Spacecraft risk posed by the 2016 Perseid outburst

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At sub-mm & mm sizes, the average flux of meteor showers is an order of magnitude below the sporadic (background) flux.
Storms vs. Sporadics

- Instantaneous storm flux required to penetrate a surface can exceed the background by several orders of magnitude.
- Penetrating fluence can range anywhere from a few days to a year’s equivalent exposure to background meteors.
Notes on meteoroid risk

• Sporadic meteoroid background is directional (not isotropic) and accounts for 90% of the meteoroid risk to a typical spacecraft
• Meteor showers get all the press, but account for only ~10% of spacecraft risk
  – Bias towards assigning meteoroid cause to anomalies during meteor showers
• Design to sporadic background, mitigate outbursts/storms by operational means
• Gun tests/damage equations focus on physical damage
  – hard to assess other anomaly causes, such as meteoroid generated plasma
Could it be a meteoroid hit?

• Are the anomaly characteristics consistent with a particle impact?
  – Sudden change in attitude most common

• Was there a meteor outburst or storm at the time of the anomaly?
  – If yes, was the shower radiant visible from the spacecraft?
  – If yes, did the affected surface “see” the shower radiant?
  – If yes, shower impact possible

• Compare meteoroid (sporadic + shower) flux to orbital debris flux at spacecraft location to establish likelihood.
  – If affected surface is sun-fixed, must use a directional meteoroid model to compute flux
Affected Panels

MM/OD Monitoring
15 Indications: 10 on Port, 5 on Stbd
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Perseid Summary

- **Parent comet:** 109P/Swift-Tuttle
- **Peak:** Max. around Aug 11-13
- **Activity range:** Jul 17 – Aug 24
- **Speed:** 59 km/s (2.5-3x average sporadic speed)
- **Radiant:** $\alpha = 48^\circ$, $\delta = +58^\circ$ at peak
- **Typical ZHR:** 100/hr

Perseid fireball recorded Aug 12, 2012
Rich in bright meteors
The 1993 Perseids

- The Perseid parent, Comet Swift-Tuttle, reached perihelion in late 1992. High Perseid rates were also seen near the last perihelion passage of the comet, in the 1860’s.
- Many astronomers postulated a dense concentration of dust near the comet’s orbit.
- Perseids had never been observed to reach storm levels, but historical record showed outbursts of a few hundred per hour.
• STS-51 launch, slated for late July delayed until after Perseid peak (August 12)
  – NASA unable to predict shower intensity
  – Head of astronaut office decided to delay launch

• Perseid outburst with ZHR of ~360 occurred, peaking at 03:30 UT on August 12.

• Cosmonauts aboard Mir space station reported hearing “pings” on outside of craft, and retreated to Soyuz (Science News, 1993)
Spacecraft struck by Perseids

**Olympus**
ESA communication satellite

Struck by a Perseid near the time of the shower peak in August 1993

Sent tumbling, fuel exhausted, end of mission

**Landsat-5**
NASA/USGS imaging satellite

Struck by a Perseid near the time of the shower peak in August 2009

Sent tumbling, stabilized, returned to normal operations

6/6/2016  Meteoroids 2016
Olympus
• Technology demonstration satellite - launched 12 July 1989; largest civilian comm satellite built up to that time

• South solar panel stopped tracking the Sun in January 1991 (particle impact?)

• 19 June 1991– attitude control issue; incorrect commands uplinked from ground resulted in tumbling and drift off station. Vehicle recovered and put back into service at 19W on 7 August 1992

• Olympus roll gyro stops at 23:32 UTC August 11 during 1993 Perseid outburst. Spacecraft enters Emergency Sun Acquisition (ESA) mode and fails to acquire the Sun
• Attempts to recover spacecraft exhausted most of remaining fuel, making it impossible to return the vehicle to service. Mission was terminated August 12, and the spacecraft was moved into a disposal orbit 200 km below GEO

• ESA anomaly investigation attributed the failure to a Perseid strike on the south solar array
  – South array had 8.5 m$^2$ of area exposed to the stream.
  – There was a possible conducting path to the gyro though the spacecraft umbilical
  – Ground hypervelocity tests showed plasma generated by a meteoroid strike to be proportional to $v^{3.5}$
Conclusion of investigation: “The impact by a small meteoroid may have generated a plasma triggering a discharge of charged surfaces entering the grounded spacecraft via the umbilical and an external sensor. Such a scenario is particularly interesting for other spacecraft since the Perseid shower is likely to be worse for the next few years.”

Recommendations:
- Minimize the area cross-section as much as possible during the peak period of the shower.
- Prepare operational contingency plans for recovery from and for observation of impacts/plasmas.
- Provide total protection from plasmas through external electrical windows such as sun sensors.
- Ground and cover all interface points such as spacecraft umbilical connections.
Landsat-5

- USGS remote sensing satellite launched into sun-synchronous LEO orbit March, 1984
- Decommissioned June, 2013
- Began tumbling at 5:23 UTC on August 13 2009, just before 3rd and strongest peak of the Perseid shower
- Perseid radiant was 37° above Earth limb at time of anomaly
- Operations restored a week later (August 17)
Thoughts

- Plasma production ($v^{3.5}$) is >40x mass limited and 5x kinetic energy
- Drives affecting particle mass down the mass scale (e.g. 1 mg to $2.3 \times 10^{-5}$ g), with corresponding increase in flux
- Both satellites aging at time of anomalies
- Neither OLYMPUS or Landsat showed momentum disturbances at the times of the anomalies
2016 Perseid model results: MSFC preliminary

Particles ($\beta=10^{-2} - 10^{-5}$) ejected hourly proportional to $r^{-6}$ while Swift-Tuttle is inside 2.5 AU.
Kinetic energy flux

--- Fluxes

- 0.04 cm
- 0.10 cm
- 0.30 cm
- 1.00 cm

SIA  NDA  PER  KCG  NIA  GDO

Flux (#/ m² hr⁻¹)

Aug 01  Aug 06  Aug 11  Aug 16  Aug 21  Aug 26
## 2016 Perseid model results
- **Summary** -

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Increased activity lasts about half a day, from late-Aug 11 to mid-Aug 12.
2016 Perseid model results: Vaubaillon

Approx. region covered by MSFC model

A Perseid outburst in 2016 is predicted by numerous forecasters, similar in intensity to 2009.

Increased activity predicted late Aug 11 – Aug 12, lasting ~half a day

Peak rates predicted between 160 – 580 per hour

Kinetic energy (physical damage) flux is elevated by a few 10’s of % above sporadic background.

The outburst represents a time of increased potential for meteoroid-induced plasmas capable of causing spacecraft anomalies.
References