Technical Concept for a European Laser Altimeter for Planetary Exploration

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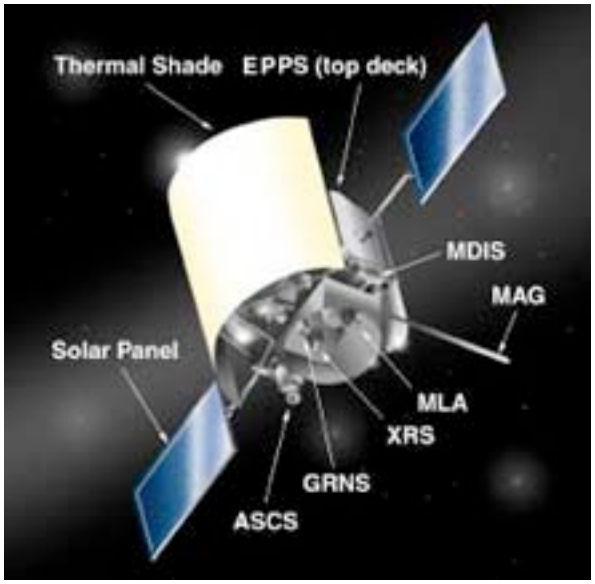
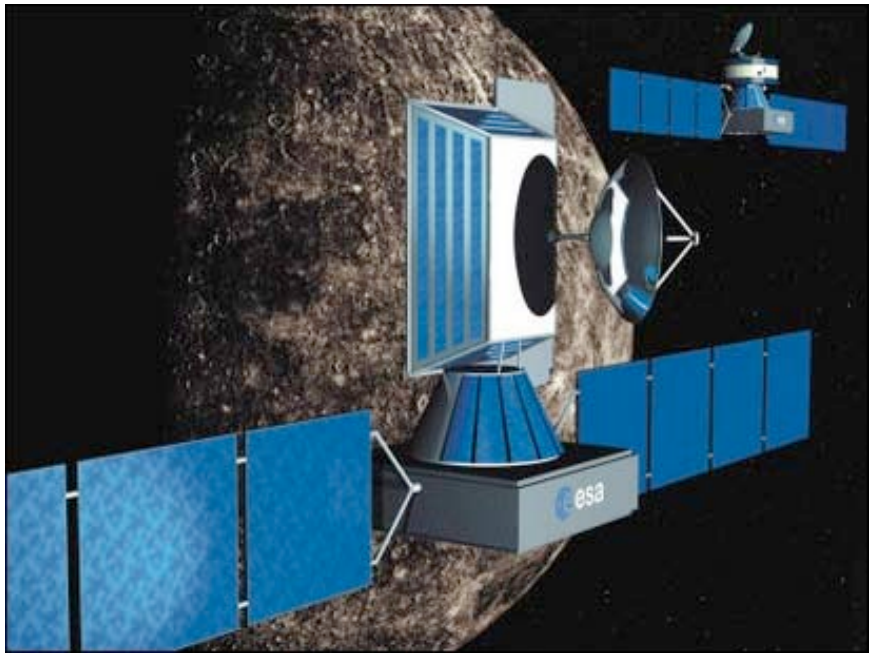
Mercury Exploration



Messenger (NASA)



BepiColombo (ESA)

Mission Details

	Messenger	BepiColombo
Launch	July 2004	Sept. 2012
Mission	1 Earth year	
Launch vehicle	Delta 7925H	Soyuz-Fregat
Launch mass	988 kg	1500 kg
Orbit details	200 - 15200 km	400 - 1500 km 400 - 12000 km
Experiment	MLA Dual Imaging System Magnetometer Spectrometers (various)	LAPE Vis. + near IR camera (stereo) Magnetometer Spectrometers (various)

Mission Requirements

- Total mass < 8.5 kg (goal 7 kg)
- Total el. Power < 30 W (goal 25 W)
- Range 300 km < R < 1000 km (1200 km)
- Range resol. 1 m
- Heat influx < 20 W

- Small telescope
- „DC-pumped“ Laser (no capacitor banks)

Laser Link Equation

$$n_{pe} = \eta_q \left(E_t \frac{\lambda}{hc}\right) \eta_t G_t \sigma \left(\frac{1}{4\pi R^2}\right) A_r \eta_r$$

Alternative Concept

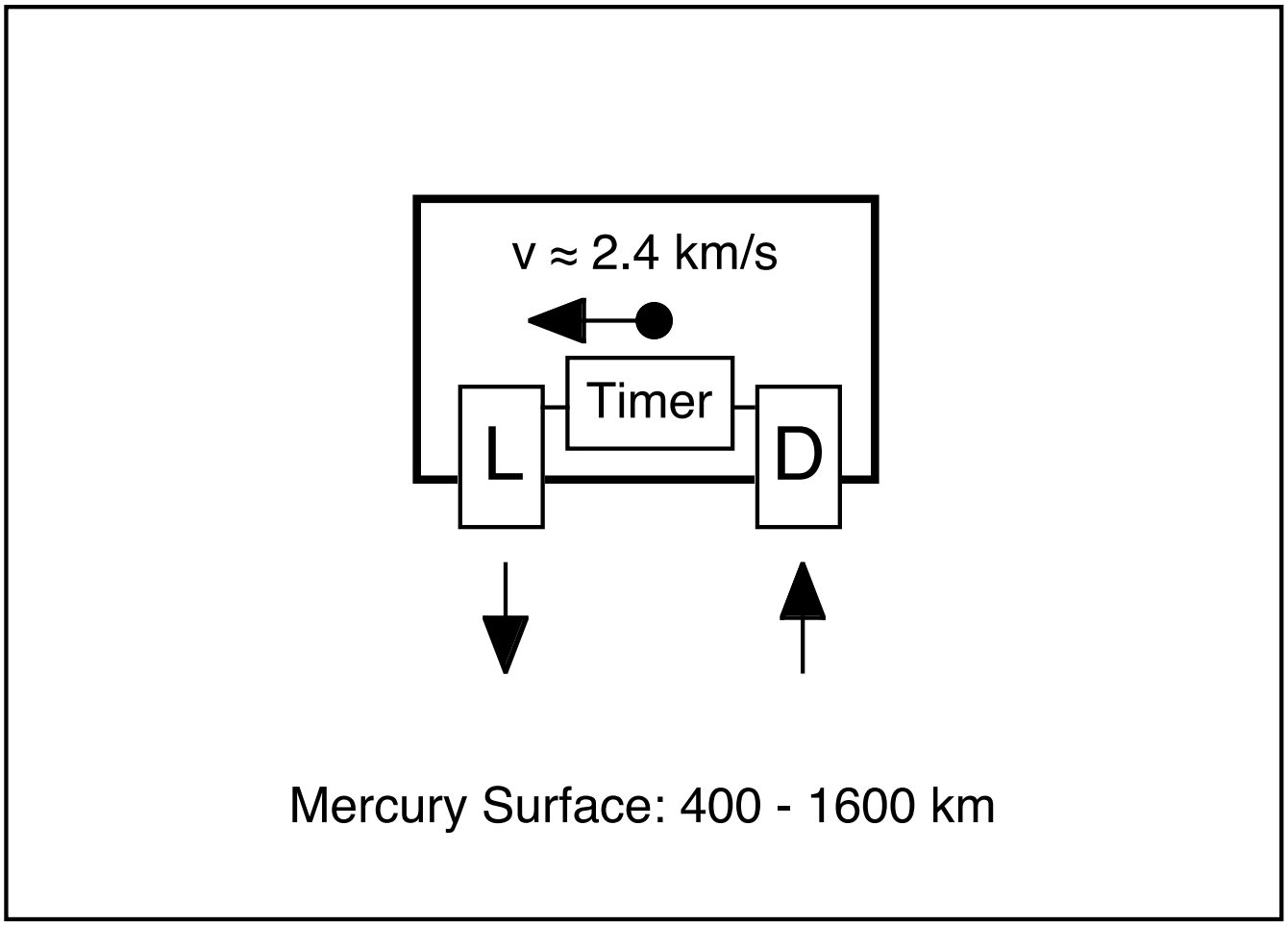
- some parameters of the link equation have penalties:
  - weight (telescope...)
  - power consumption (laser...)
  - heat influx (telescope...)

- some parameters are trade- offs
  - system transmission
  - detector quantum efficiency

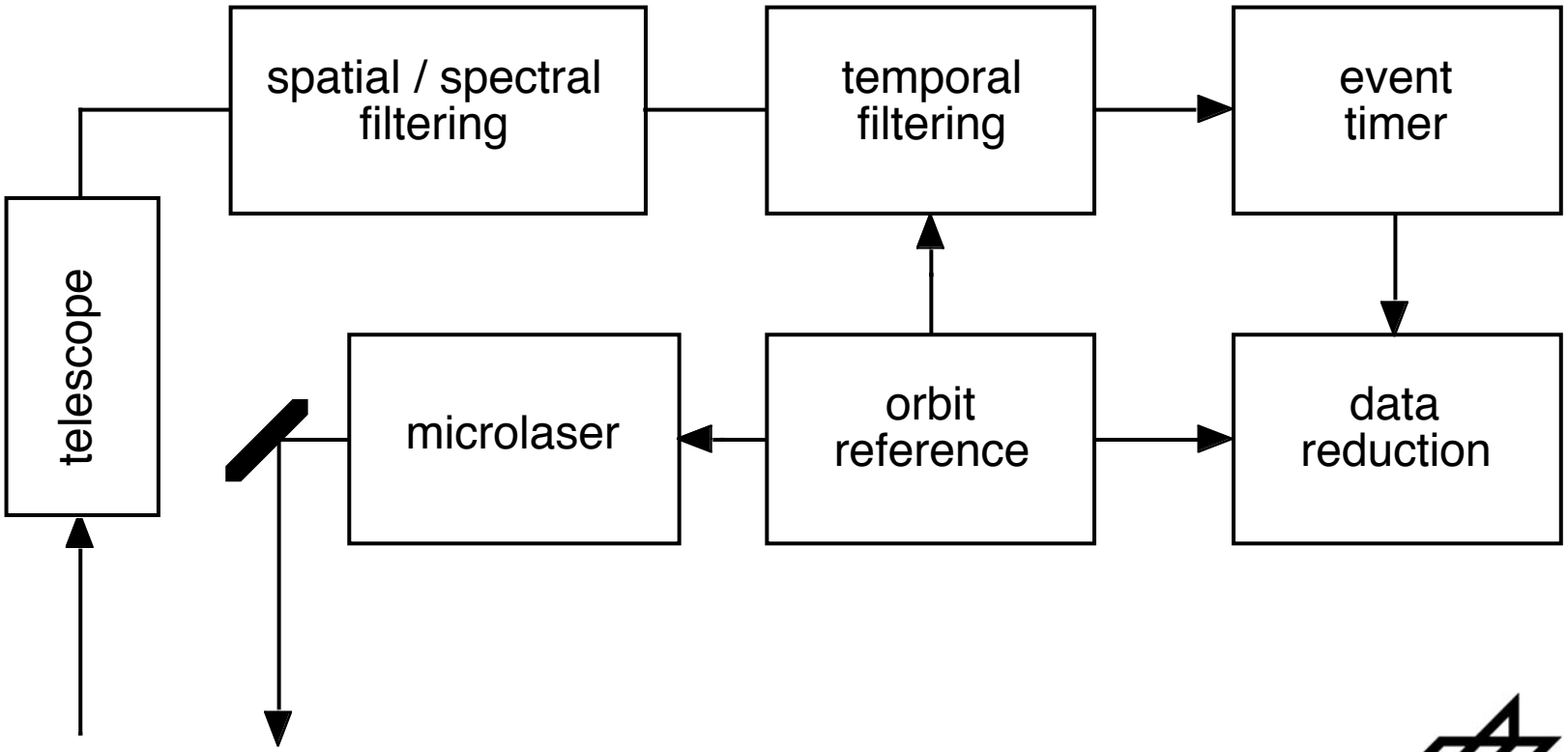
--> Find the combination for the best solution

Alternative Concept

- reduction of n_{pe} to small values ($n_{pe} < 1$)
- high quantum efficiency by **a**valanche **p**hoto **d**iodes
- high repetition rate and statistical pre-processing
- aperture size 15 cm to avoid heat influx over 20 watts


v ≈ 2.4 km/s
Timer
L
D
Mercury Surface: 400 - 1600 km

Altimeter Block Diagram



I. Micro-Laser

JDS Uniphase Micro-Laser

Model	NG-00121-100	NP-00321-100
Wavelength [nm]	532	1064
Energy / Pulse [μJ]	> 1	> 6*
Pulse Width [ns]	< 1	< 1
Repetition Rate [kHz]	10 – 20	10 - 20
Beamprofile	TEM_{00}	TEM_{00}

* 100 μJ if fibre amplifier applied

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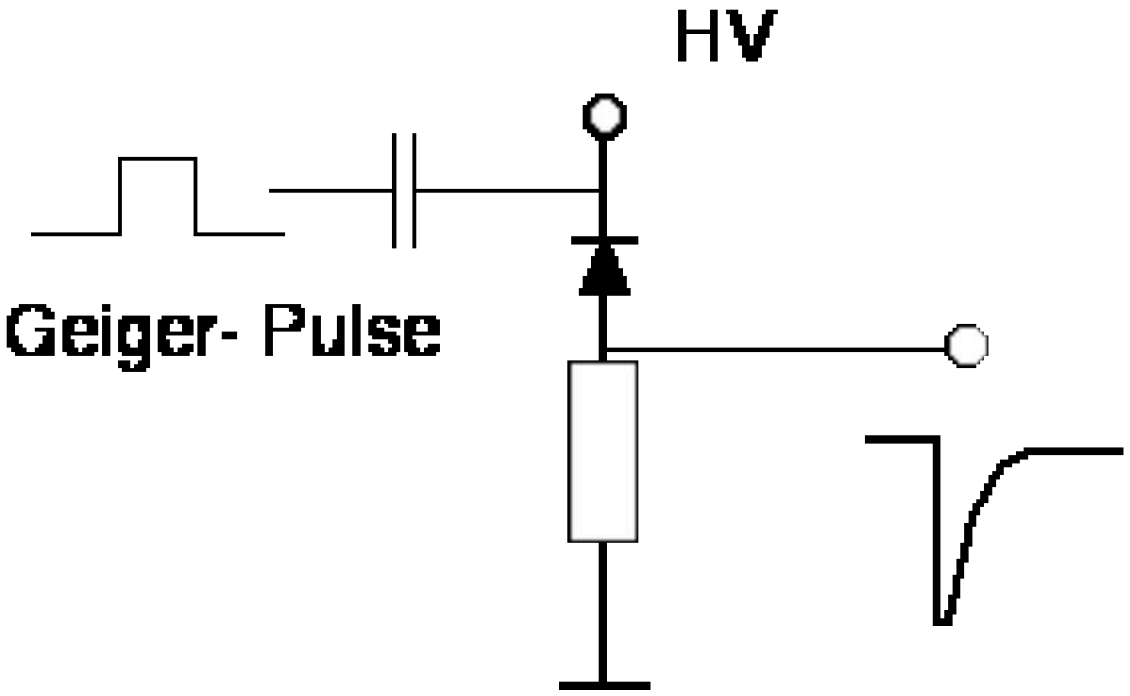
II. Semiconductor Detector

Geigermode Operation

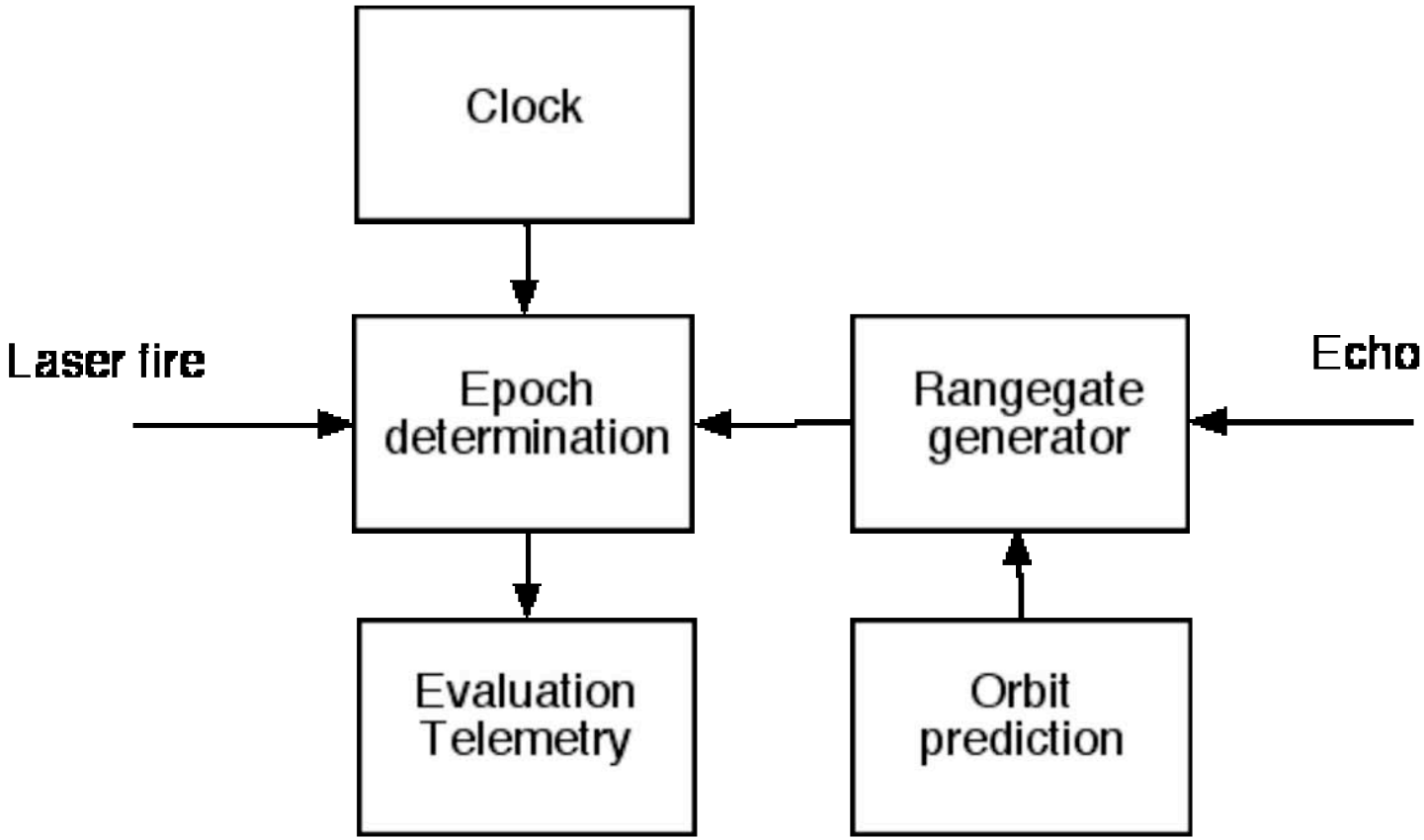


Noise Reduction

- spatial filtering
- spectral filtering
- temporal filtering

- pattern recognition

Altimeter Operation



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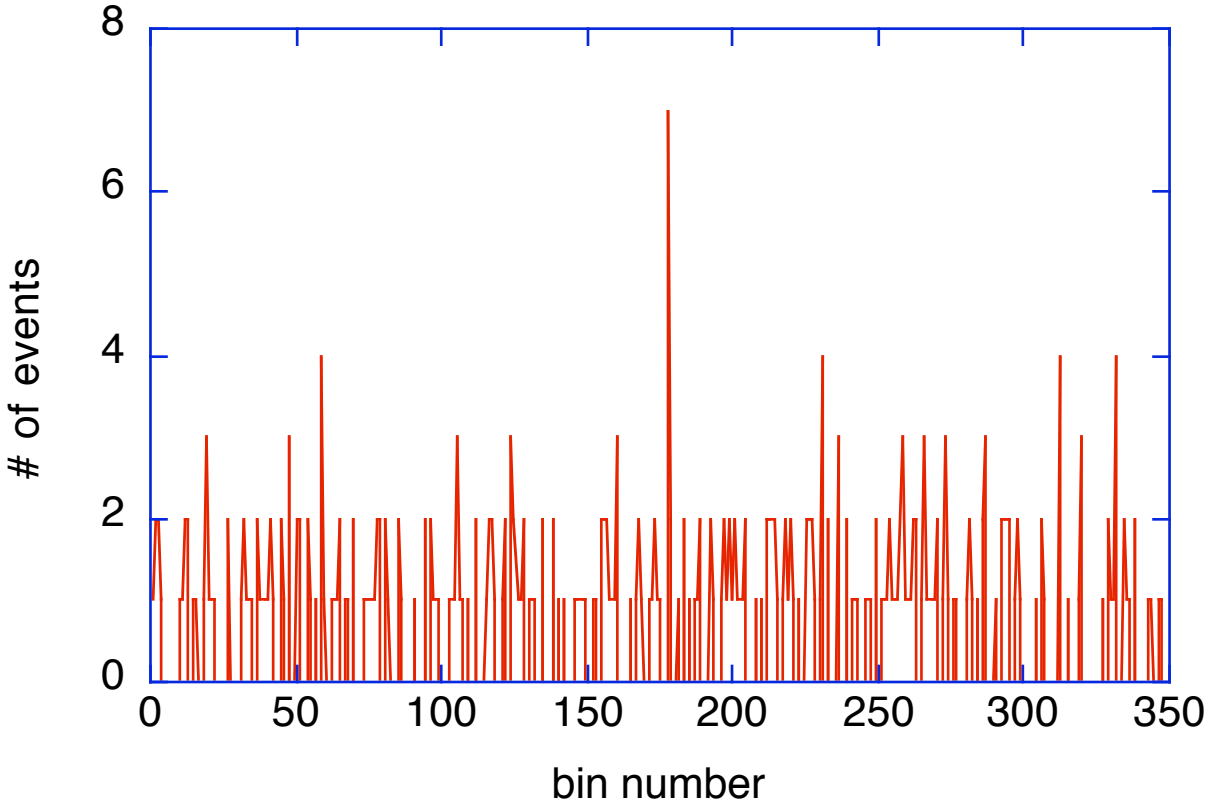
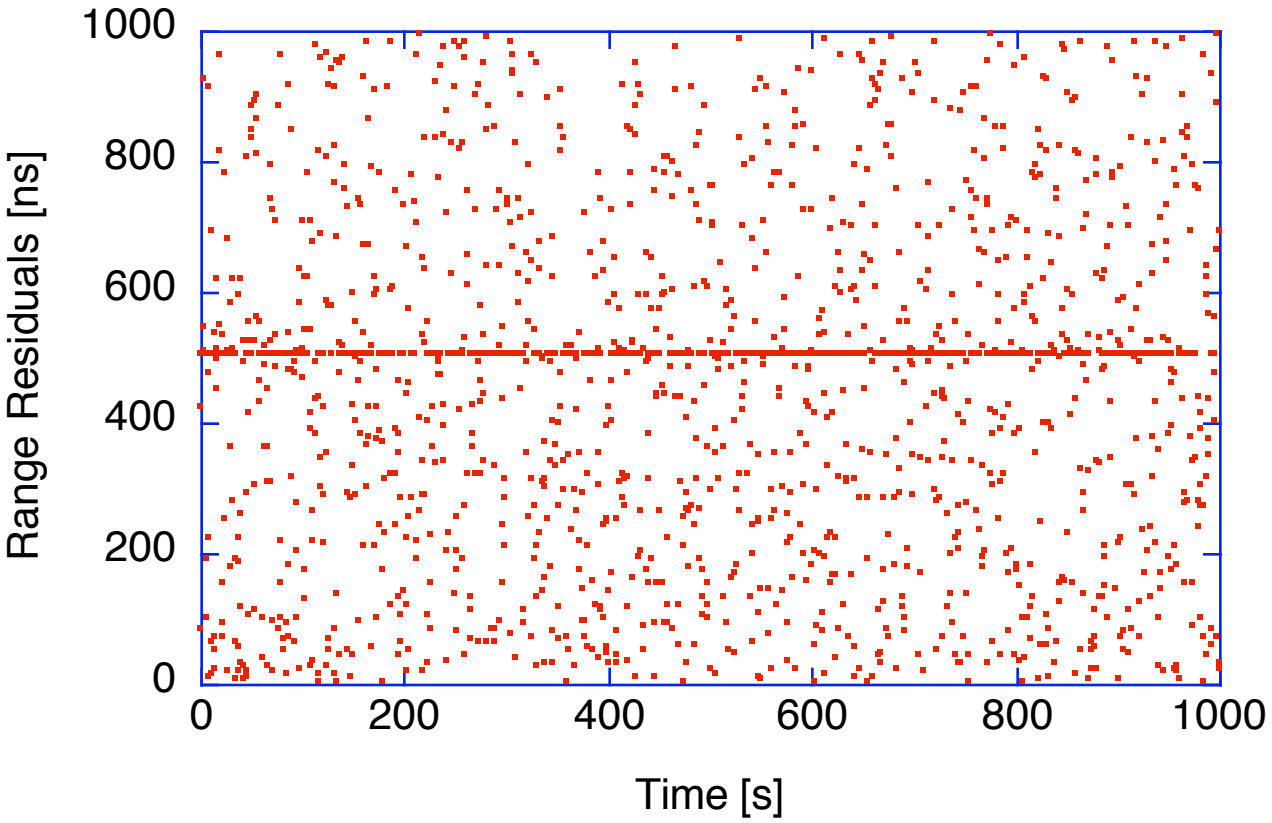
III. Statistical Data Reduction

Data Simulation



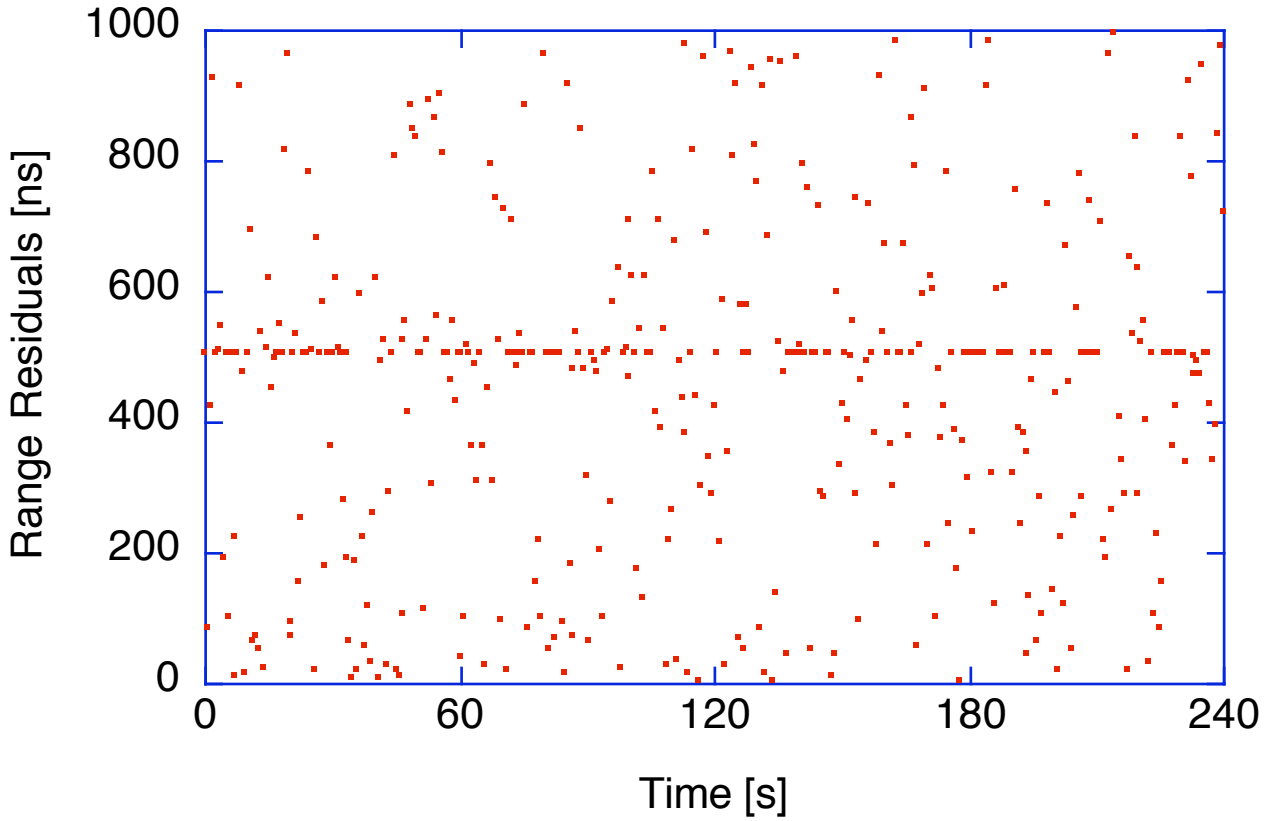
h = 800 km, P = 2 μJ, d = 15 cm, Rep.Rate = 16 kHz, Sampling = 0.1 s

Worst Case scenario



h = 1600 km, P = 2 μJ, d = 15 cm, Rep.Rate = 16 kHz, Sampling = 0.6 s

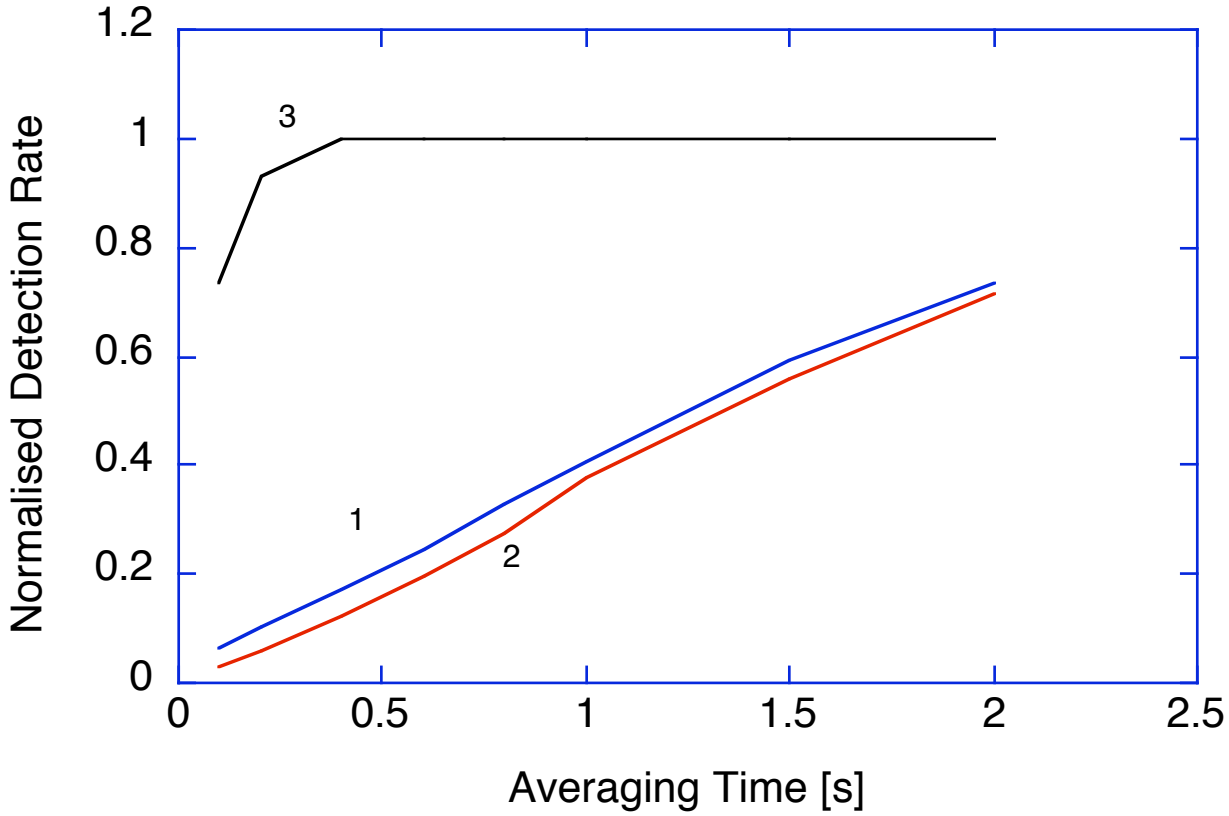
Expansion: Det.Prob. 20%



h = 1600 km, P = 2 μJ, d = 15 cm, Rep.Rate = 16 kHz, Sampling = 0.6 s

Altimeter at Apogee

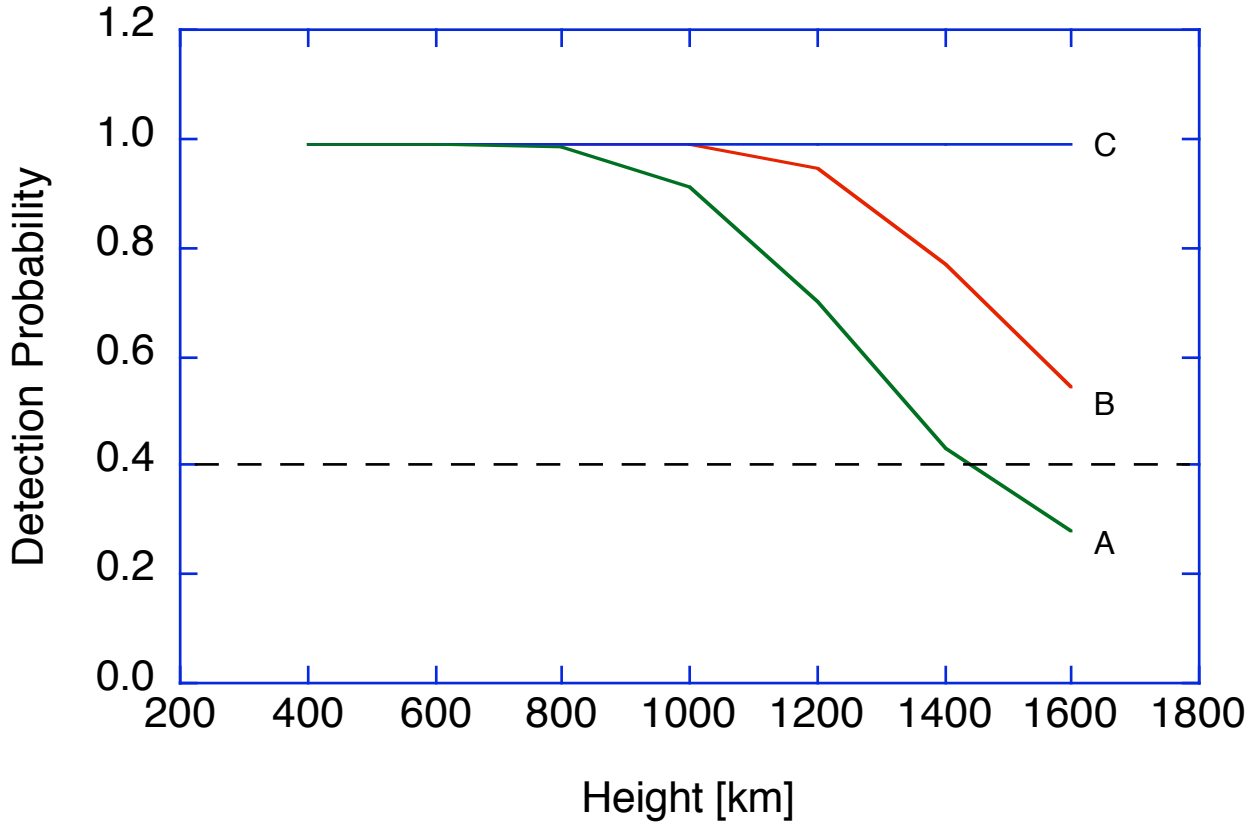
Parameter	Case 1	Case 2
Aperture Size [cm]	15	15
Energy / Pulse [μJ]	2	8
Receiver Transmission	0.5	0.6
Repetition Rate [kHz]	16	16
Detector Efficiency	0.6	0.7



(1) Simple noise reduction model, (2) Case-1 settings, (3) Case-2 settings

Performance depending on Range

Parameter	Case A	Case B	Case C
Pulse Energy [μJ]	2	4	6
Telescope Diameter [cm]	15	15	15
Repetition Rate [kHz]	16	16	16
Detector Efficiency	0.7	0.7	0.7
Averaging Time [s]	0.5	1.0	1.0
Mercury Albedo	0.2	0.1	0.1

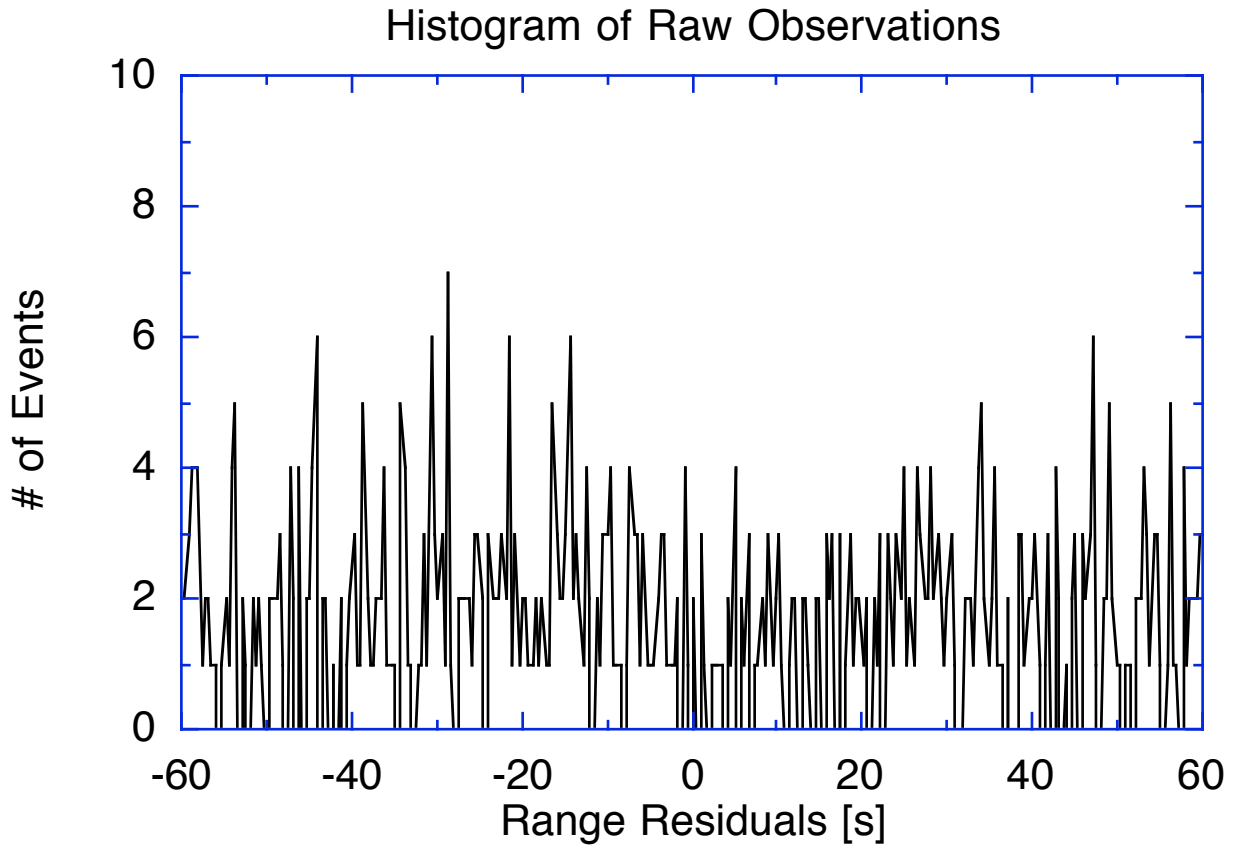

1.2
1.0
0.8
0.6
0.4
0.2
0.0
Detection Probability
200
400
600
800
1000
1200
1400
1600
1800
Height [km]
C
B
A

IV. General Considerations

Telemetry

- Limited Bandwidth (500 bps)
- Data reduction
- Single return transfer on demand

Signal Processing...



L.A.P.E. ... by Correlation Techniques

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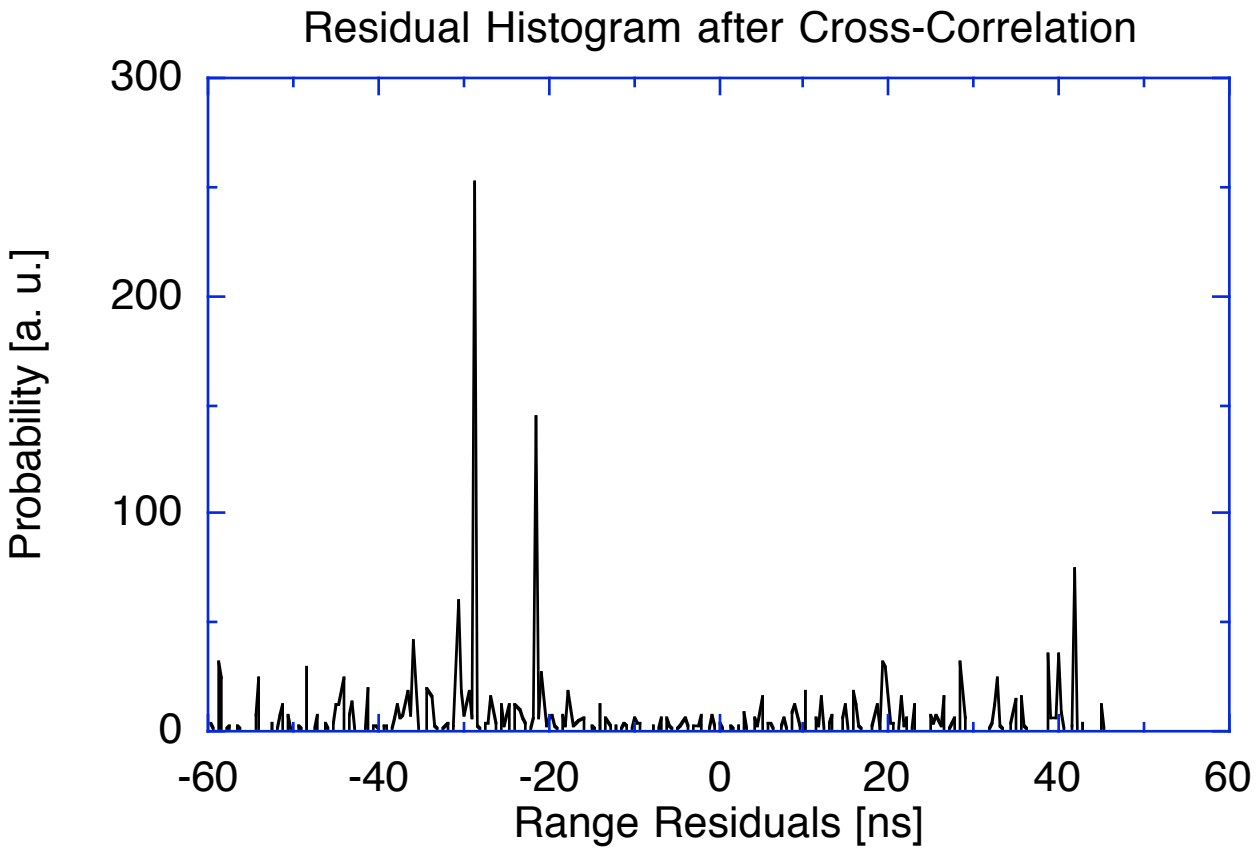
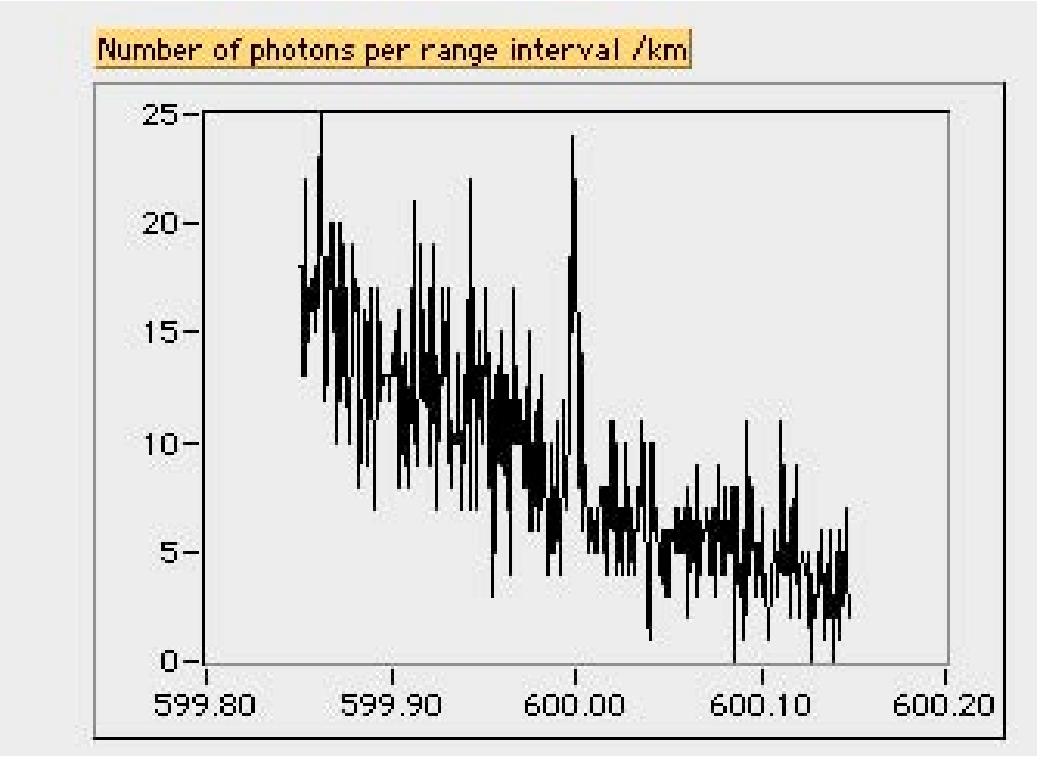
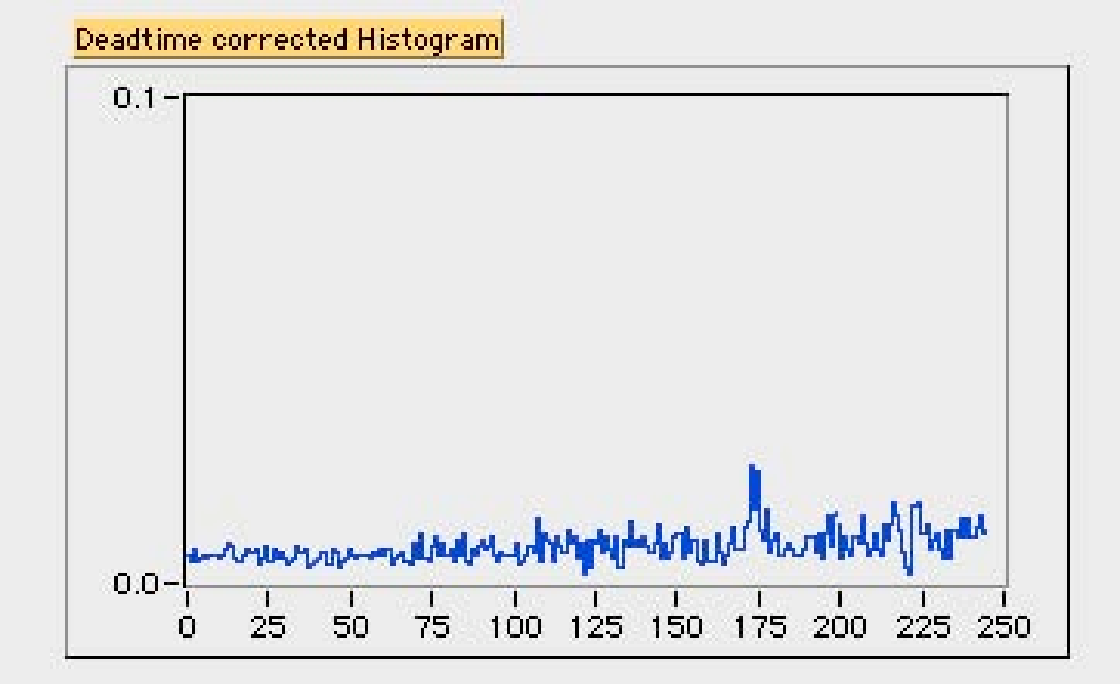


Daylight Ranging



moderately rough surface: Sigma = 1 m

Deadtime Correction



same dataset as before

Summary

- the laser link equation leaves room for adjustments
- single photon counting helps against the weight, heat influx and power consumption penalty
- high repetition rate and statistical pre-processing is then required