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2001 Leonid Meteoroid Storm

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Prepared by

D. K. LYNCH and R. W. RUSSELL
Space Science Applications Laboratory
Laboratory Operations

G. E. PETERSON
System Analysis and Simulation Subdivision
Systems Engineering Division

Prepared for

SPACE AND MISSILE SYSTEMS CENTER
AIR FORCE SPACE COMMAND
2430 E. El Segundo Boulevard
Los Angeles Air Force Base, CA 90245

Engineering and Technology Group

THE AEROSPACE CORPORATION
El Segundo, California

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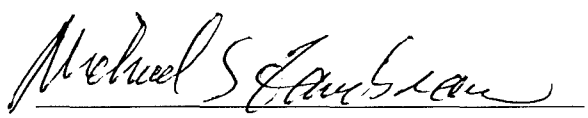

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We present the latest predictions about the November 2001 Leonid Meteor storms and discuss their possible consequences and mitigation strategies.

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2001 Leonid Meteoroid Storm

David K. Lynch and Ray W. Russell

Remote Sensing Department

Laboratory Operations

Glenn E. Peterson

Astrodynamics Department

The Aerospace Corporation

October 11, 2001

310 336-6686 david.k.lynch@aero.org

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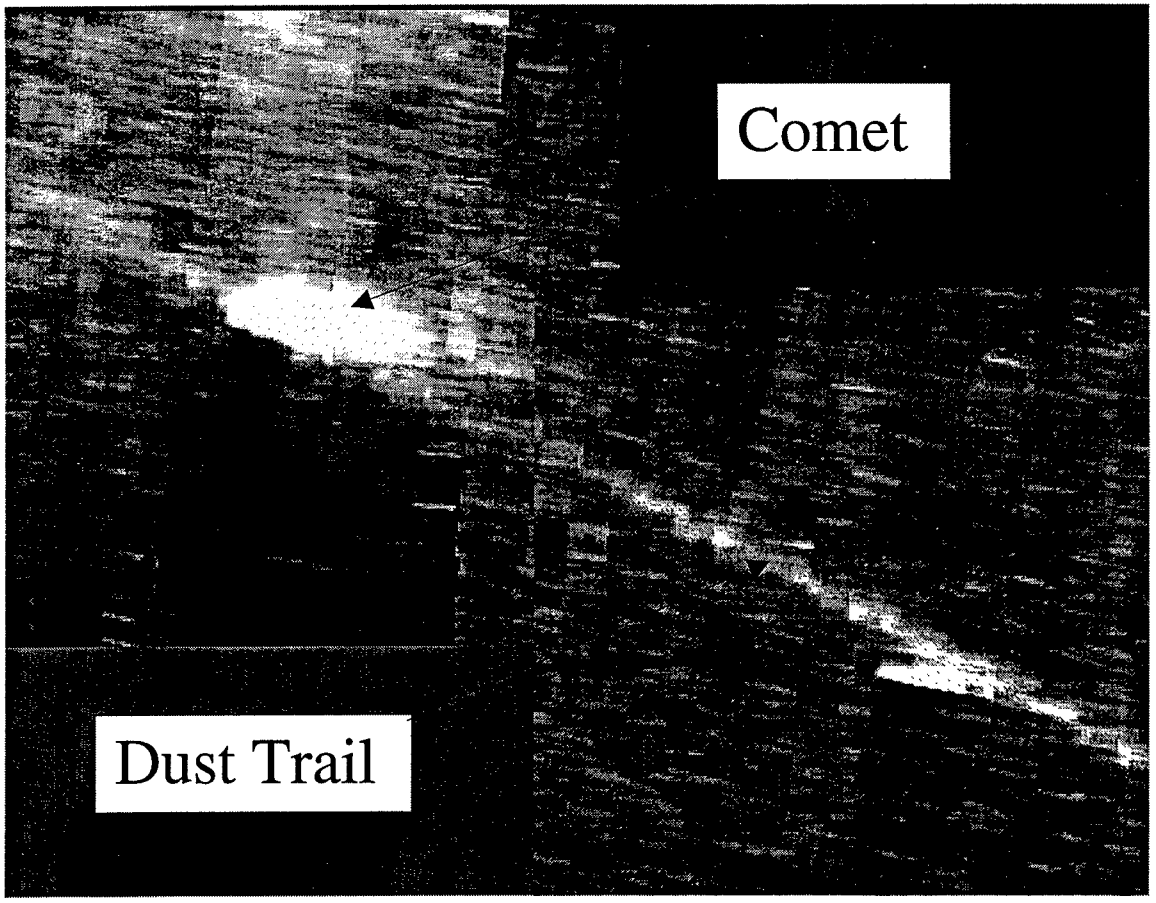
2001 Leonid Storm: *Comparison to Annual Threat*

- The integrated annual visual fluence of normal background meteors is about 9000 (shower and sporadic combined)
  - Mass > 2×10^{-5} g, high-speed ~70 km/sec, Leonid-like.
- The integrated visual fluence of 2001 Leonid storm meteors, also high-speed and in low earth orbit, is about 11,000.
- Given the uncertainties, the 2001 storm will be equivalent to 1-2 year's worth of normal high-speed background meteoroid exposure.

The Leonid threat is not behind us.

2001 Leonid Storm:

Meteoroid Showers Come From Comets



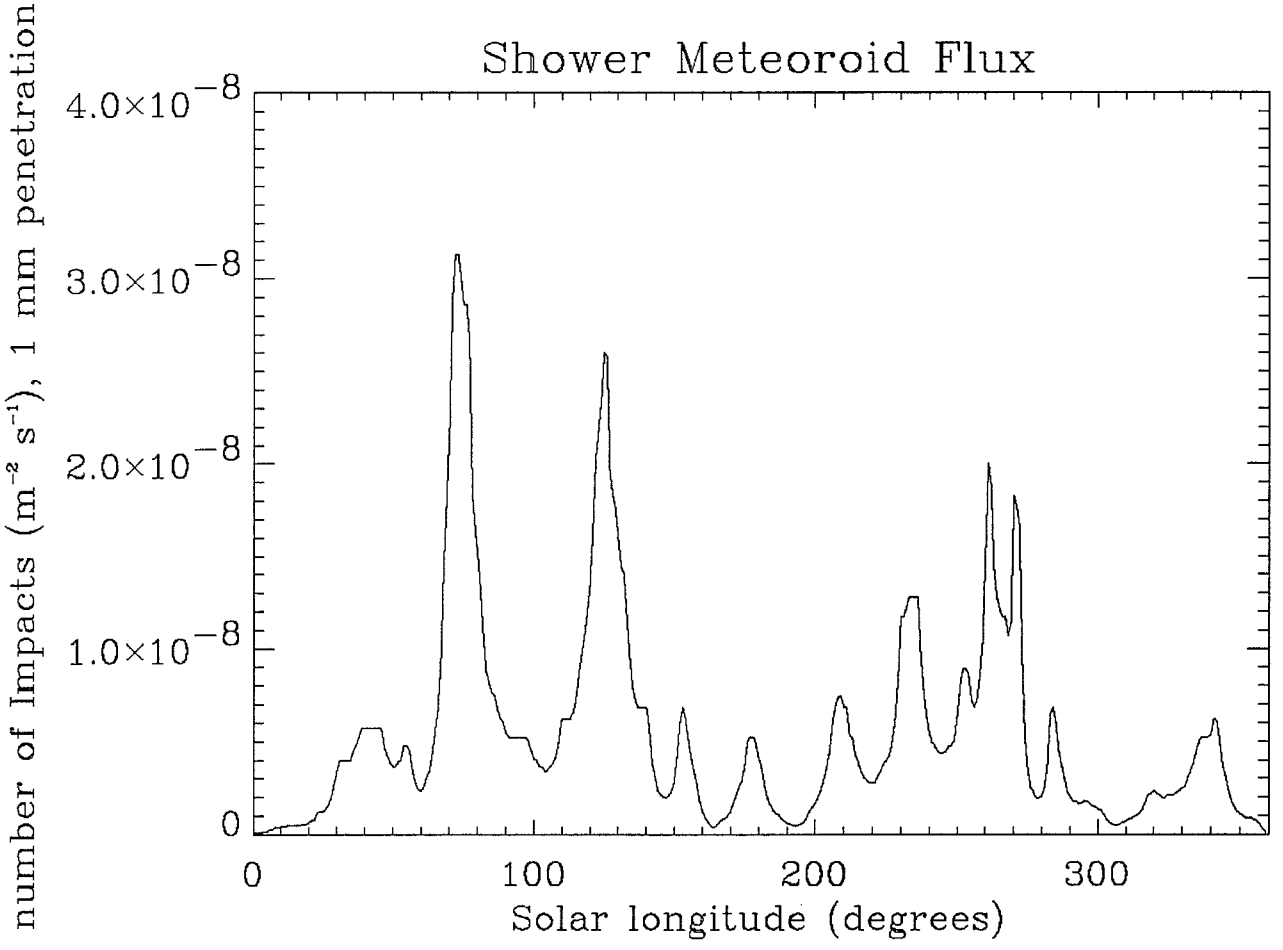
Comet Tempel/2, NASA IRAS imagery at 12 μm by M. Sykes, Univ. Arizona

Each perihelion passage produces a trail in a slightly different orbit.

Showers occur when the Earth passes through the trails.

2001 Leonid Storm:

Normal Shower Background



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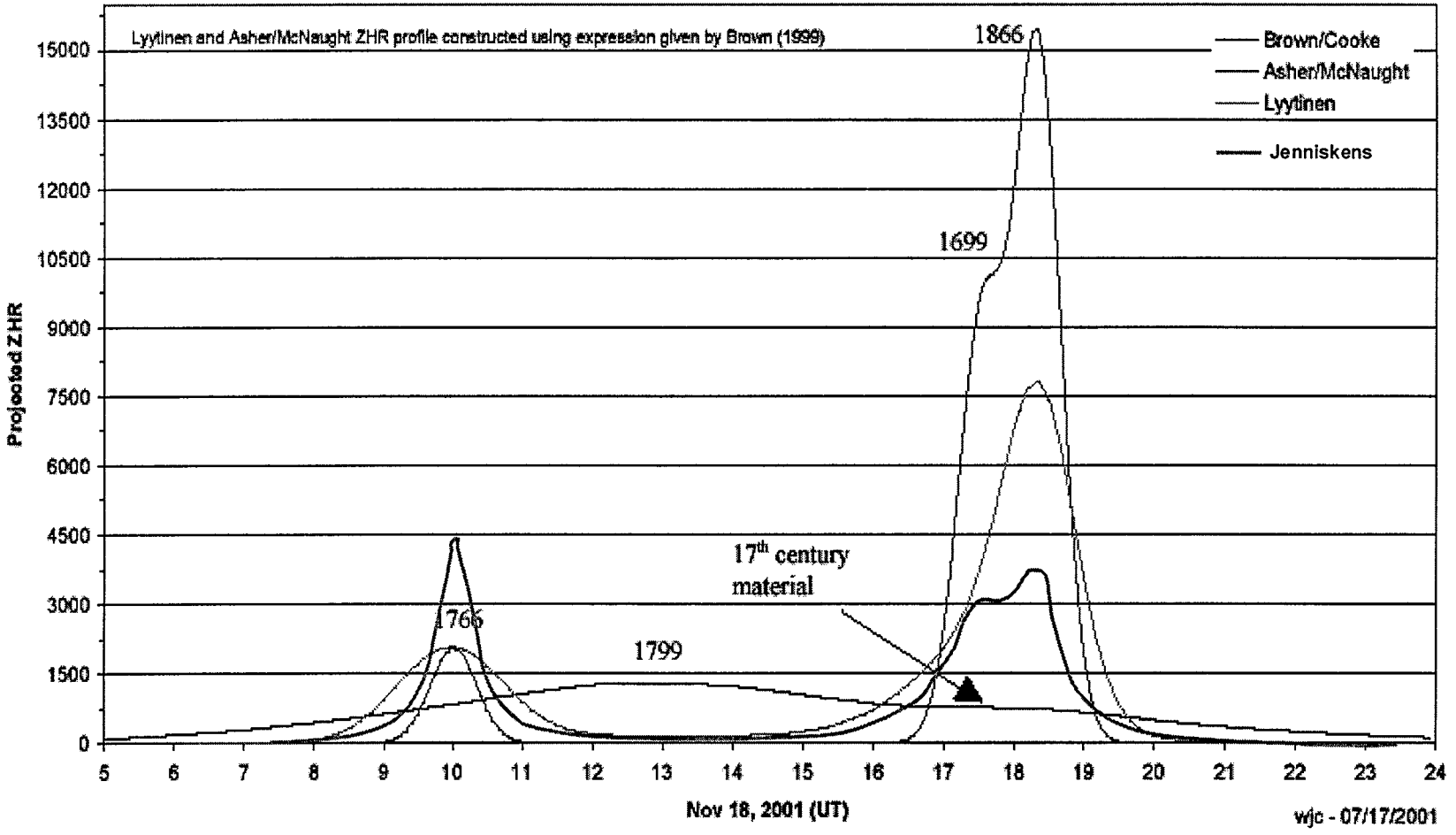
2001 Leonid Storm: Predicted Time Profiles



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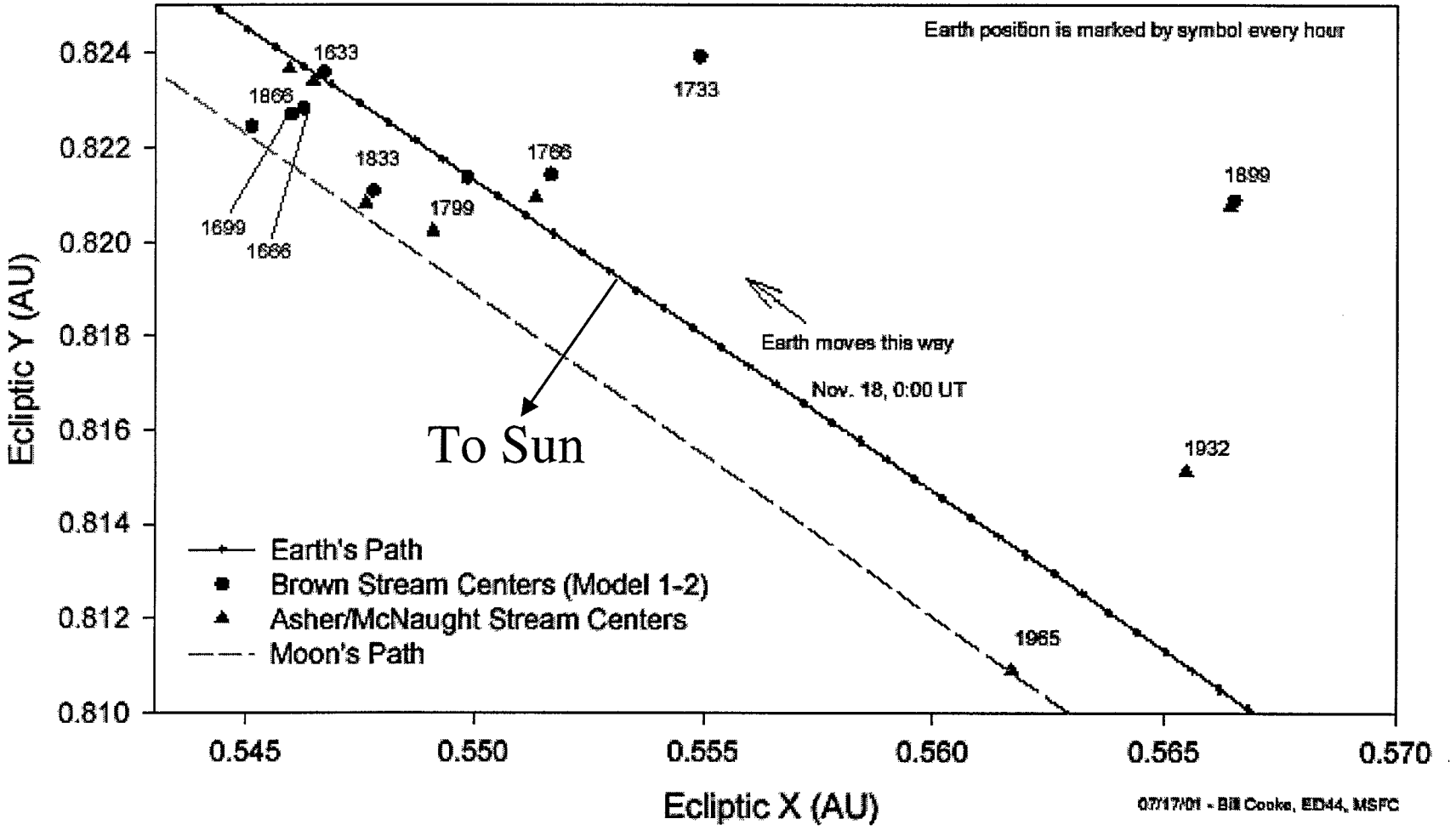
2001 Earth Passage Through Meteoroid Debris Trails



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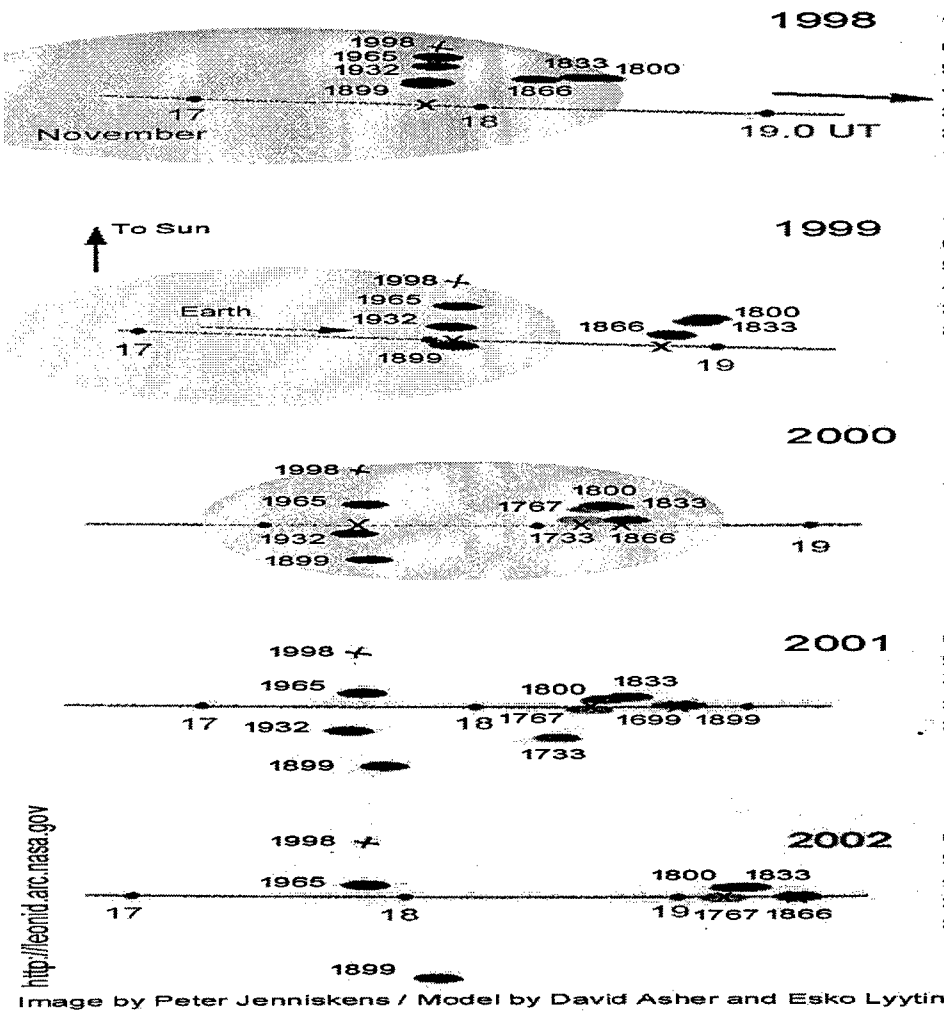
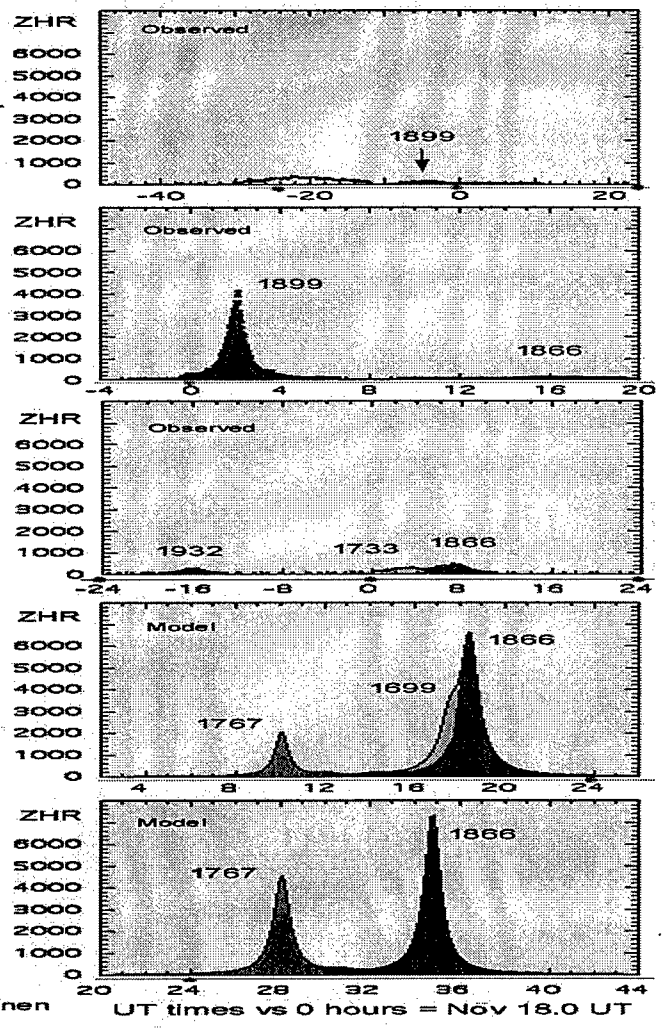
2001 Leonid Storm: The Numbers:

- 1999: mass > 2 x 10^{-5} g. — 2.8 x 10^{-6} m^{-2}
  - Integrated over the main peak
- 2001 is 5 stronger — 1.4 x 10^{-5} m^{-2}
- Satellite cross section of 10 m^2 gives — 1.4 x 10^{-4} hits
- Mass index uncertainties may raise it to — 1.0 x 10^{-3} hits
  - *Hit probability for a single satellite is* — 10^{-4} - 10^{-3}

2001 Leonid Storm:
Recent Fluence History





http://leonid.arc.nasa.gov

Image by Peter Jenniskens / Model by David Asher and Esko Lyytinen

2001 Leonid Storm: Current Approach

- Draft 2001 procedures are based on 1999 response plan developed by Aerospace and AF. Plan summarized by Capt. D. Hembroff AFSPACE/A3. Essentially no problems that year.
- Each system has its own approach.
- Most are reactive in nature.
  - DMSP, DSP, DSCS III, Milstar, UFO, GPS

2001 Leonid Storm: Why make measurements of it?

- To improve the models and therefore our predictive capabilities.
  - Each model has significantly different predictions
    - data from 01 and 02 could discriminate among models
    - improve the best model and improve our predictive capability.
  - Some models predict significant storms in 2002 but need verification.
    - no Leonid storms expected between 2003 and 2099
  - Threat of other known showers could be evaluated if model fidelity can be improved.
    - e.g. Perseids in ~2004-2005, 2028
    - About 20 new comets are discovered every year - improved models should be in place to assess/ predict potential risk (or lack thereof).

2001 Leonid Storm: *Summary*

- Impact probability per square meter of $m>2x10^{-5}$ g particles is 1/10,000 - 1/100,000.
  - For a 10 square meter satellite, impact probability is 1/1000-1/10000.
  - Range is due to uncertainties in dust ejection velocities and in the numerical stability of the codes used to numerically integrate the orbit over many years.

- Knowledge of the damage done by such a particle depends upon where it hits the spacecraft and whether the systems on the s/c can report the hit or its damage can be easily characterized.
  - Hits could pass unnoticed (erosive damage to optics, radiators...)
  - Others could affect electronics or software.
  - Damage potential must be evaluated by SPOs based on each satellite system and its mission.

2001 Leonid Storm: Aerospace Recommendations

- Follow Capt. Hembroff's 1999 approach.
- Spacecraft owners/operators should take measures to log and report all incidents +/- 1 week of Nov 18, 2001 to correlate with other findings.
- If operational impact is low, then it may be possible to:
  - Position solar array edge-on to meteoroid direction
    - Normal sunbathing orientation is close to edge-on.
  - Point telescope away from shower radiant.
  - Minimize commanding of spacecraft during storm window.

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Defense Technical Information Center
8725 John J. Kingman Rd., Ste 944
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