Research Topics in the Upper Atmosphere

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For: High Altitude Balloon Workshop
Taylor University, Upland IN
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Outline

1) Some Background

- Personal
- High Altitude Balloons at NASA Glenn

2) Solar Cell Calibration – A low Cost Payload

3) Cosmic Ray Detection

4) Photography

- Astronomical

Background – Personal

- Physics
  - PhD Washington State University 1981
- NASA Glenn over 30 yrs
  - Solar Array interactions with plasma environment.
    - Ionosphere
    - GEO environment, geomagnetic substorms
  - Solar Cell measurements
    - Measurements under simulated space illumination
    - Make calibration standards based on high altitude measurements.
      - NASA GRC Lear 25, near 50 – 35 kft.
      - Interest in Weather balloon platform.

Background – NASA Glenn Programs

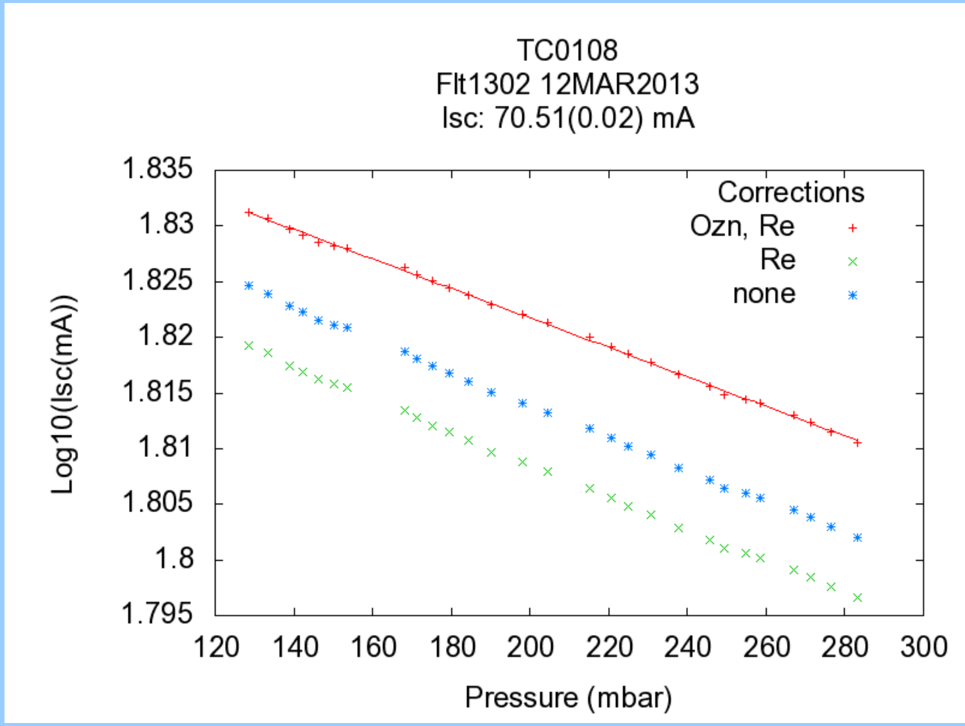
- "SunTracker:" Grant with Wayne State University 1999-2005
- Explorer Post 632: BalloonSat
  - High School Students
  - Began 2004, first flight 2005.
  - 19 flights (including some development flights)
  - Spring flight flies student projects.
- BHALF Program (Balloonsat High ALtitude Flight)
  - Two seasons (2010, 2011)
    - 3 flights
  - National Contest for High School groups
  - Selected four teams from proposals to fund experiments and invite to Cleveland launch.

High Altitude (AM0) Solar Cell Calibration

- Application
  - Provide Short Circuit Current (Isc) standards for laboratory measurements.
  - Verify on-orbit performance.
- Current High Altitude Calibration Facilities
  - NASA Glenn Lear Jet
    - Uses Langley plot to extrapolate Stratospheric measurements to AM0 (Air Mass Zero)
  - High Altitude Balloon Facilities
    - Near AM0 measurements, ~120k ft
    - CNES CASABOLA Balloon Facility
    - NSCAP, Near-Space Characterization of Advanced Photovoltaics, AFRL, NRL, NASA

“Langley Plot” Extrapolation

- “Calibrate” solar cell short circuit current to AM0
  - Used to adjust laboratory solar simulators for space light intensity
  - Air Mass Zero – Above Atmosphere, 1 au from sun.
  - With cells illuminated, plane descends from 48kft to 35kft
- Like “Beer's Law” exponential absorption
  - Use pressure instead of distance.
- Extrapolate to zero pressure (AM0, space)
- But plane flies at lower edge of Ozone Layer
  - Need to correct for ozone adsorption.



Potential for Weather Balloon Payload

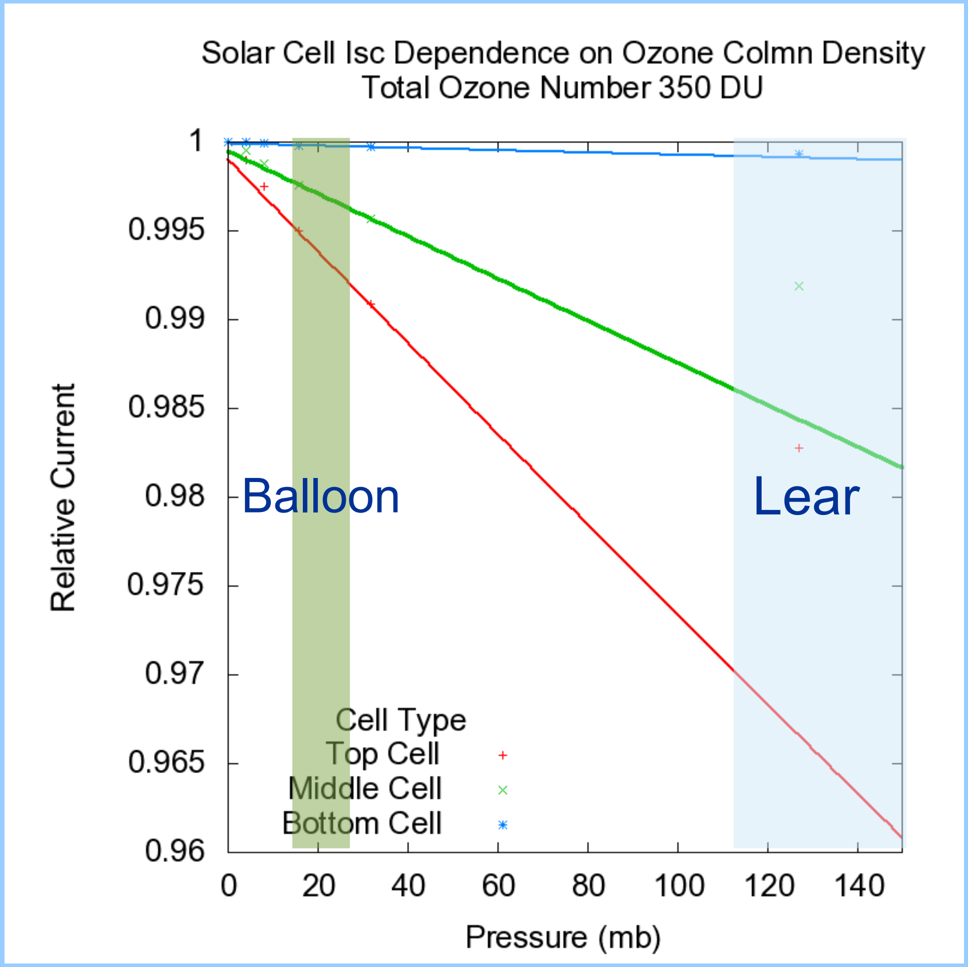
- Low cost
- Flights as needed
- Less Seasonal Limitations
- More Risk
  - Potential for loss of payload, damage
  - Less precise measurements.
    - Presently not "instrumentation" measurements.
    - Using available Integrated Circuits
- Suntracker experience
  - Dr J. Woodyard (Wayne State University)
  - 14 flights between 1999 and 2005
  - Actively searched for sun
  - FAR 101.1(4) "Exempt" payload

Approach

- Develop a 1% class measurement
  - insufficient resolution for space mission planning, power system sizing.
  - sufficient to track development of new generation Space Power Photovoltaics, i.e. support technology development
- Fly multiple cells at once
  - four 2x2 cm subcells in NSCAP holders
  - two 4x8 cm subcells in NSCAP holders
- Cell holder stage is shaded from from ground and balloon reflections.
- Adjust angle of Cell Holder Stage to track Sun Altitude
  - Use sun sensor to flag valid data.
- Apply Langley Plot method to extrapolate low air mass measurements to AM0.

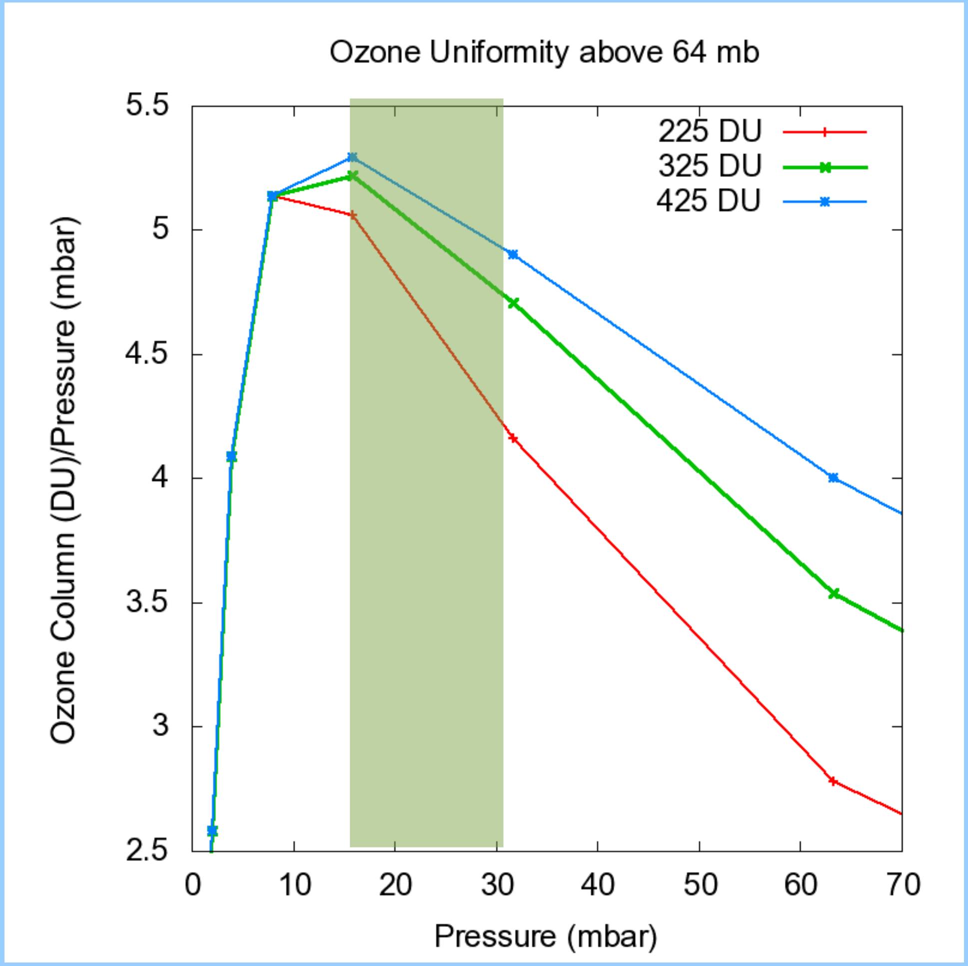
Langley Plot Method

- Extrapolate via "Beer's" Law and air mass to space conditions, air mass zero.
- Assumes uniformly mixed gasses that don't absorb too much.



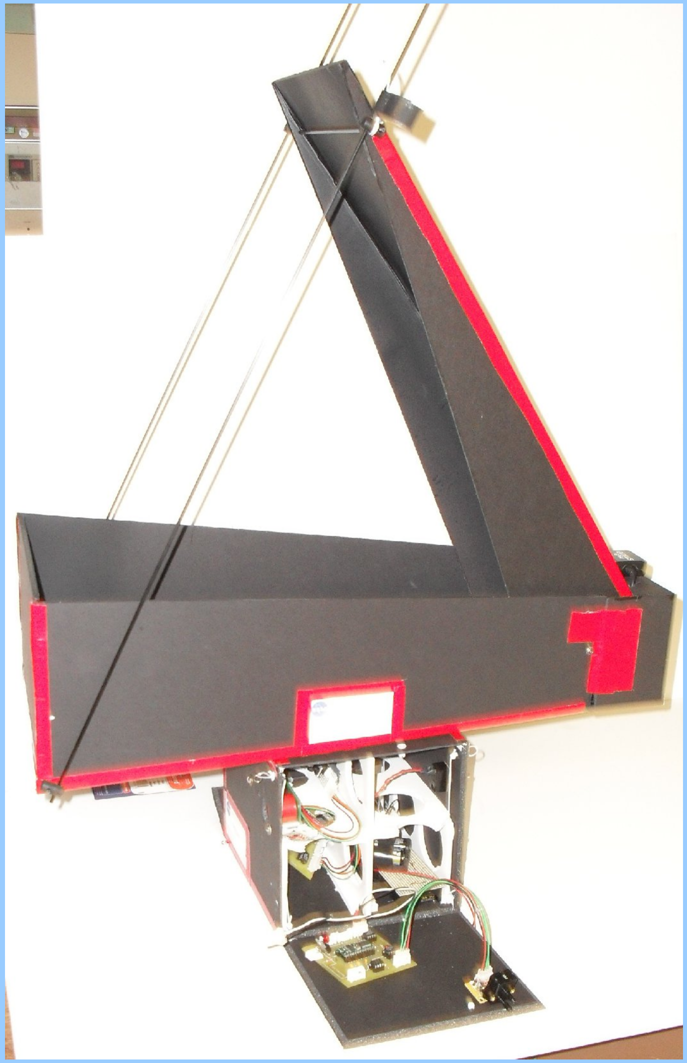
Langley Plot Method

- Plan to take data above where ozone ratio with pressure declines too much
  - Above 30 millibars, 78 kft
  - Desire data to 15 mb, 93 kft



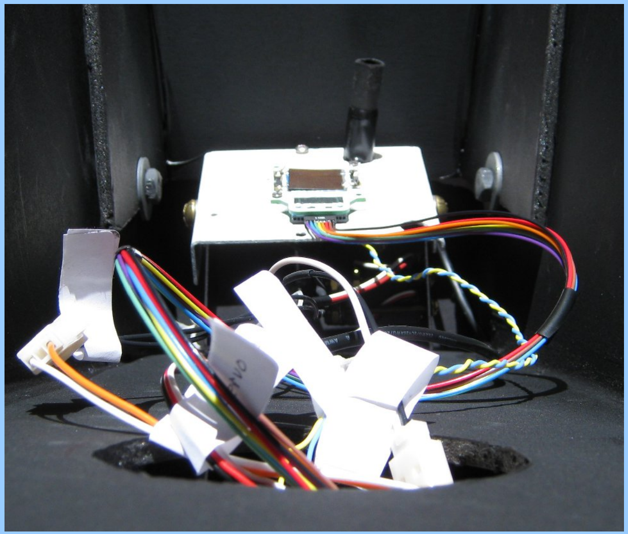
Equipment

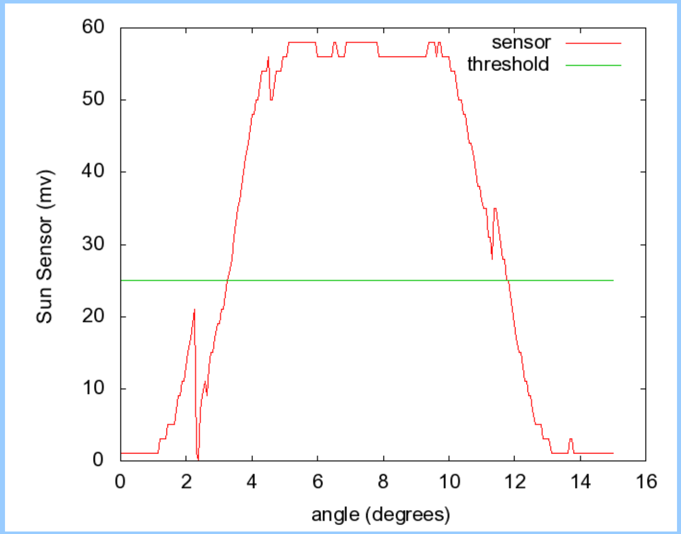
- Balloon
  - 1200g to 1500g balloon carries 6 lbs (2.7 kg) to 95 to 100 kft,
  - Rise rate about 1000 ft/min,
    - 100 min rise time.
    - 40 min descent w/ 7 ft parachute.
- Payload boxes
  - Consists of two parts,
    - cell holder shade system.
    - Electronics box
    - Communications not included. Provided by additional payload(s).
  - Provide 10° (0.18 radian) clearance of ground and balloon.



Equipment (2)

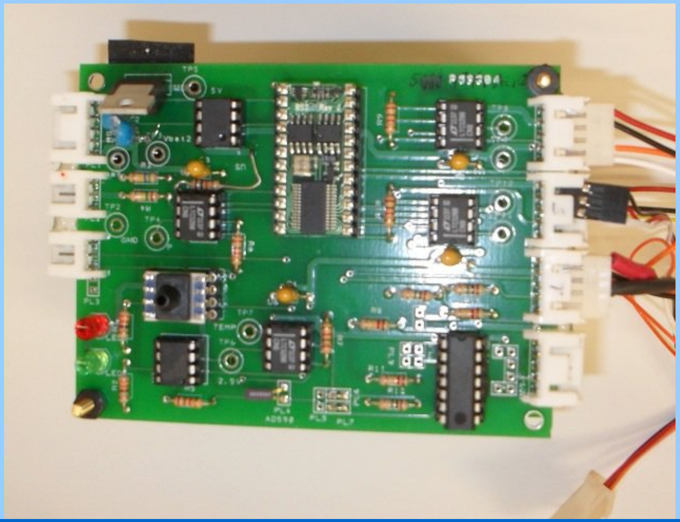
- Cell Holder
  - Initially 8x8 cm (next generation 10x12 cm)
  - 9Ω resistive heaters
  - RTD temperature sensor
  - ~5º sun sensor
    - 0.5% from direct intensity
    - Dexter Research 2M Thermopile
  - Parallax Standard servo
  - Parallax Basic Stamp
    - controls stage angle based on GPS time and location
    - Logs location data at 30s intervals





Sun Sensor response (on ground)

Equipment (3)

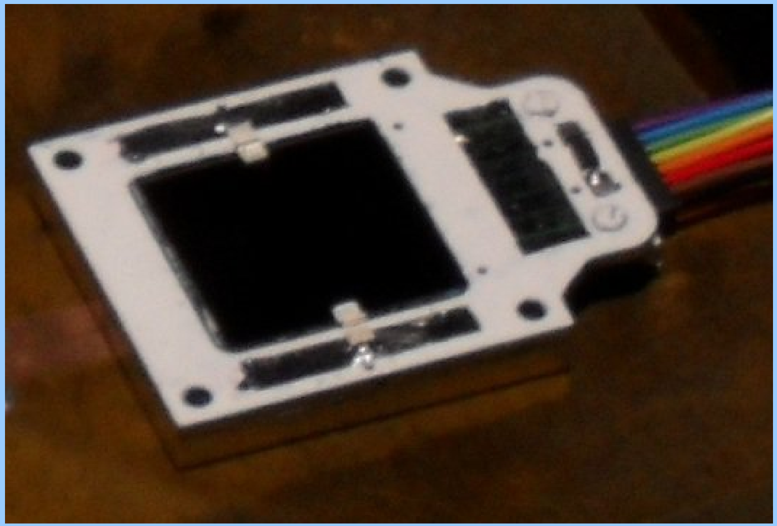


- General purpose flight computer
  - Stage angle
  - Heater relay
  - Cell Isc Measurements
    - Plan for one card per cell
- Parts
  - Pressure sensor used to correlate data across boards.
  - Op amps used for 10x amplification.

quantity	name	ID
1	computer	Basic Stanp 2
1	pressure	015PAAB5 SSC
4	2 chan 12 bit A/D	LTC1298
1	Quad Op amp	LM2902
1	128 kbyte	24AA1025
1	Temperature	AD590

Isc Measurement

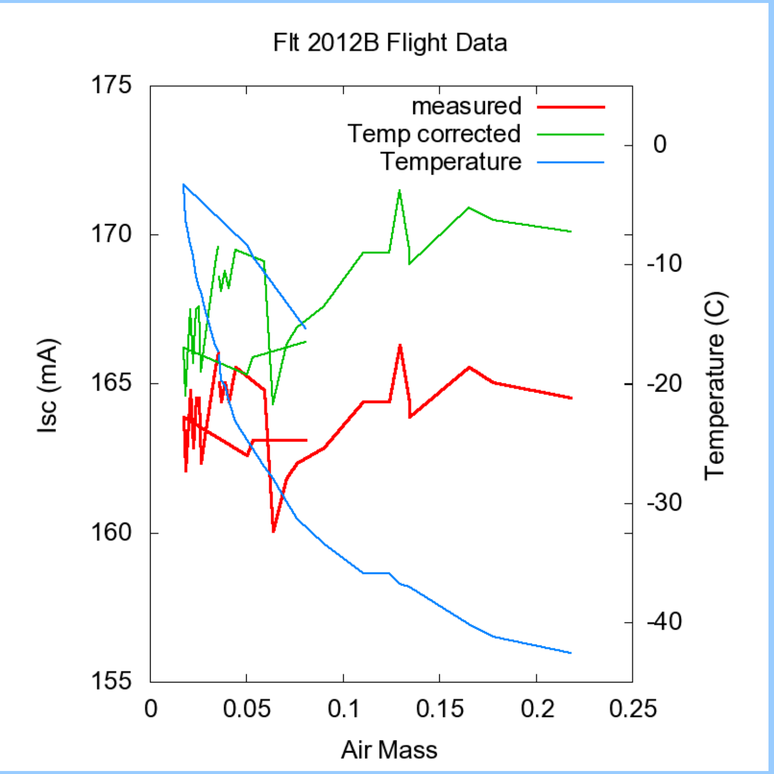
- Isc is read as voltage across 1Ω resistor
- AD590 current read as voltage across 1kΩ
  - Both for NSCAP Cell holder and board
- Isc and sun sensor voltage read
  - If sun sensor is above a threshold (25mv) this data is stored
- In addition to initial data
  - Battery bus voltage
  - Pressure
  - Vref (AD584)
  - Board Temp AD590
  - Cell Isc
  - Cell temp (AD590)
  - Sun Sensor



* Rereading Isc and sun sensor gives an Idea of how fast these change.

Result – Flt 2012B, 12 May 2012

- Pressure is corrected to air mass based on logged angles from positioning computer.
- Isc and sun angle change significantly by 2nd reading of record
- Data with sun angle <60 mV has been removed.
- Temperature corrected curve based on Isc thermal coefficient of 0.05%/C.
- Standard deviation for Isc @ air mass < 0.035 (above 30 mb) is 1.3 mA, 0.8%
- Data (so far) not suitable for Langley extrapolation.
  - Expected change for GaAs subcell 0.4% to 0.8%
  - Noise (or temperature? or dynamic?) effects overwhelm the observation



Noise sources?
Reflections
- Wires/box surface
- Electronic?

Solar Cell Calibration Conclusions

- Positive
  - Obtained 10 valid measurements
  - Initial measurement has a 0.8% standard deviation.
- Negative
  - Lower altitude, higher current measurements disturbing.
    - Reflection?
  - Data not high quality enough for Langley extrapolation.
  - No room in error “budget” for flight to flight variation.
  - Temperature control not working yet.
- Another flight test to reduce noise, improve temperature control.
- Looking for flight-to-flight reproducibility of subcell measurements.

Cosmic Rays

Poor Man's High Energy Physics

Cosmic rays:

- Gamma ray, from nuclear reactions, magnetic field processes
- Atomic Nuclei (Z=1- 26(Fe) – 92(U))

Sources:

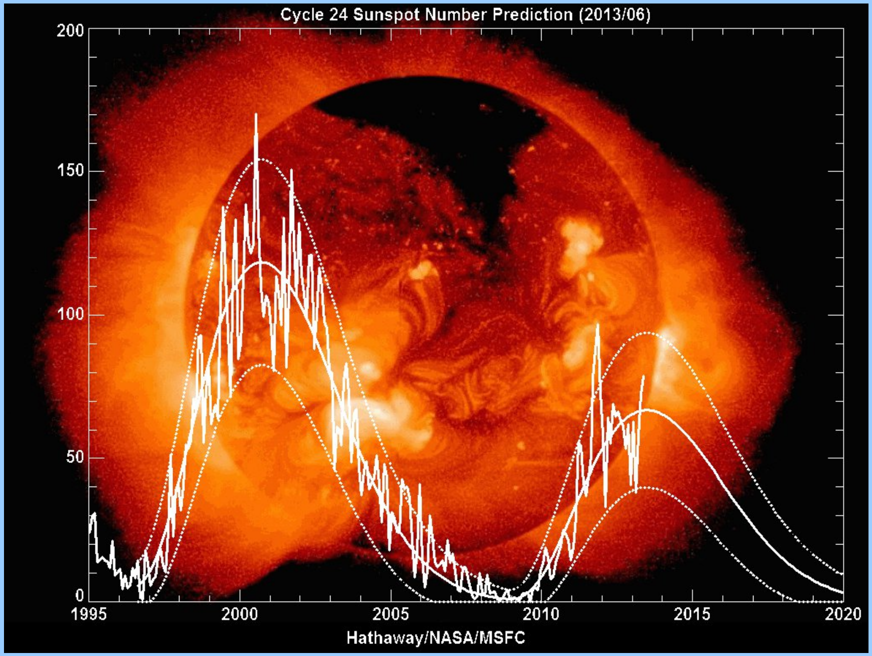
- Sun, solar Flares (X-rays, Gamma rays?, protons) nuclear processes
- (most) Galactic (extragalactic) Sources
  - Nova, Supernova
  - Black Hole
  - Other very energetic processes
- Thunder Storms???

Cosmic Rays

CLOUD experiment at CERN suggests Cosmic rays may play a role in atmospheric aerosol production (and cloud production?)

Cosmic Ray collisions with atmospheric gases can produce neutrons which thermalize and lead to $N_{14} + n \rightarrow C_{14} + p$

Solar wind magnetic field may "deflect" charged cosmic rays, reducing the flux to Earth orbit when sun is more active. Cosmic Ray flux related to solar activity, flux reduced with increasing activity.



http://solarscience.msfc.nasa.gov/images/ssn_predict_l.gif

Simple Detectors:

- Geiger Counters
- Polycarbonate films (Lexan, CR39)

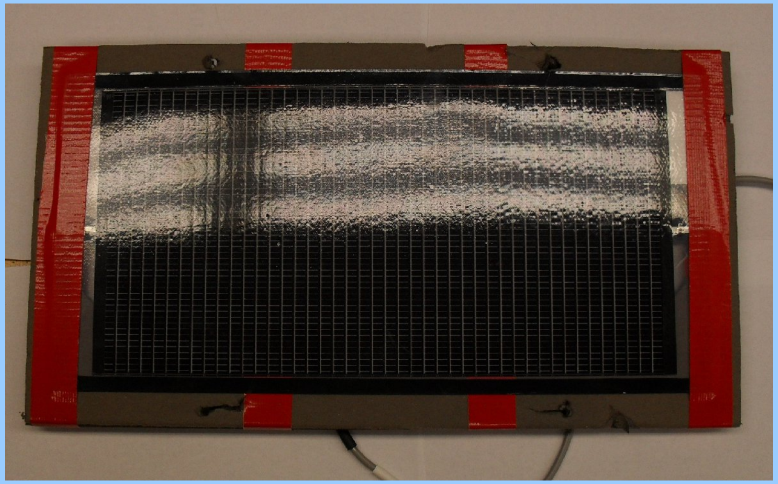
Polycarbonate Films

Films are etched after flight.

- Polycarbonates are transparent and hard. CR39 used for eyeglasses
- 6-7M NaOH solution, Heated (40-70C?), "developing" time: hours
- Examined for (sub-mm) pits, size indicates source – higher Z, bigger pit.
- Layered film correlation
  - Confirms event occurred during flight.
  - Direction information.

Disadvantages

- Desire long exposure times (at >50 kft)
- Large Areas
  - ≥Carbon, $1/s*m^2$
  - ≥Fe $1/(15s)*m^2$

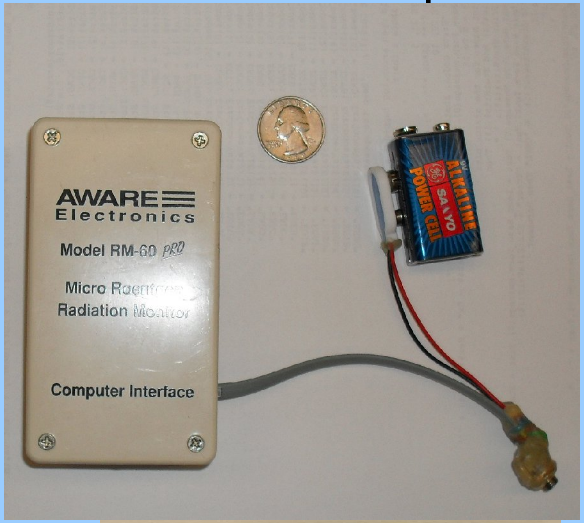


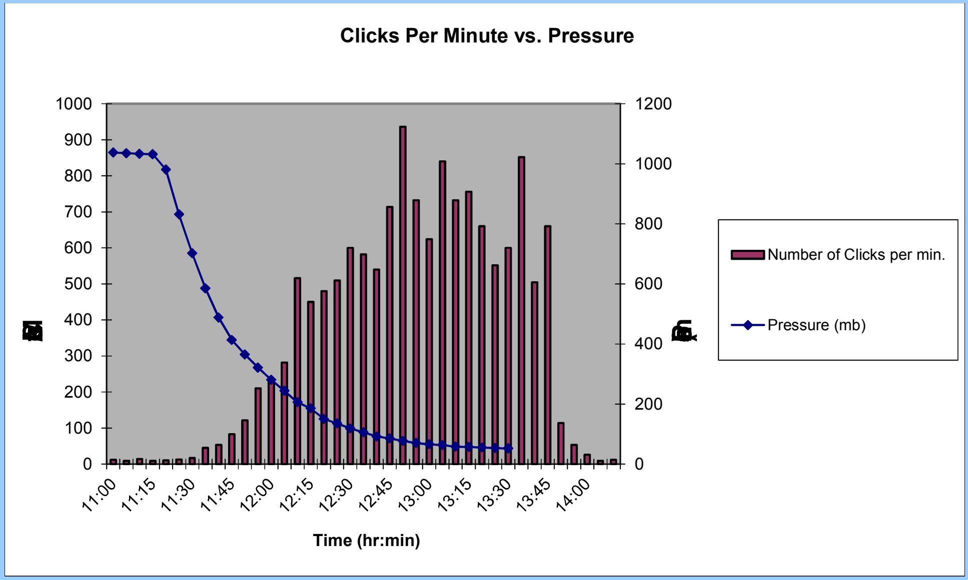
20x35 cm, $0.07m^2$ PC Films w/15W Solar Array

Geiger Counter

Provides a compact instrument.

- Aware Electronics (RM-60) + voice recorder +9V battery
- Recording examined with sound processing software (Audacity).
- Count pulses at various times during the flight.





Geiger counter

Improvement goals:

- Pulse rate counter on microcontroller
  - Voice recorder rate limit kHz
  - Geiger counter rate limit about 10 kHz
- Log GPS: Altitude/Time/Location
- Log Pressure

"Expected" Relationships

- Geiger counter is responding to muon showers from nearby passage of Cosmic Rays
- Collision rates should be proportional to air density
  - Approximately pressure
  - Decreases when cosmic rays "stopped"
  - "Peak rate" altitude/pressure may be characteristic point.

Geiger Counter

Small Balloon Opportunities

Build a data base (and baseline)

- Location/Time (Planetary Magnetic Field vs Sun orientation)
- Peak altitude
- Peak Rate (Calibrated or correlated? Instruments)
- Geomagnetic Parameters: Kp, Ap indices
- F10.7 Solar Flux?
- Solar Cycle relationship (smoothed sunspot number/F10.7 flux)

Rapid response opportunities

- Solar Flares
- Nearby? Nova/Super Nova
- Thunder Storms ???

Astronomy

Astronomy offers challenges for a high altitude small balloon payload

Attractions:

- Better "seeing", less atmospheric turbulence than ground telescopes.
- Brighter stars, less atmospheric adsorption.
- Opening of adsorption bands. UV/Ozone, IR Water

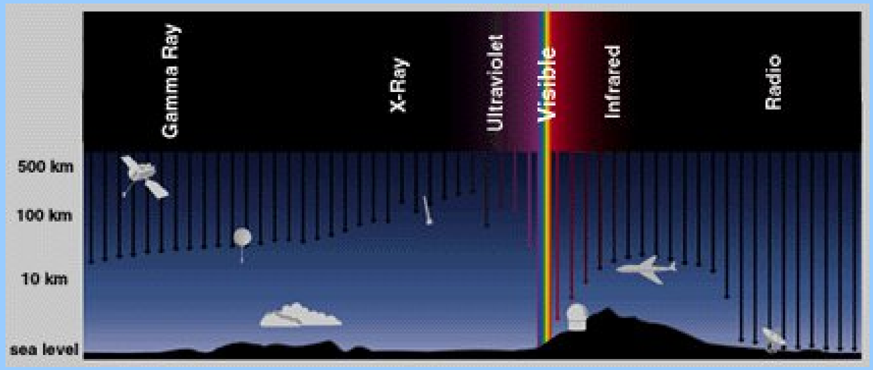
Challenges:

- Working in Sunlit atmosphere – bright background
- Short mission times
- Platform stability/ Pointing
  - Small balloon – low inertial
  - Astronomers want 0.1 to 0.01 arc second control
    - Show dimmer stars
    - Planetary detail

Astronomy

Last year NASA Glenn held a workshop to support Solar System research using NASA high altitude balloon program.

- Small (50lb) payloads may have application
- 8” scopes
- Planetary observations
- IR investigations of Venus may be of interest
  - Flir/Fluke have sub $10k IR imagers
- Occultations
- Rapid deployment



http://science.hq.nasa.gov/kids/imagers/ems/atmosphere.gif

Astronomy

Our Initial goals have been to identify bright astronomical objects in wide field photographs (Jupiter, Venus)

- Inexpensive cameras seem to compensate for dark sky by increasing exposure time
- Camera motion blurs any image during long exposures

Ideas:

* We are experimenting with “pointing” based on compass heading
* Programing Cameras to limit exposure time (sub second)
  - Canon “CHDK” system
* One payload system – simplify motion
  - Dedicated flight
  - Keep It a Simple Pendulum (KISP?)
    - Accelerometers could identify good times to snap photos.

Conclusions

Research from small balloons can have value

- Education and Technology development
- Low cost instruments
- Rapid deployment
- Data base development
  - Frequent flights

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