alt = 10.068
- All points: 5
- 03:00:02 -> 03:00:06, Azi = 13.79, Alt = 16.218
- 03:00:52 -> 03:00:56, Azi = 26.506, Alt = 16.691
- 03:01:42 -> 03:01:46, Azi = 39.038, Alt = 15.891
- 03:02:32 -> 03:02:36, Azi = 50.39, Alt = 14.049
- 03:03:22 -> 03:03:26, Azi = 60.056, Alt = 11.581

SL-16 R/B (23405): Thu 18/Jul/2024 03:00:02 -> 03:05:10 - 308s

H-2A R/B (27601): Thu 18/Jul/2024 03:00:02 -> 03:02:36 - 154s

SL-16 R/B (31793): Thu 18/Jul/2024 03:03:50 -> 03:13:40 - 590s

KORONAS-FOTON (33504): Thu 18/Jul/2024 03:05:26 -> 03:12:28 - 422s

SL-8 R/B (21876): Thu 18/Jul/2024 03:12:12 -> 03:24:00 - 708s

SL-16 R/B (23705): Thu 18/Jul/2024 03:23:00 -> 03:32:14 - 554s

SL-3 R/B (14208): Thu 18/Jul/2024 03:31:50 -> 03:37:58 - 368s

COSMOS 2219 (22219): Thu 18/Jul/2024 03:48:22 -> 03:58:58 - 636s

SL-16 R/B (25407): Thu 18/Jul/2024 03:50:04 -> 04:00:26 - 622s

SL-14 R/B (18153): Thu 18/Jul/2024 04:03:26 -> 04:10:18 - 412s

SL-16 R/B (22803): Thu 18/Jul/2024 04:15:58 -> 04:26:56 - 658s

SL-3 R/B (13819): Thu 18/Jul/2024 04:18:40 -> 04:25:34 - 414s

SL-16 R/B (24298): Thu 18/Jul/2024 04:18:52 -> 04:30:08 - 676s

OA0 2 (03597): Thu 18/Jul/2024 04:22:02 -> 04:28:14 - 372s

SAOCOM 1B (46265): Thu 18/Jul/2024 04:28:28 -> 04:32:40 - 252s

SL-8 R/B (05730): Thu 18/Jul/2024 04:36:20 -> 04:49:12 - 772s

Tonight mode for all satellite in selected category

Observation log

Site: ExploraScience

Longitude: 109.212927798986, Latitude: 13.7184543262769, Altitude: 0

Telescope: 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

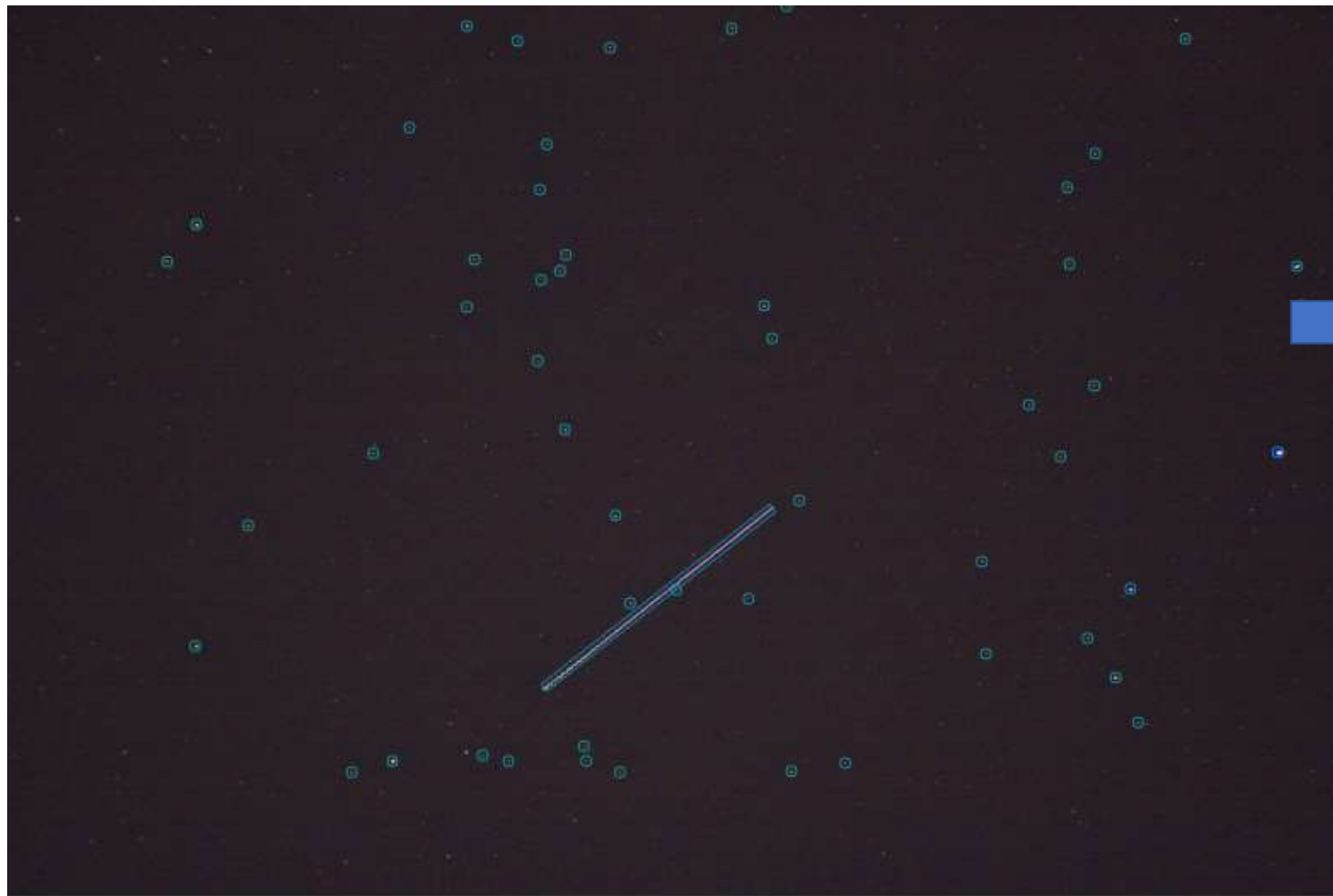
Satellite images



Satellite images



Stars and satellite track coordinates



(α_1, δ_1)

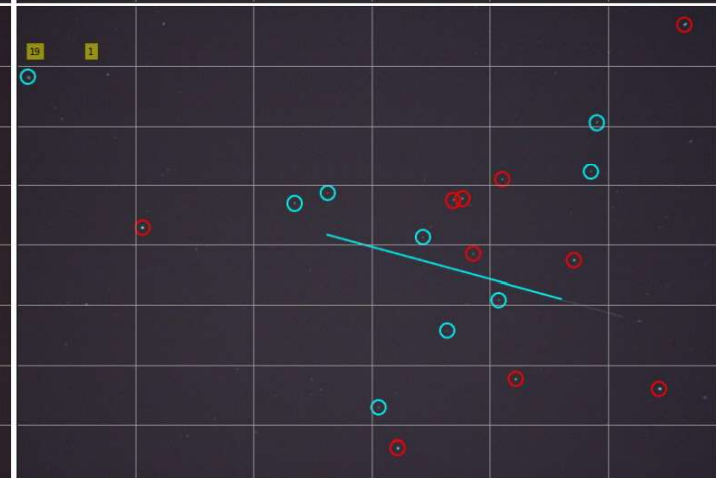
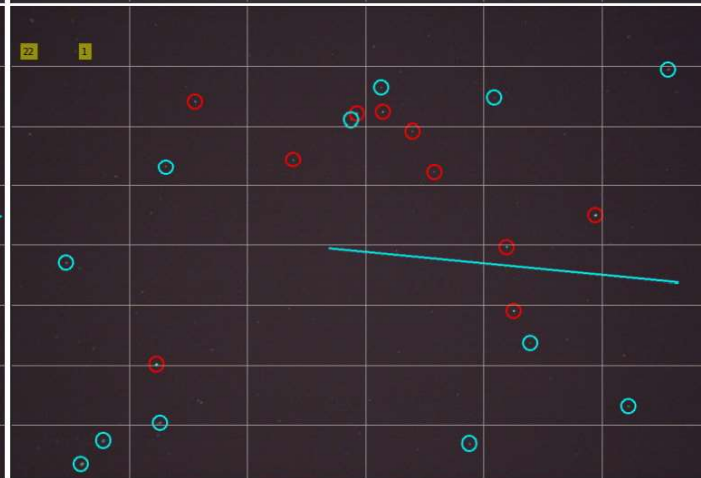
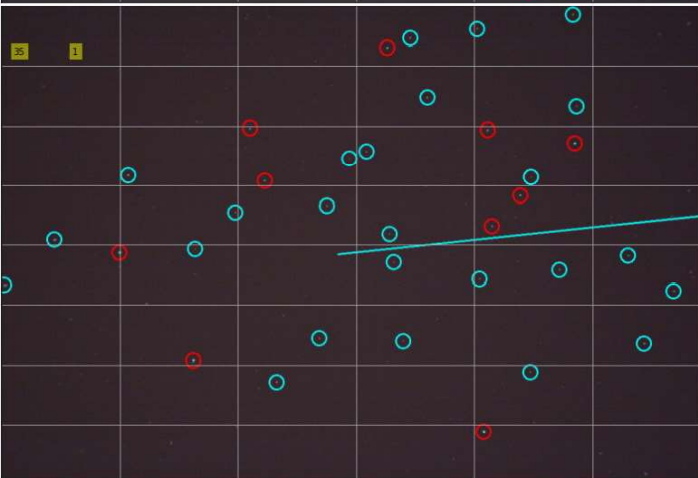
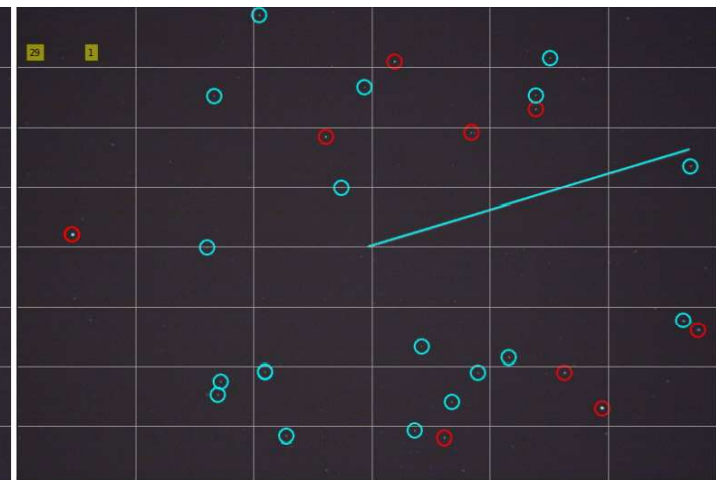
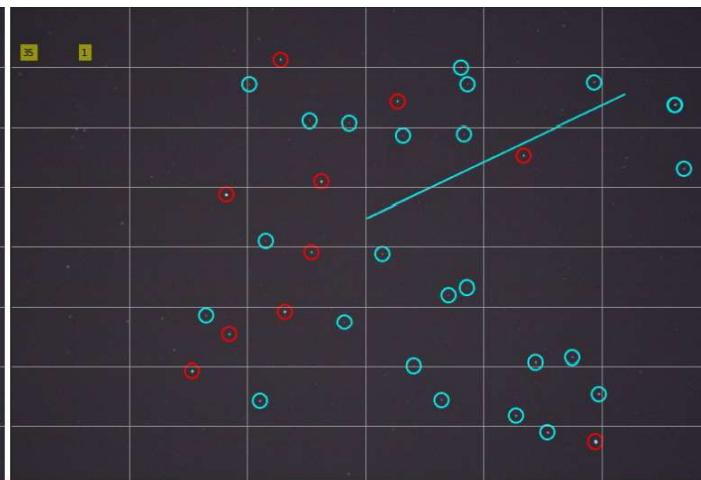
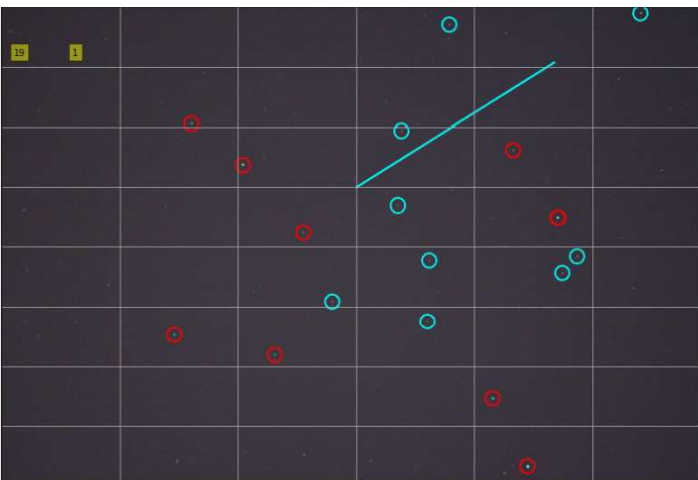
(α_2, δ_2)

(α_3, δ_3)

(α_4, δ_4)

...

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.

