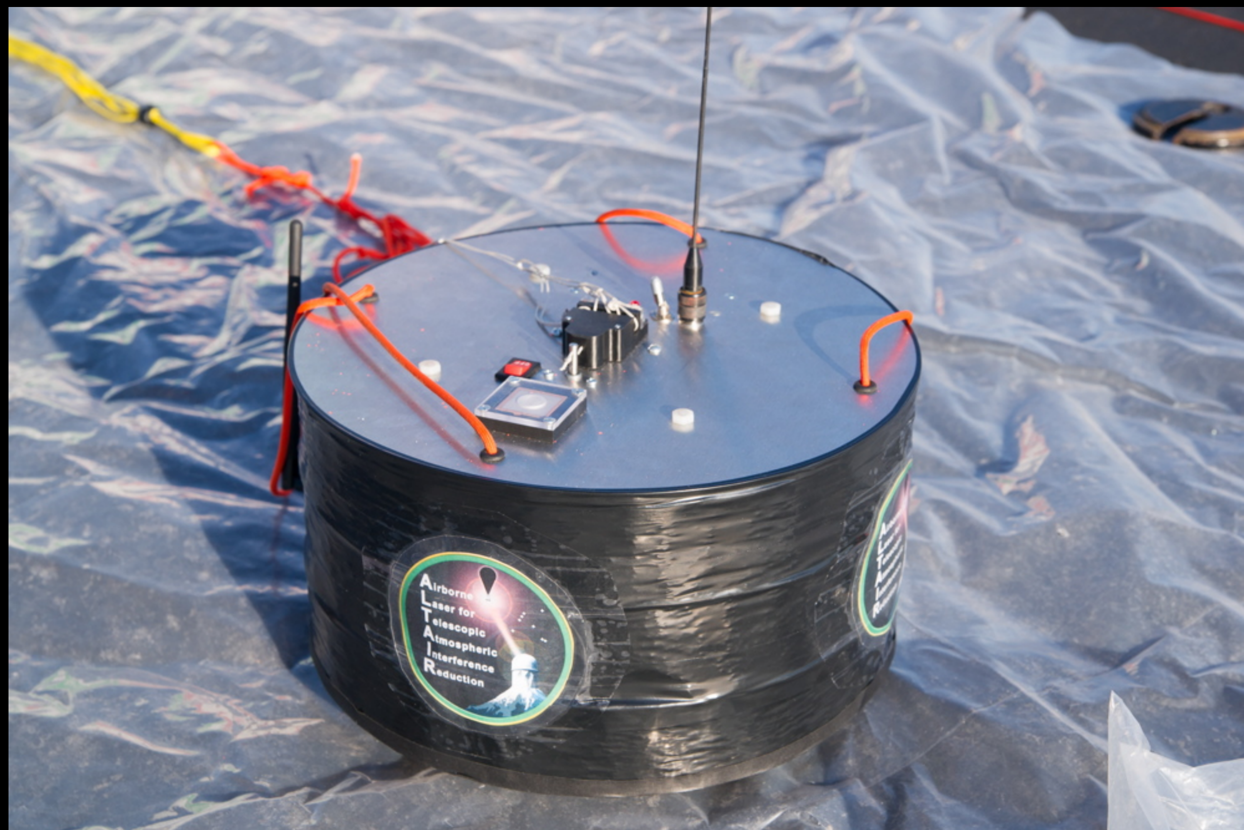
A Balloon-Borne Light Source for Precision Photometric Calibration



Maxwell Fagin[1], Yorke Brown[1], Justin Albert[2], Christopher Stubbs[3]
(1) Dartmouth (2) University of Victoria, (3) Harvard

CalCON, Aug 2012

Background

(Stubbs and Tonry, The Astrophysical Journal, August 2006)

<1% (absolute) optical photometry needed for ground based cosmology surveys

Current dominant source of error is **atmospheric extinction**, Due to:

H_20	Molecular	Aerosol

Can be computed in real time with atmospheric models (MODTRAN) and ground based measurements.

Goal:

Provide a technique for real time measurement of aerosol extinction and enable <1% absolute photometry

Technique

1) Backlight atmosphere with balloon borne polychromatic light source

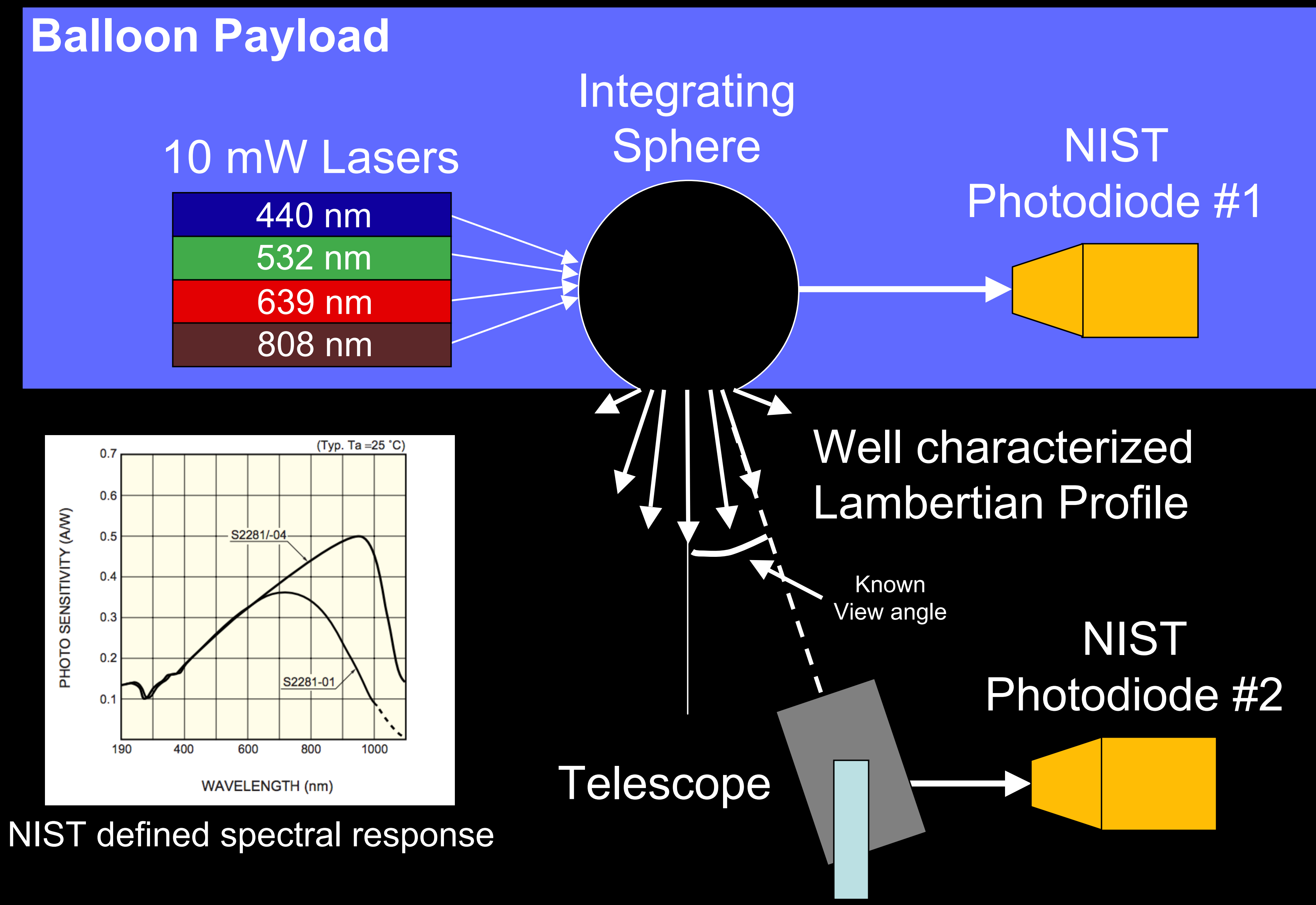
2) Use an on board NIST photodiode to measure absolute mag of source

3) Use a ground based NIST photodiode to measure apparent mag at detector

4) Account for extinction due to H_20 and molecular scattering with MODTRAN

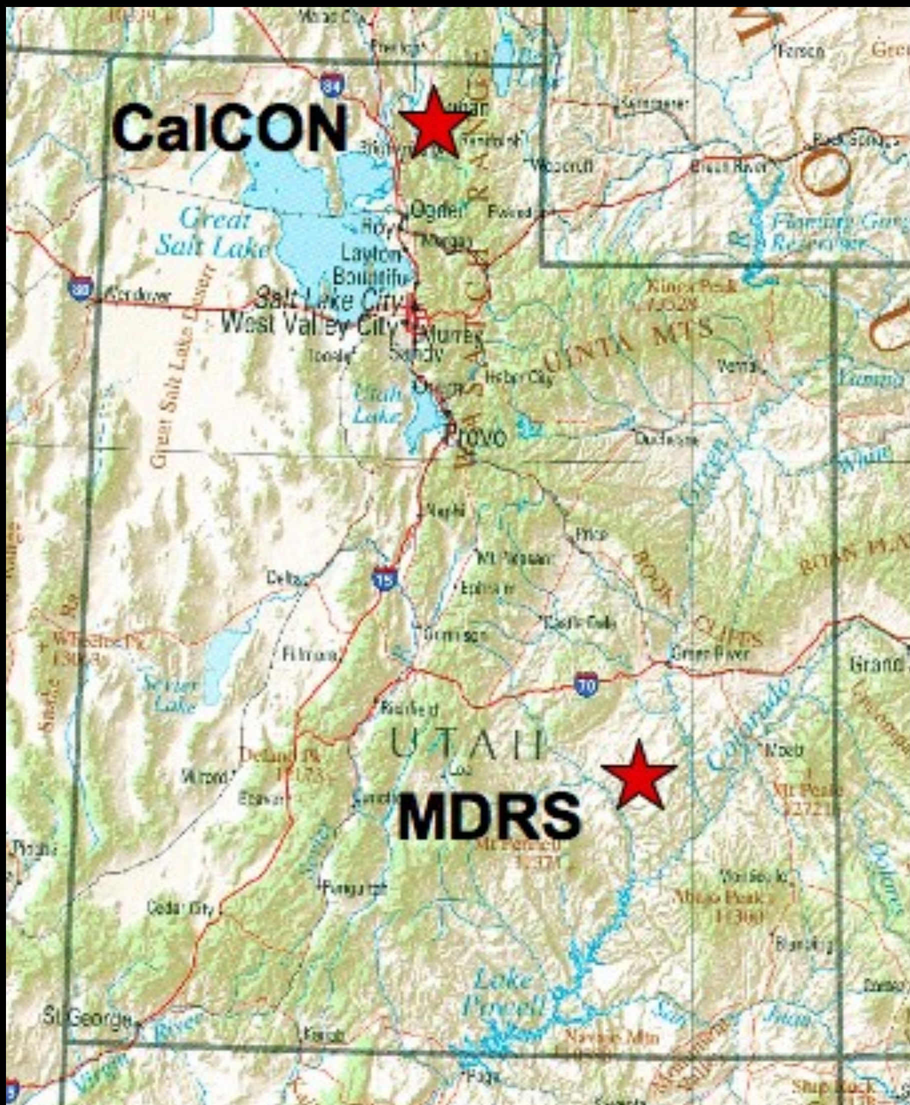
5) Remaining difference must be due to aerosol extinction

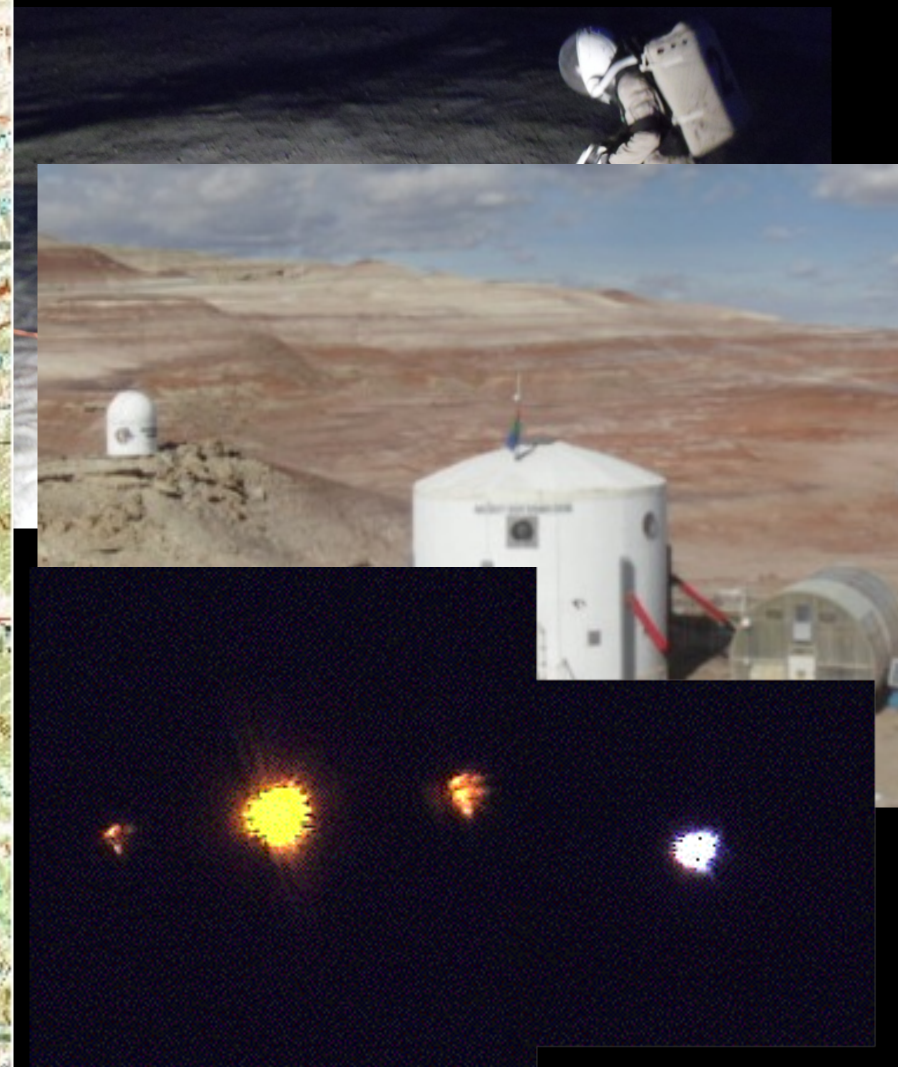
Technique



Balloon Payload
10 mW Lasers
440 nm
532 nm
639 nm
808 nm
Integrating Sphere
NIST Photodiode #1
Well characterized Lambertian Profile
Known View angle
Telescope
NIST Photodiode #2
(Typ. Ta =25 °C)
PHOTO SENSITIVITY (A/W)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
S2281/-04
S2281-01
190
400
600
800
1000
WAVELENGTH (nm)
NIST defined spectral response

First flight, Hanksville Utah at the Mars Desert Research Station (2010)





Why a balloon?

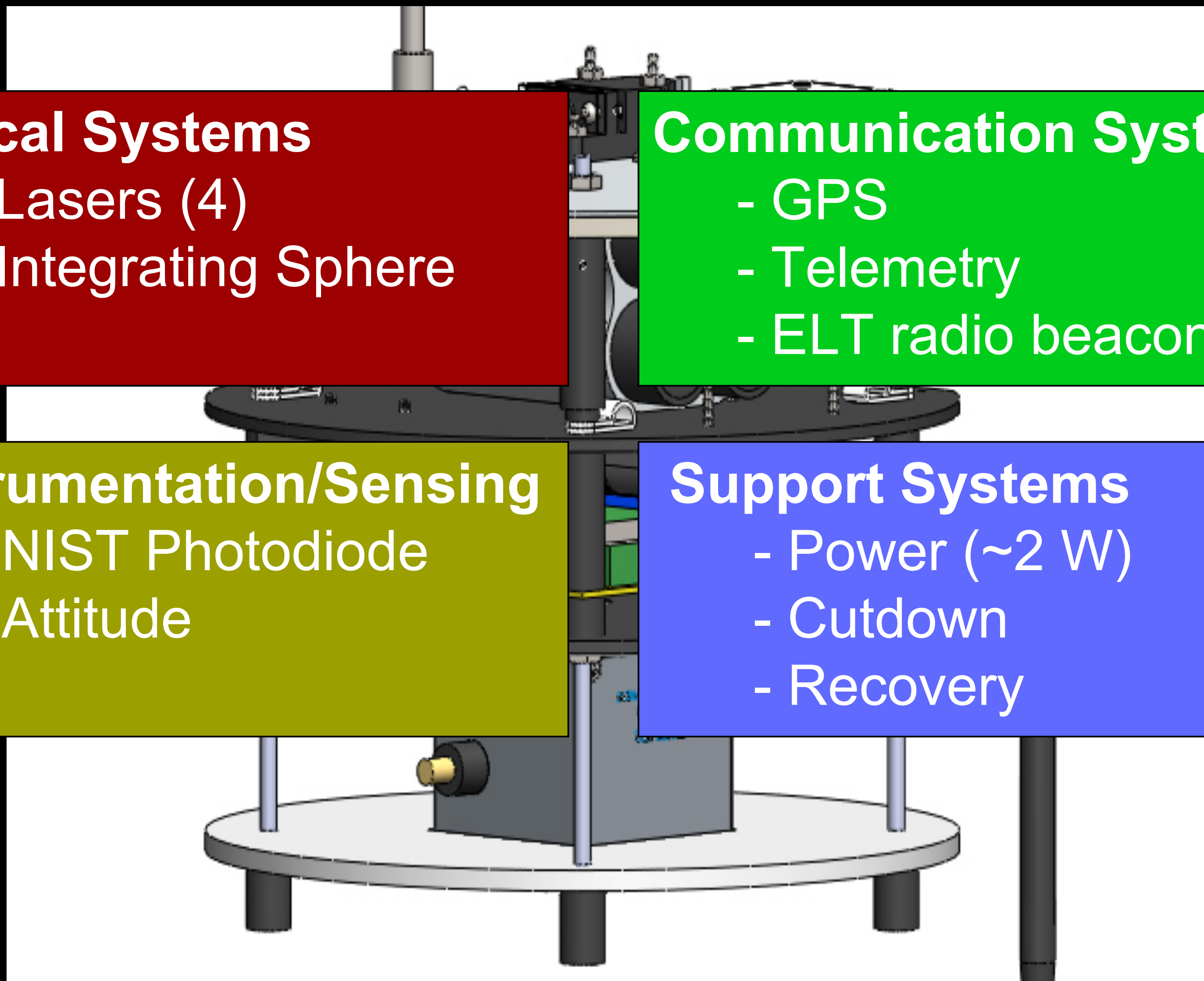
- Long integrations times (>2 min) for a 2° FOV (SDSS)

- Best possible SNR for fixed photometric output

- All instrumentation is recovered after flight
  - Calibration can be re-checked in the lab

- Logistically simple
  - 4 people (2 launch, 2 recovery)
  - All equipment fits in a 4-door sedan
  - Multiple launches per night if required

Payload Design



Optical Systems
- Lasers (4)
- Integrating Sphere

Communication Systems
- GPS
- Telemetry
- ELT radio beacon

Instrumentation/Sensing
- NIST Photodiode
- Attitude

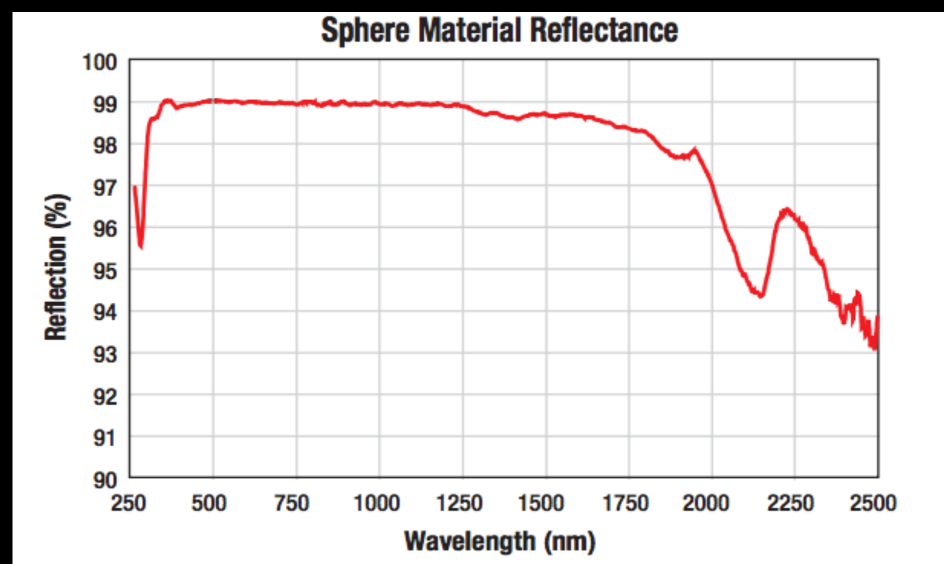
Support Systems
- Power (~2 W)
- Cutdown
- Recovery

Total weight < 6 lbs

Optical Systems

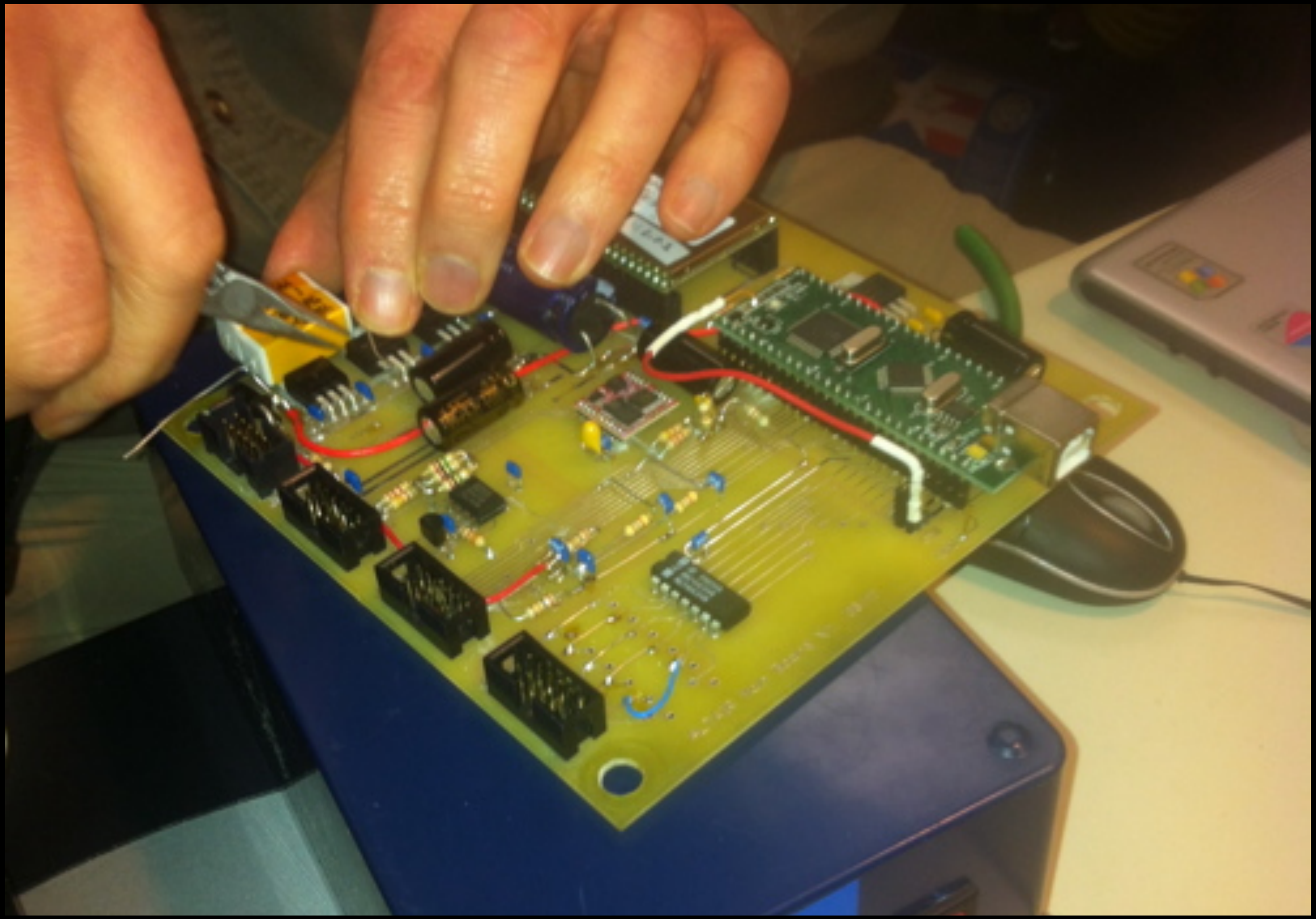
Laser Diodes
Photometric stability <.5%
100 g, <.5 W per laser

Integrating Sphere



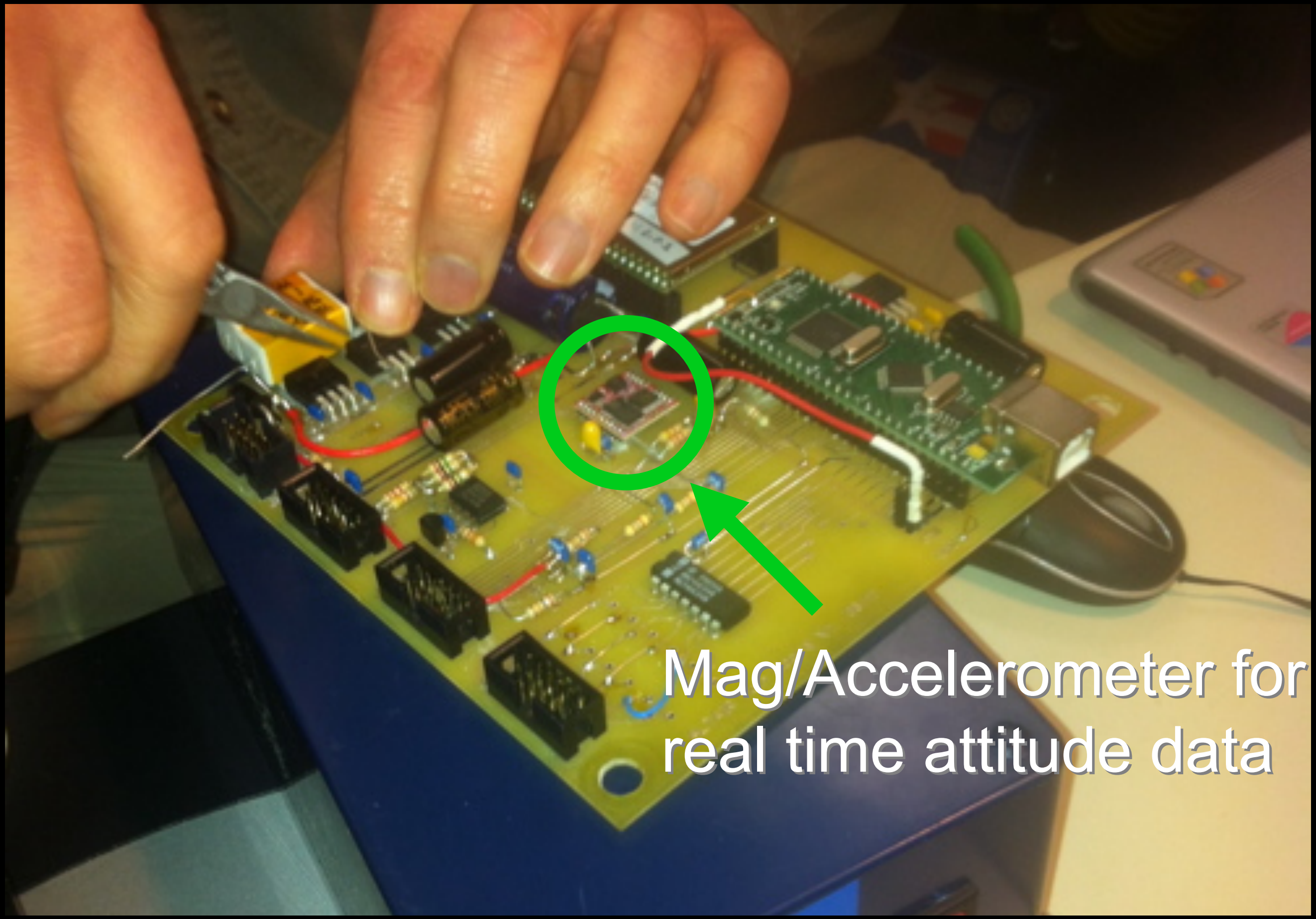
Communication Systems

900 MHz (UHF) DNT Transceiver Radio



Robust line of sight communication

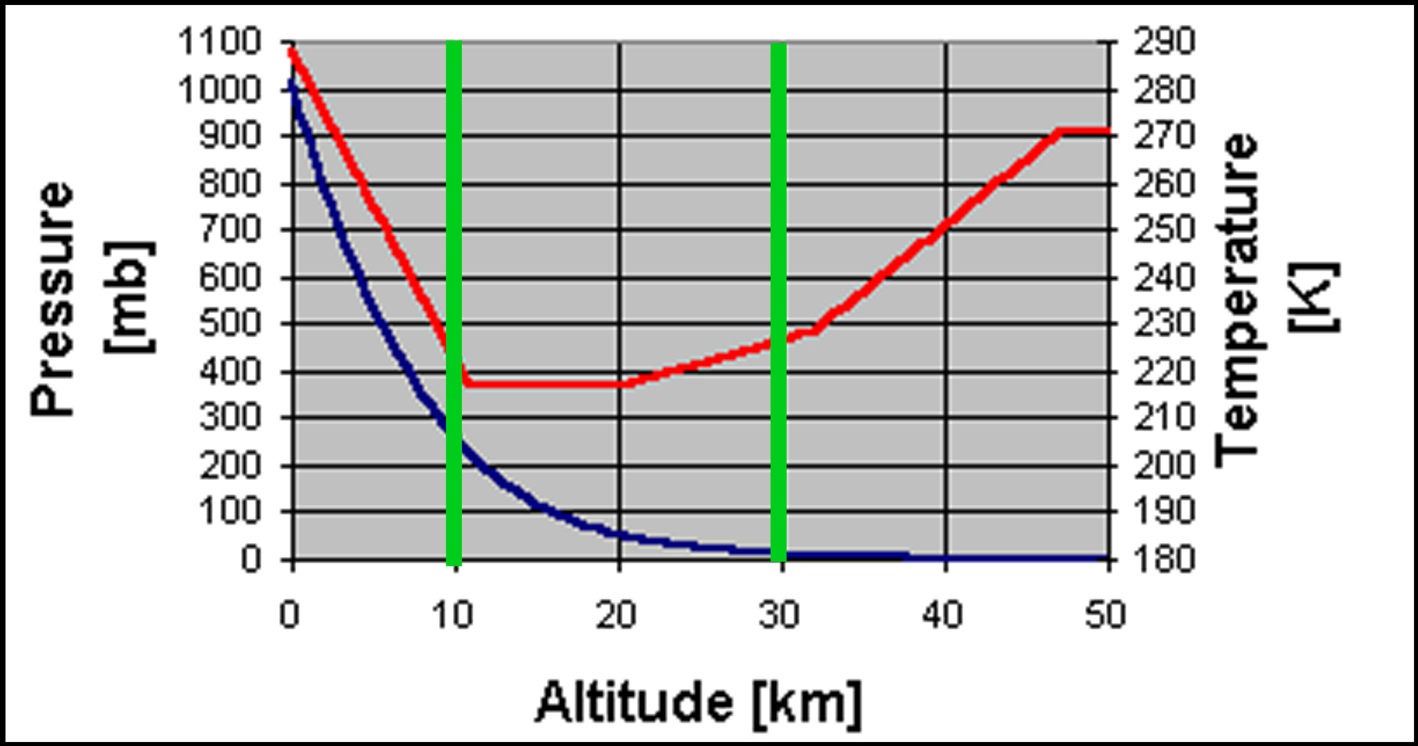
Instrumentation/Sensing



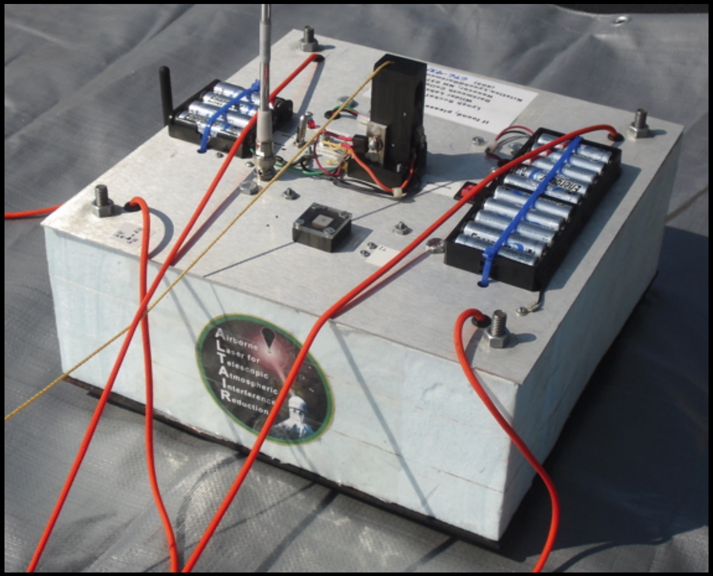
Challenge: Thermal Management

Peak Cooling
Ascent: airspeed 5 m/s through 30% atm at -55 °C

Peak Heating
Floating: airspeed 0 m/s in 2% atm at -45 °C



Flight Systems Test: ALTAIR 1
2011

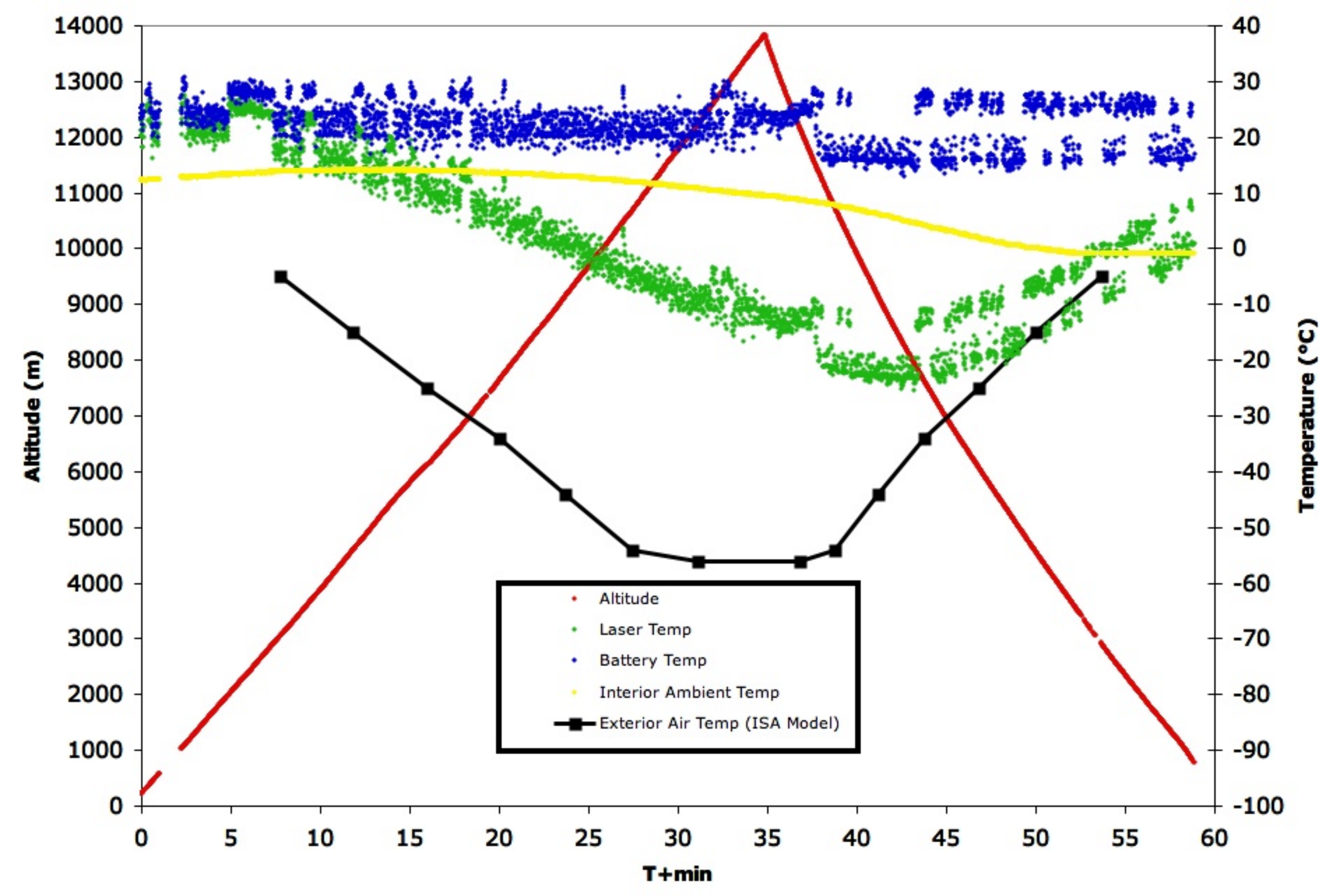


Flight Systems Test: ALTAIR 2
April 13, 2012

Flight Systems Test: ALTAIR 3 & 4

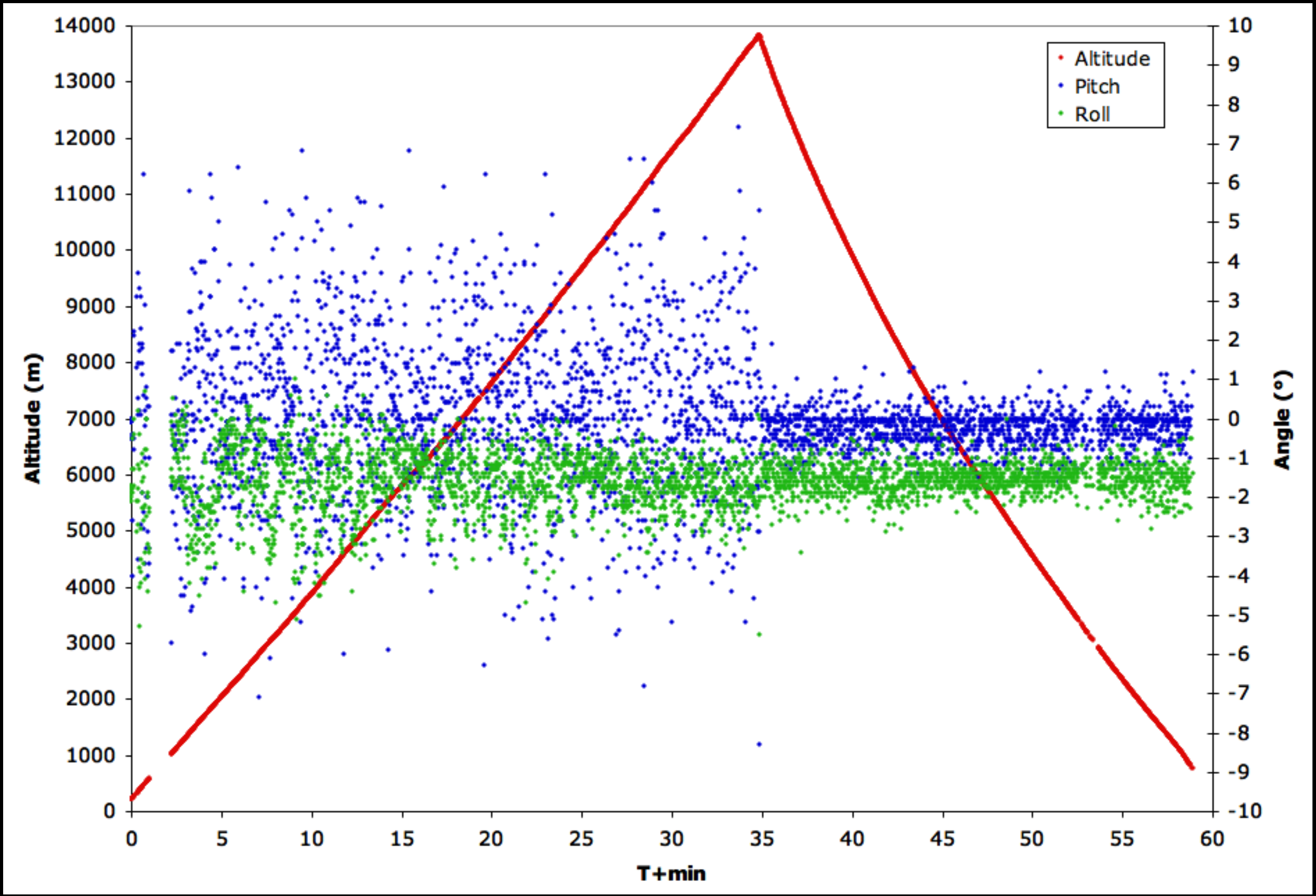
Aug 16 & 24, 2012

Test Flight Results



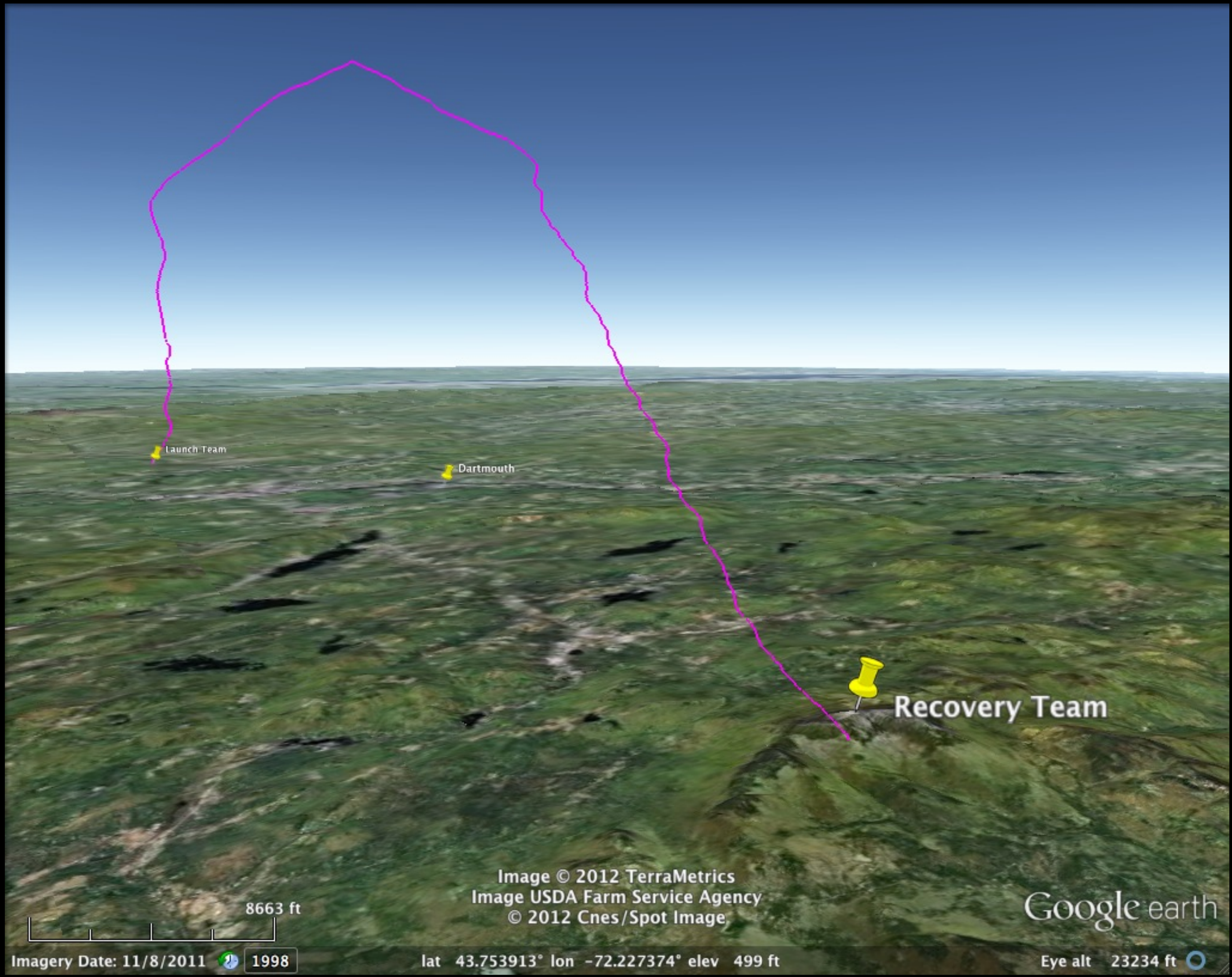
Can maintain lasers and NIST optics at viable temperatures

Test Flight Results



Can measure attitude and source brightness in real time

Test Flight Results



Can position light source at 30 km altitude, within 2° FOV

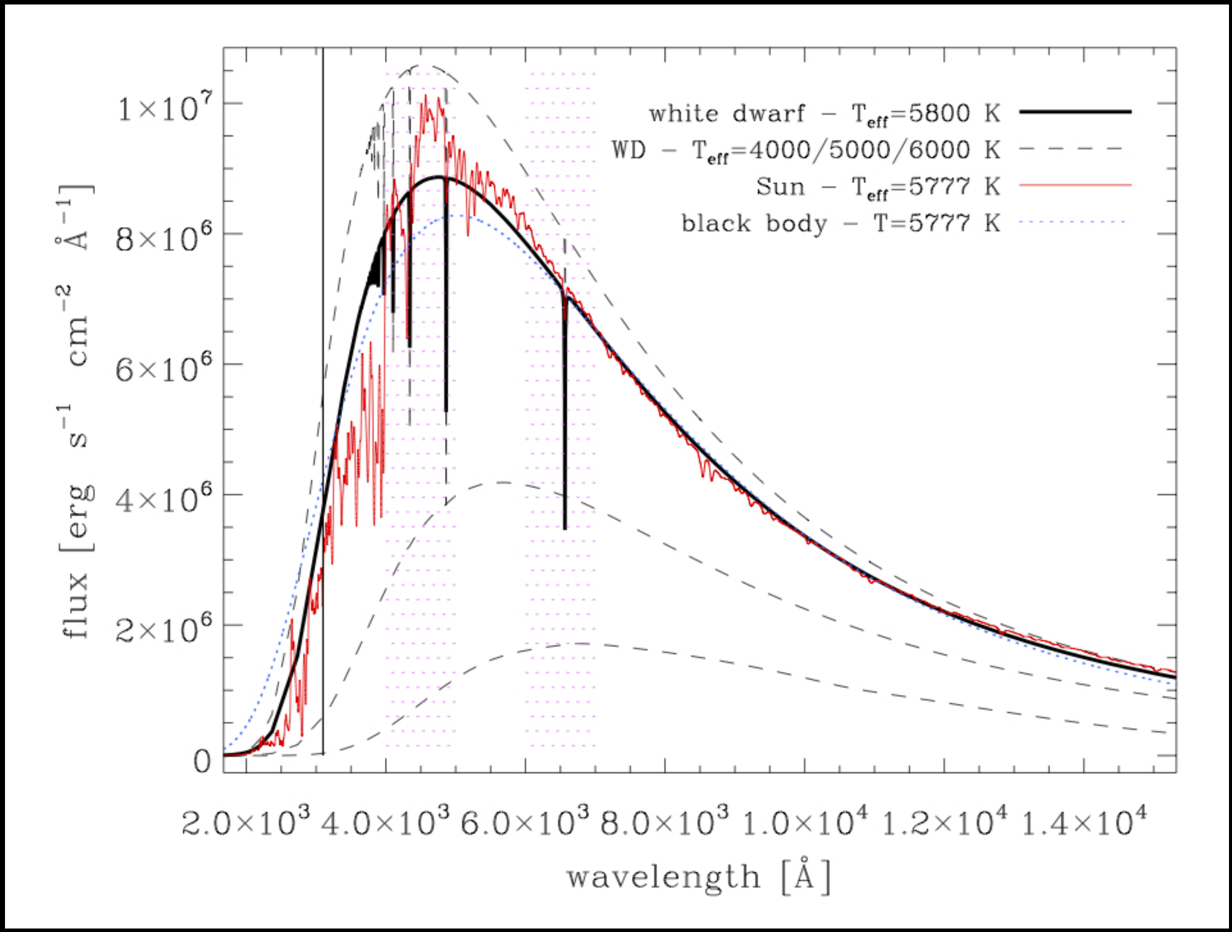
Test Flight Results

Can track light source from incoming GPS telemetry

Long term?

Calibrate an all sky catalog of **White Dwarf** standards

- Stable <1%, ~1000 yrs
- Near black body
- Full sky coverage
- magnitudes 8-20



Credit: Fossati, Bagnulo, ApJ 08/01/12

Goals Completed:

- Maintain stable thermal conditions for flight
- Sufficient power for >2 hours of data collection
- Control, communication and data handling
- Cutdown and separation from balloon
- Telescope and radio tracking
- Precision landing targeting (+/- 2 km)
- Real-time Telescope tracking
- Night launches

Still to do:

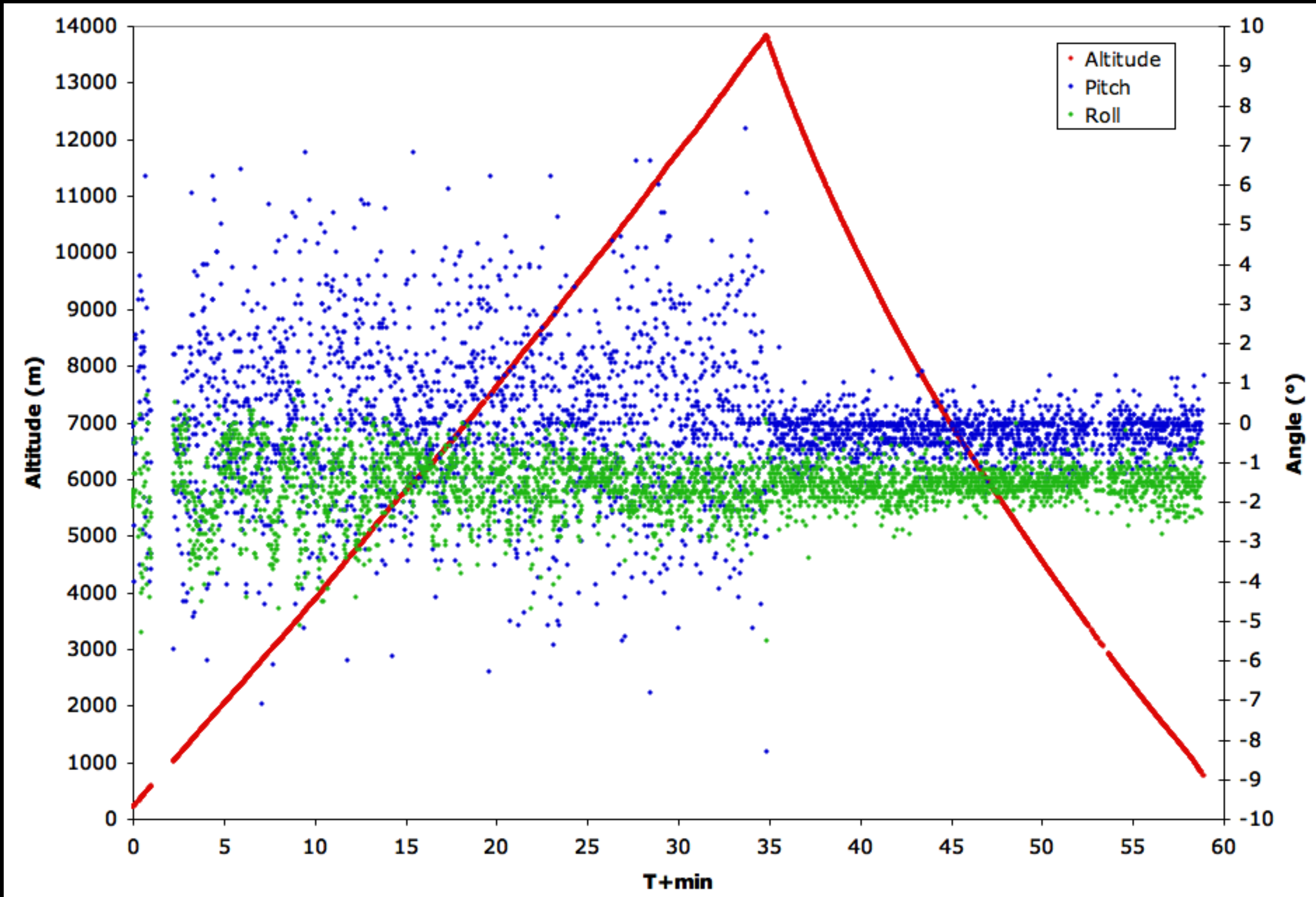
- Zero pressure “float” balloon
- Flight over Mt. Hopkins
- First astronomical flight in early 2013

Thanks to:

Yorke Brown, Chris Stubbs, Kristina Lynch and Justin Albert

Questions?

Appendix: Flight Data



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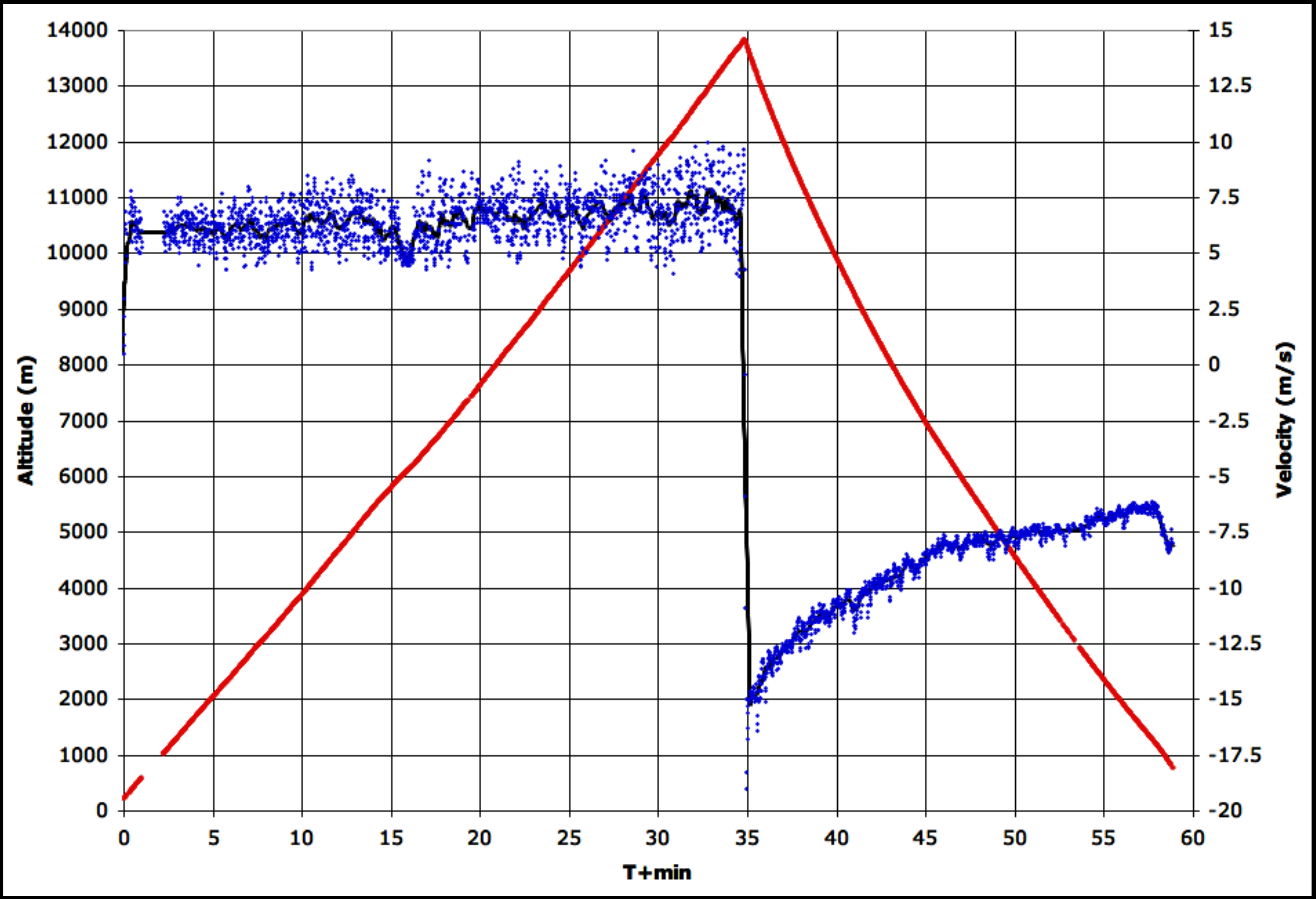

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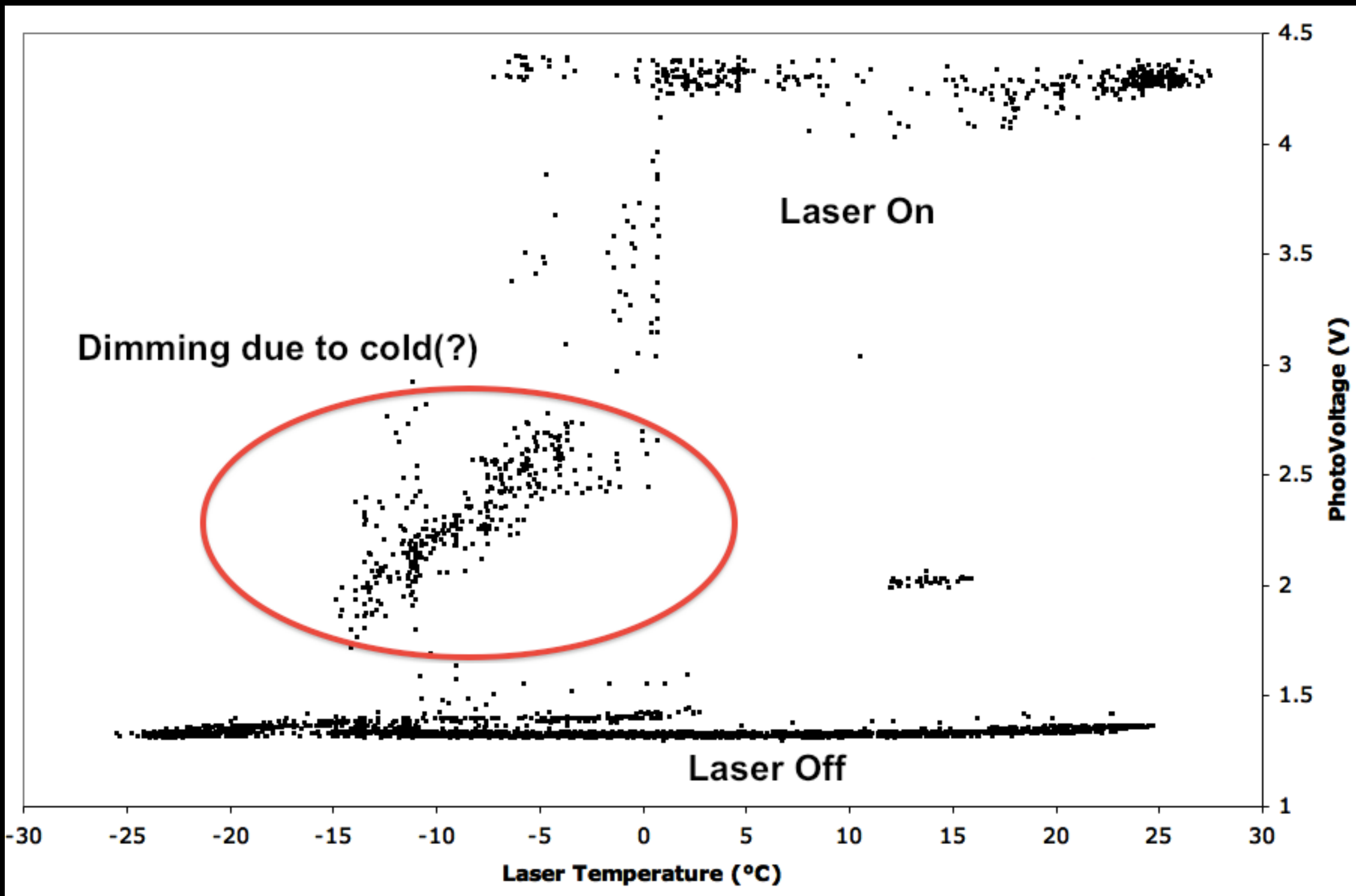

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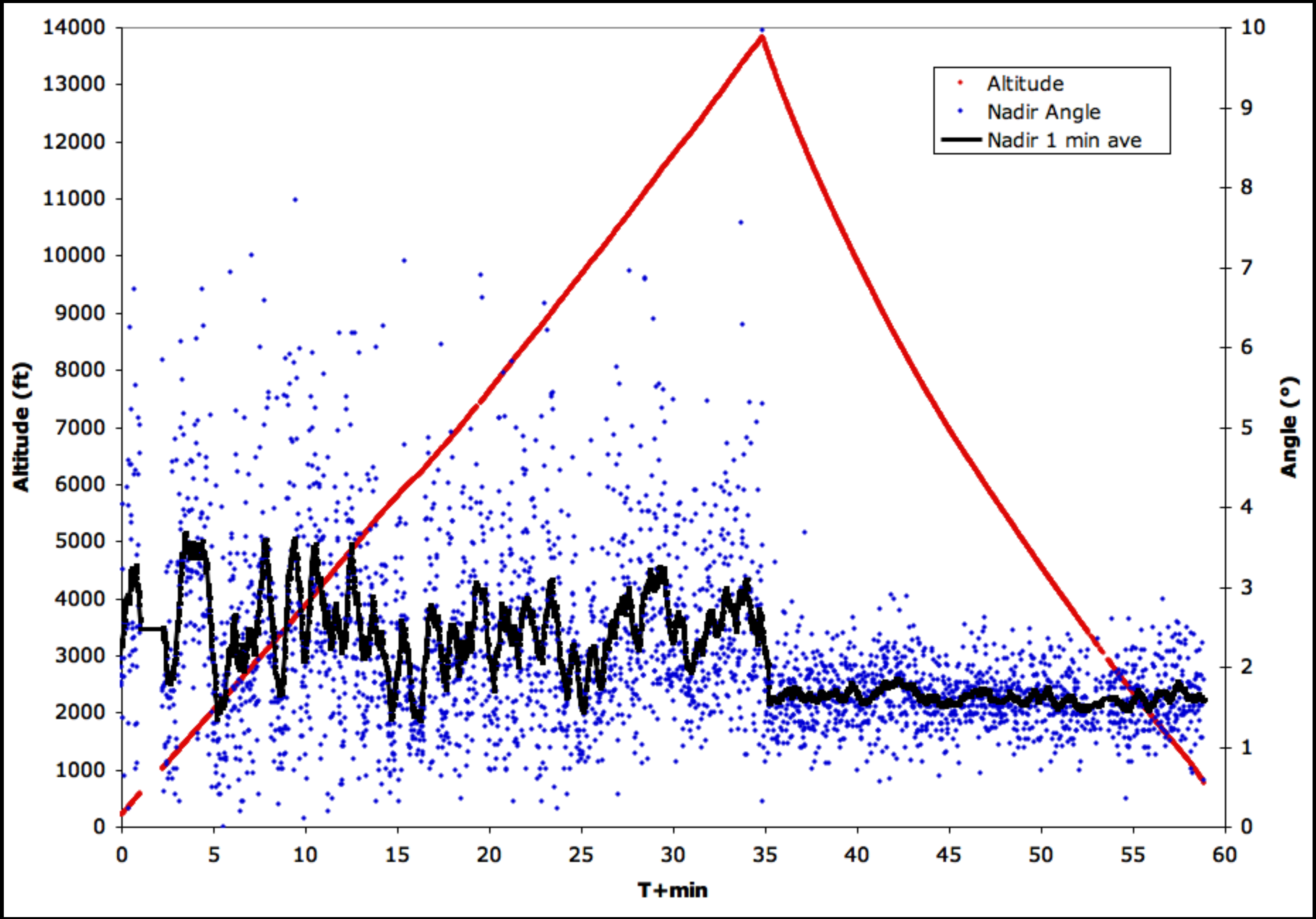

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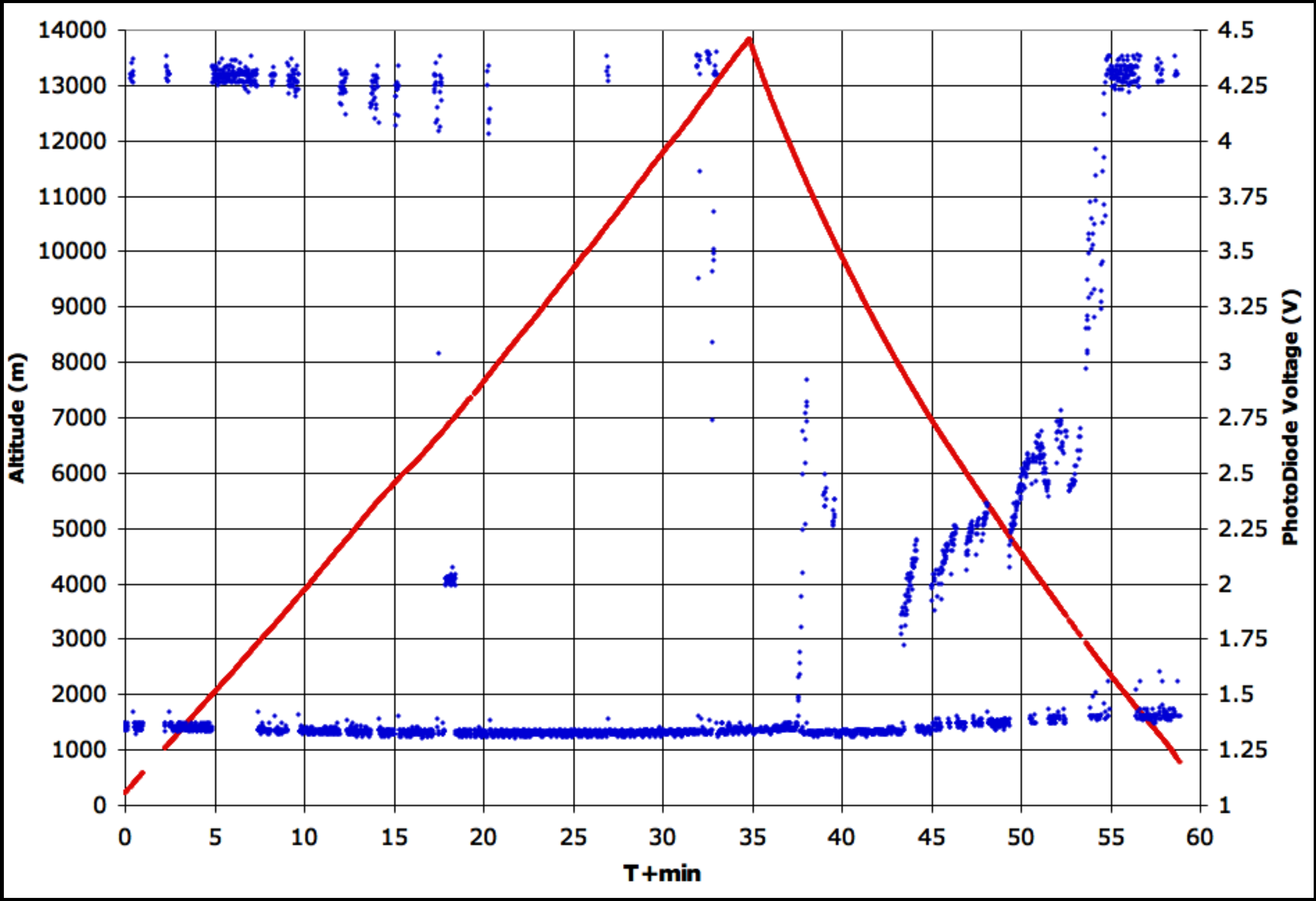

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