Possible applications of AMOS meteor all-sky system for space debris reentry events detection and analysis

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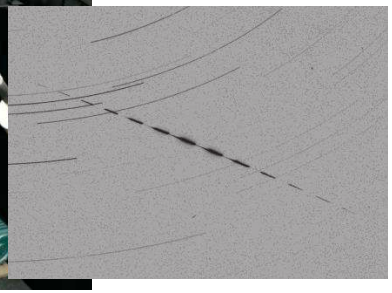
Overview

- Meteor research at Comenius University
- AMOS and AMOS-Spec systems
- Possible reentry example of Flock 1E fragment
- Tiangong 1 reentry case

Meteor research at Comenius University

- Long tradition at CU, namely at FMPI's the Astronomical and Geophysical observatory in Modra (AGO)
  - Radar measurements (revised)
  - **Photographic measurements (not used anymore)**
  - Video measurements (constantly improving)
- In the past was the focus on the bright meteors (bolids, mag < -2)
- Photographic method by using all sky cameras with fish-eye lens
- Part of the European Fireball Network



Video measurements

- All-Sky Meteor Orbit System - AMOS
- Program active since 2007
- Two parallel programs, AMOS and AMOS-Spec
- **AMOS**, primary focus:
  - orbit determination
  - brightness extraction
  - association with meteor streams
  - identification of new streams, parent bodies
  - meteorite recovery
- **AMOS-Spec/-HSpec**, primary focus:
  - spectra observation and analysis

A meteor detected by the AMOS-LP (Canary Inslands), apr. 04. 2015

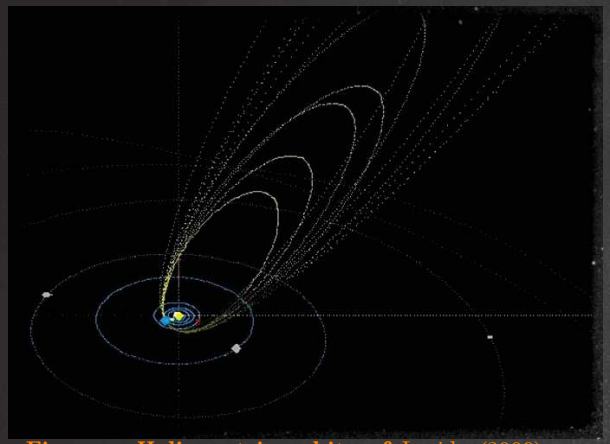


Figure – Heliocentric orbits of Lyrids (2009) calculated from AMOS observations.

One thousand Geminidis above Tenerife by AMOS-Cam, dec. 13/14, 2017

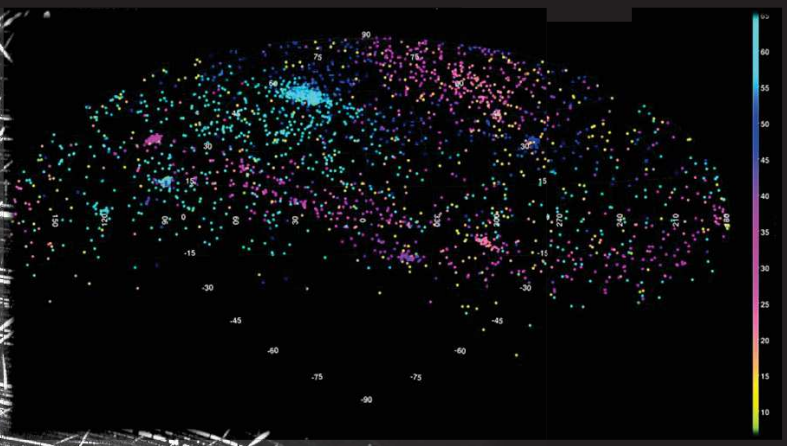


Figure – Meteor radiants distribution from SVMN dataset (2009–2014), Slovakia. From the left to right, concentrations of radiants of Geminids (green), Orionids (red), Perseids (orange), and Lyrids (yellow) are visible..Taken from Tóth et al. (2015).

AMOS-TE, Teide, IAC
Tóth et al., 2017

Meteor and its spectrum lines detected by AMOS-Spec

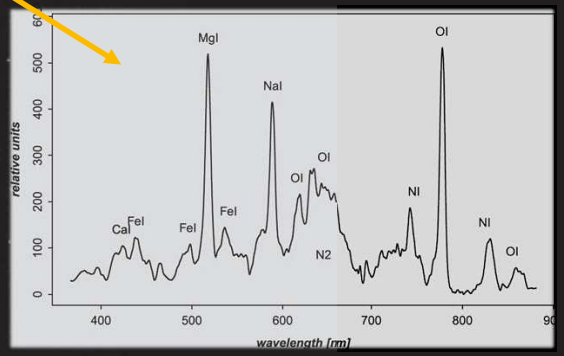


Figure – Example of meteor spectra of o Hydrids. Taken from Rudawska et al. (2016).

AMOS-Spec, AGO

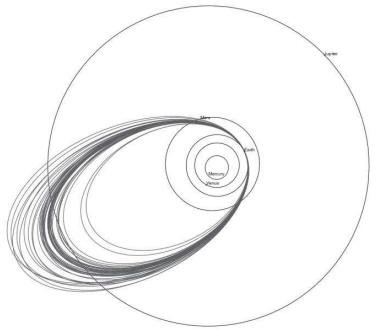
AMOS system products

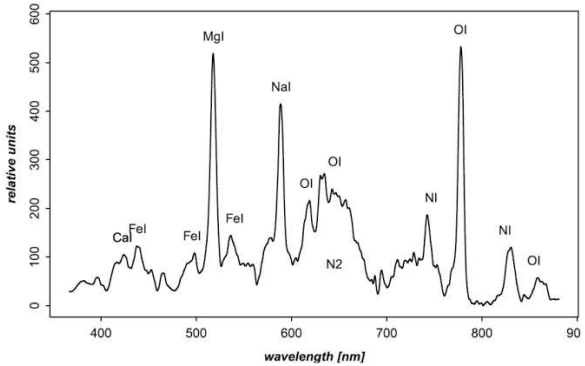
AMOS

- Detection: UFO Capture / FMPI's S/W
- Image processing: UFO Capture / FMPI's S/W
- Astrometry: UFO Analyzer, FMPI's RedSky
- Trajectory deter.: FMPI's MeteorTrajectory
- Orbit deter.: FMPI's MeteorTrajectory
- Products: astrometric position, brightness, state vector, heliocentric orbit

AMOS-HSpec

- Detection: UFO Capture, FMPI's S/W
- Image processing: AstroImageJ
- Spectra extraction: FMPI's methodology
- Products: spectrum, chemical composition

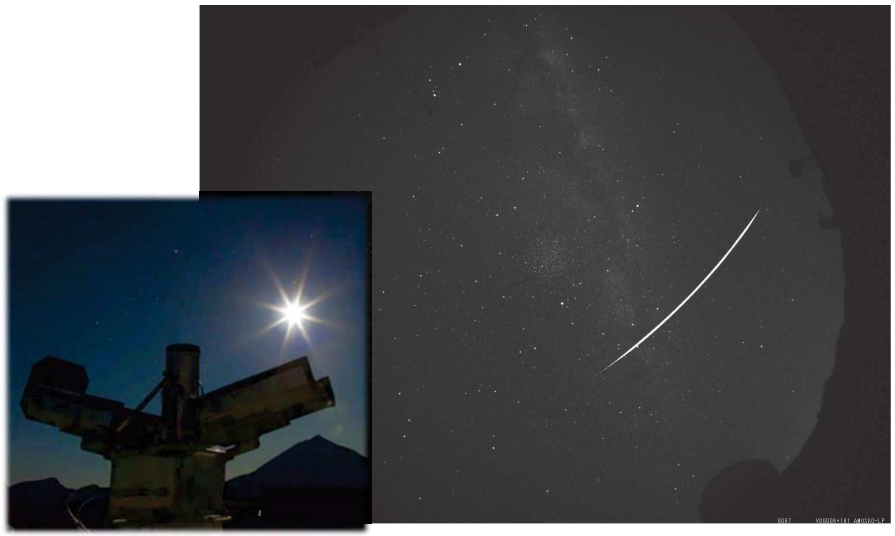


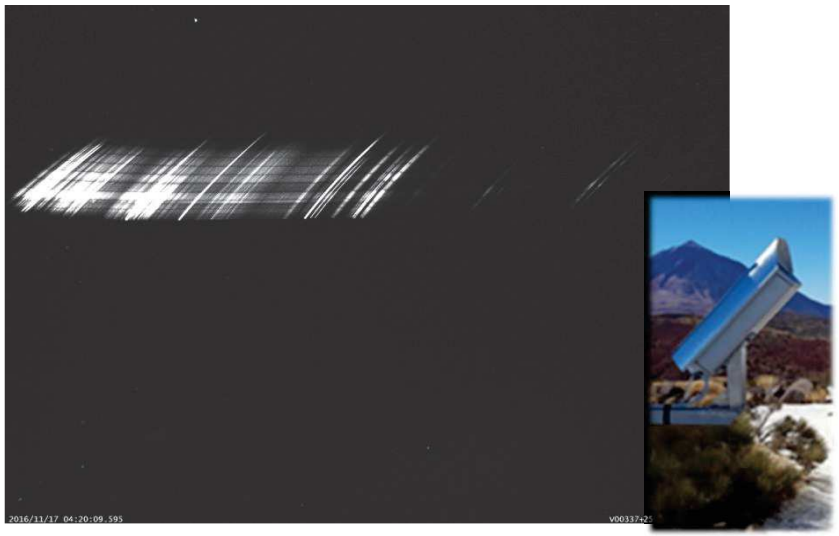


AMOS system parameters

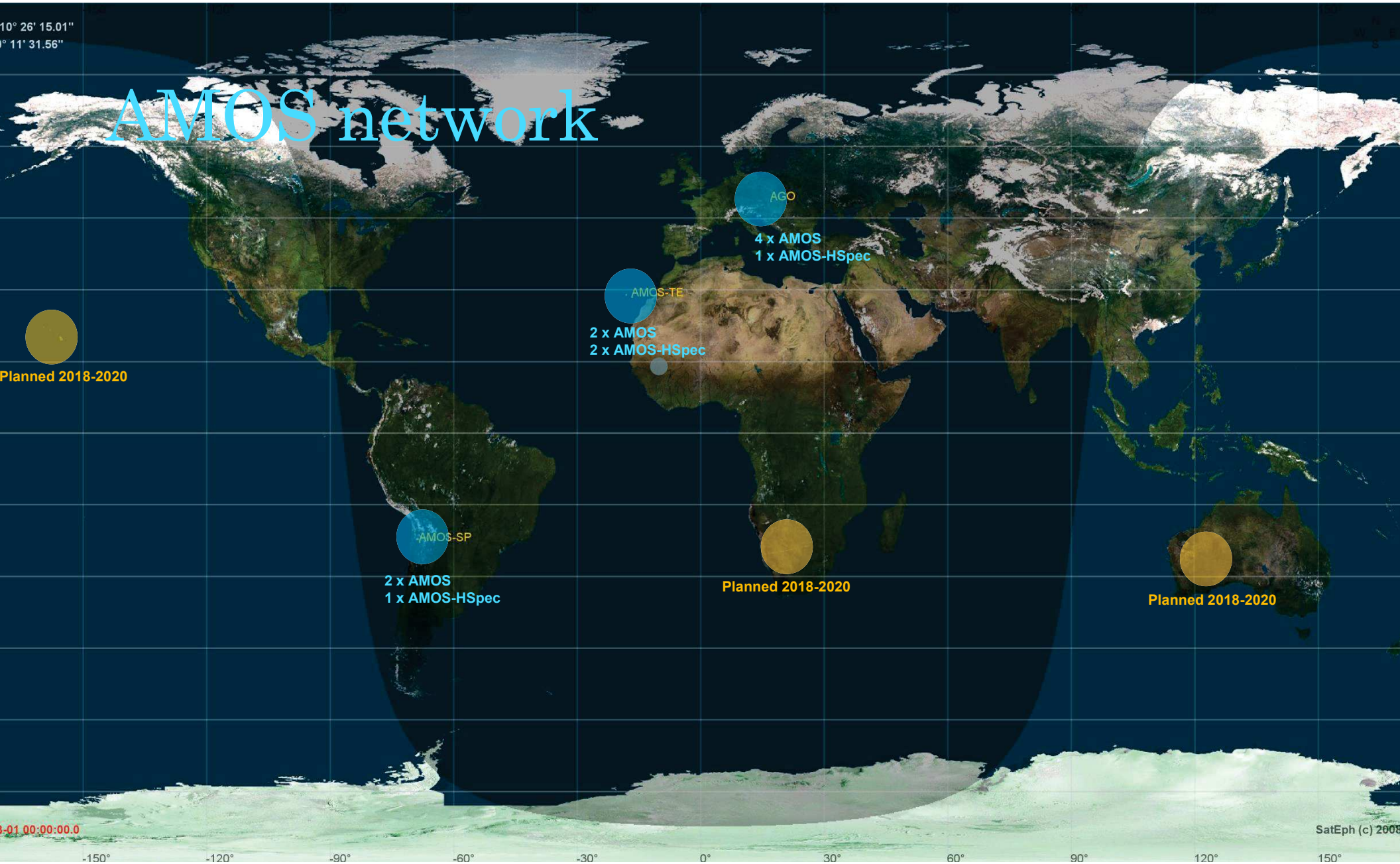
AMOS	
• Camera:	DMK 23U274 1280x960
• Lens:	fish-eye 30 mm, f/3.5
• Grating:	1000 grooves/mm
• Resolution:	1.0 - 1.5 nm/px
• FOV:	180 x 140 deg
• Lim. mag.:	+ 5.0

AMOS-HSpec	
• Camera:	Point-Grey 2048x1536
• Lens:	6 mm, f/3.5
• Grating:	1000 grooves/mm
• Resolution:	0.5 nm/px
• FOV:	60 x 45 deg
• Lim. mag.:	+ 6.0 / - 1.5



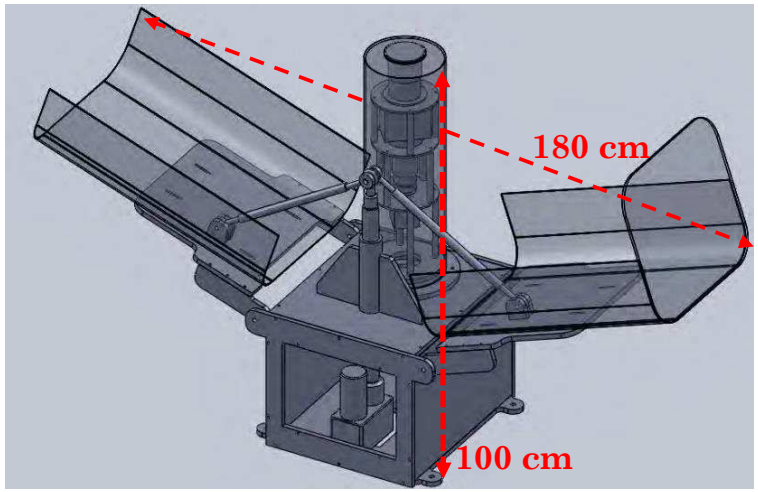


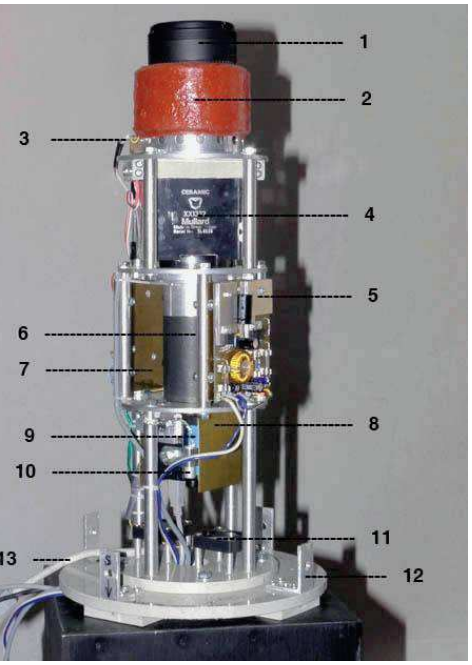
AMOS configuration

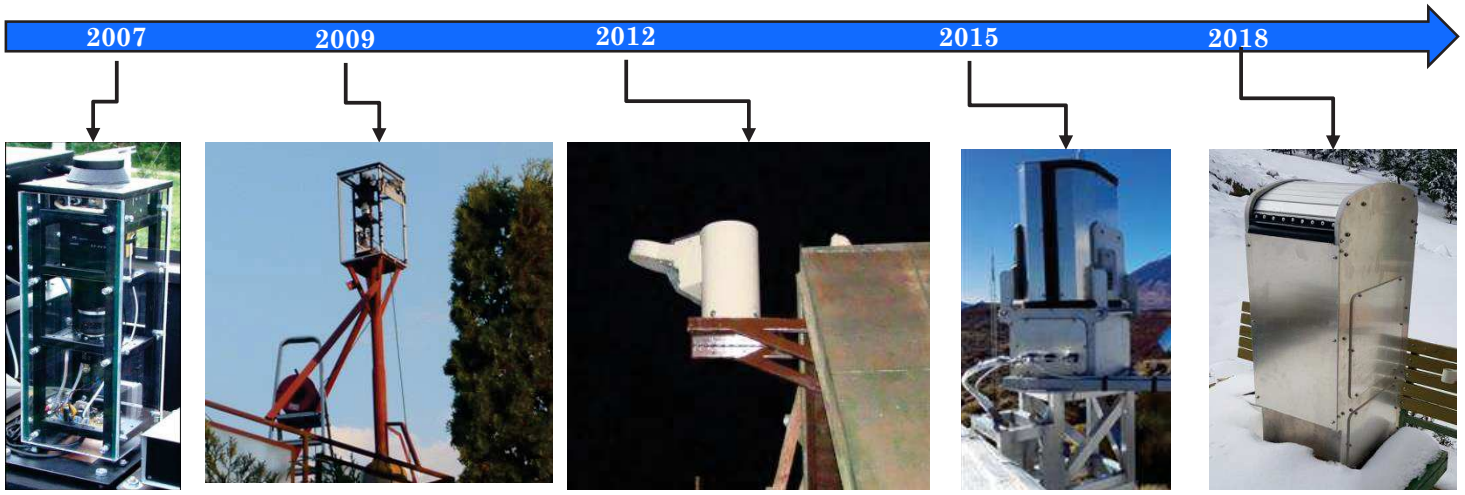

10° 26' 15.01"
° 11' 31.56"
AMOS network
AGO
4 x AMOS
1 x AMOS-HSpec
AMOS-TE
2 x AMOS
2 x AMOS-HSpec
Planned 2018-2020
AMOS-SP
2 x AMOS
1 x AMOS-HSpec
Planned 2018-2020
Planned 2018-2020
-01 00:00:00.0
SatEph (c) 2008
-150°
-120°
-90°
-60°
-30°
0°
30°
60°
90°
120°
150°

AMOS system development

- The camera and housing developed at CU since 2006
- AMOS program active since 2007
- Funded from national and university's resources
- H/W and S/W development ongoing, improvement necessary to get more accurate data and more robust system





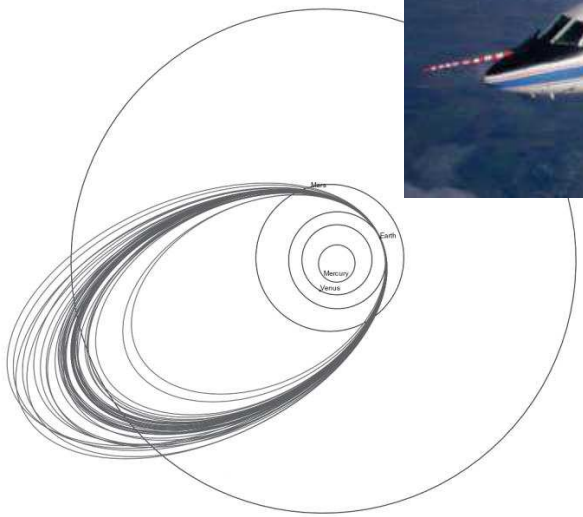


AMOS system portability

- AMOS cameras are portable, possible to use for meteor showers campaigns

- Example is a first European meteor observation airborne campaign in 2011 to Draconid meteor airborne

- Two airplanes, SLR (Comenius University, ESA, Ondrejov observatory) and Safire (IMCCE, INSA/ESA, USU)



Possible reentry example

- Video M20160809_001049_AGO-TEST_.avi

Bolid M20160809_001049

Possible reentry example, overview

- Bolid observed by AMOS at AGO in 2016-08-09, 00:10:50 UTC
- Trajectory toward East
- Unusually long duration for a meteor, dozens of seconds, low velocity
- Observed visible break-up
- Several different observers in Slovakia, Czech Republic, Slovenia, Italy
- Used Meteor Trajectory to estimate the atmospheric trajectory, two sets of observations used, AGO AMOS and amateur observations from Martin Popek (Nýdek, Czech Republic)

Possible reentry example, trajectory

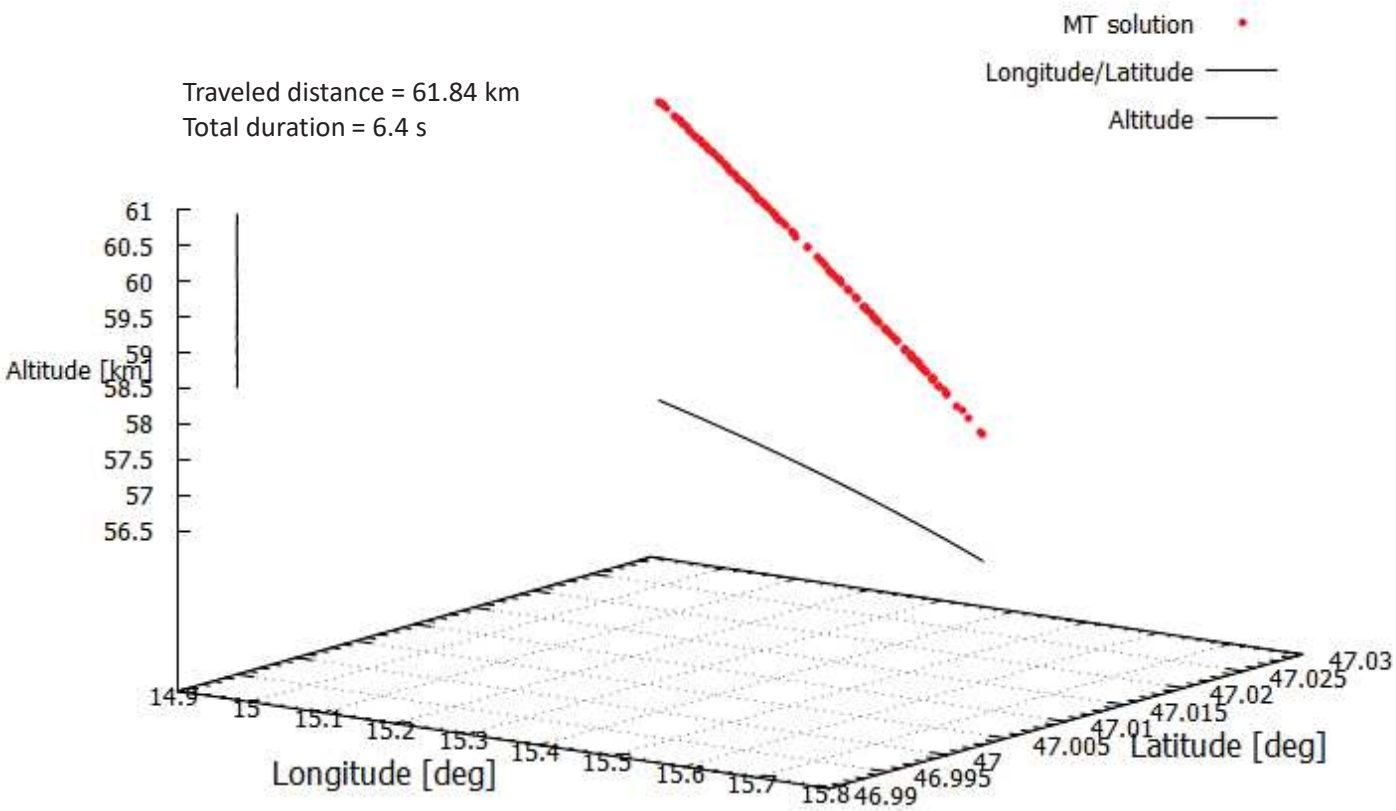
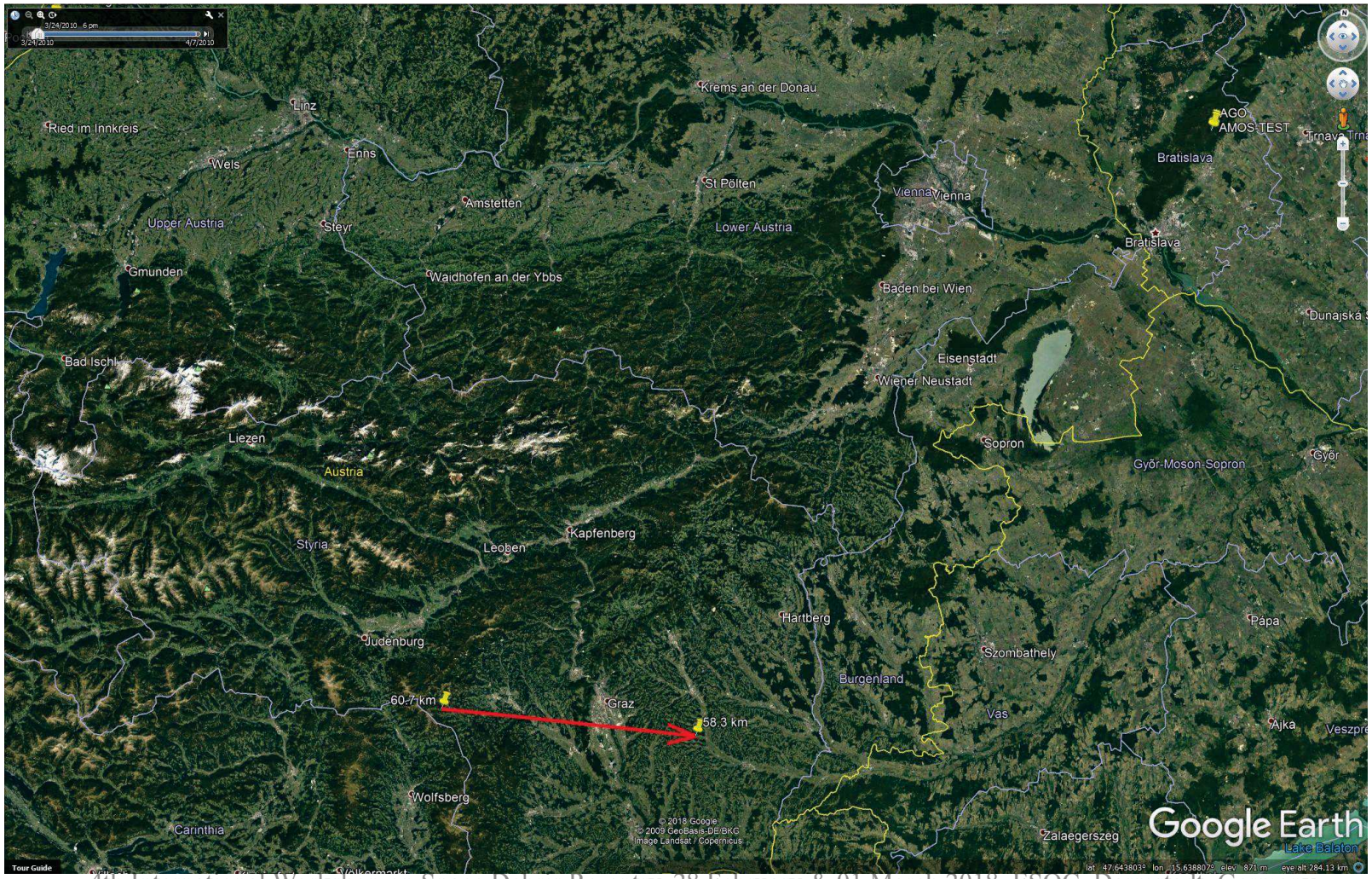


Figure – Determined atmospheric trajectory for bolid M20160809_001049_AGO-TEST.

Possible reentry example, trajectory



Possible reentry example, trajectory

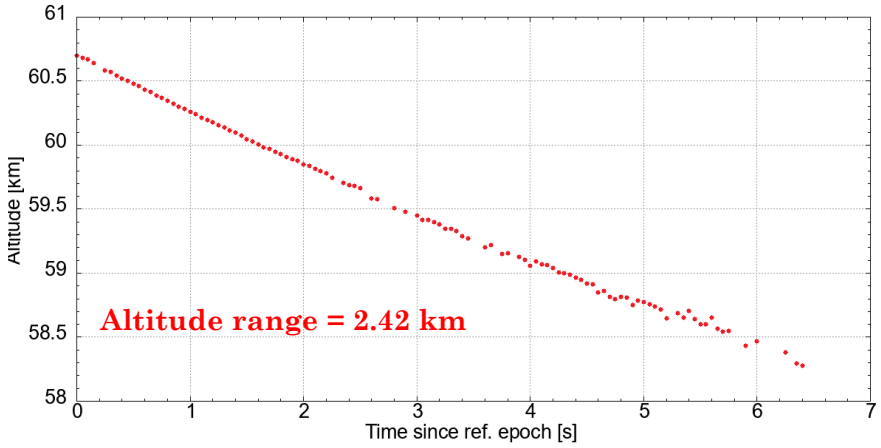


Figure – Estimated altitude [km] of bolid M20160809_001049 as a function of time.

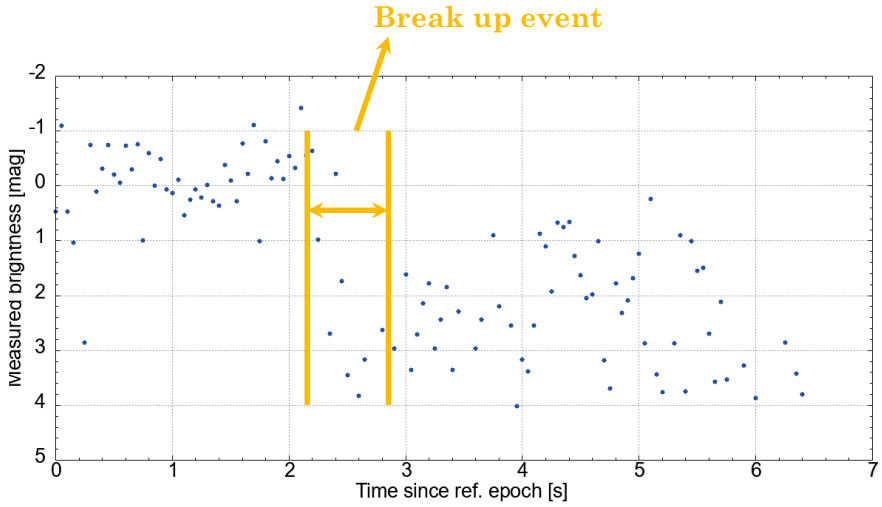


Figure – Measured brightness (calibrated) of bolid M20160809_001049 as a function of time.

Possible reentry example, heliocentric orbit solution

- Solution for heliocentric orbit indicates meteoroid orbit with very low inclination and perihelion close to 1 AU

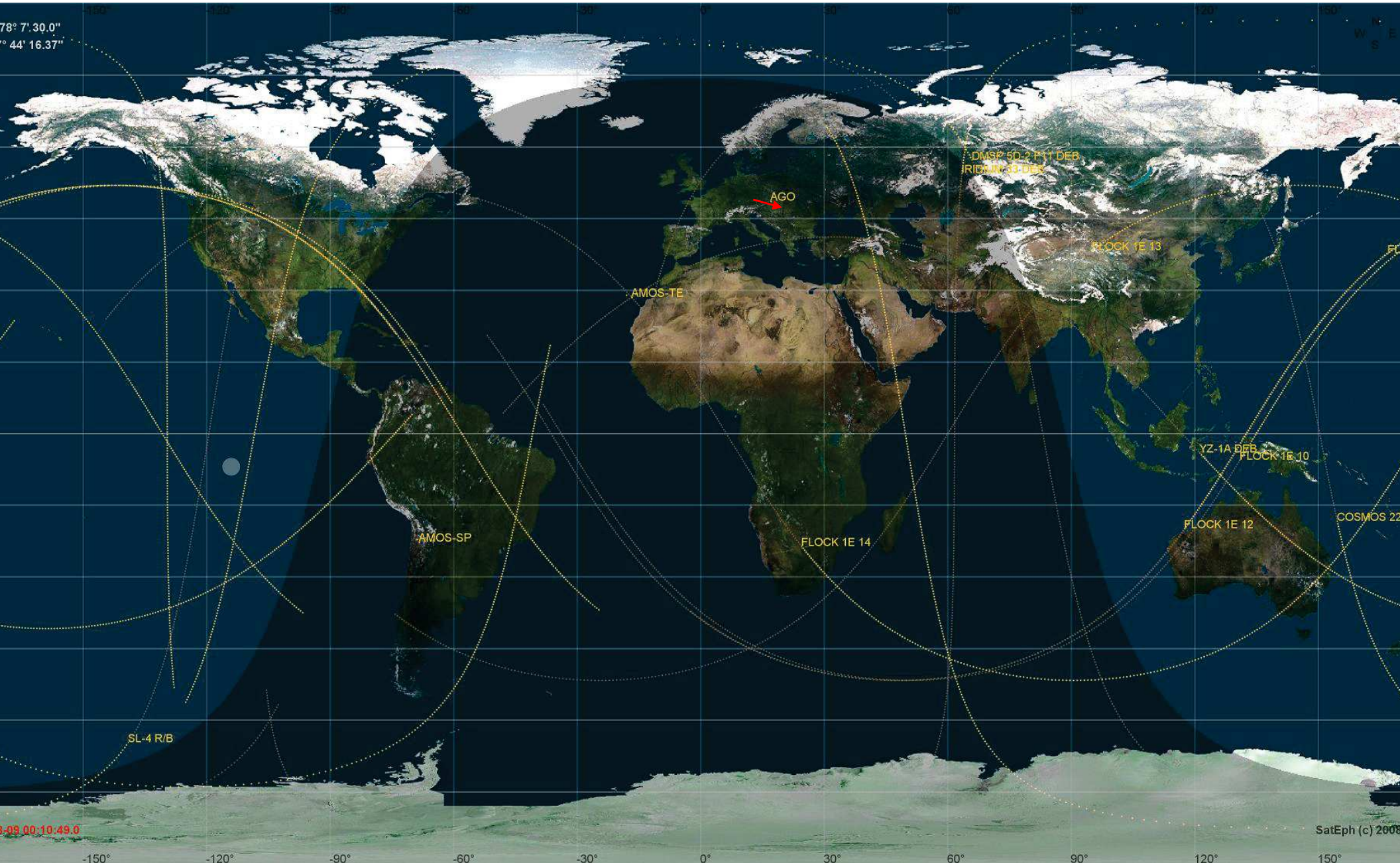
- In case object on geocentric orbit, expected low inclination and SMA ~ 1 AU

Parameter	Value
Final velocity	7.9 km/s
Semi-major axis	1.45 AU
Eccentricity	0.3
Inclination	1.44°
Perihelion	1.01 AU

Possible reentry example, candidates

- Used space-track.org webpage to associate the event with TLE objects
- 10 objects re-entered during period ± 1 week from the bolide observation
- 5 objects debris from Flock 1E satellite

- Other 5 objects, 1 R/B (SL-4 R/B) and 4 debris (Iridium 33 DEB, DMSP 5D-2 F11 DEB, YZ-1A DEB, COSMOS 2251 DEB)


78° 7'.30.0"
° 44' 16.37"
AGO
AMOS-TE
AMOS-SP
FLOCK 1E 14
FLOCK 1E 13
FLOCK 1E 12
FLOCK 1E 10
YZ-1A DEB
SL-4 R/B
SatEph (c) 2008
-150°
-120°
-90°
-60°
-30°
0°
30°
60°
90°
120°
150°

Reentry example, geocentric orbit solution

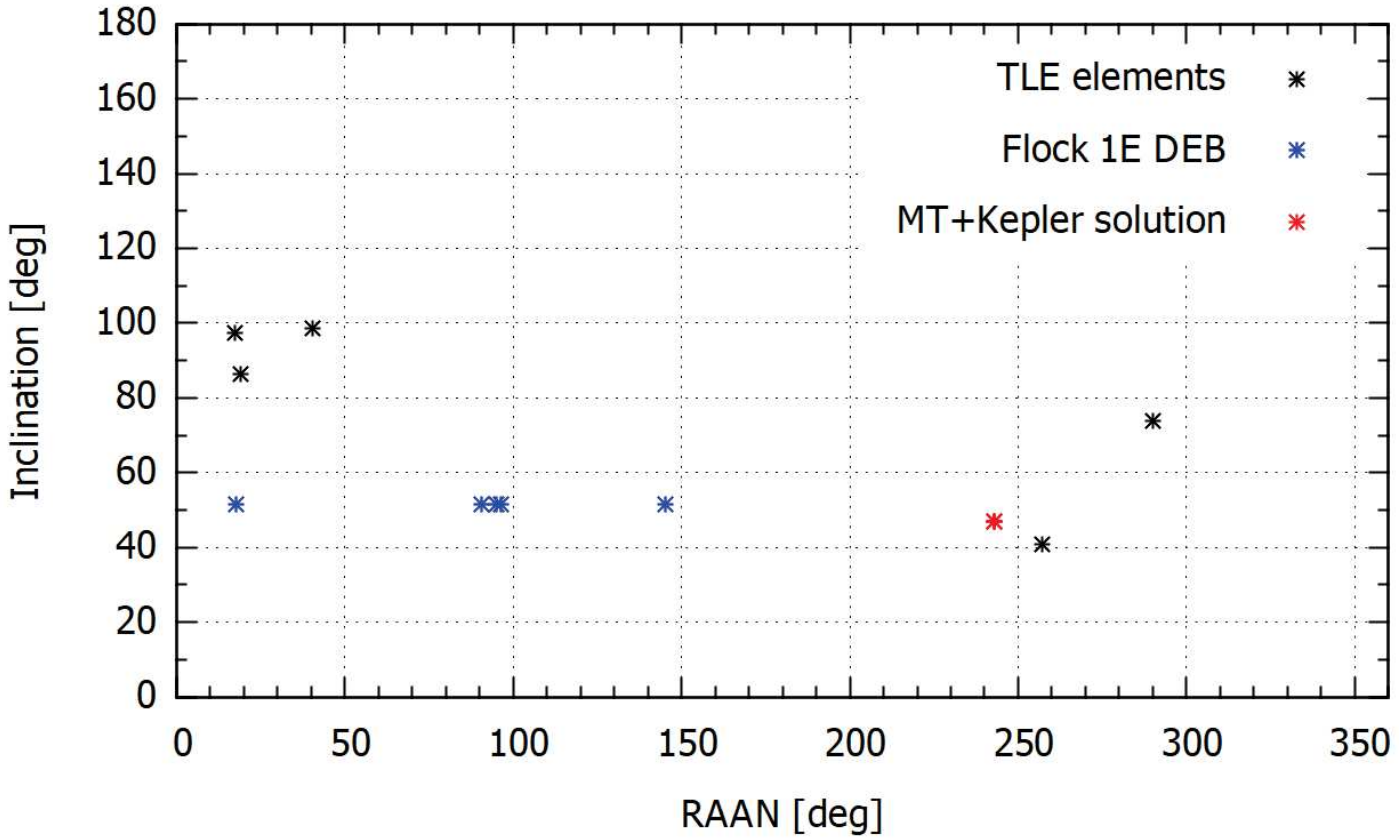
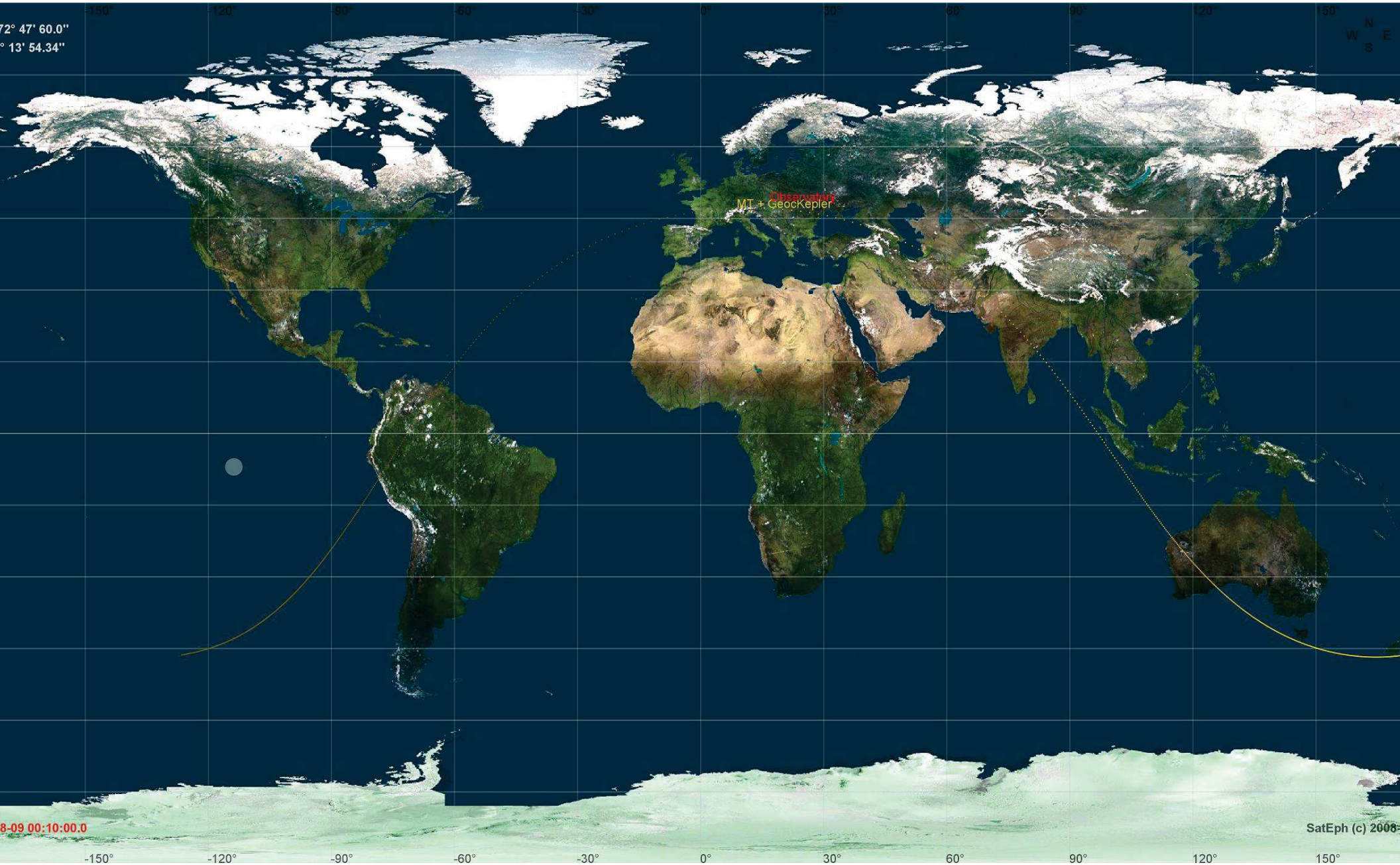


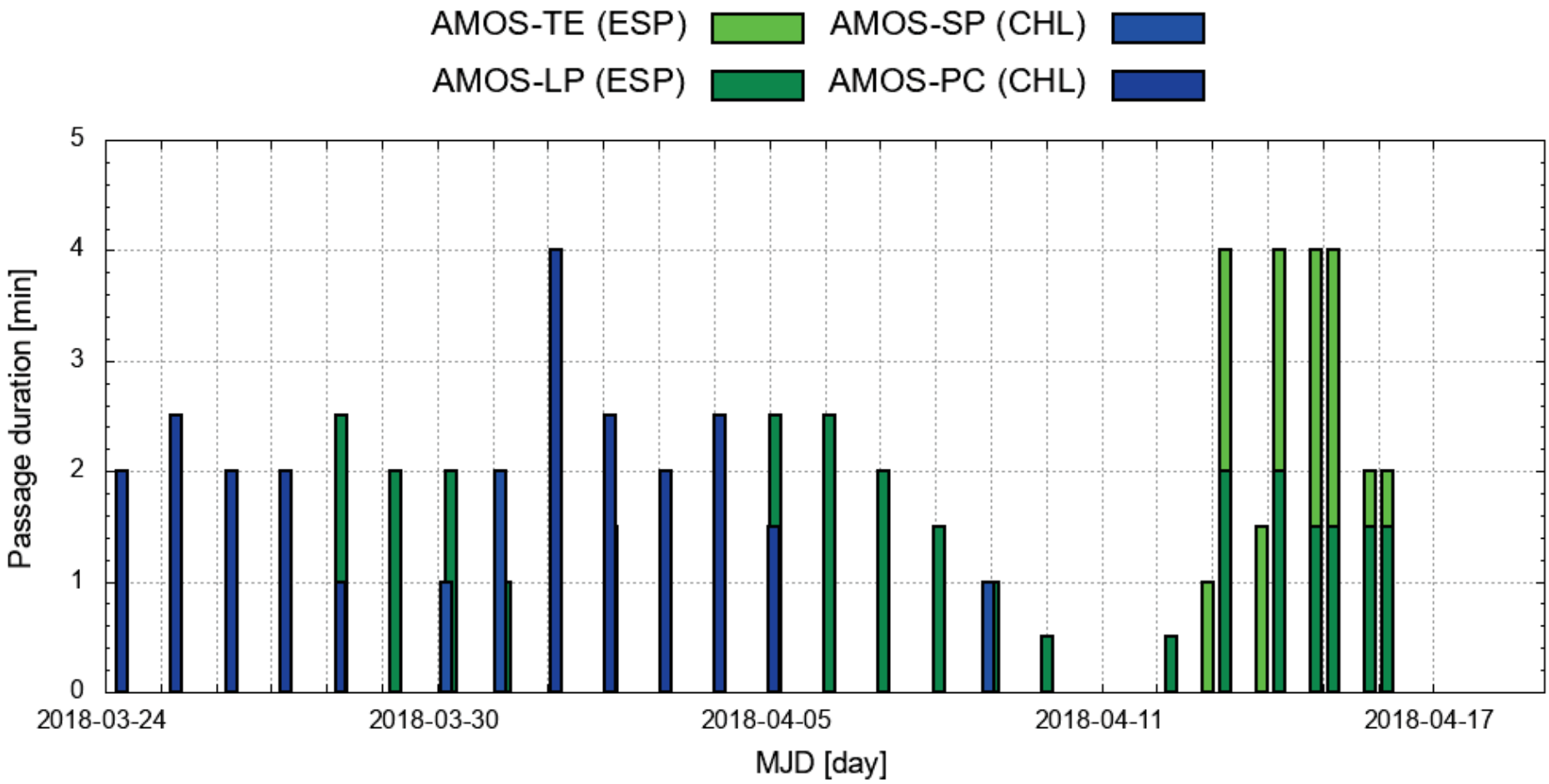
Figure – RAAN vs inclination for 10 TLE objects (black and blue asterix) and a solution for geocentric plane obtained for bolide M20160809_001000 from vectors calculated by MeteorTrajectory S/W (red asrterix).


72° 47' 60.0"
° 13' 54.34"
Observatory
MI + GeocKepler
8-09 00:10:00.0
SatEph (c) 2008
-150°
-120°
-90°
-60°
-30°
0°
30°
60°
90°
120°
150°

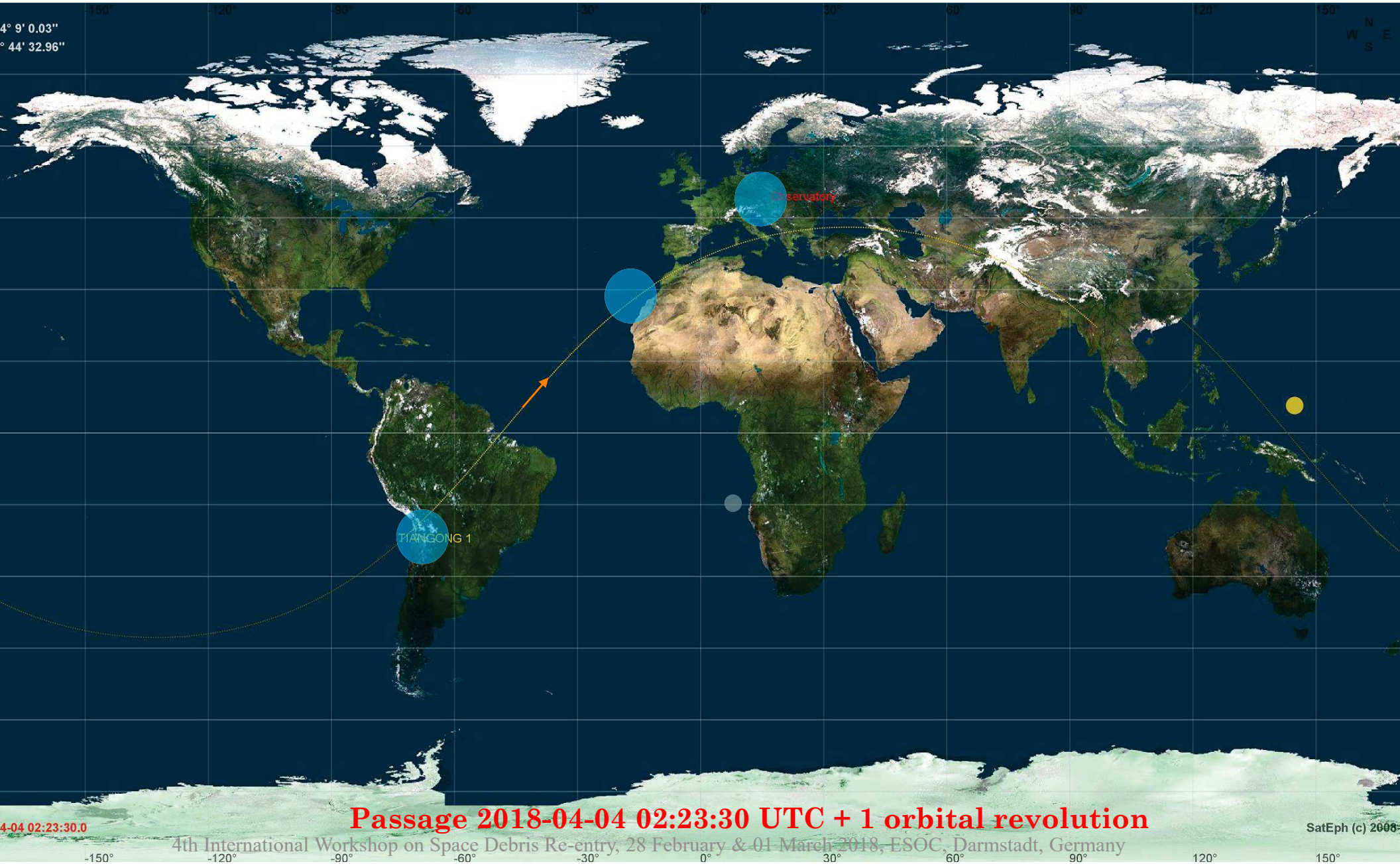
Tiangong 1 case

- According to space-track.org (ref. date 2018-02-21) reentry expected 2018-04-10
- According to ESA the reentry window (ref. date 2018-02-23) is 2018-03-24 – 2018-04-19
- Still large error margin of ± ~2.0 weeks
- Investigated the observation windows for AMOS cameras, used SGP4 and TLE (ref. epoch 2018-02-23)
- Investigated period **2018-03-24 – 2018-04-19**

Tiangong 1 case, observation window



ıre – Reentry visibility windows for four different AMOS sites situated on Canary islands (AMOS-TE and AMOS-LP) and in Chile (AMOS-PC and OS-SP). Condition for valid window is sun elevation < -10° and object's elevation > 20°.



Passage 2018-04-04 02:23:30 UTC + 1 orbital revolution

AMOS products, summary

- AMOS, possible contribution if event (e.g. Tiangong 1) captured with AMOS systems:
- **Before reentry**
  - Photometric measurements – attitude, cadence is 20fps, lim. mag < +5
  - Astrometric measurements (only selected stations or portable stations) – orbit improvement, accuracy 0.03° – 0.05° (1.8' – 3.0')
- **During reentry**
  - Brightness variation
  - Atmospheric trajectory – accuracy of ~ 30 – 50 m
  - Atmospheric velocity – accuracy of 0.1 – 0.3 km/s
  - Time and position of fragmentation events
  - Spectra and its change – resolution of spectra ~ 0.5 nm
- **After reentry**
  - Impact location calculation – accuracy ~ 0.1 – 1.0 km (including wind model)

Thank you for your attention.

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W: http://www.daa.fmph.uniba.sk/debris_sk