Shower signatures on the Pegasus Spacecraft

All Points

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Overview

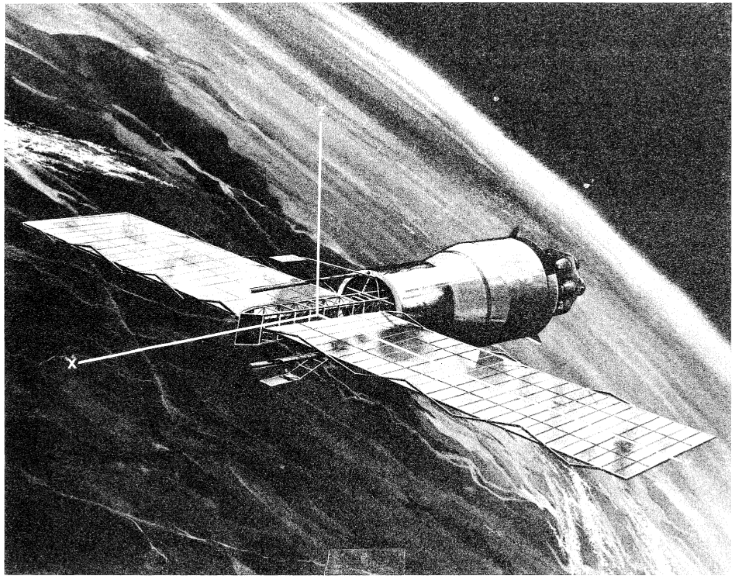
Objective: Examine whether the meteoroid impact detectors on Pegasus I, II, III recorded any shower signatures

Outline:

- Background on the Pegasus Spacecraft
- Review of previous analysis on the meteoroid detector data
- Current Analysis:
  - Shower identification
  - Case study of 1966 Leonids
  - Radiation Pressure effects
  - Case study of Geminids, Arietids, Quadrantids, Ursids
- Conclusions

Introduction to Pegasus:

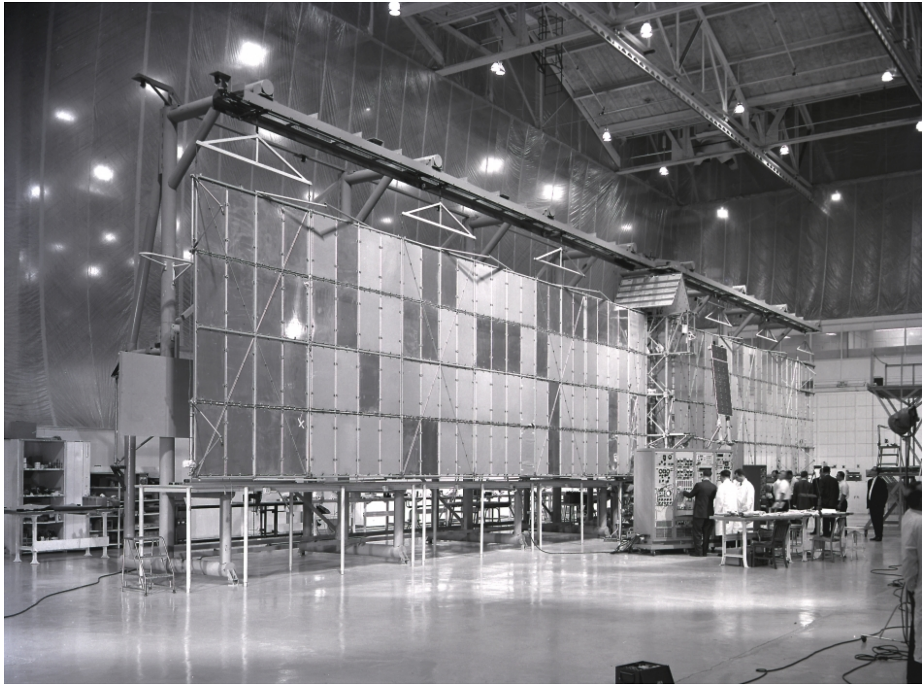
- 3 identical satellites – all launched in 1965.
- Objective: measure meteoroid abundances in mass range 10^{-7} to 10^{-4} grams where the Apollo missions would orbit.
- Method: collection of meteoroid penetration data in aluminum panels of 3 different thicknesses in near-earth orbits.



Naumann (1965)

Introduction to Pegasus:

- Launched on Saturn I.
- Satellites remained attached to the 2nd stage of Saturn I in space.
- Once in orbit, the satellite unfolded a series of panels.
- Each wing was 29.3 m across & 4.1 m wide – which yielded~200 m^2 collecting area on each satellite.



NASA

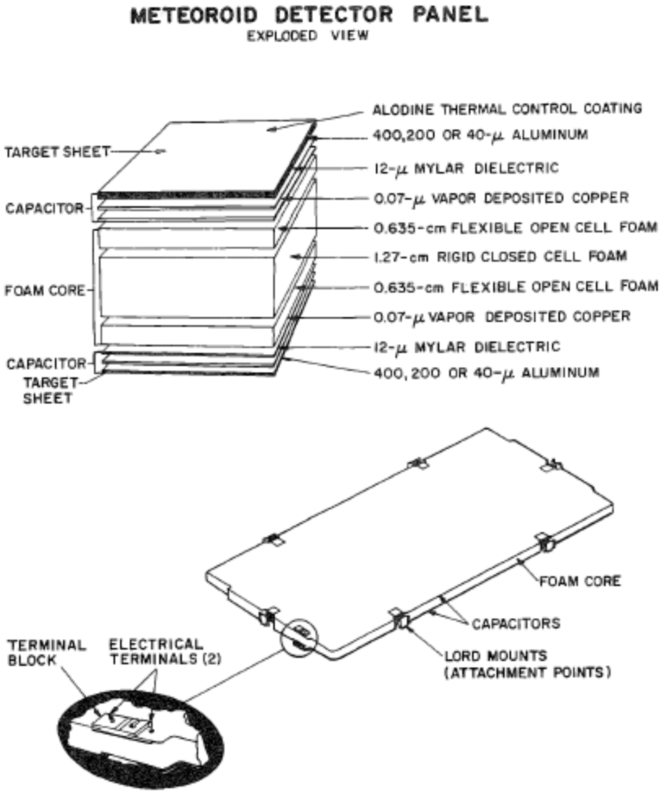
The panels

- The meteoroid detector is a parallel-plate capacitor with a mylar layer as a dielectric.

- 208 panels, composed of 2024 aluminum – either with 0.4, 0.2 or 0.04-mm thickness.

- 8 m^2 were of 0.04-mm thick detectors; 17 m^2 of 0.2-mm thick detectors, 175 m^2 of 0.4-mm thick detectors

- The detectors are isolated by a resistor-diode circuit between the detector and signal lead.

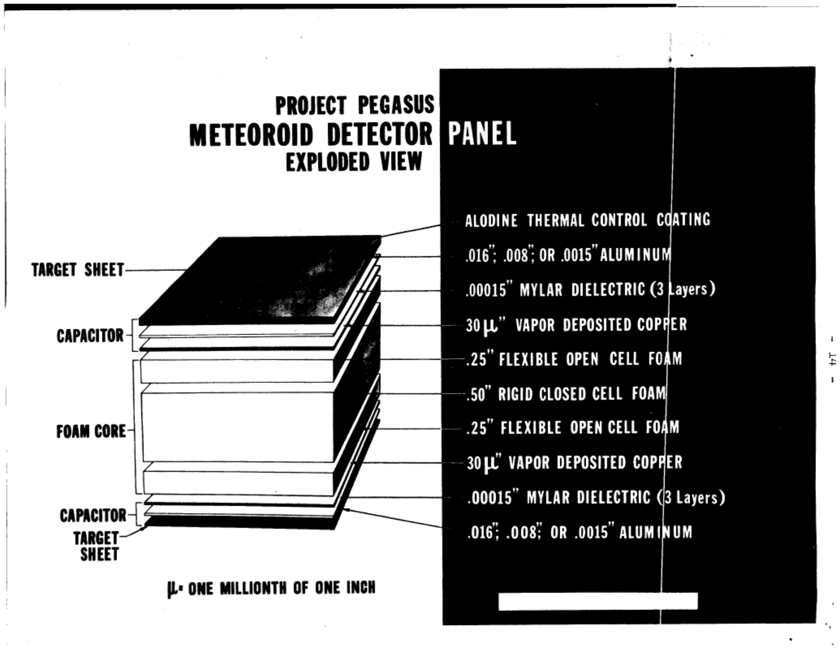


D'Aiutolo, Kinard, Naumann (1967)

The panels

▪From NASA press kit prior to Pegasus III

▪July 14, 1965: “The engineering experiment consists of 48 aluminum sub-panels of ‘coupons’ attached to Pegasus which could be quickly unhooked by an astronaut and carried back to Earth. NASA officials emphasize that no decision has been made for an astronaut to rendezvous and retrieve the panels.”



The panels

- A penetrating impact of a detector produces a momentary short of the capacitor resulting in a rapid drop in impressed voltage. (Johnson 1966)

- The energy stored in the capacitor is dumped into the shorted area, which burns away the copper-capacitor deposit and clears the detector in approximately 1 sec. (D’Aiutolo 1967)

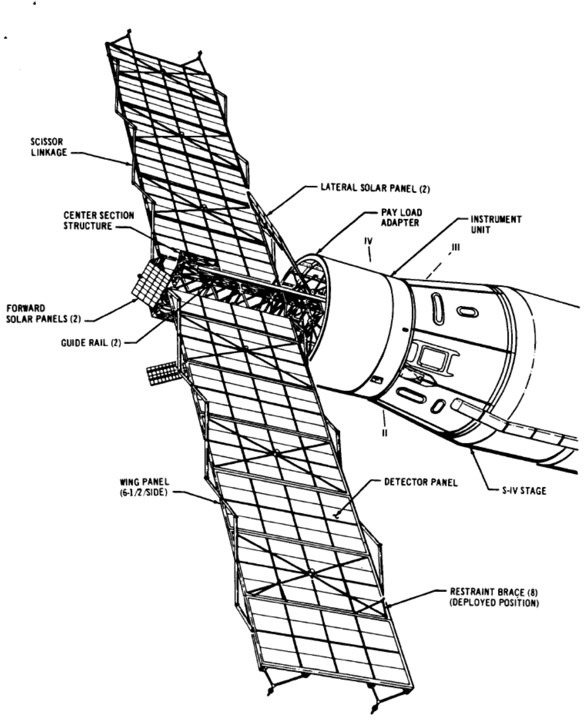


FIGURE 1. PEGASUS SPACECRAFT

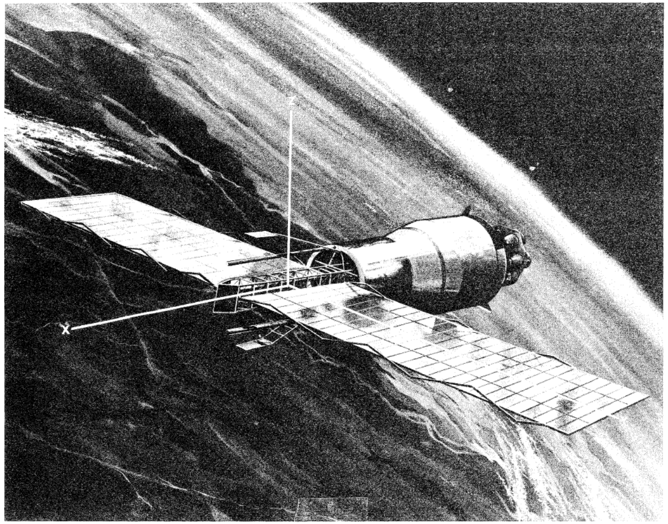
The Meteoroid Satellite Project Pegasus – First Summary Report – MSFC, Bill Johnson 1966

Pegasus I, II, III:

▪Pegasus I: Launched 16 Feb 1965

▪Detector shorting was found to be a more frequent occurrence on Pegasus I than had been indicated from laboratory tests of the detector panels, particularly at higher temperatures. (Johnson 1966)

▪"Within the first few orbits … it was noted that the rate of shorting in the 0.2 and 0.4-mm thick detectors was appreciably higher than the test loss rate… [there were] problems with attitude sensing system (though it was still usable)" (Johnson 1966)



Naumann (1965)

▪0.4 and 0.2-mm data are unusable
▪0.04-mm data are fine

Pegasus I, II, III:

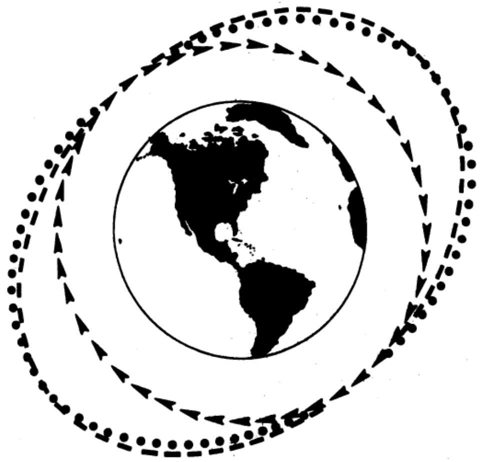
▪Pegasus II: 25 May 1965

▪"The only major subsystem failure occurred in the telemetry system. Beginning about eight days after launch. Intermittent failures of both …channels occurred. The data loss is not sufficiently great to be alarming at this time." (Johnson 1966)

▪Pegasus III: 30 July 1965

▪Fixed some issues discovered in Pegasus I and II and thus far working well (Johnson 1966)

THE ORBITS OF PEGASUS SPACECRAFT



PEGASUS C: Apogee - 332 Statute Miles, Perigee - 332 Statute Miles
PEGASUS I: Apogee - 462 Statute Miles, Perigee - 308 Statute Miles
PEGASUS II: Apogee - 464 Statute Miles, Perigee - 315 Statute Miles

Comments about the data:

- Experiment results were returned to Earth by radio

- When Pegasus was active, orbital debris was not a problem – any impact was natural

- Main question: Can we detect meteor showers or is it all sporadic? Can we get an overall flux and separate shower fluxes?

Previous Analysis:

- The most complete results:
- (Naumann 1965), covers Feb-July 1965 data, published December 1965
- (Johnson 1966), covers Feb-Aug 31 1965 data, published November 1966
- (Clinton & Naumann 1966), covers Feb–Dec 1965 data, published December 1966

Naumann – Dec 1965 TM

- Data from Feb-July, 1965

- Pegasus I:

  Four hit indications on the 0.400 mm panels in the first 11 days before these panels became unusable.

  Nine hits on 0.2-mm panels before they became unusable.

  0.040 mm panels: 104 penetrations

Pegasus II: all usable, but only in orbit for a couple months at time of study.

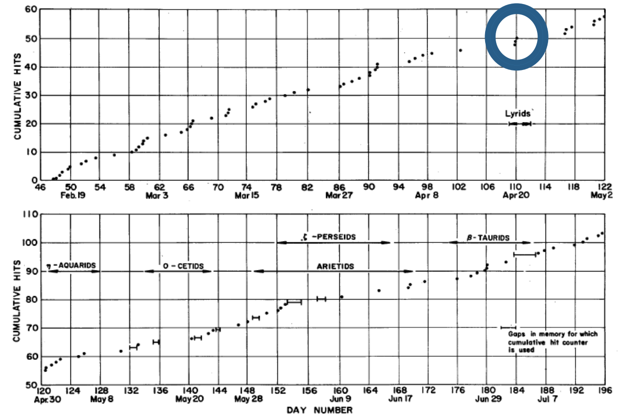
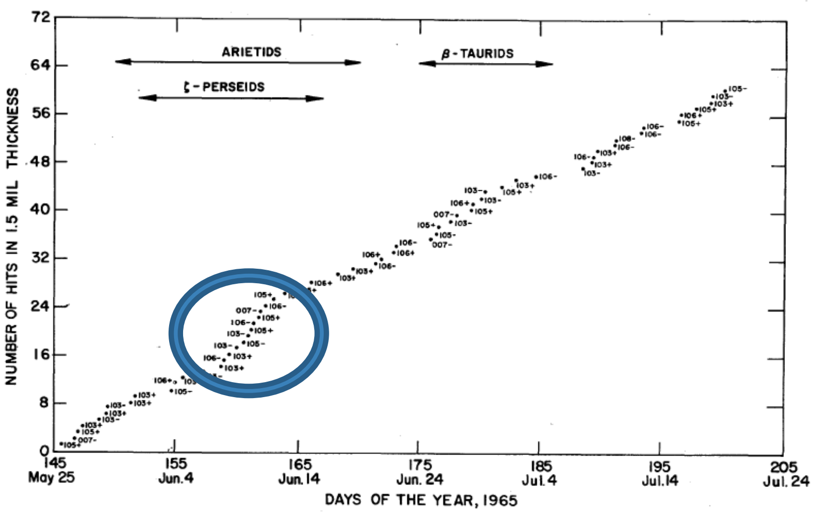


Figure 4 - Time history of accumulated penetrations for 40μ panels on Pegasus I.

	Number of Penetrations	Area-Time (m^2 day)	Frequency of Penetrations (No. / m^2sec)
Pegasus I			
400μ	4	1925	2.4×10^{-8}
200μ	9	248	4.2×10^{-7}
40μ	104	858	1.4×10^{-6}
Pegasus II			
400μ	30	8457	4.0×10^{-8}
200μ	14	734	2.2×10^{-7}
40μ (total)	61	357	2.0×10^{-6}
40μ (shower peak)	12	26	5.3×10^{-6}
40μ (sporadic)	40	299	1.5×10^{-6}

Naumann – Dec 1965 TM



- PEGASUS II
- There appeared to be increase June 6-12 – Arietids and Zeta Perseids?
- 'Preliminary analysis of Pegasus I indicated that the normal to the sensor plane made angles of 50 and 65 degrees with Arietid and Zeta Perseid radiant at peak.'
- Thus Pegasus I may have missed those showers.

Johnson 1966

Data from Feb – Aug 31, 1965 (two more months than Naumann's report)

The flux results are fairly consistent between spacecraft, even with the low number fluxes.

TABLE III. PEGASUS PENETRATION DATA

(as of Aug. 31, 1965)

	No. Penetrations	Area-Time (m^2 day)	Frequency (No./m^2 sec)	Frequency (No./m^2 day)
PEGASUS I				
0.4 mm	4	1925	2.4×10^{-8}	2.1×10^{-3}
0.2 mm	9	248	4.2×10^{-7}	3.6×10^{-2}
0.04 mm	121	1020	1.4×10^{-6}	1.2×10^{-1}
PEGASUS II				
0.4 mm	58	14387	4.7×10^{-8}	4.1×10^{-3}
0.2 mm	18	1234	1.7×10^{-7}	1.5×10^{-2}
0.04 mm	121	651	2.2×10^{-6}	1.9×10^{-1}
PEGASUS III				
0.4 mm	11	3667	3.5×10^{-8}	3.0×10^{-3}
0.2 mm	4	239	2.0×10^{-7}	1.7×10^{-2}
0.04 mm	23	109	2.4×10^{-6}	2.1×10^{-2}

Johnson 1966

Johnson 1966

Pegasus II

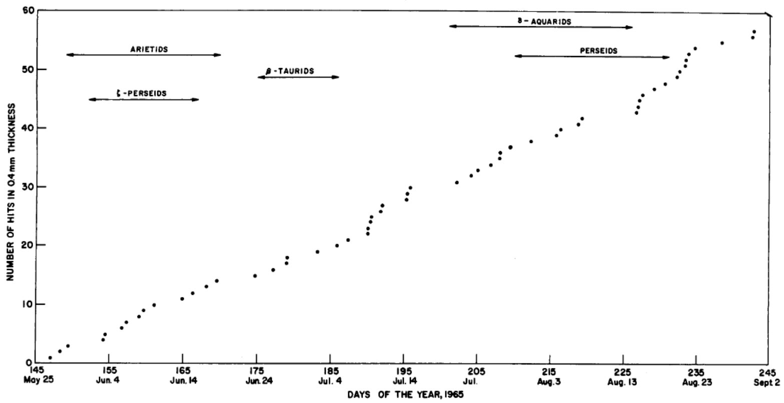


FIGURE 32. TIME HISTORY OF CUMULATIVE HITS FOR 0.4-mm PANELS (PEGASUS II)

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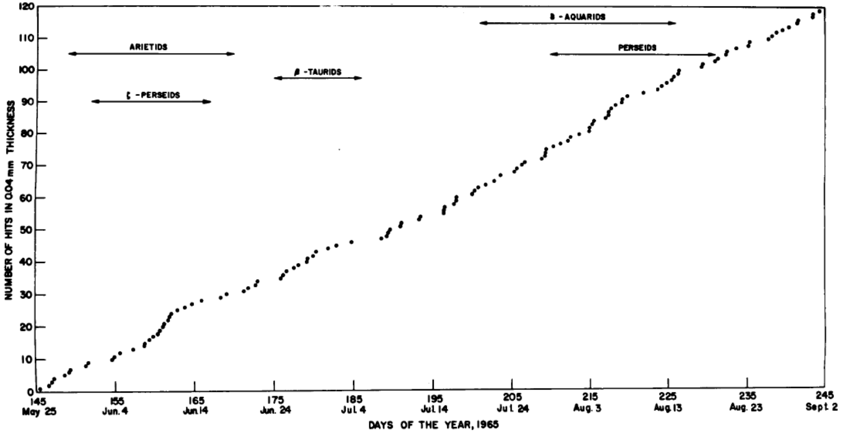


FIGURE 30. TIME HISTORY OF CUMULATIVE HITS ON 0.04-mm PANELS (PEGASUS II)

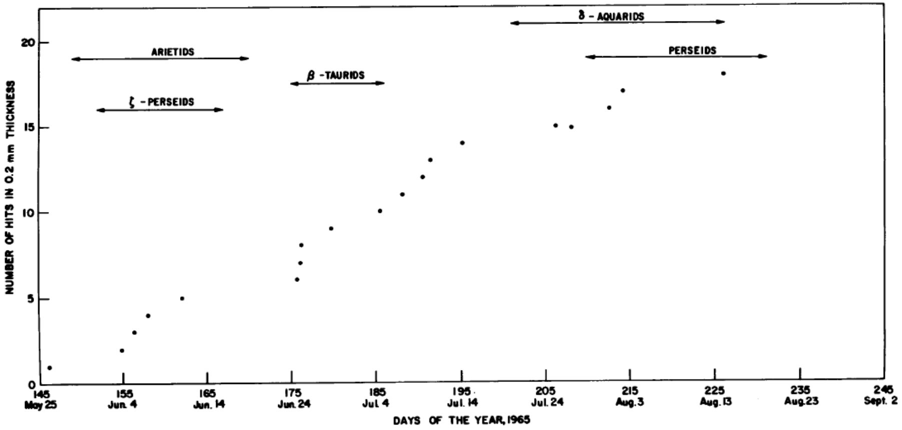


FIGURE 31. TIME HISTORY OF CUMULATIVE HITS FOR 0.2-mm PANELS (PEGASUS II)

Clifton & Naumann - Dec 1966

- NASA TM – data from Feb – Dec 1965
- Temporal effects were analyzed – diurnal or seasonal effects
- ‘No significant/unexpected diurnal or seasonal effect has been observed with any certainty during the months from June to December’
- ‘Pegasus II recorded high penetration rates throughout the periods of June 6-12 and Oct 2-4. The first of these coincides with the Zeta Perseids and Arietids, the second period coincides with no major showers.’

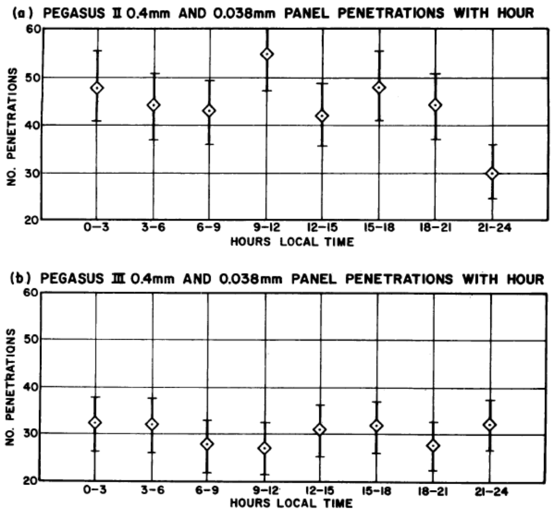


FIGURE 8. DISTRIBUTIONS OF PANEL PENETRATIONS WITH HOURS OF LOCAL TIME

Clifton & Naumann - Dec 1966

- Looked at times in 0.04-mm panel from Pegasus II and III where flux deviated by at least two-sigma.
- Six periods of high activity: Aug 19-21, Oct 6, Oct 17-21, Nov 10, Nov 15-17, and Dec 1-3. Only two of these periods relate to meteor showers.
- 'On purely statistical grounds, you would expect some two and three sigma variations.'

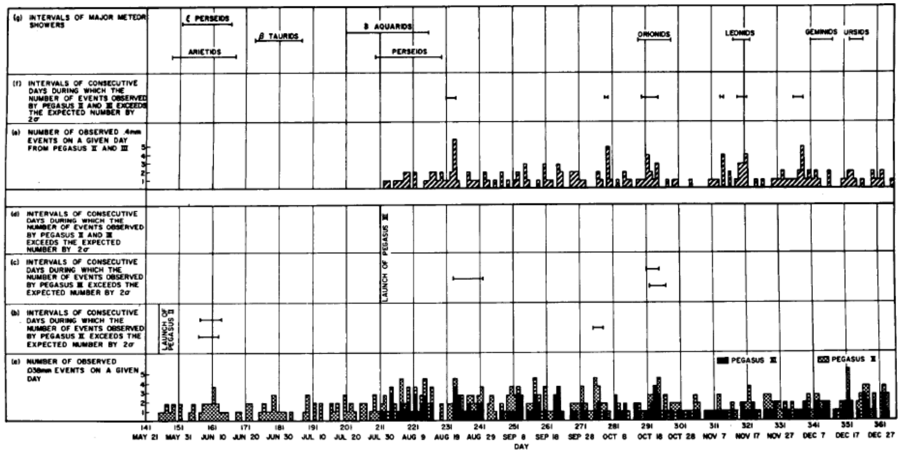


FIGURE 11. DAILY DISTRIBUTION OF METEOROID PENETRATIONS IN COMPARISON WITH PERIODS OF MAJOR PERMANENT METEOR SHOWERS

Naumann 2008

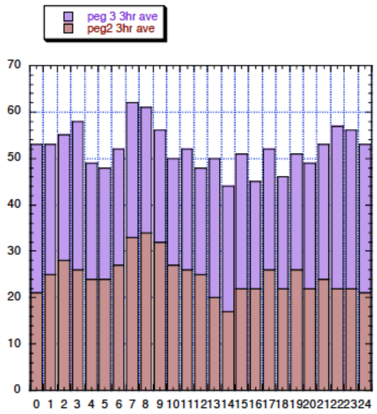


Fig. 3. Three hour moving sum of events recorded on the Pegasus 2 and 3 16 mil panels.

- ‘Pegasus II and III continued to operate through 1967 and their data are available in the NSSDC archives and have never been analyzed.’
- Examined whether diurnal variation showed differing fluxes between sporadic sources.
- They conclude there is no seasonal effect, as well.
- Showers: Unusual activity: Pegasus III: Day 487 (May 2, 1966), Day 490 (May 5, 1966), and again on Day 514 (May 27, 1966). On Day 682 (Nov 13, 1966), 6 events were recorded in the space of 24 minutes (they attribute to 1966 Leonids outburst)

Current analysis

- The following data was retrieved from the NSSDC for each spacecraft and detector:

- Day, year, hour, and minute of penetration
- Satellite penetrated
- Side penetrated
- Panel penetrated
- Thickness penetrated
- Pulse verify
- Temperature probe on each side when penetrated
- Satellite clock time
- Local time
- Longitude and Latitude
- Ecliptic longitude and ecliptic latitude
- Right ascension and declination when penetrated

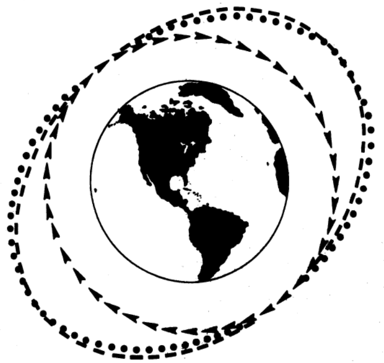
Current analysis

- NOT included was…. Attitude info! Nor is it readily available. Some clues...

- Johnson 1966: “Orientation of the spacecraft with respect to center of the earth can be determined with an accuracy of 3-5 degrees through a knowledge of sensor states.” “Attitude data was recorded every 1.25 seconds.”

- Clifton & Naumann 1966: “The rotational dynamics of Pegasus II and III is such that an analysis of the directional distribution is not yet possible.”

THE ORBITS OF PEGASUS SPACECRAFT



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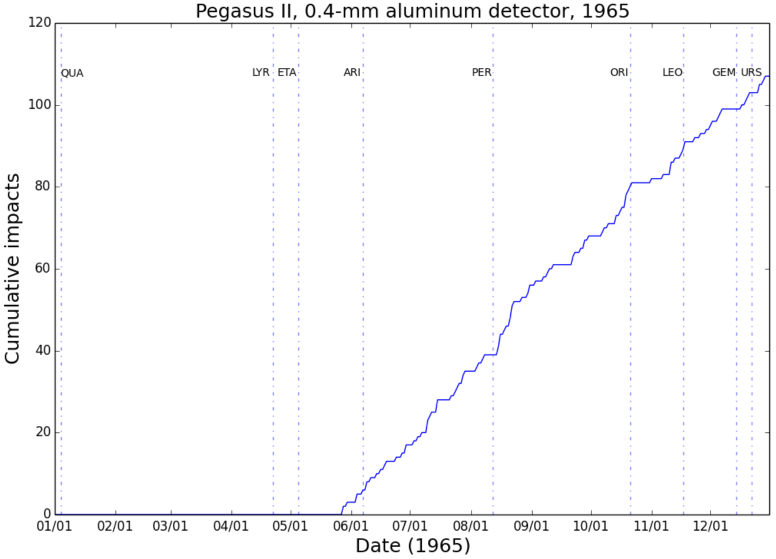
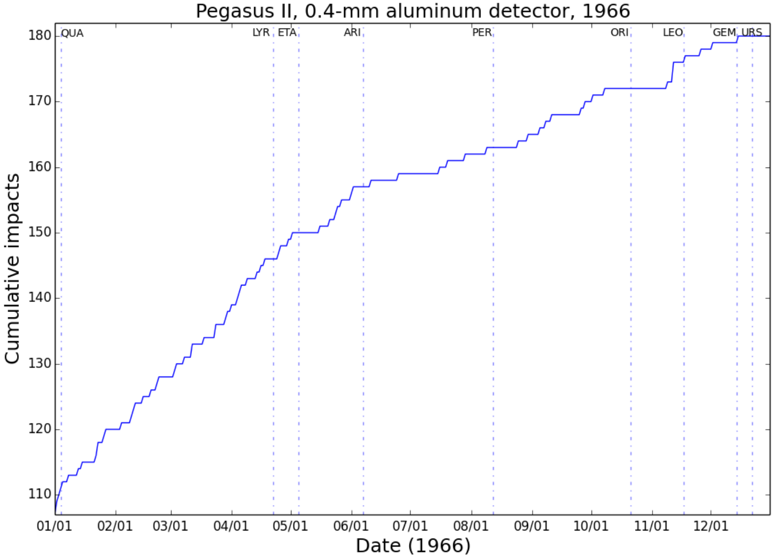
Current analysis

- Data from Pegasus I spanned February 17, 1965 - March 29, 1966
- Pegasus II: May 25, 1965- October 31, 1967
- Pegasus III: July 30, 1965- August 15, 1967

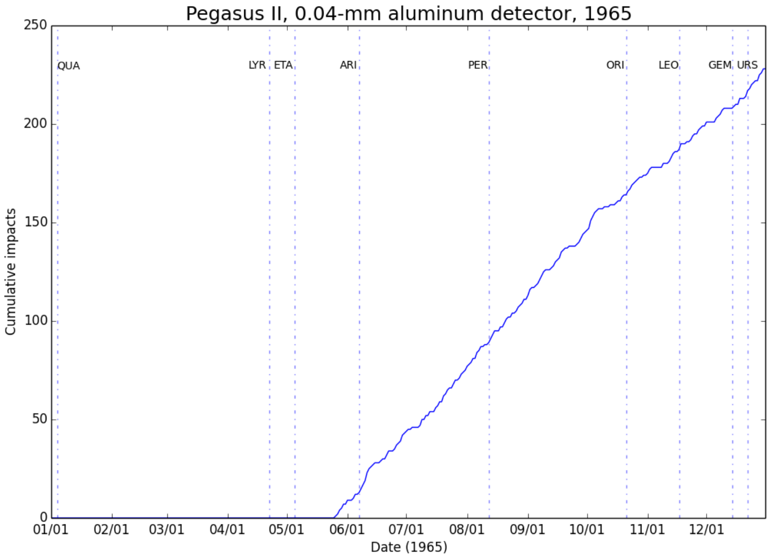
Spacecraft	Detector	Days Active	Number of Impacts
I	0.04-mm	402	300
II	0.4-mm	889	198
II	0.2-mm	889	33
II	0.04-mm	889	654
III	0.4-mm	746	218
III	0.2-mm	746	15
III	0.04-mm	746	867

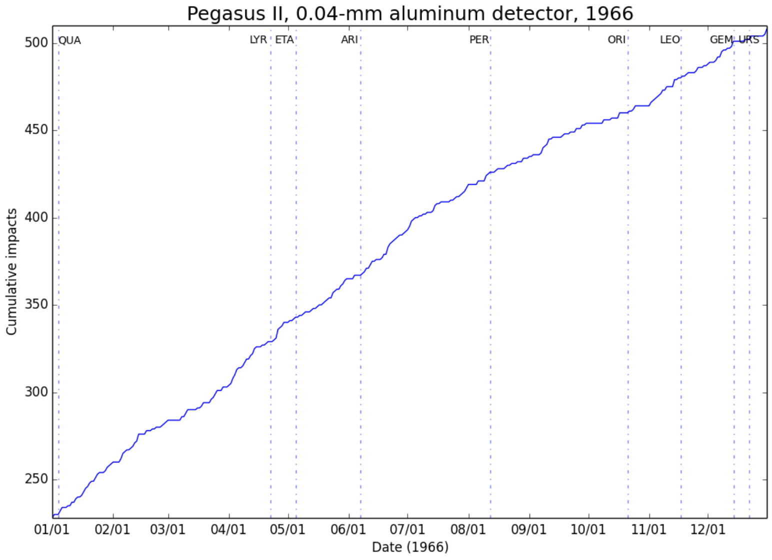
Impacts with time



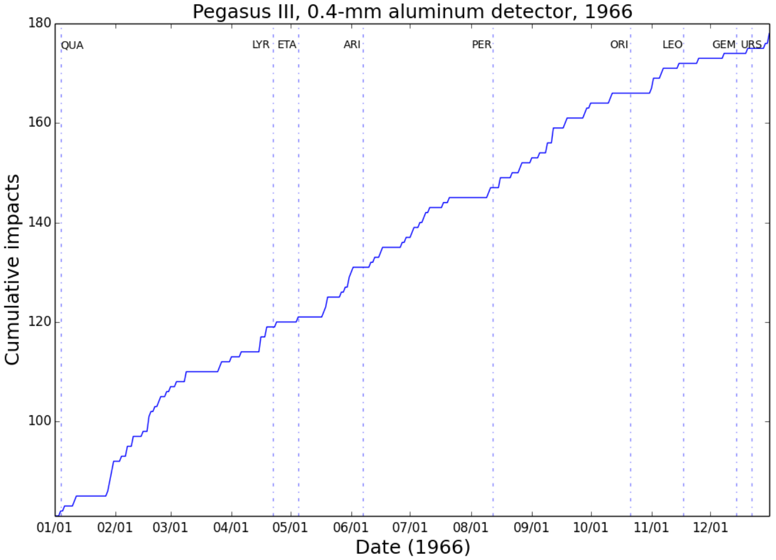


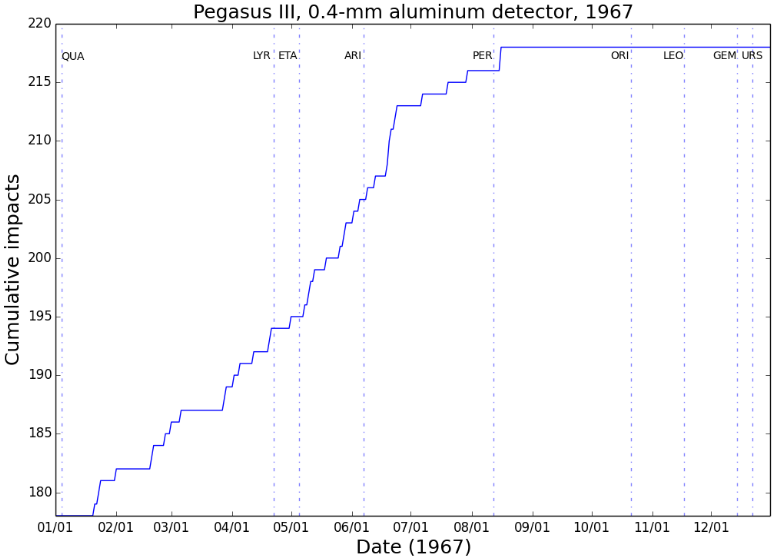
Impacts with time



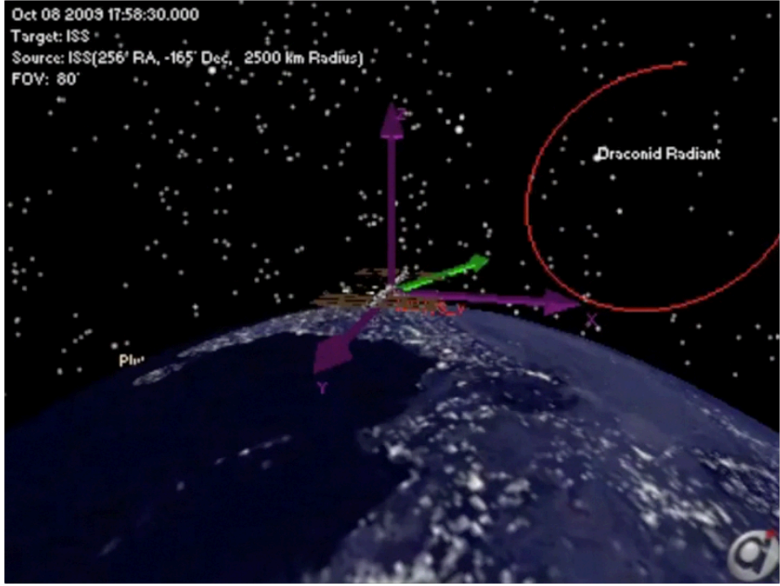


Impacts with time



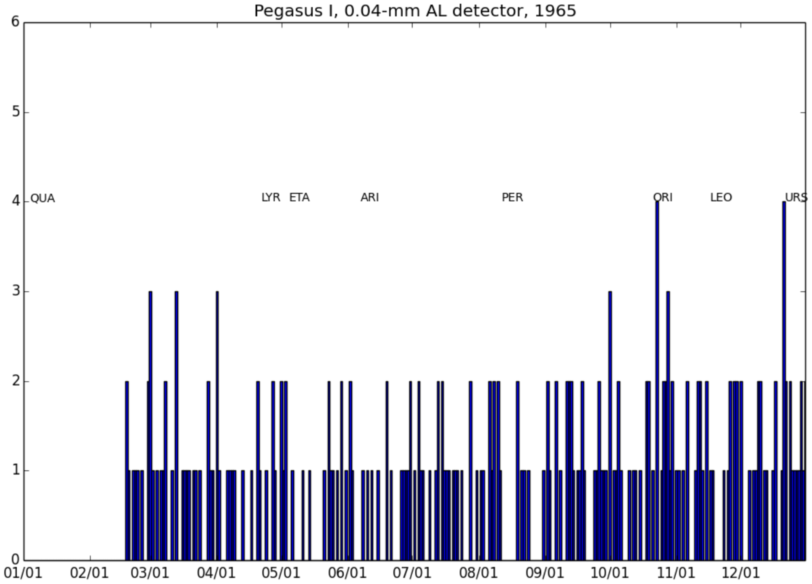


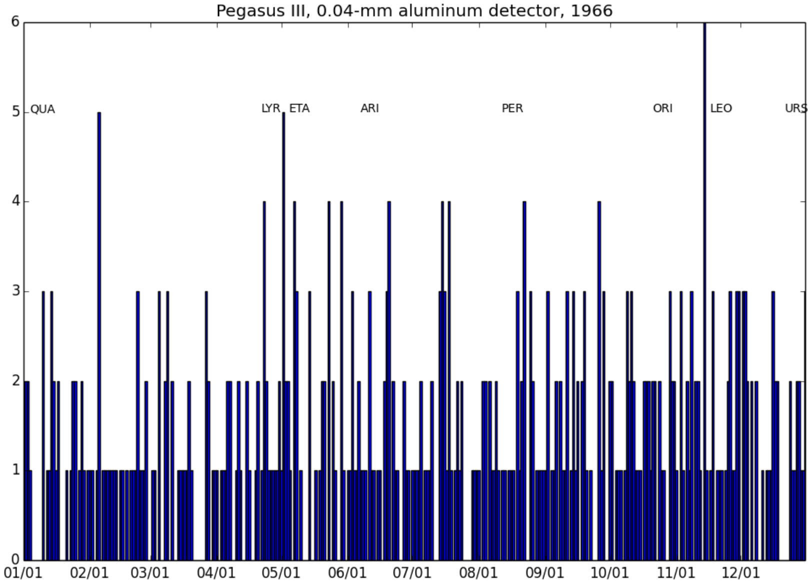
Shower Identification



- Began looking at times when the activity was above normal, how close to shower peaks those times were, and whether the shower radiant was visible to the spacecraft.
- To systematically look at this:
  Separated hits vs. time into periods in which there is an average of 1 hit per period
  Examined periods with at least four hits.
  Were there active showers during that time?
  Was the spacecraft visible to the aberrated radiant?
- Example:
  Pegasus I, 0.04-mm, 1965 [avg 1hit/1.33 SL]: SL 213.2 - 214.1 had four hits.
  Orionid signature? Only two of those hits were visible to the radiant.
- Shower catalog used: The showers included in the forecast, with ASGARD's shower specs, except the ZPE's, received from the IMO.

Shower Identification





Name	Code	Start SL	Max SL	End SL	RA	DEC	RA drift	DEC drift	Velocity	Mass Index	Pop Index	ZHR
Lyrids	LYR	30.0	32.0	36.0	272.2	32.6	0.62	-0.33	46.6	1.8	2.1	18
Eta Aquariids	ETA	30.0	45.0	66.0	337.9	-0.90	0.70	0.33	63.6	1.9	2.4	45
Zeta Perseids	ZPE	65.0	72.4	79.0	62.9	23.0	0.00	0.00	29.0	1.9	2.7	20
Arietids	ARI	62.0	81.0	99.0	45.70	25.00	0.86	0.17	39.10	2.0	2.7	60
So. Sagittariids	SSS	84.0	87.0	90.0	278.60	-25.30	0.0	0.0	29.30	2.0	2.9	2
Beta Taurids	BTA	89.0	94.0	101.0	82.80	20.10	0.82	0.05	26.80	2.0	2.7	10
Phoenicids	PHE	107.0	110.3	113.0	31.60	-47.7	0.0	0.0	47.00	2.0	3.0	5
Pis. Austrinids	PAU	124.0	135.0	142.0	357.10	-21.50	0.52	0.39	44.00	2.26	3.2	3
So. Delta Aquariids	SDA	114.0	126.0	164.0	340.8	-16.3	0.78	0.30	40.70	2.3	3.2	30
Alpha Capricornids	CAP	108.00	123.00	140.00	303.10	-10.70	0.60	0.30	22.00	2.0	2.5	4
Perseids	PER	123.00	140.00	147.00	48.00	57.20	1.39	0.29	61.40	1.8	2.6	120
Kappa Cygnids	KCG	130.18	145.00	152.19	286.00	59.00	0.30	0.10	22.30	2.0	3.0	3
Alpha Aurigids	AUR	154.20	158.60	167.68	93.00	39.00	1.00	0.20	66.10	2.04	2.6	9
Sept. Eps. Perseids	SPE	161.94	166.70	178.40	48.00	40.00	0.0	0.0	65.00	2.0	2.9	5
Daytime Sextantids	DSX	174.00	186.00	197.00	154.30	-1.00	0.56	-0.54	31.30	2.0	2.7	5
Draconids	DRA	192.23	195.40	197.08	262.00	54.00	1.90	0.30	16.60	2.04	2.6	2
Leonis Minorids	LMI	199.00	210.00	213.00	160.70	35.70	1.22	-0.40	59.80	2.0	2.7	2
Orionids	ORI	198.00	208.00	227.00	95.50	15.20	0.78	0.02	65.40	2.0	2.5	23
So. Taurids	STA	173.00	196.00	217.00	30.90	8.10	0.82	0.29	28.20	2.0	2.3	5
No. Taurids	NTA	217.00	219.00	241.00	48.90	17.70	0.84	0.25	28.10	1.9	2.3	5
Leonids	LEO	226.00	237.00	237.00	155.10	21.10	0.55	-0.37	67.30	2.16	2.9	20
Leonids	LEO	226.00	233.35	237.00	155.10	21.10	0.55	-0.37	67.30	2.16	2.9	6000
Puppids Velids	PUP	248.26	255.00	263.41	123.00	-45.00	0.0	0.0	38.40	2.0	2.9	10
Dec. Monocerotids	MON	257.00	261.00	266.00	102.30	8.60	0.69	-0.24	40.60	2.2	3.0	3
Sigma Hydrids	HYD	251.00	258.00	267.00	127.70	2.50	0.96	-0.26	59.20	2.0	3.0	2
Geminids	GEM	240.0	261.0	273.0	112.5	32.10	1.12	-0.17	34.50	2.0	2.6	118
Ursids	URS	267.00	270.00	273.00	222.10	74.80	1.77	-0.05	35.60	2.2	3.0	12
Quadrantids	QUA	232.00	283.00	291.00	231.50	48.50	0.78	-0.38	41.70	1.81	2.1	120
Gamma Normids	GNO	335.87	354.0	1.77	251.60	-51.30	0.0	0.0	54.90	2.0	2.4	8

Shower Identification

- Altogether: 115 of these periods across the three spacecraft, three detectors, and three years.
- Inconclusive! No significant periodsof increase occur near shower peak. No case of heightened activity can be conclusively or even likely attributed to a shower.
- Generated a figure of merit based on flux, proximity to the peak, and elevation of radiant. This figure did not help.
- Note this exception: there were 6 hits registered within 10 hours on November 13, 1966 on Pegasus III’s 0.04-mm detector, 4 days before 1966 Leonid outburst. However, the LEO radiant was not visible for two of these hits.

Case Study: 1966 Leonids!

2001 Leonids. Credit: Koen Miskotte

- The most significant meteor shower in the 20th century! And all three spacecraft were in orbit!
- Objective: predict how many impacts should have impacted each detector, based on measured activity of the 1966 Leonids.

Predicting impacts from a meteoroid stream

Eqn 1 $$Q(m \leq 6.5) = \frac{ZHR(13.1r - 16.5)(r - 1.3)^{0.748}}{37200km^2}$$

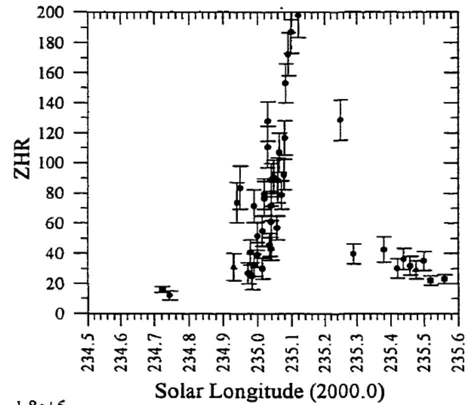
Eqn 2 $$Q(M \geq 10^{-3}g) = Q(m \leq 6.5)r^{9.775\log(\frac{29km/s}{v_{\inf}})}$$

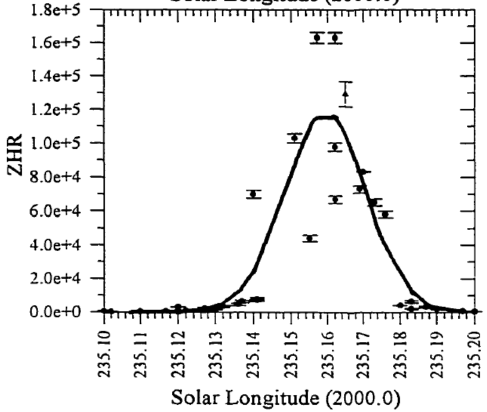
Eqn 3 $$(1 - s) = \frac{\log(Flux_2) - \log(Flux_1)}{\log(Mass_2) - \log(Mass_1)}$$

1. Read in Pegasus data from specific spacecraft and detector
2. Read in TLE file that corresponds to spacecraft
3. Read in Leonid ZHR profile (taken from Brown's thesis)
4. Loop through Leonid activity in 0.001 SL increments (every 1 min, 30 sec).
5. Find Leonid ZHR closest to that time, from the ZHR profile (Peter Brown's peak and activity near the peak + Sirko Molau's activity before/after the peak).
6. Find the LEO radiant at that SL.
7. Find the azimuth, elevation for the Leonids, and Earth's limb elevation.
8. Find the flux at magnitude +6.5 (Eqn 1):
9. Find the flux at 1 mg (1e-3 grams) (Eqn 2):
10. Scale flux to limiting mass of each detector (Eqn 3):
11. Take into account the radiant elevation (don't have attitude data yet…so only using elevation), and converting flux from meteors/km^2/hr to meteors/m^2/minute.
12. Since each 0.001 SL equals 1.5 minutes, integrate over whole duration of Leonids to get the total # of Leonids expected.

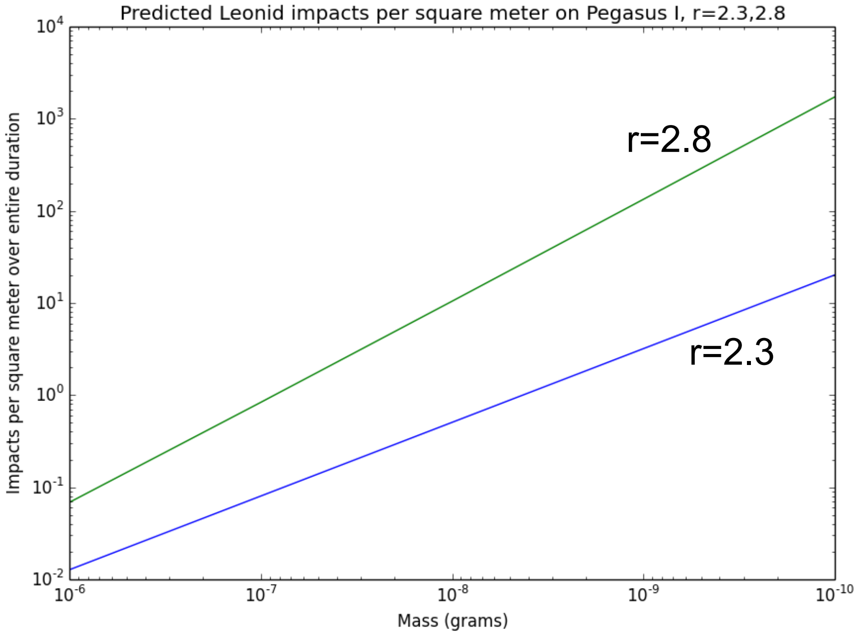
Case Study: 1966 Leonids!

- Worst case scenario: High ZHR and high population index!
- Used Brown's (PhD thesis) 1966 Leonid activity curve with ZHR of 115,000.
- Used IMO visual activity curve and IMO video fluxes (via Sirko Molau) to find activity leading up to/after the peak.
- Leonid population indices varied from 1.8 up to 2.8. Frequently they are 2.3-2.5. Found results using 2.8 (worse case scenario) and 2.3, for comparison.
- The impact prediction takes into account that the 0.4-mm AL detectors covered 175 m^2, 0.2-mm detectors covered 17 m^2, and 0.04-mm covered 8 m^2.
- Prediction done for each spacecraft as their orbits were unique. This particularly matters in such a short and extreme outburst.
- Found impact predictions during entire active period of shower (128-140 SL), and for 12 hours around the peak (235.0-235.5 SL).





Case Study: 1966 Leonids!



Case Study: 1966 Leonids!

Detector	Pegasus I (12-h peak, r=2.8)	Pegasus I (12-h peak, r=2.3)
0.04-mm	19.09	1.47
0.2-mm	0.59	011
0.4-mm	1.26	0.29

Results! Impacts predicted on each detector.

r=2.8

Detector	Limiting Mass (g)	Peg I (entire shower)	Peg I (12-h peak)	Peg II (peak)	Peg III (peak)
0.04-mm	3.6e-10	20.39	19.09	44.01	32.75
0.2-mm	1.7e-8	0.63	0.59	1.35	1.01
0.4-mm	7.0e-8	1.35	1.26	2.88	2.16

r=2.3

Detector	Limiting Mass (g)	Peg I (entire shower)	Peg I (12-h peak)	Peg II (peak)	Peg III (peak)
0.04-mm	3.6e-10	1.58	1.47	3.29	2.52
0.2-mm	1.7e-8	0.11	0.11	1.73	0.17
0.4-mm	7.0e-8	0.30	0.29	0.63	0.48

If population index was high, we don’t see these # of impacts… why? Radiation Pressure?

Radiation Pressure

$$\beta = \frac{3.5 \times 10^{-4} kg/m^2}{\rho s} \geq (1 - e)/2$$

- At what mass limit does radiation pressure start to remove meteoroids from the stream?
- β is the radiation force over the gravitational force, and is a function of the orbit of the particles. ***ρ*** is the bulk density of a particle, and *s* is the particle radius.
- When β ≥ (1-e)/2, the particle ejected from a comet can become unbound.
- For example, 55P/Tempel-Tuttle (parent body of the Leonids), has a density of 0.806 g/cc and an eccentricity of 0.9055.
- Particles can become unbound from 55P's orbit if they are ≤ 1.1e-8 grams.
- This can be broken down into a refined calculation of β for leading ejecta and trailing ejecta. Leading: 2.18e-8 grams, trailing: 5.91e-9 grams.

Radiation Pressure

parent body	shower	0.4-mm limit (g)	0.2-mm limit (g)	0.04-mm limit (g)	M_0
55P/Tempel-Tuttle	LEO	6.99e-8	1.67e-8	3.65e-10	1.13e-8
3200 Phaethon	GEM	2.87e-8	6.89e-8	1.49e-9	3.28e-10
109P/Swift-Tuttle	PER	9.48e-8	2.27e-8	4.94e-10	1.92e-7
C/1961 G1 (Thatcher)	LYR	1.46e-7	2.52e-8	7.65e-10	2.11e-6
1P/Halley	ETA	8.10e-8	1.94e-8	1.09e-9	2.69e-6
2003 EH1	QUA	2.09e-7	5.03e-8	1.09e-9	7.90e-12
8P/Tuttle	URS	2.87e-7	6.89e-8	1.49e-9	1.63e-9
1P/Halley	ORI	8.10e-8	1.94e-8	4.22e-10	2.69e-7
96P/Machholz	ARI	2.32e-7	5.56e-8	1.21e-9	1.4e-7

- Thus for many showers, extrapolating ZHR or flux to these size ranges is not realistic, as radiation pressure would have removed particles.
- What showers are NOT unbound that we can use as a check?
- Showers that CAN be extrapolated: LEO (to 0.4 and 0.2-mm), GEM, QUA, URS (to 0.4 and 0.2-mm), ARI (to 0.4-mm)

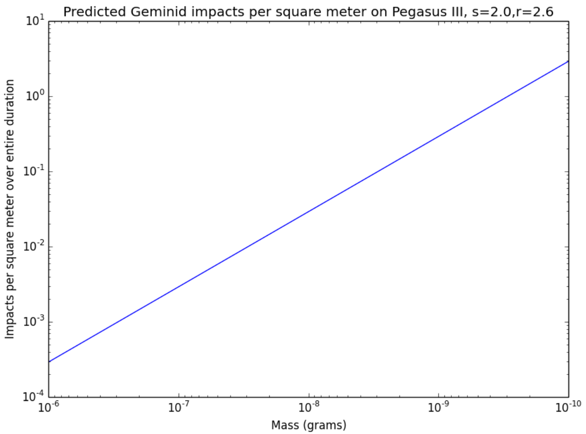
More Case Studies - Geminids

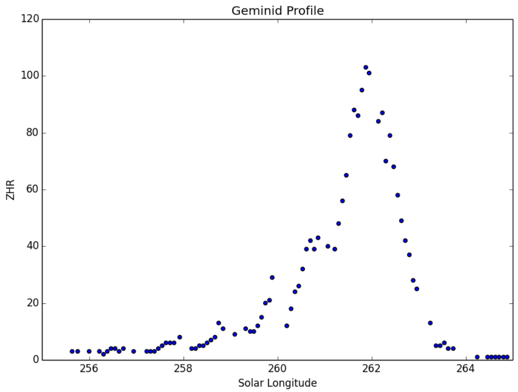
- Radiation pressure does not take particles away until 3.28e-10 grams, which is below the limiting mass of all detectors.
- Activity profile from IMO visual activity and IMO video network fluxes.
- s=2.0, r=2.6

Detector	Limiting Mass (g)	Peg I	Peg II	Peg III
0.04-mm	1.5e-9	2.71	2.19	1.55
0.2-mm	6.9e-8	0.13	0.10	0.07
0.4-mm	2.9e-7	0.31	0.25	0.18

- s=1.69, r=1.95

Detector	Limiting Mass (g)	Peg I	Peg II	Peg III
0.04-mm	1.5e-9	0.016	0.013	0.009
0.2-mm	6.9e-8	0.002	0.002	0.001
0.4-mm	2.9e-7	0.009	0.008	0.005





More Case Studies - Arietids

- Activity from CMOR Arietid Decadal Survey Paper by Bruzzone et al. (2015)
- 0.2 and 0.04-mm detectors are affected by radiation pressure, we can examine results of 0.4-mm detectors.
- Arietids are long-duration (45 SLs!), and have significant flux for most of that time, thus integrated impact probabilities over duration of shower may be significant.
- s=2.0,r=2.7

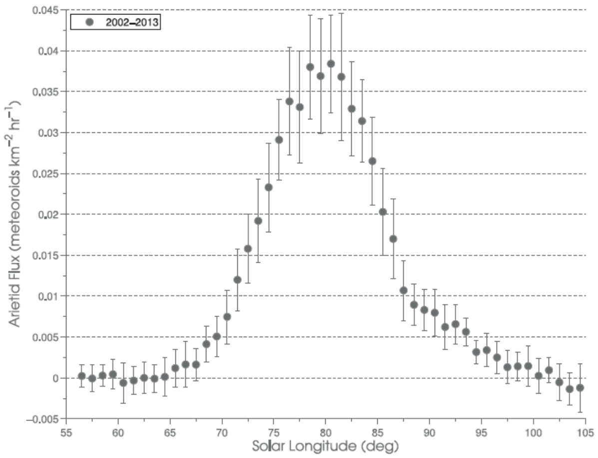
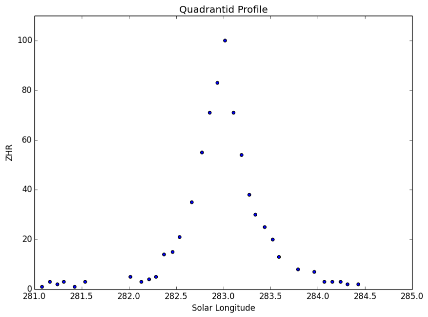


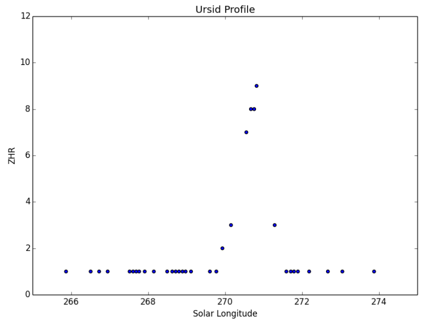
Figure 9. Daytime Arietd average fluxes to a limiting radio meteor magnitude of +6.5 between 2002 and 2013 as a function of solar longitude (J2000.0). The uncertainty bounds represent the standard deviation in the individual measured bins across all years.

Predicted number of impacts:

Detector	Limiting Mass (g)	Peg I	Peg II	Peg III
0.04-mm	1.2e-9	7.67	9.66	9.00
0.2-mm	5.6e-8	0.35	0.45	0.42
0.4-mm	2.3e-7	0.87	1.10	1.03

More Case Studies – QUA, URS





QUA:

- Radiation pressure does not remove particles unless they are smaller than 7.2e-12 grams.
- All detectors should be unaffected by radiation pressure.
- Activity from IMO Video fluxes + IMO visual
- s=1.81, r=2.1

Table 10: Number of impacts predicted on each detector for the Quadrantid meteor shower, s=1.81,r=2.1

Detector	Limiting Mass (g)	Peg I	Peg II	Peg III
0.04-mm	1.1e-9	0.014	0.018	0.019
0.2-mm	5.0e-8	0.001	0.002	0.002
0.4-mm	2.1e-7	0.004	0.005	0.006

URS:

- Radiation pressure does not remove particles unless they are smaller than 1.6e-9 grams.
- All detectors should be unaffected by radiation pressure.
- Activity from IMO Video fluxes + IMO visual
- s=2.2, r=3.0

Table 11: Number of impacts predicted on each detector for the Ursid meteor shower, s=2.2,r=3.0

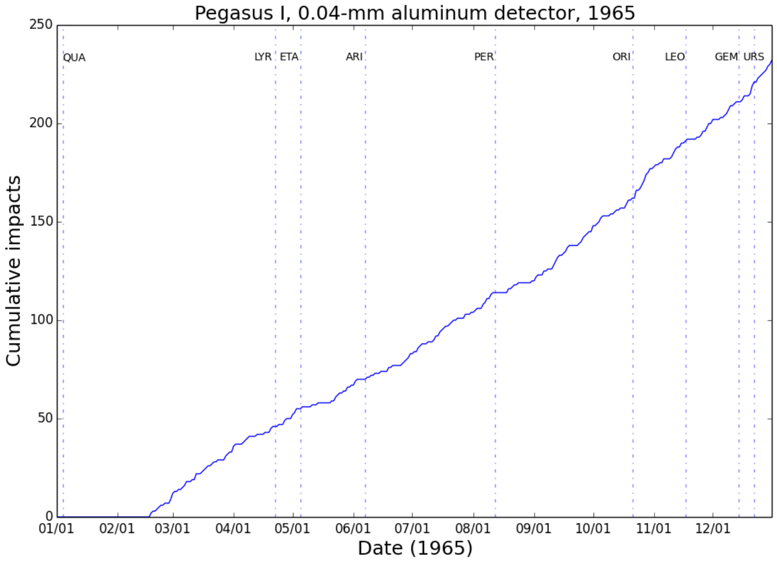
Detector	Limiting Mass (g)	Peg I	Peg II	Peg III
0.04-mm	1.7e-9	1.63	1.67	1.99
0.2-mm	7.8e-8	0.03	0.04	0.04
0.4-mm	3.2e-7	0.06	0.07	0.08

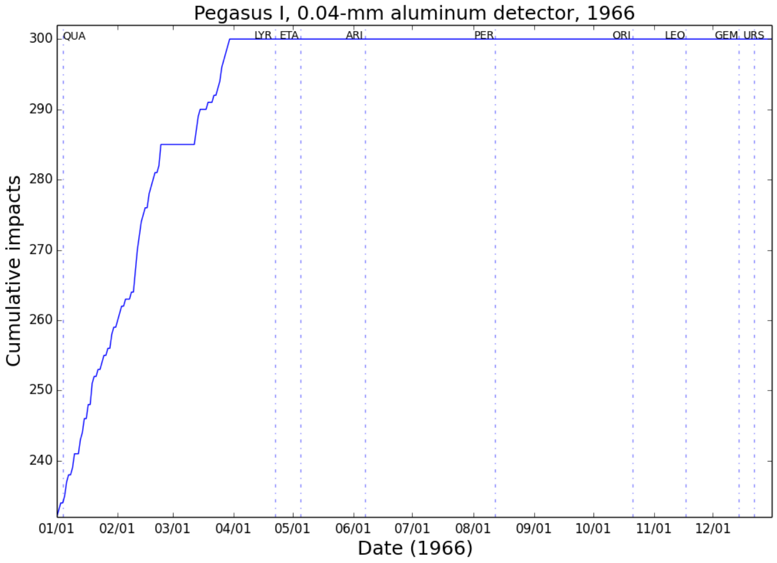
Conclusions:

- Pegasus Spacecraft = huge collecting area.
- No obvious shower signatures – even for 1966 Leonids.
- Projected impacts would indicate there should be heightened activity during some major showers.
- After considering radiation pressure affects, there are only a few possible showers and a few detectors that are not affected by radiation pressure and we can examine projected impacts by scaling the flux: Geminids, Arietids, Quadrantids, Ursids.
- For those showers & detectors not affected by radiation pressure, the flux is too low to be noticeable from background flux.
- No confirmed or even probable showers seen in Pegasus data.

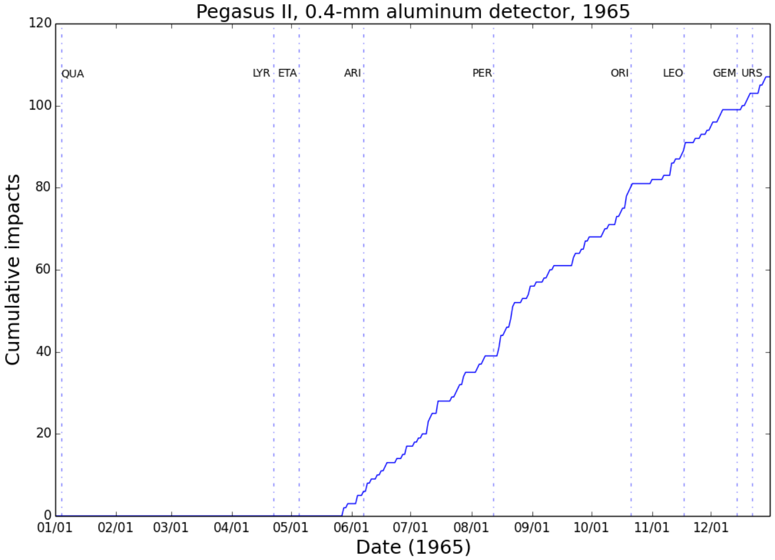
Backup Slides

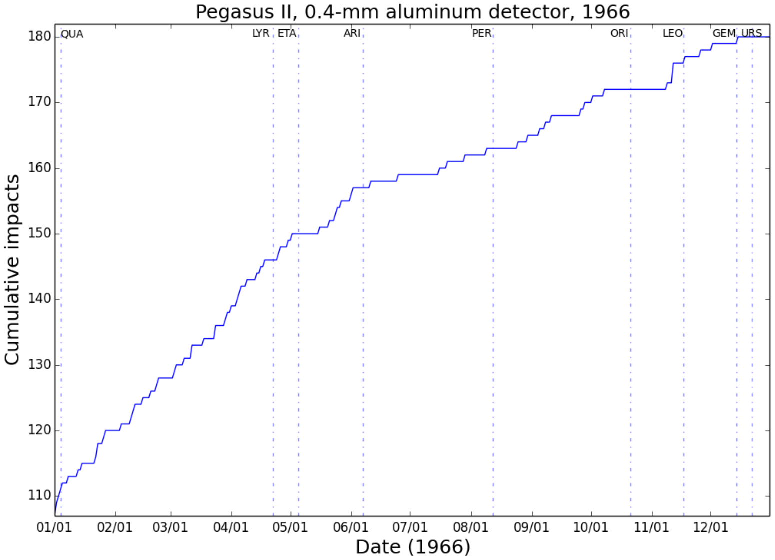
Pegasus I, 0.04-mm



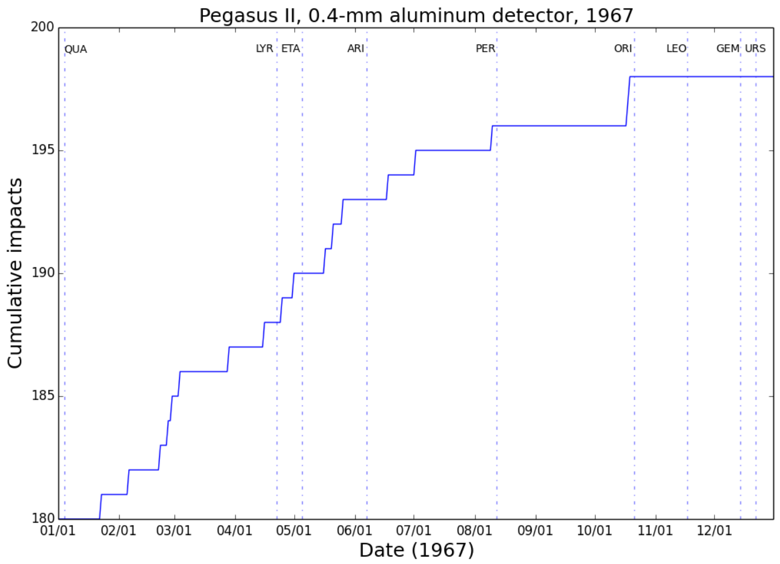


Pegasus II, 0.4-mm

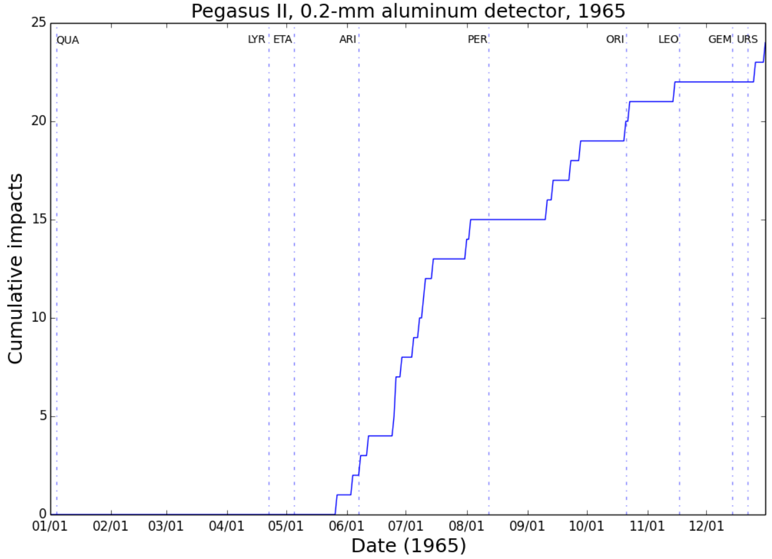


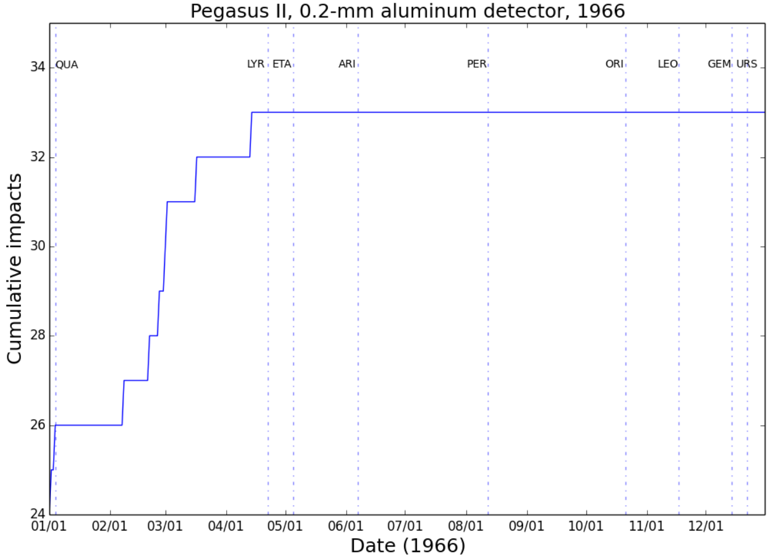


Pegasus II, 0.4-mm

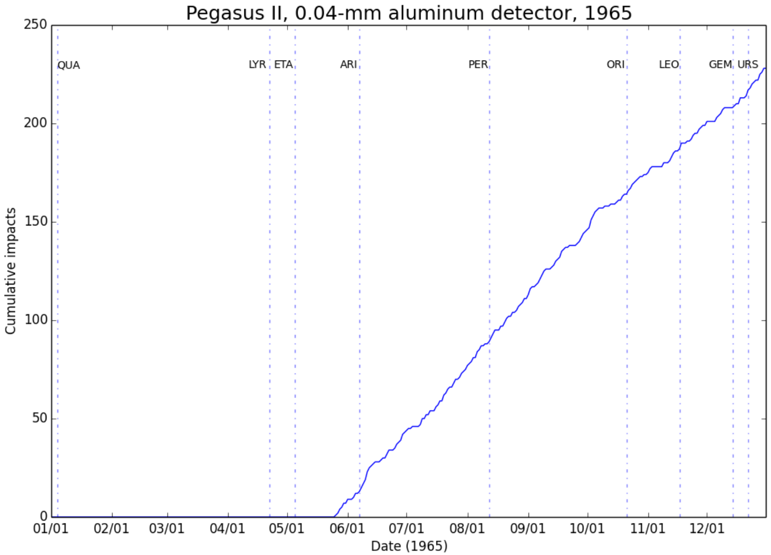


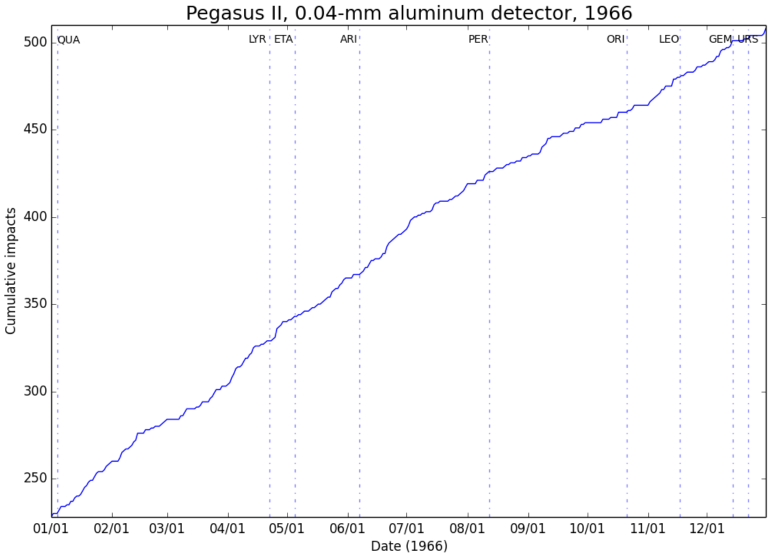
Pegasus II, 0.2-mm



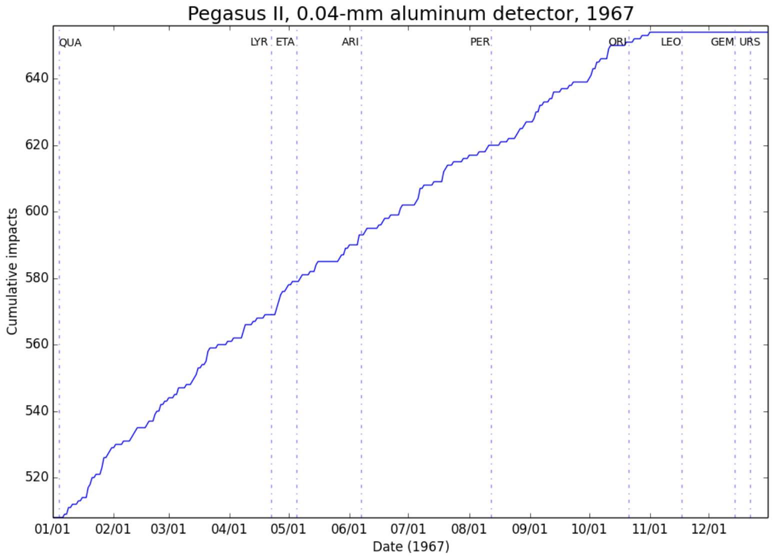


Pegasus II, 0.04-mm

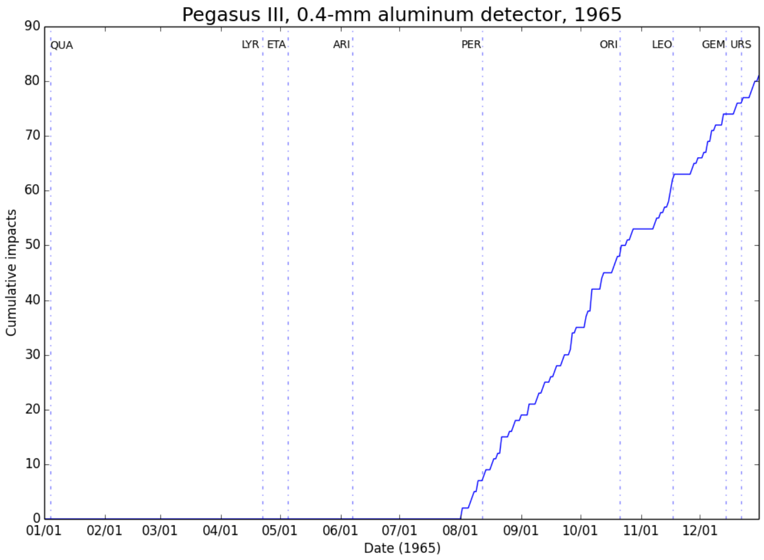


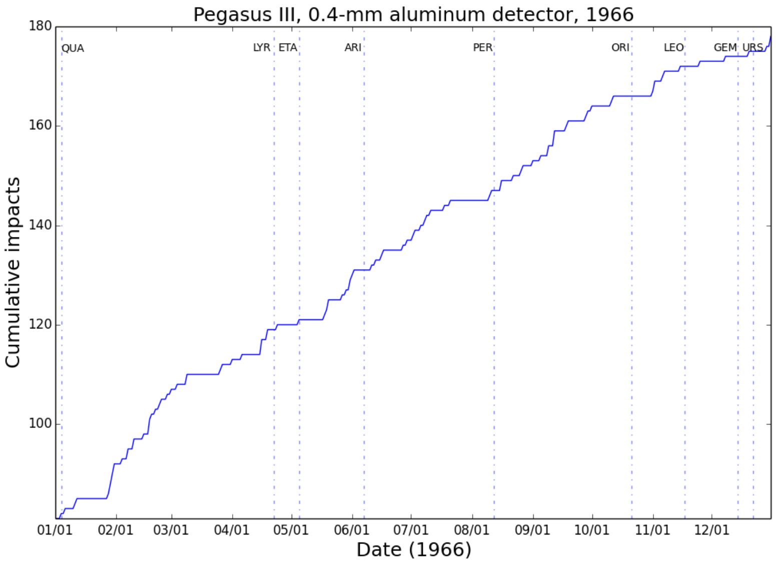


Pegasus II, 0.04-mm

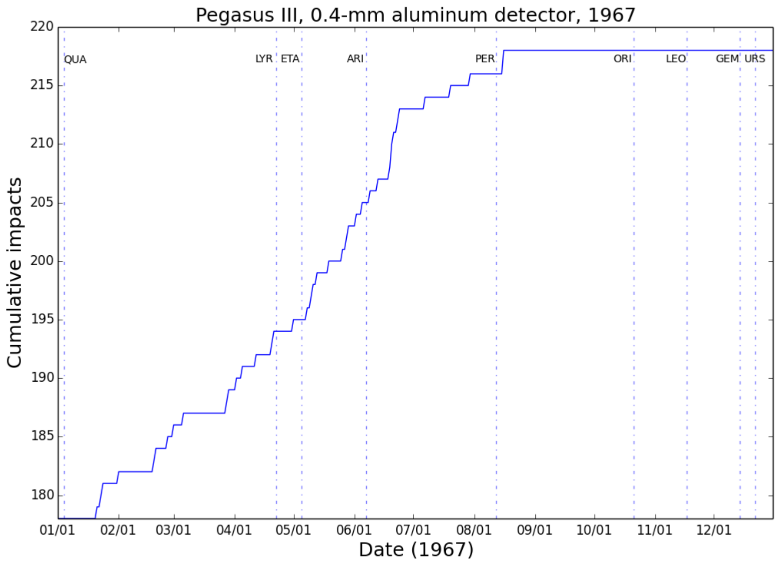


Pegasus III, 0.4-mm

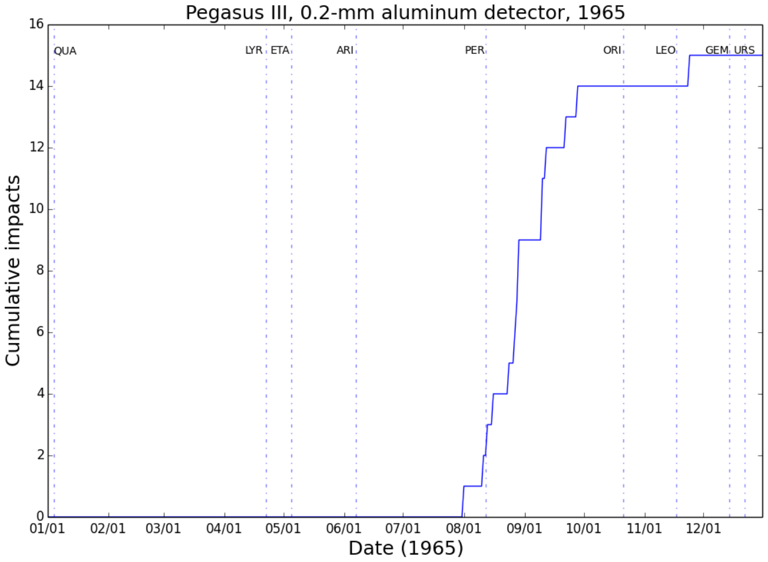




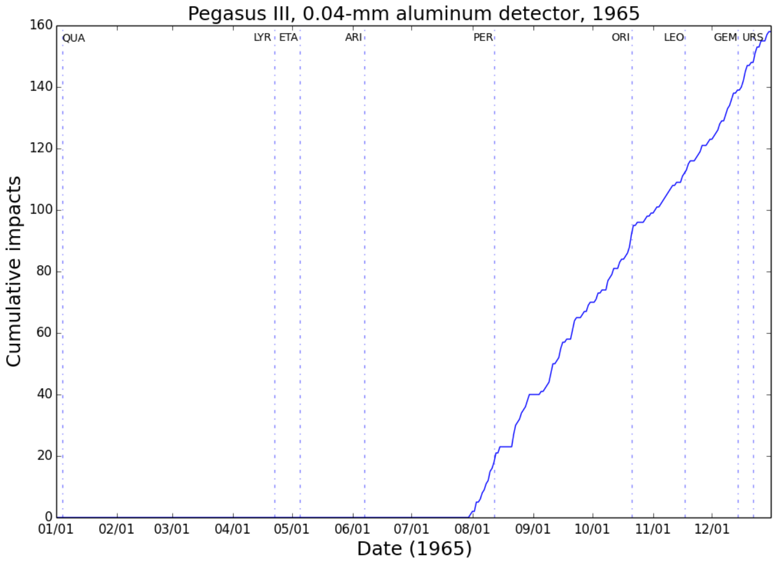
Pegasus III, 0.4-mm

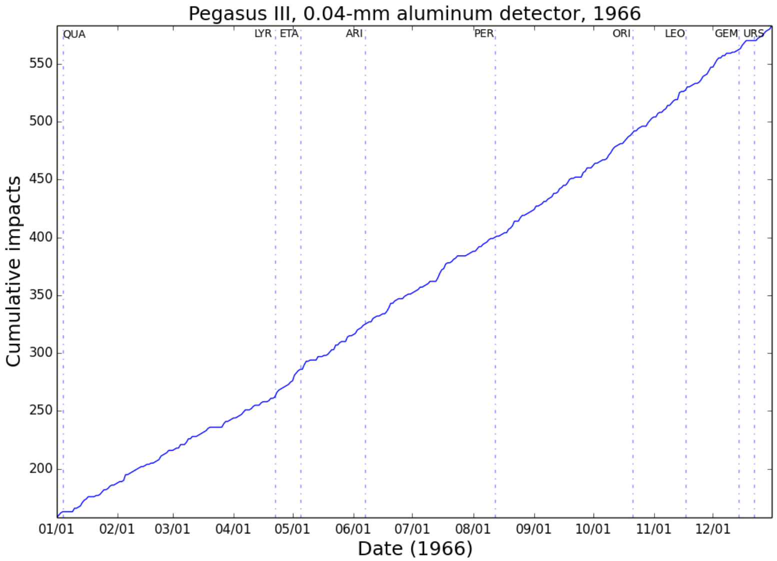


Pegasus III, 0.2-mm



Pegasus III, 0.04-mm





Pegasus III, 0.04-mm