The 2011 Draconid shower risk to Earth-orbiting satellites

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Current meteor shower forecast models project a strong Draconid outburst, possibly a storm, on October 8, 2011, with a duration of approximately 7 hours and peaking between 19 and 21 hours UT. Predicted rates span an order of magnitude, with maximum ZHRs ranging from a few tens to several hundred. Calibration of the NASA MSFC Meteoroid Stream Model[1] to radar and optical observations of past apparitions, particularly the 2005 Draconid outburst[2], suggest that the maximum rate will be several hundreds per hour. Given the high spatial density of the Draconid stream, this implies a maximum meteoroid flux of 5-10 Draconids km^{-2} hr^{-1} (to a limiting diameter of 1 mm), some 25-50 times greater than the normal sporadic flux of 0.2 km^{-2} hr^{-1} for particles of this size. Total outburst fluence, assuming a maximum ZHR of 750, is 15.5 Draconids km^{-2}, resulting in an overall 10x risk increase to spacecraft surfaces vulnerable to hypervelocity impacts by 1 mm particles.

It is now established that a significant fraction of spacecraft anomalies produced by shower meteoroids (e.g. OLYMPUS and LandSat 5[3]) are caused by electrostatic discharges produced by meteoroid impacts. In these cases, the charge generated is roughly proportional to $v^{3.5}$[4], giving a Draconid moving at 20 km s^{-1} approximately 1/80th the electrical damage potential of a Leonid of the same mass. In other words, a Draconid outburst with a maximum ZHR of 800 presents the same electrical risk as a normal Leonid shower with a ZHR of 15, assuming the mass indices and shower durations are the same. This is supported by the fact that no spacecraft electrical anomalies were reported during the strong Draconid outbursts of 1985 and 1998. However, the lack of past anomalies should not be taken as *carte blanche* for satellite operators to ignore the 2011 Draconids, as the upcoming outburst will constitute a period of enhanced risk for vehicles in near-Earth space. Each spacecraft is unique, and components have differing damage thresholds; programs are encouraged to conduct analyses to determine whether or not mitigation strategies are necessary for their vehicles.

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[1] D. E. Moser and W. J. Cooke, *Earth Moon Planet.*, 102, 285 (2008).
[2] M. Campbell-Brown et al., *Astron. Astrophys.*, 451, 339 (2006).
[3] S. Close, personal communication (2009).
[4] R. D. Caswell et al., *Int. J. Impact Eng.*, 17, 139 (1995).

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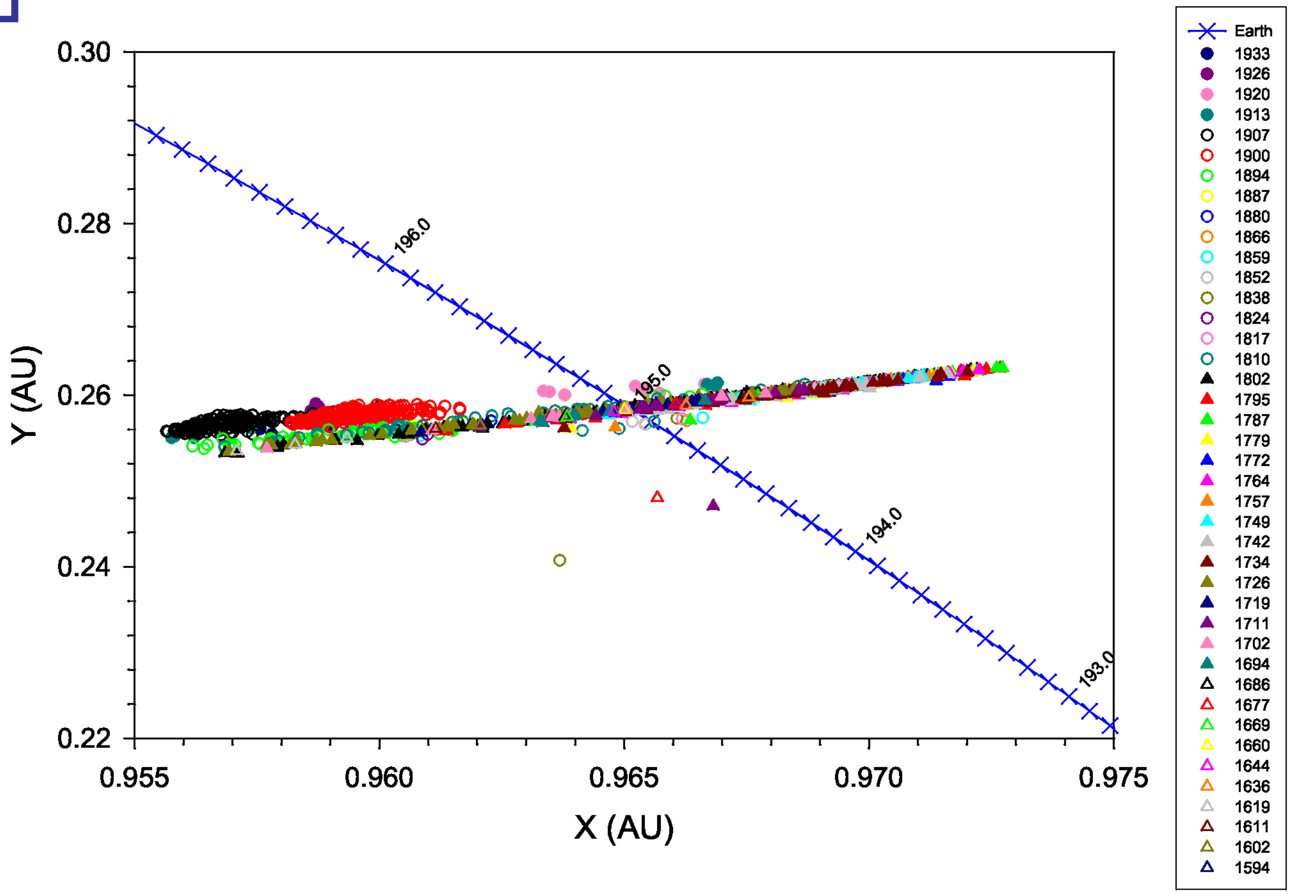
Visual forecast summary

	Peak UT	Max ZHR
NASA/MSFC	Oct 8 19:52	~750
Vaubaillon/Sato/Watanabe	Oct 8 19:56	<200
Maslov	Oct 8 20:42	40-50

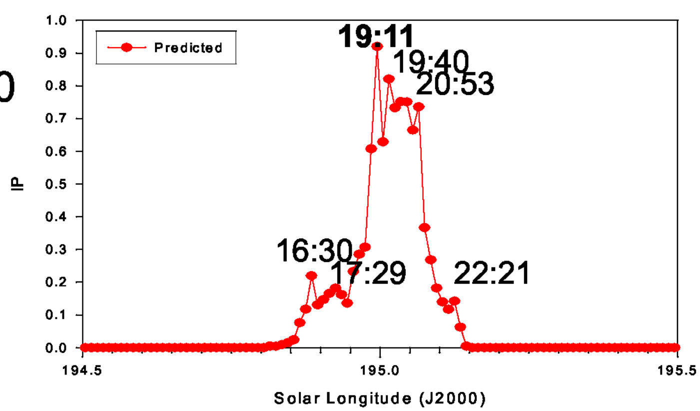
- Draconid outbursts are not noted for bright meteors
- Moon will strongly interfere (waxing gibbous, 90% illumination)

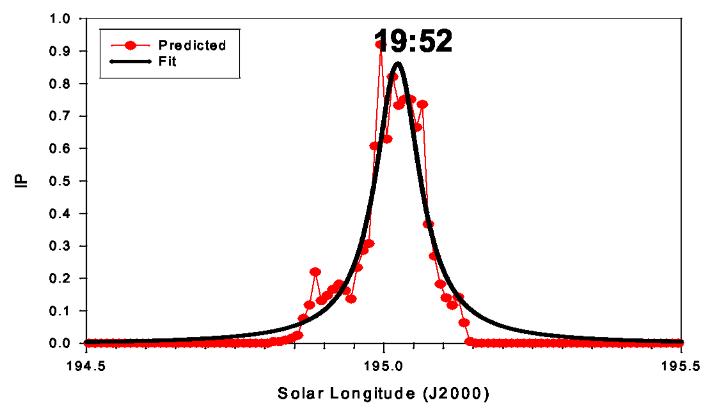
MSFC Model

2011 Draconids

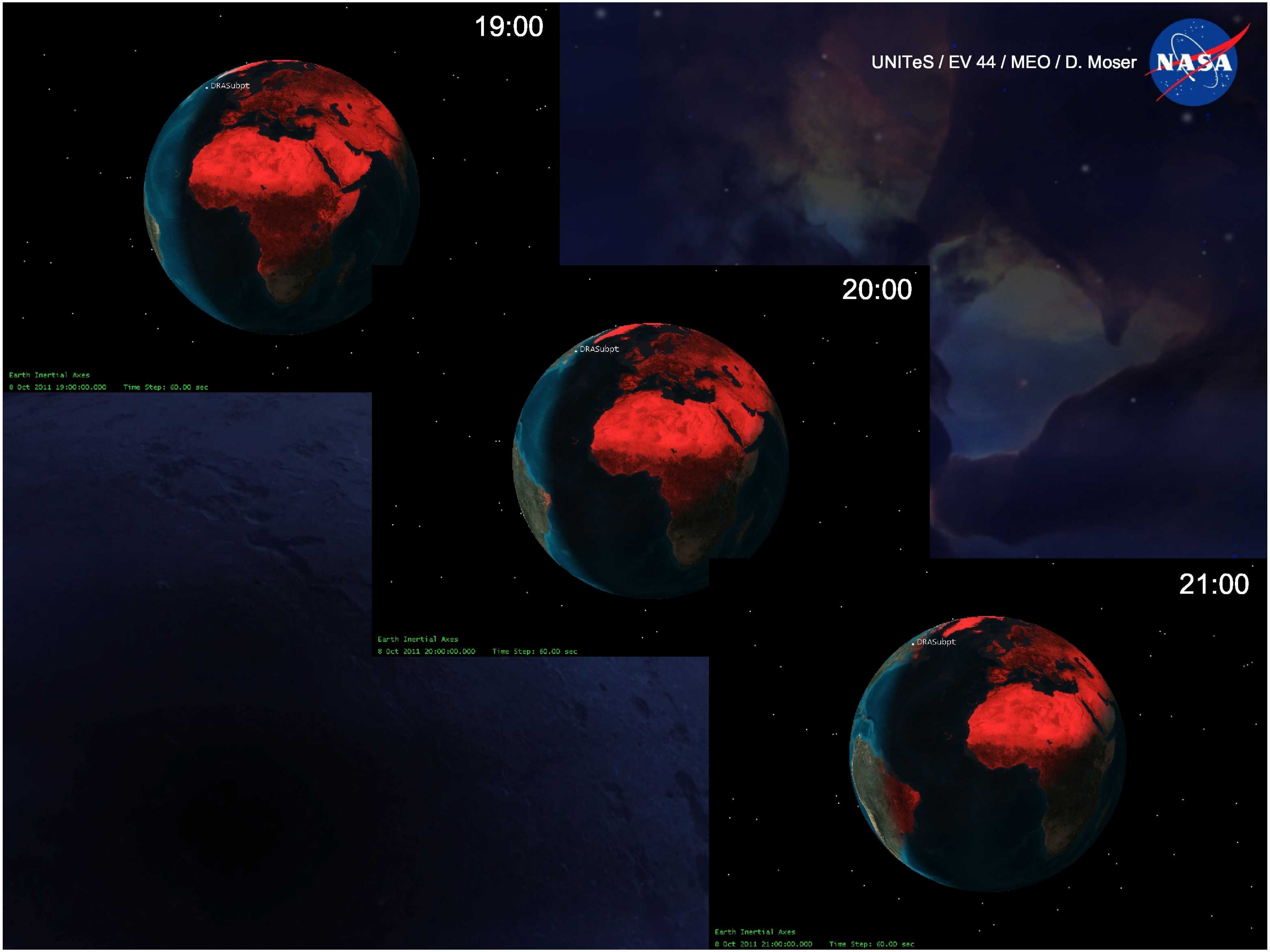


12/2007
ZHR 800

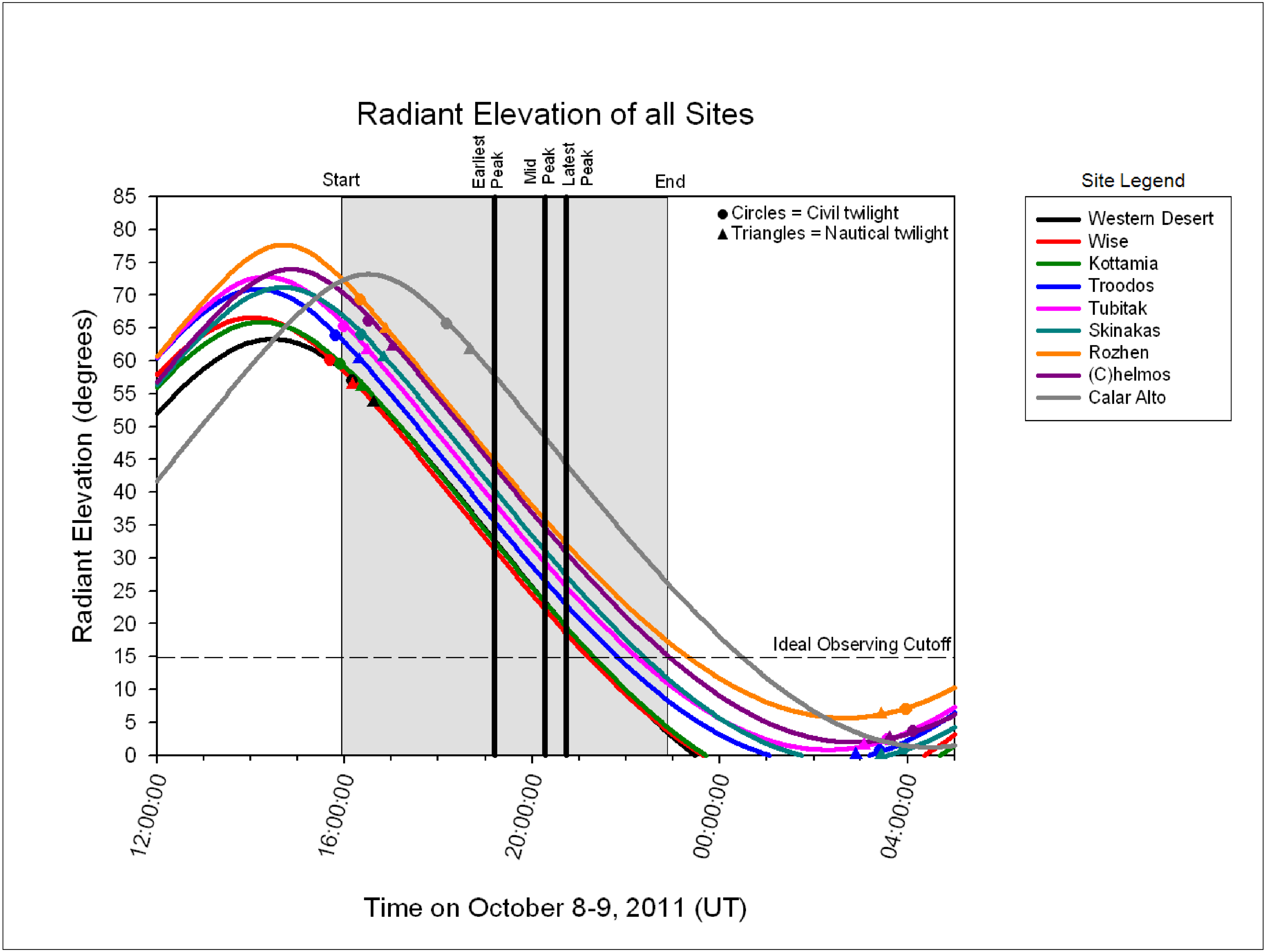




4/2008
ZHR 750

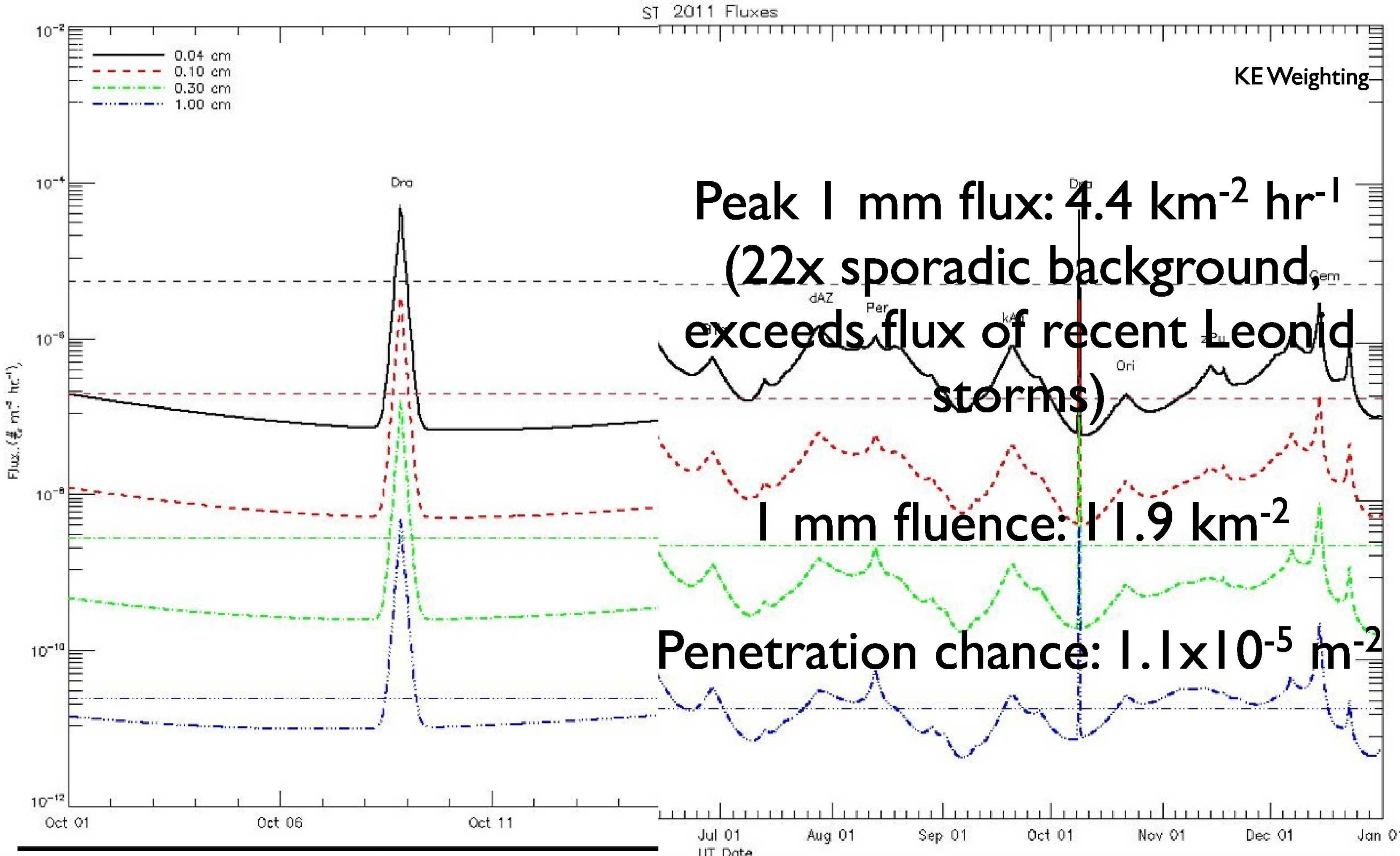

19:00
UNITeS / EV 44 / MEO / D. Moser
DRASubpt
Earth Inertial Axes
8 Oct 2011 19:00:00.000 Time Step: 60.00 sec
20:00
DRASubpt
Earth Inertial Axes
8 Oct 2011 20:00:00.000 Time Step: 60.00 sec
21:00
DRASubpt
Earth Inertial Axes
8 Oct 2011 21:00:00.000 Time Step: 60.00 sec

Site Locations



Radiant Elevation of all Sites
Start
Earliest Peak
Mid Peak
Latest Peak
End
● Circles = Civil twilight
▲ Triangles = Nautical twilight
Ideal Observing Cutoff
Radiant Elevation (degrees)
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
12:00:00
16:00:00
20:00:00
00:00:00
04:00:00
Time on October 8-9, 2011 (UT)
Site Legend
Western Desert
Wise
Kottamia
Troodos
Tubitak
Skinakas
Rozhen
(C)helmos
Calar Alto

LEO Fluxes



Peak 1 mm flux: 4.4 km^{-2} hr^{-1} (22x sporadic background, exceeds flux of recent Leonid storms)

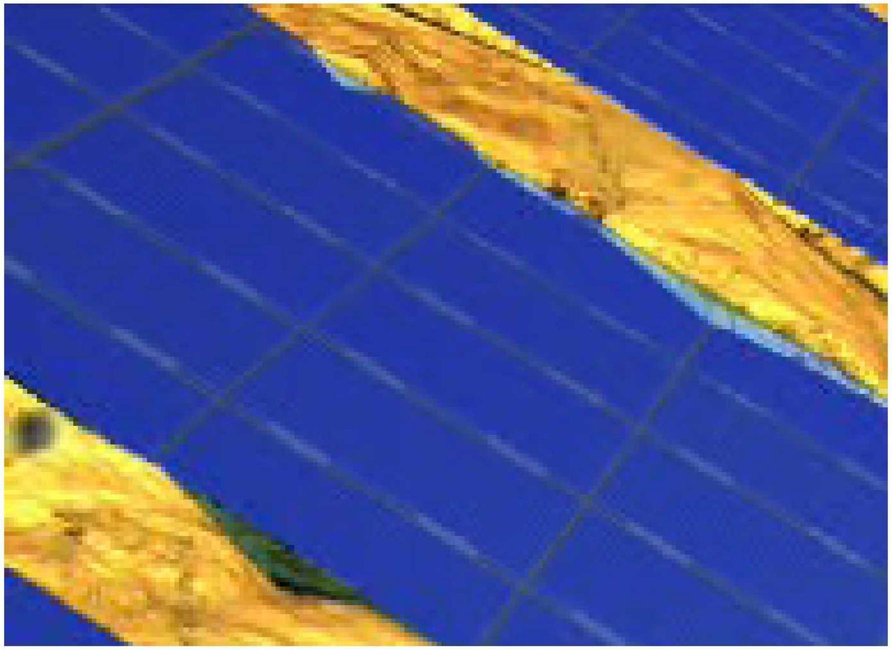
1 mm fluence: 11.9 km^{-2}

Penetration chance: $1.1x10^{-5}$ m^{-2}

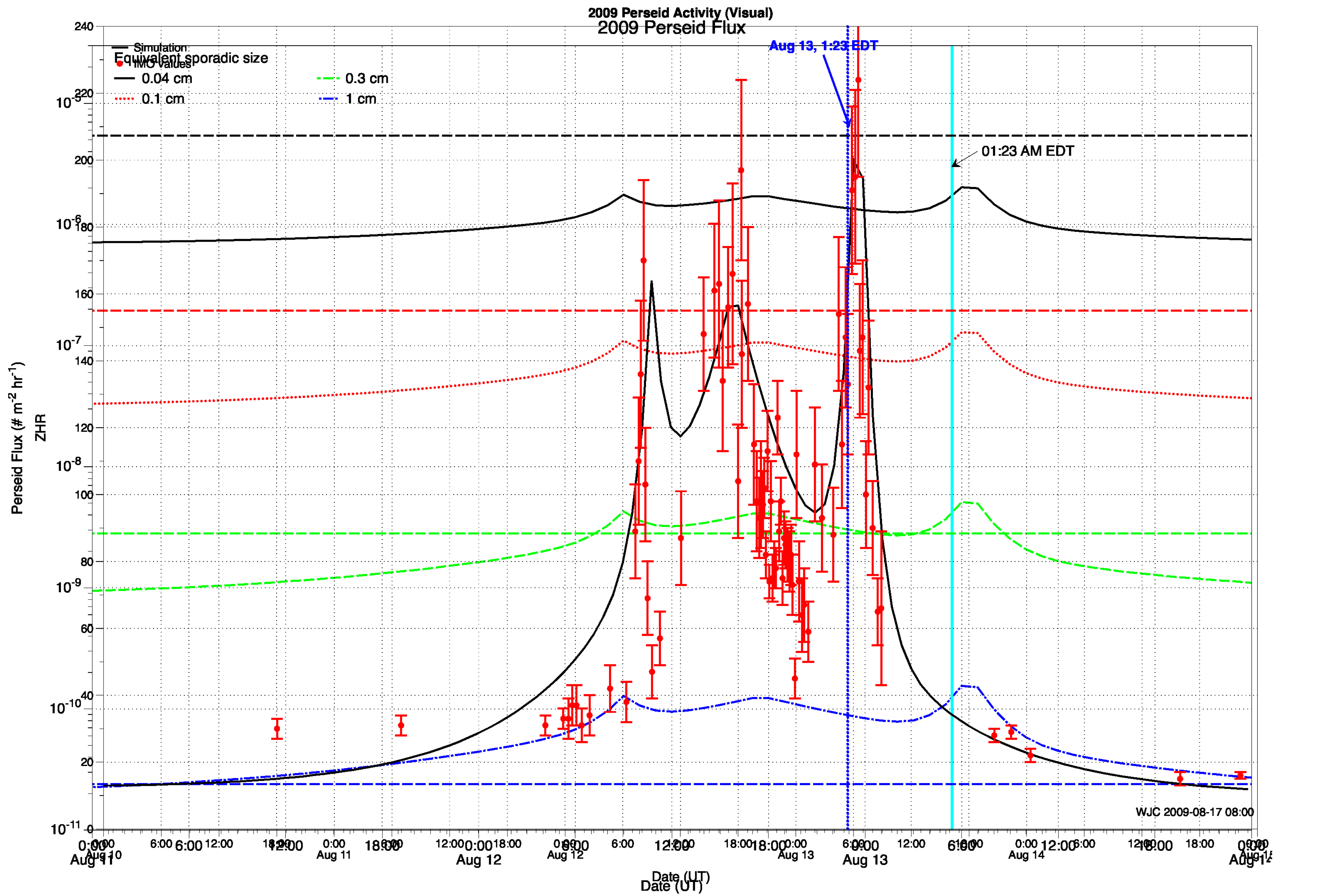
Spacecraft concerns

- Meteoroid-induced spacecraft anomalies generally fall into two categories:
    - Attitude displacements (e.g. Chandra, 2003)
    - Electrical/component failures (e.g. OLYMPUS, 1993)
- Electrical failures occur during meteor showers with fast meteoroids (Perseids, Leonids)
- Potential current produced by a meteoroid strike on a charged surface:

$$I = k\, m^{1.02}\, v^{4.48}\, L^{-1}$$



ESA video generated to explain
OLYMPUS anomaly



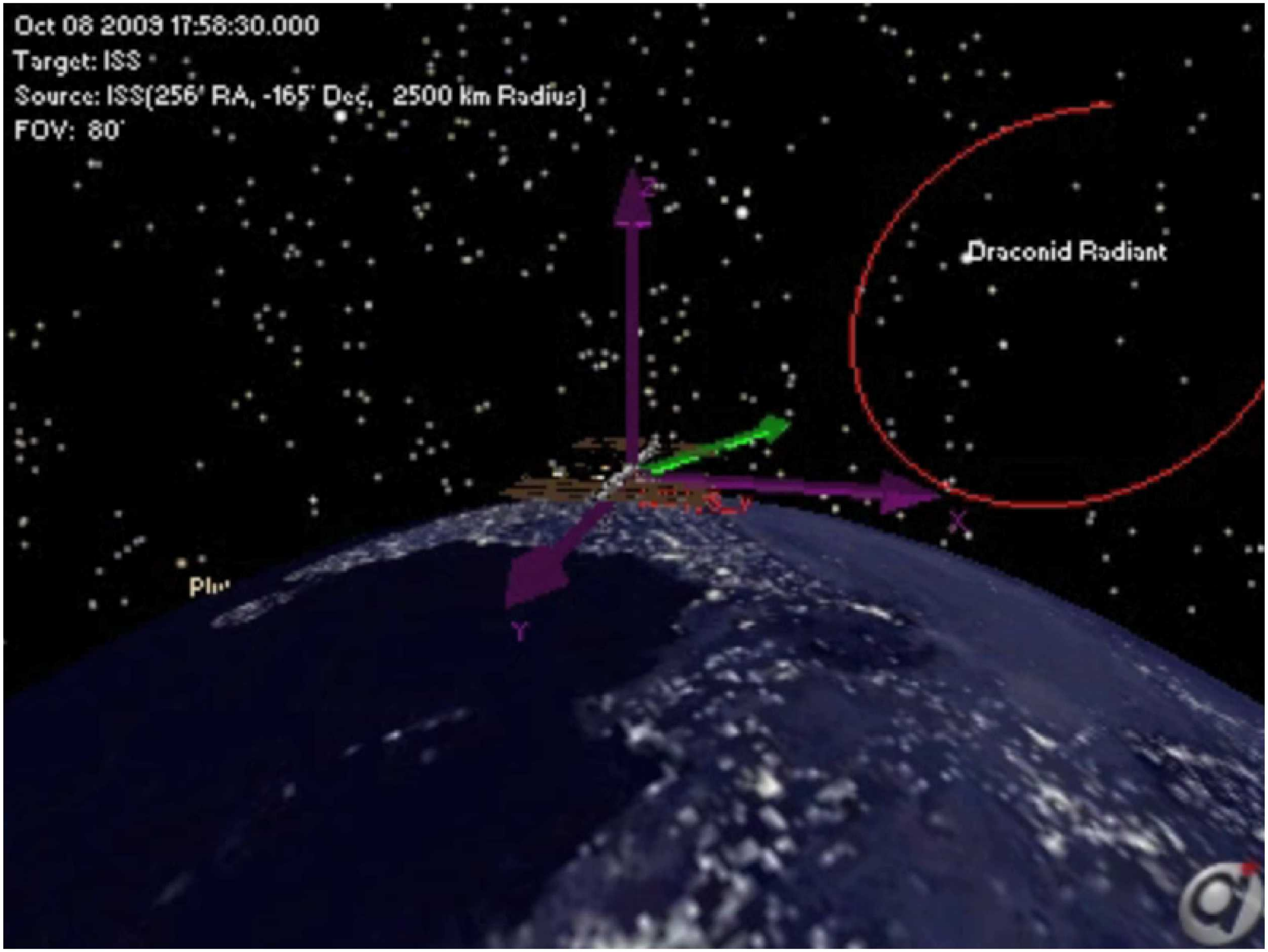
2009 Perseid Activity (Visual)
2009 Perseid Flux
Simulation
IMO values
Equivalent sporadic size
0.04 cm
0.1 cm
0.3 cm
1 cm
Aug 13, 1:23 EDT
01:23 AM EDT
Perseid Flux (# m-2 hr-1)
ZHR
Date (UT)
Aug 11
Aug 12
Aug 13
Aug 14
WJC 2009-08-17 08:00

Draconid Electrical Risk

- Draconid speed is ~20 km s^{-1}; that for Perseids is 59 km s^{-1}
- Electrical risk for Draconids is therefore $(20/59)^{4.48}$ or 1/127 that of a Perseid
- Explains why we do not have any known Draconid electrical anomalies, even during 1998 and 2005 outbursts

2011 Draconids from ISS

- Radiant only 20° from orbit pole - Draconid radiant always visible from ISS in 2011
- ISS motion causes significant aberration in radiant direction
- ISS heavily armored



Oct 08 2009 17:58:30.000
Target: ISS
Source: ISS(256' RA, -165' Dec, 2500 km Radius)
FOV: 80'
Z
Draconid Radiant
X
Y

Summary

- Bright Moon + small meteoroids + downward trend in forecast zhr indicate 2011 Draconids may not be visually impressive. Radiant circumpolar from CMOR radar.
- Flux levels in Earth orbit should be comparable to recent Leonid storms; however, chance of electrical anomalies lower due to Draconid slow speed
- Forecast will be released to spacecraft operators in early 2011. Will encompass range of existing predictions and will be updated as needed
- Already working with NASA programs to assess specific spacecraft risks