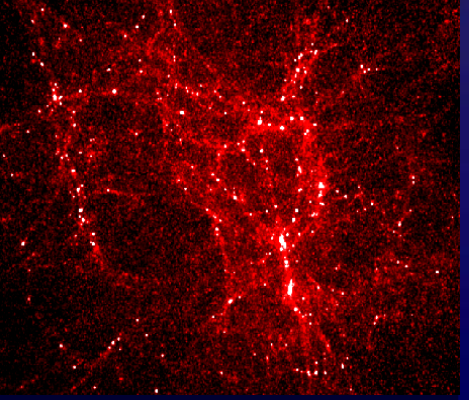


EVENT
(Earth Viewing Extreme Nature Telescope)

Space telescope to observe extreme energy cosmic ray quanta & atmospheric phenomena

Il H. Park (Ewha W. Univ., Seoul)

Discussion at SINP, Moscow State University (Oct. 19, 2005)

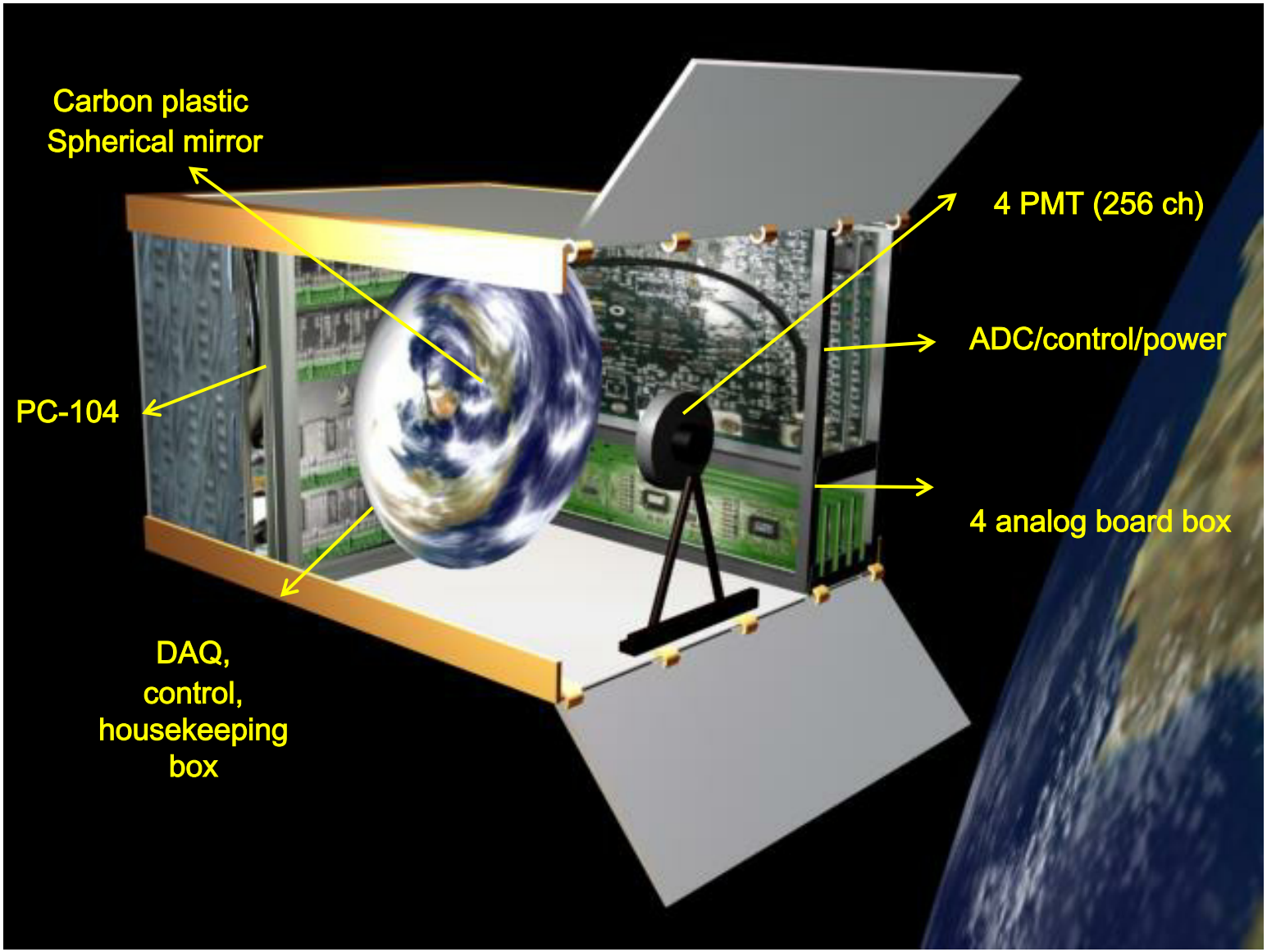
Seminar at JINR, Dubna (Oct. 21, 2005)

To be in preparation for
Announcement of Opportunity from
Korean 3rd Science Satellite Program

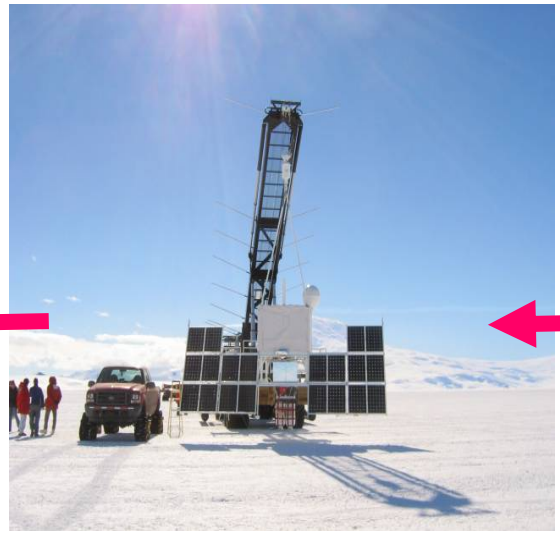
Korean Science Satellite Program

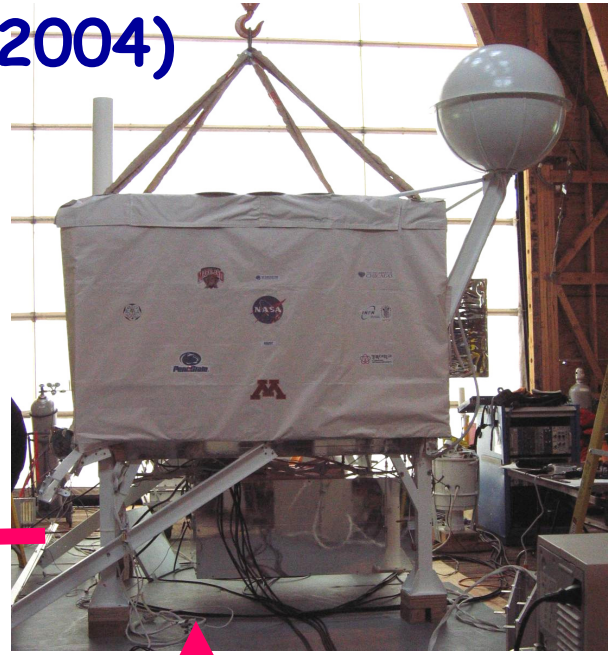
- 1st science payload (FIMS, UV astronomy), satellite launched in Russia in 2003
  - Scientific results not great because of problem in poor positioning accuracy
- 2nd science payload AO made, and payload of radiometer selected in 2004
  - Requirements: 50kg, 270x200x330 mm3, 20W, 200 kbps, 300~1500km orbit, 80 degree inclined
  - will be launched in 2006 or 2007 by using Korean launching facility (~100kg)

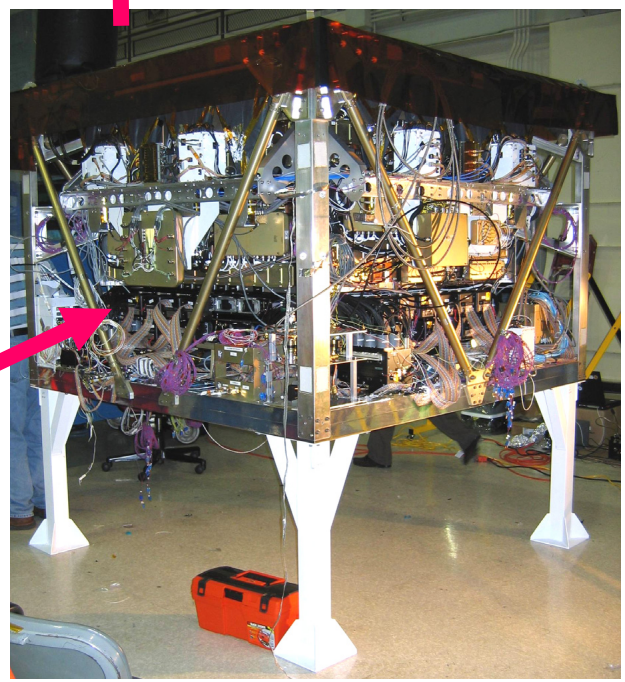
STSAT-2 Payload

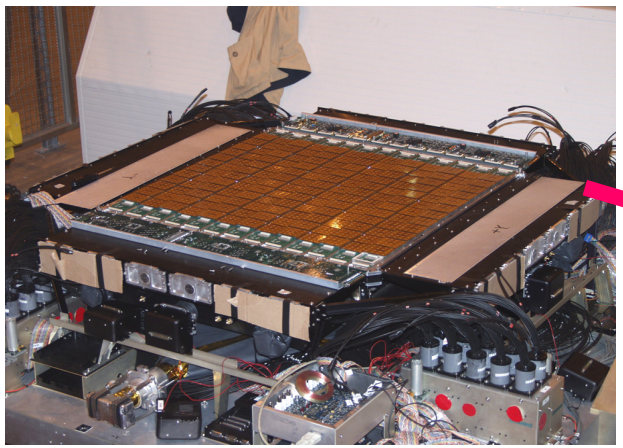


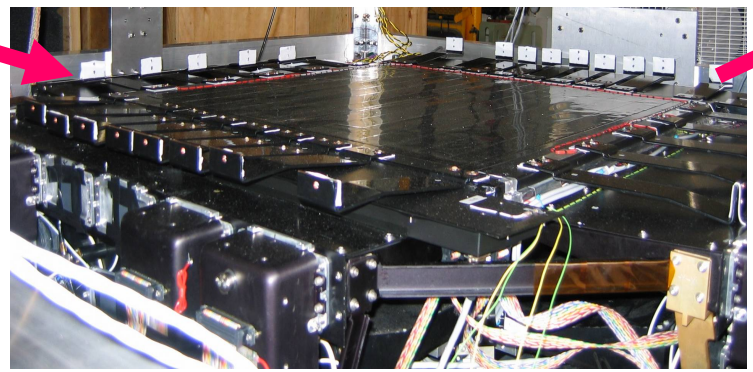
CREAM Balloon Mission (2004)











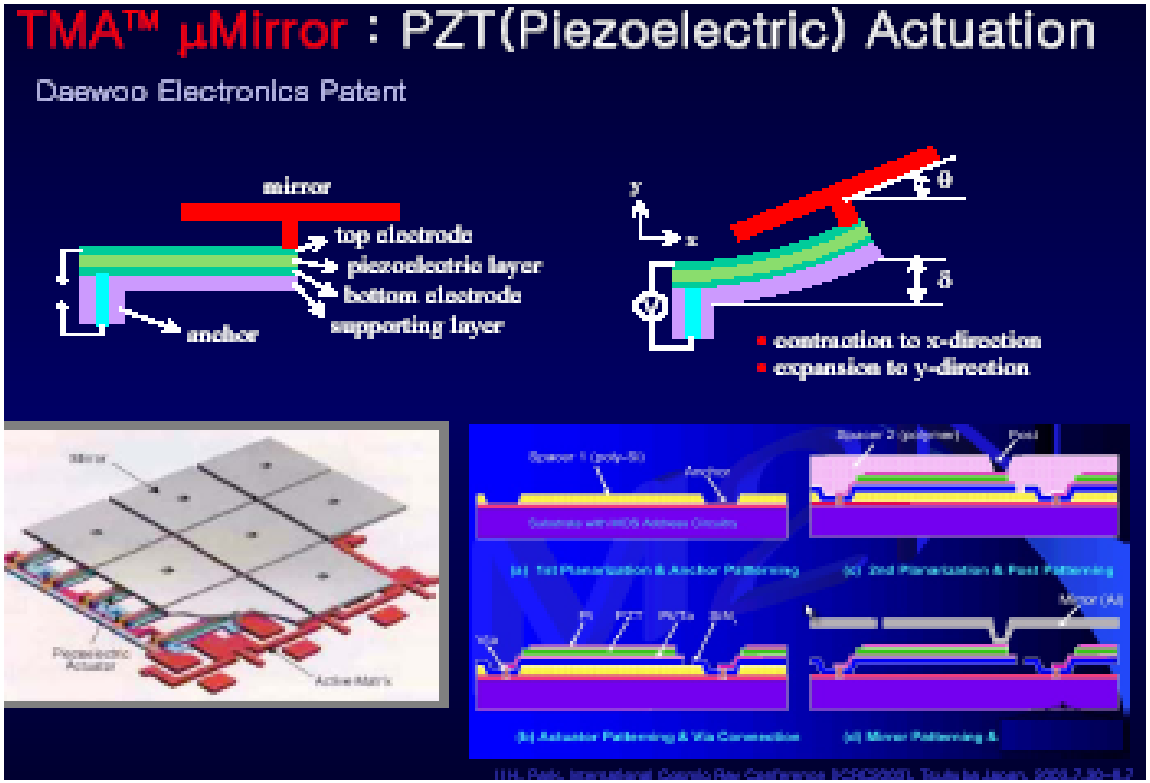
EVENT

Korean Science Satellite Program

TUS

- **3rd science payload AO will be announced at the end of 2005**
  - Final selection will be made no later than summer 2006, and project immediately starts (no phase A, B, …, once selected, the project are guaranteed
  - Launch foreseen 2008~2009, preferably using Russian launching facility
  - Overall cost including launch should not exceed $20M
  - Favor will be given to proposal which can give some scientific impact(?) and technological feedback and improvement in the area of payload, platform and space parts
  - A few proposals, UHECR, infrared telescope, earth shinning, …, are likely to be in competition
  - I propose a collaboration for UHECR, named EVENT, same members as TUS
    - EVENT before TUS, EVENT after TUS, or same time TUS EVENT
    - Provide a sort of pilot experiment for future mission like EUSO, KLYPVE
- 4th AO will be announced and selected around 2007
  - Plan to propose "tracking mirror telescope for observation of UHECR"

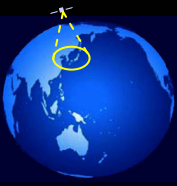
New Idea of the Next Generation Telescope with a "Tracking Mirror" (EWHA University, Seoul)



I.H.Park, et al. ICRC 2003
I.H.Park, SpacePart 2003
I.H.Park, et al. COSPAR 2004

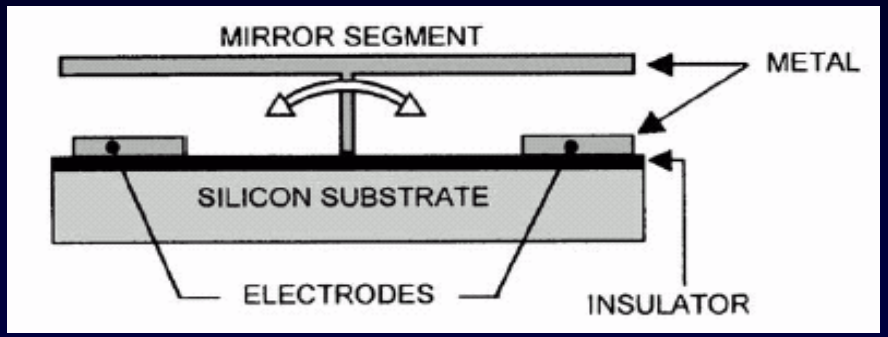
"New MEMS technology of the controlled micro mirror arrays allows to design a mirror, arranging its focus in direction of the EAS particle disc. Preliminary direction to the EAS disc is determined by the photo receiver rough pixels. The computer rearranges the micro mirror array and focuses the disc image to the fine pixel receiver part. The tilting velocity of micro mirrors has to be high (about 1^{o} per microsecond)."

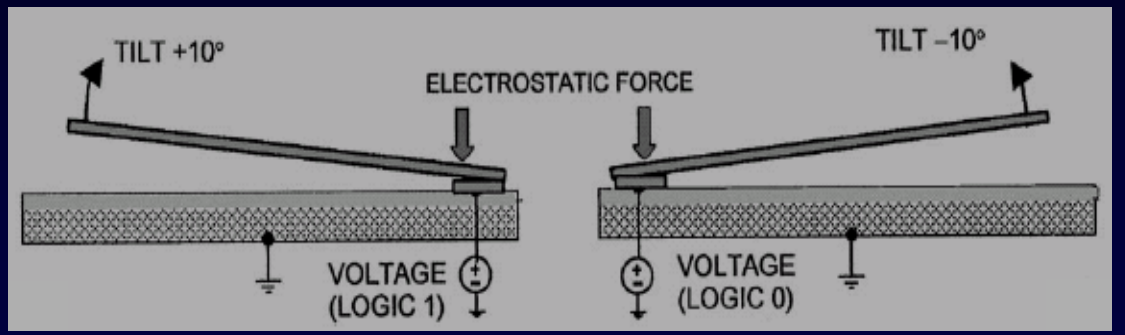
DMD μMirror : Electrostatic Actuation

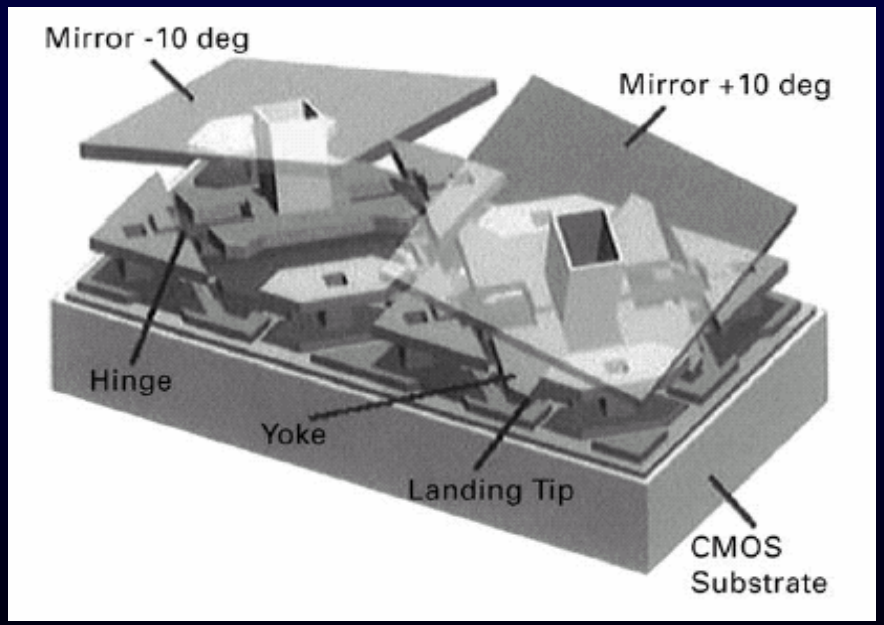


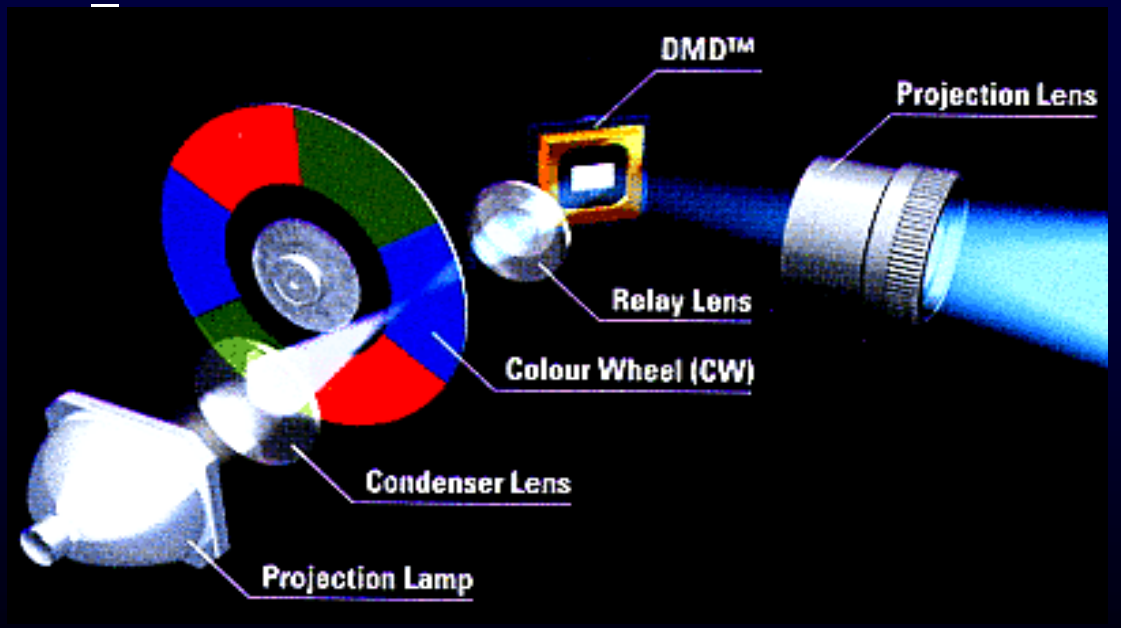
Texas Instrument

Digital -> Two preset directions only





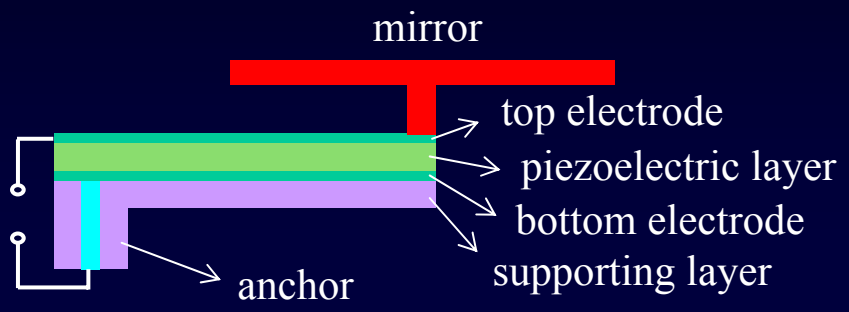


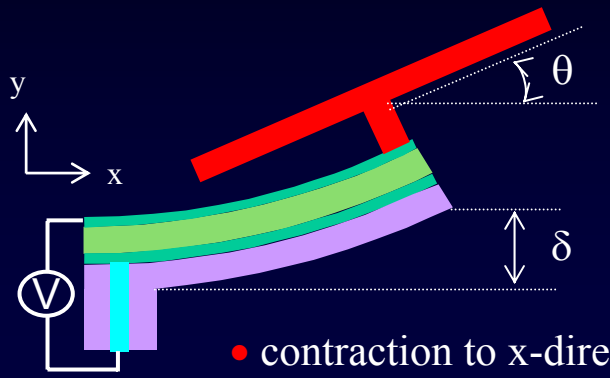


TMA mMirror : PZT(Piezoelectric) Actuation

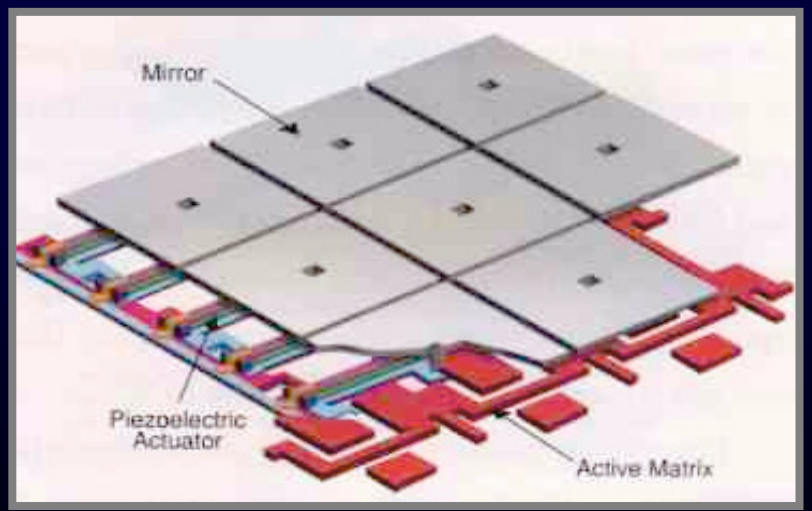
Daewoo Electronics

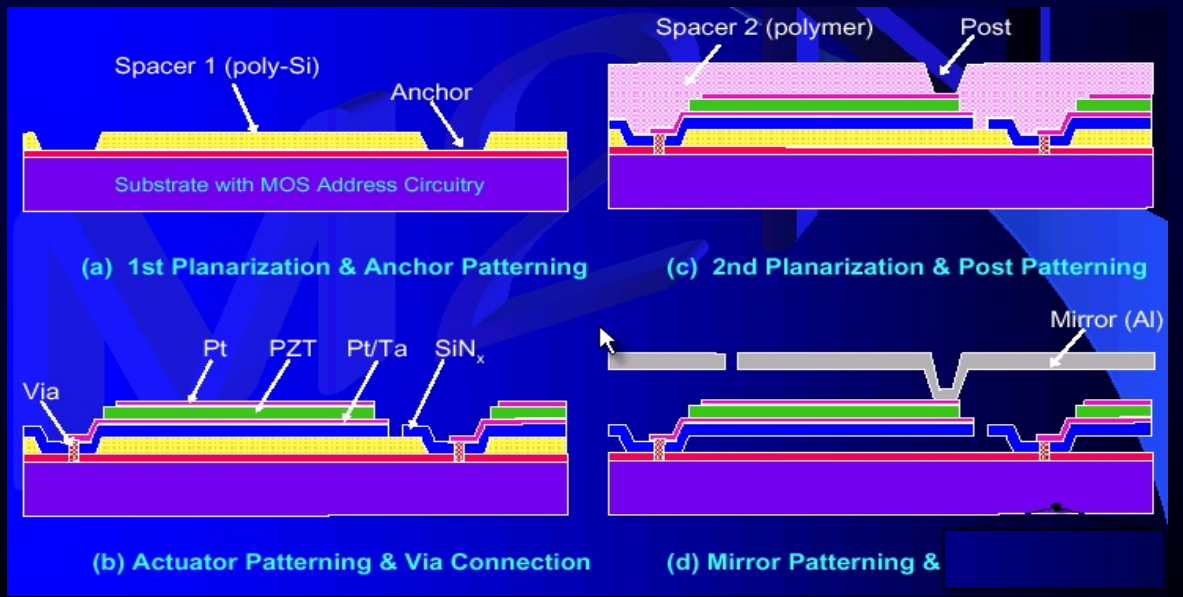
Analog -> Variable direction





- contraction to x-direction
- expansion to y-direction





Third Order Optics

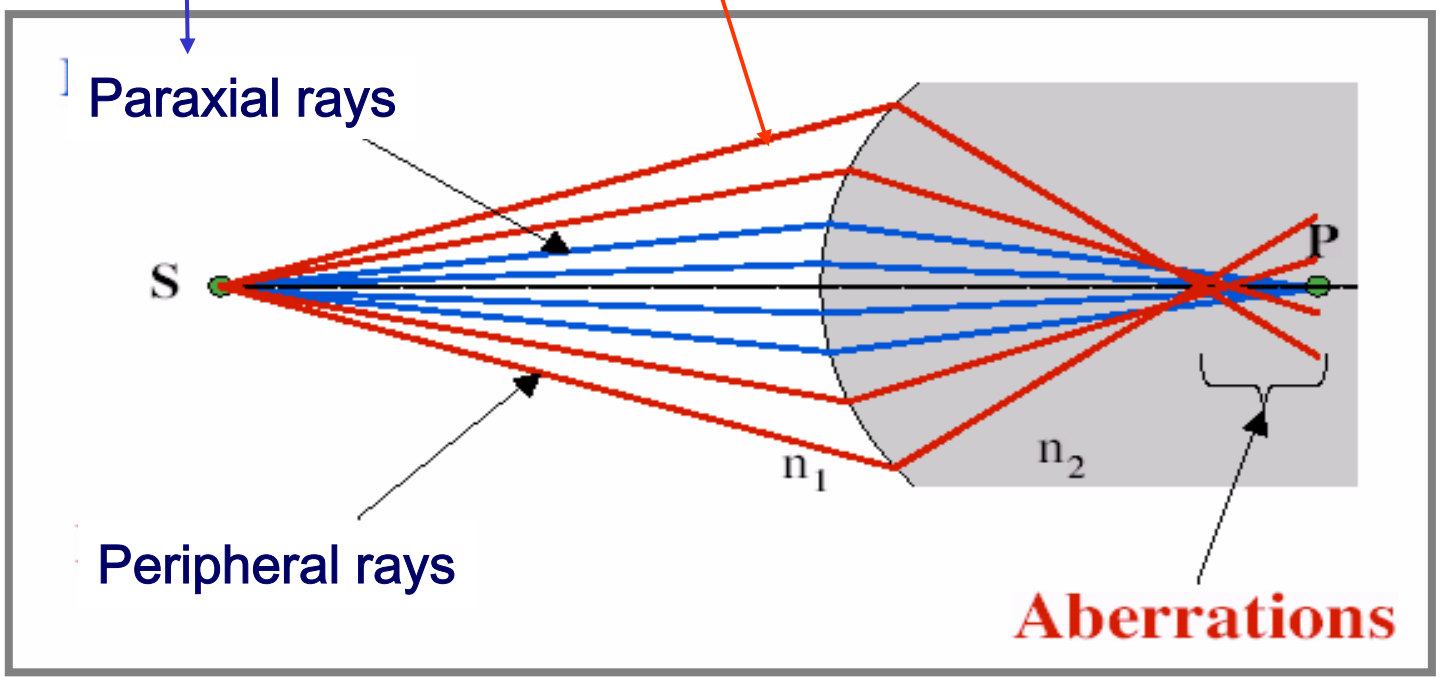
The paraxial approximation, *sin* θ ~ θ, is somewhat unsatisfactory if rays from the periphery of a lens are considered

Lens maker's formula

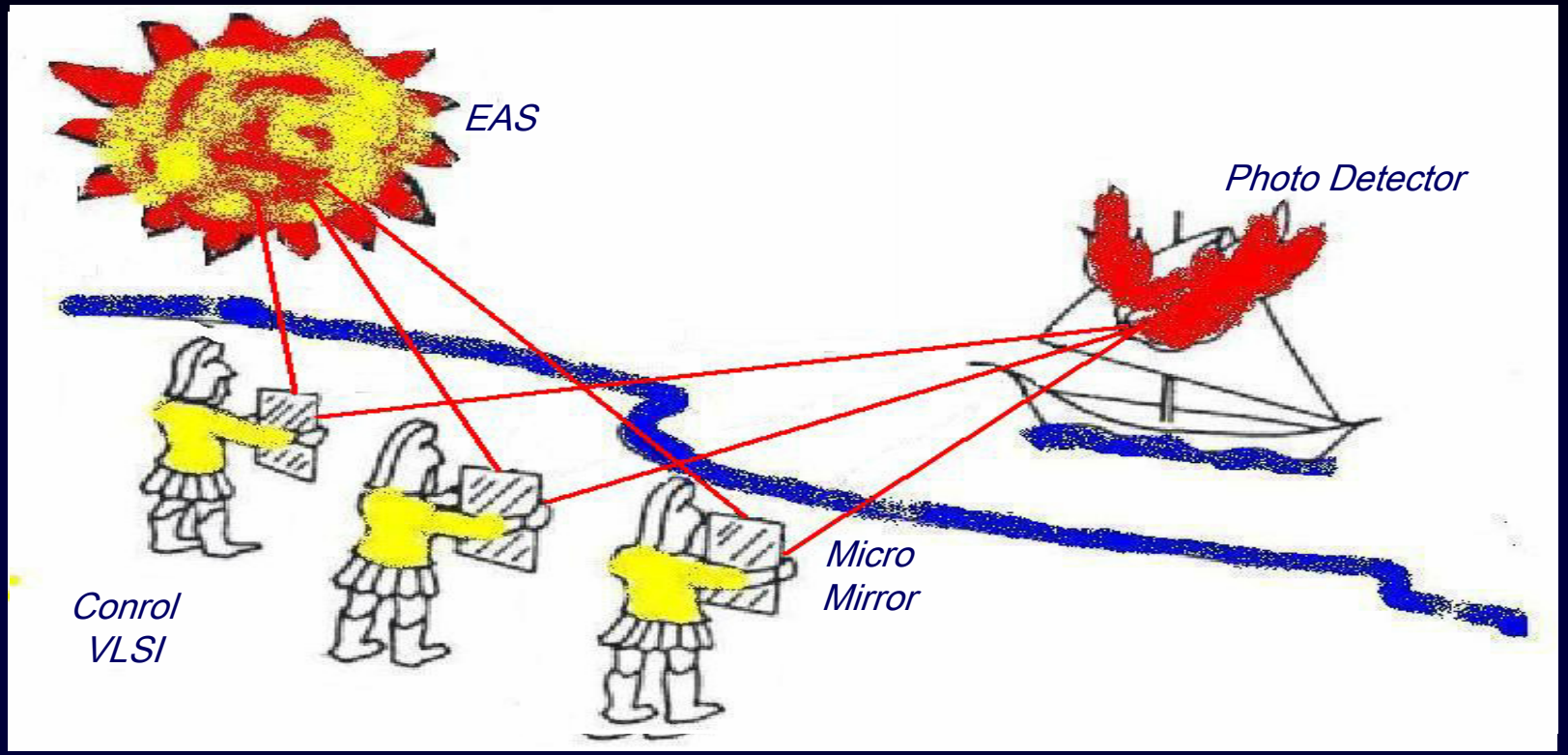
$$\sin\theta = \theta - \frac{\theta^3}{3!}$$

$$\frac{n_1}{s_o} + \frac{n_2}{s_i} = \frac{n_2 - n_1}{R} + h^2\left[\frac{n_1}{2s_o}\left(\frac{1}{s_o} + \frac{1}{R}\right)^2 + \frac{n_2}{2s_i}\left(\frac{1}{R} - \frac{1}{s_i}\right)^2\right]$$

3rd order



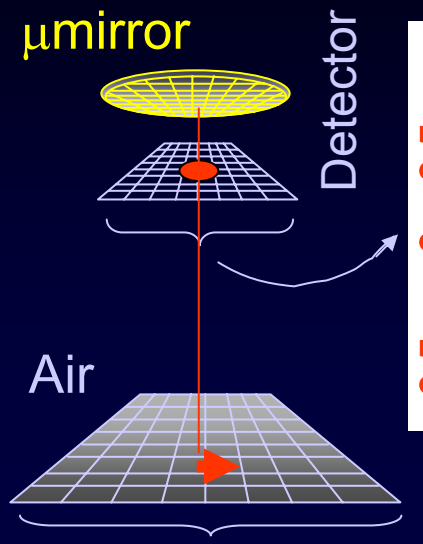
How to remove Aberrations

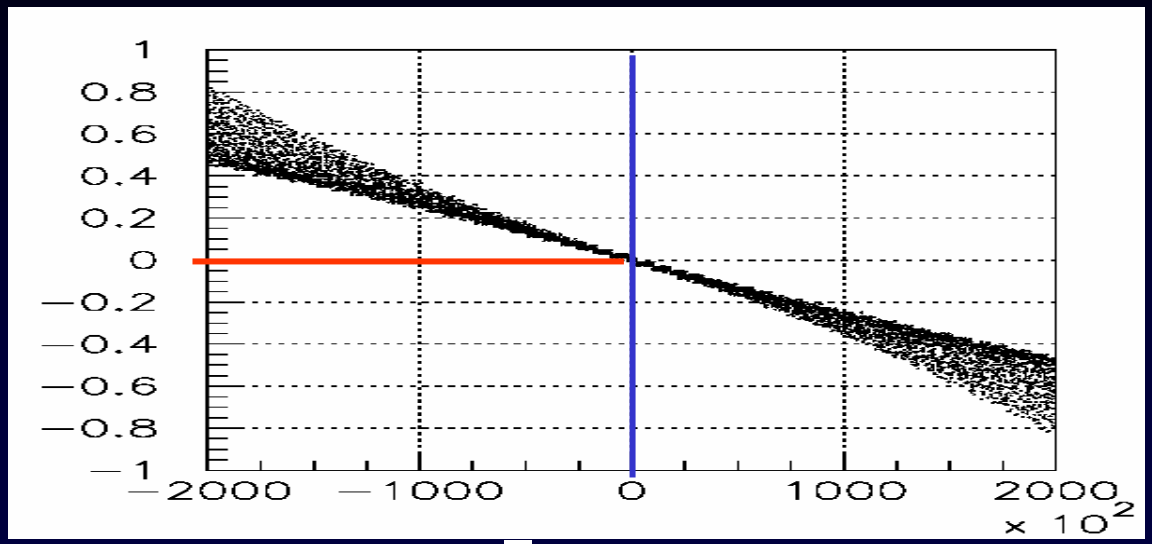


- Archimedes' Mirror : **mirror, control by solders**
  - Focusing of sun at any incident angles
  - Tracking of object(sun) at any angles allows an aberration free optics

- **Tracking Mirror : micromirror, control by VLSI electronics (I.H.Park, 2003)**
  - **"Zoom"** -> "Adjustable Field Resolution" -> Wide FOV
  - **"Tracking"** -> Aberrations Free Image and Only Small No. of Detector Channels

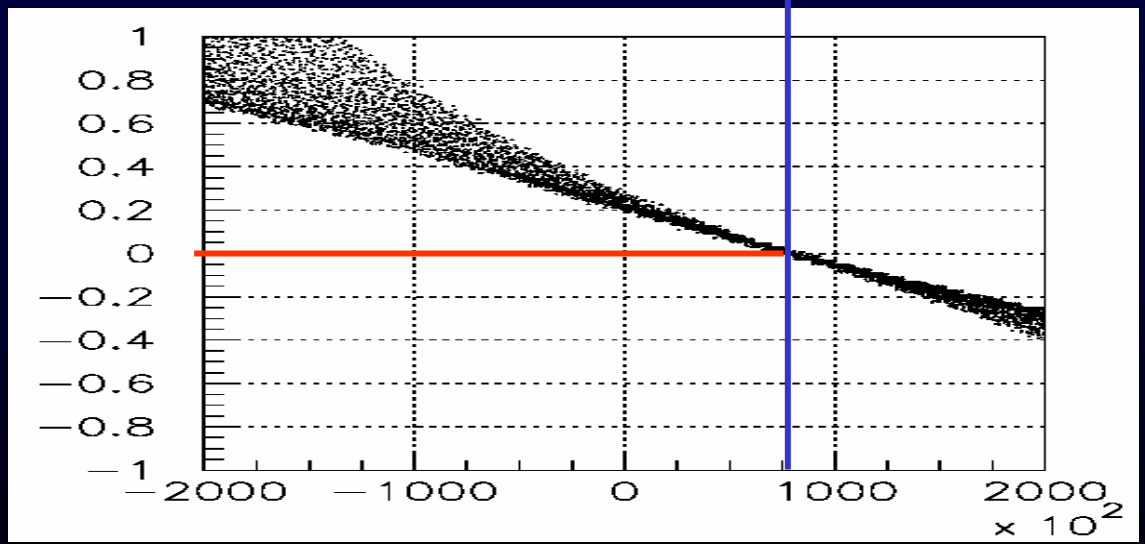
Tracking : aberration free imaging

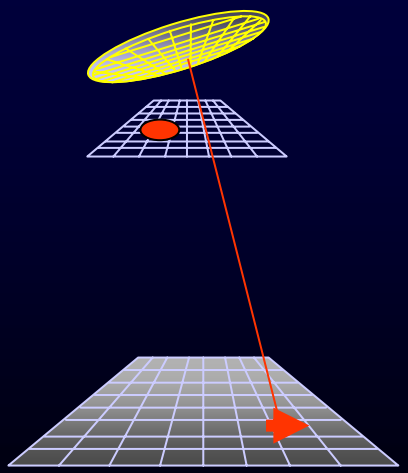




1D-simulation

-200km 0 80 200km

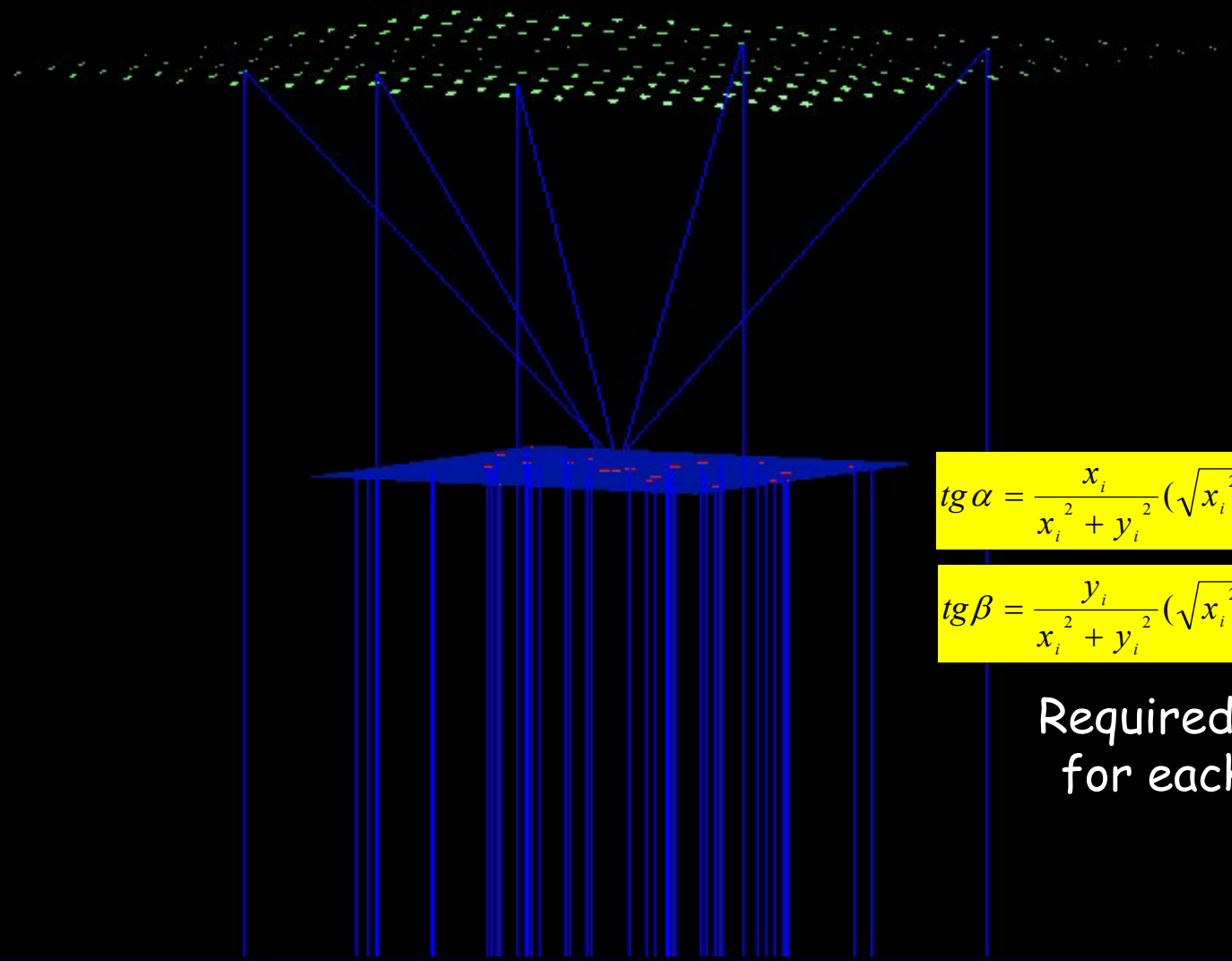




MEMS Mirror (ZEMAX Simulation)

MEMS micromirror array

Photo detector array

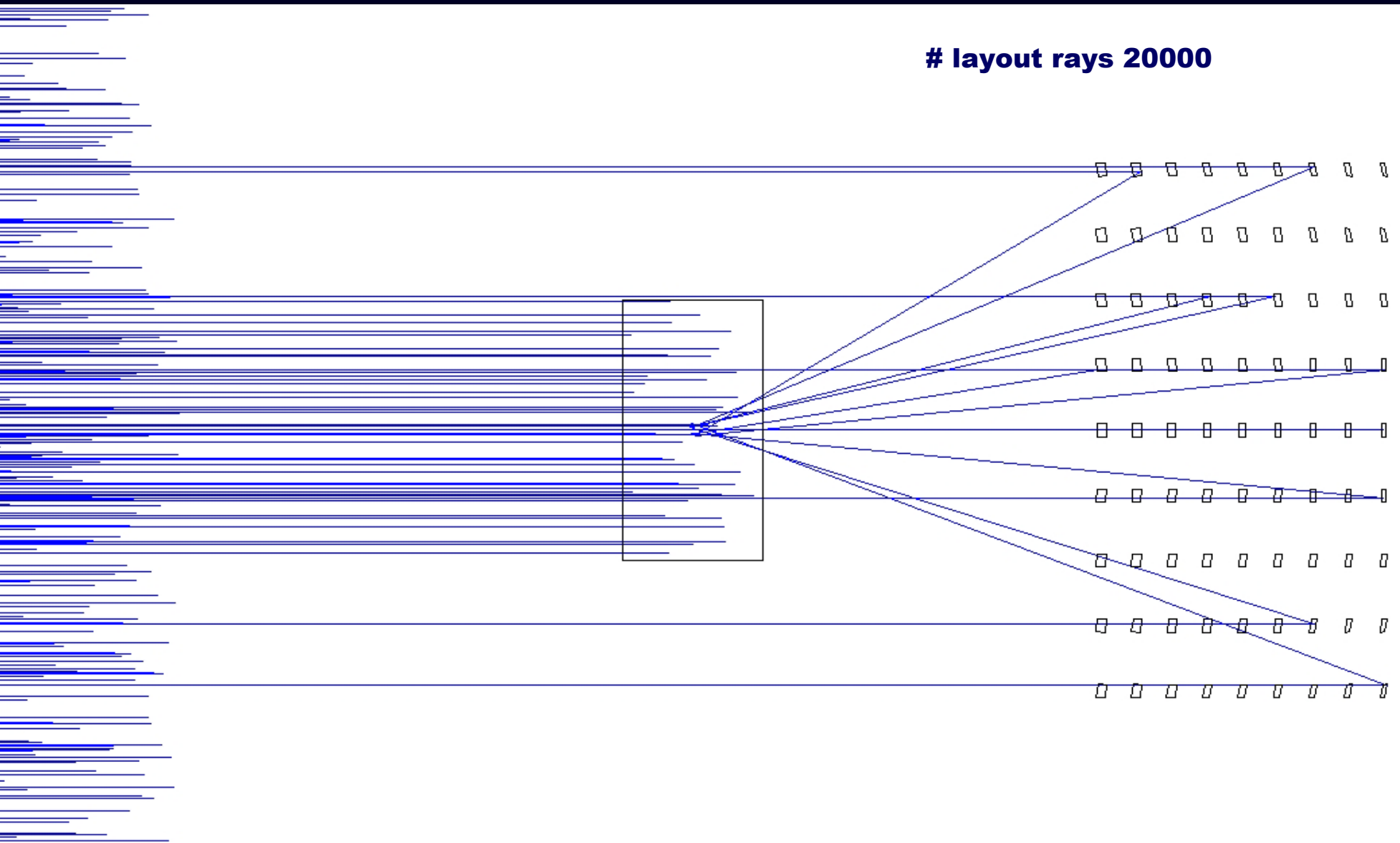


$$tg\alpha = \frac{x_i}{x_i^2 + y_i^2}\left(\sqrt{x_i^2 + y_i^2 + f^2} - f\right)$$

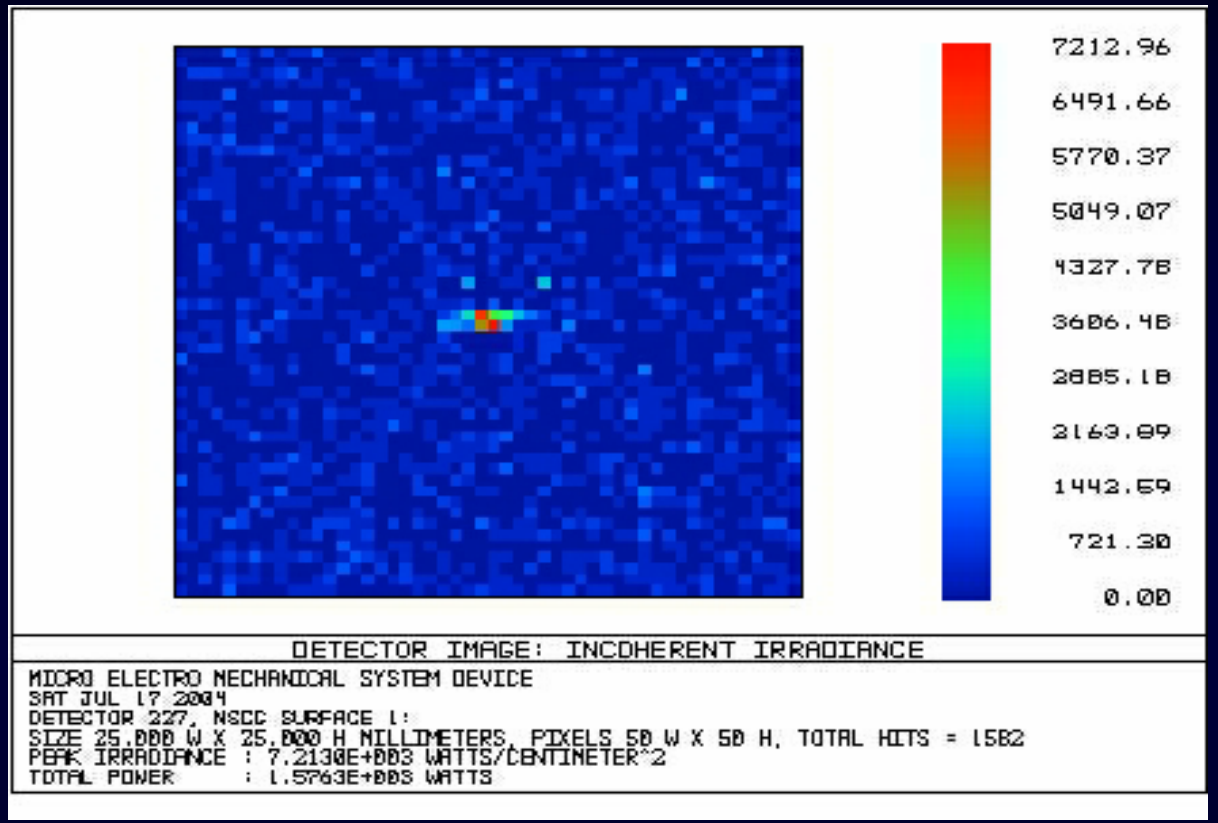
$$tg\beta = \frac{y_i}{x_i^2 + y_i^2}\left(\sqrt{x_i^2 + y_i^2 + f^2} - f\right)$$

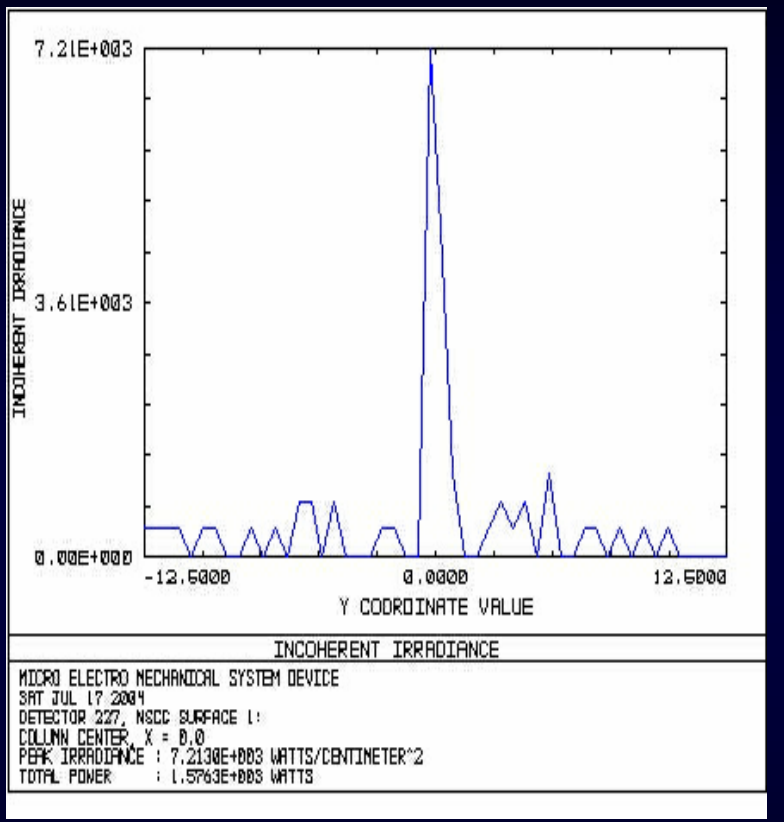
Required angle for each cell

MEMS 9 by 9 cells ZEMAX Simulation (김정영)



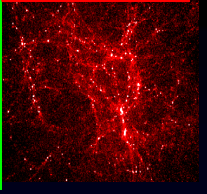
MEMS Tracking Mirror (ZEMAX Simulation)

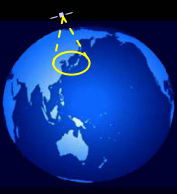




Only ~ 5 % of diffraction & scattering effects

Design Parameters of MEMS Tracking Mirror

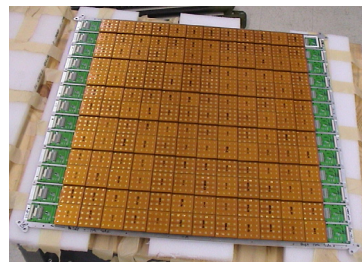




	MEMS Tracking Mirror	simple mirror
Orbit height	400 km	400 km
Mirror diameter	1 m	1 m
Focal distance	1 m	1 m
No. of Photo Detector Channels	1,600	60,000
FOV	40 ~ 70° (variable)	Less than 28°
Field resolution	10 - 2.5 - 0.6 km (variable)	0.8 km (2 mrad)
Trigger latency	3 ~ 10 μsec	
Aperture (Field coverage)	85,000 ~ 300,000 km^2	40,000 km^2

Advantage of MEMS Telescope

- Proposed idea provides
- Zoom-in feature -> large FOV
- Tracking feature -> Aberration free system, large mirror size, only small no. of photo detector channels required -> significant reduction of cost, power, weight

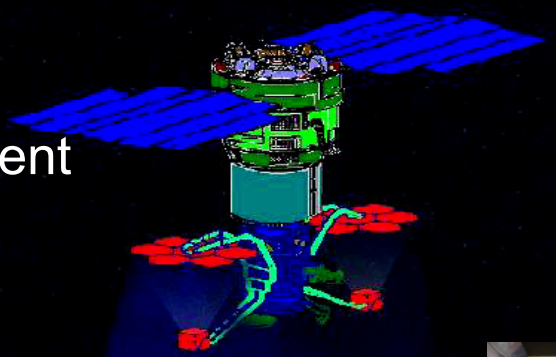


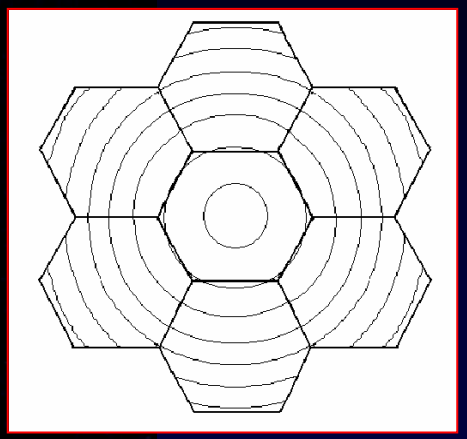
- Silicon allows Light weight, thin, large mirror
  - Experience of ~1m^2 silicon detector shows
  - Low power consumption : < 1 μW per 200μm cell, so ~25 W/m^2
  - Light Weight : 10 kg/m^2 including electronics
  - Low Production Cost : \$30/cm^2, so \$300,000/m^2

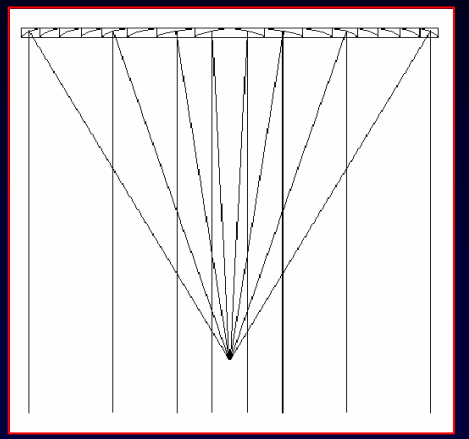
- Multi-band measurements with 2nd, 3rd, … photo detector
- In situ calibration: improve focusing accuracy
- Sun shield: protect photo detectors
- Power generation: direct lights to solar cells

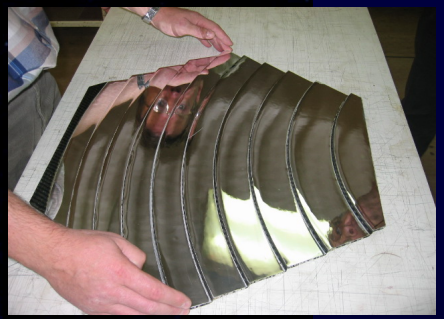
TUS Satellite Platform

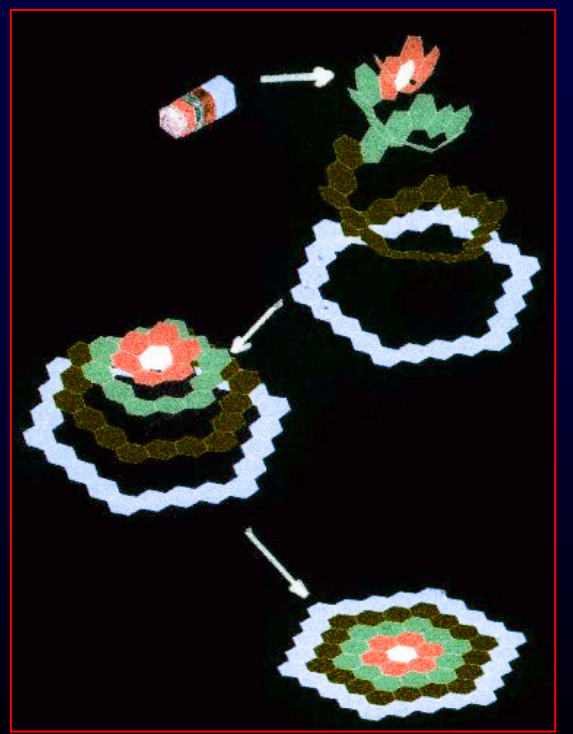
Russian Satellite in 2008
Fresnel Mirror + PMT
Stereo Eyes
Aperture double
Tau-nu measurement











EECR
(10^{20} eV)

fluorescence

Cerenkov

Earth

EVENT

TUS

Requirements of μmirror for MOS of SPICA

MOS: Multi-Object Spectrometer, SPICA: future Japanese IR mission

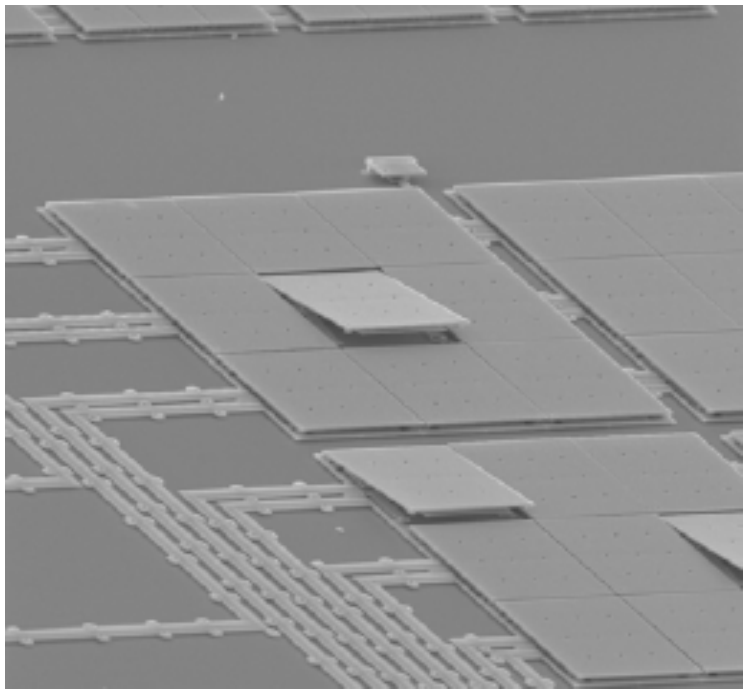
- Tilting Speed : 1 degree/μsec possible at present technology
- Large Tilting Angle : Close to 10 degrees
- Linearity (Tilting Angle .v. Applied Voltage) : Good linearity shown
- Angle accuracy : 0.1° of resolution at present
- Angle fixing stability
- High Fill Factor > 90%

- Mirror cell size : 100 um
- Acceptable wavelength : 0.5-1-10 um
- Operating temperature : 20-60K

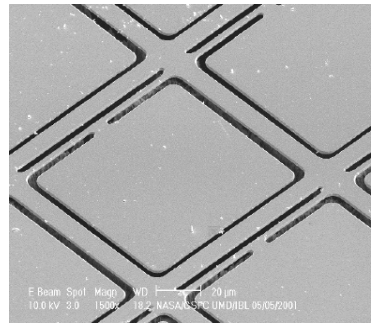
- Low power consumption : < 1 μW per 200μm cell, so ~25 W/m^2
- Light Weight : 10 kg/m^2 including electronics
- Low Production Cost : \$30/cm^2, so \$300,000/m^2

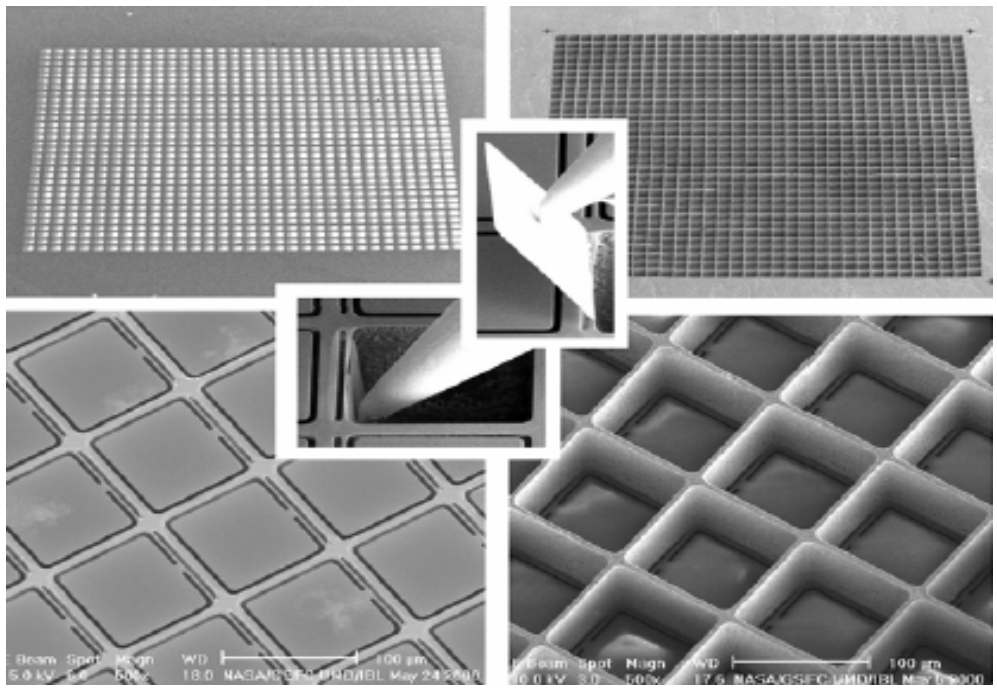
Micromirror & Microshutter for MOS of NGST

Sandia Micromirror



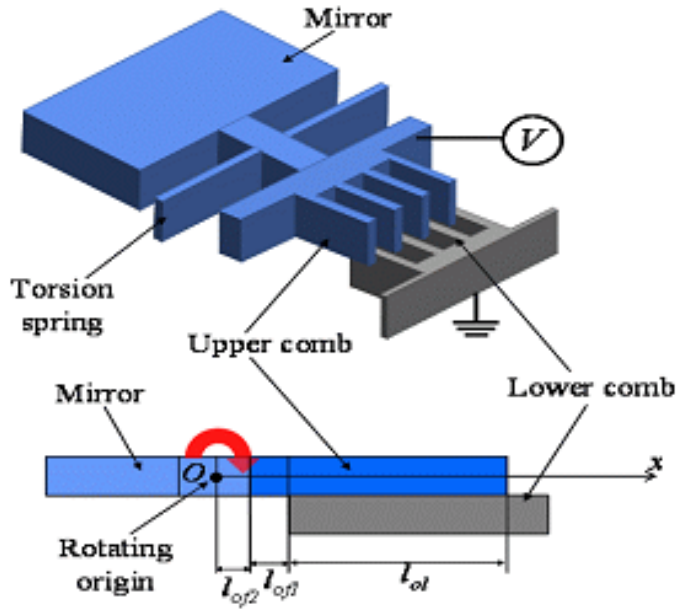
GSFC Microshuttors

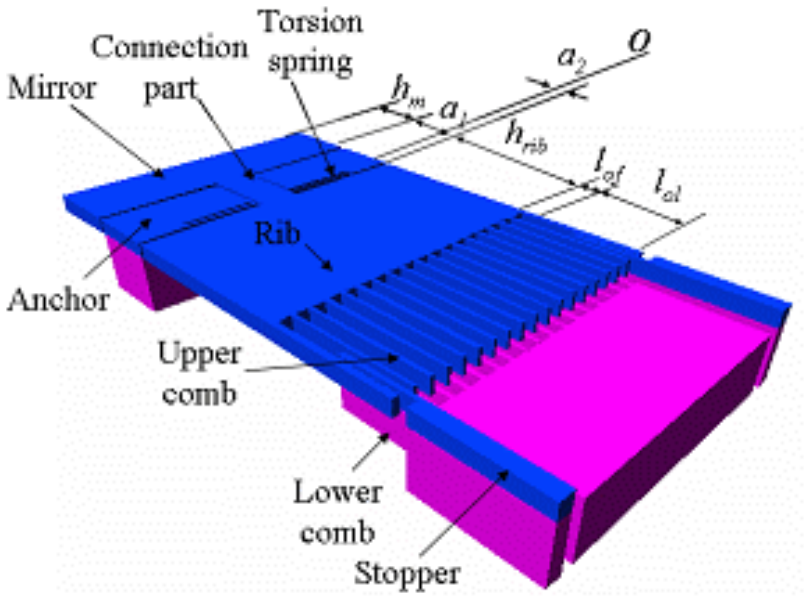


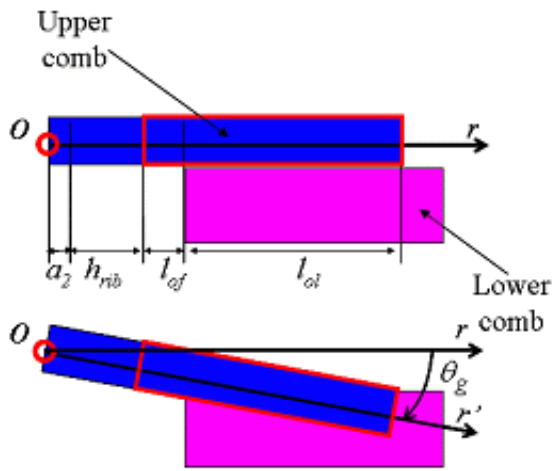


Vertical Comb-drive Actuator in 2005 R&D in Korea

- 1 axis, electrostatic comb drive actuator, designed, fabricated, test in preparation
  - May be used for 3rd Satellite mission, EVENT, 2008
- 2 axes, electrostatic comb drive actuator is being designed, simulated, will be fabed in 2006
  - Aimed for 4th Korean Satellite, EVENT-II, 2012



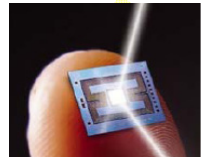




Remarks and Plan for MOS for SPICA

- Remarks
  - Needs comprehensive study to find the best solution for MOS
    - Comparisons between DMD, shutter, "our own design"
  - Our design is under way with a help of KIST
  - Multi-spectrum measurements with micromirror being tried
- Plan
  - Study of micromirror and microshutter (-2005.8)
  - Design of our micromirror prototype (-2005.5)
    - How to actuate ? - Actuation material study
  - Completion of the process flowchart (-2005.6)
  - Fabrication of 1-axis micromirror prototype (-2005.10)
    - Fab at KIST, ETRI, or/and SNU-ISRC
  - Test bench setup (optics, table, etc.) and Test of the prototype
  - Feedback to the next prototype design (-2006.1)

Comb-drive 2d Micromirrors (in Korea)



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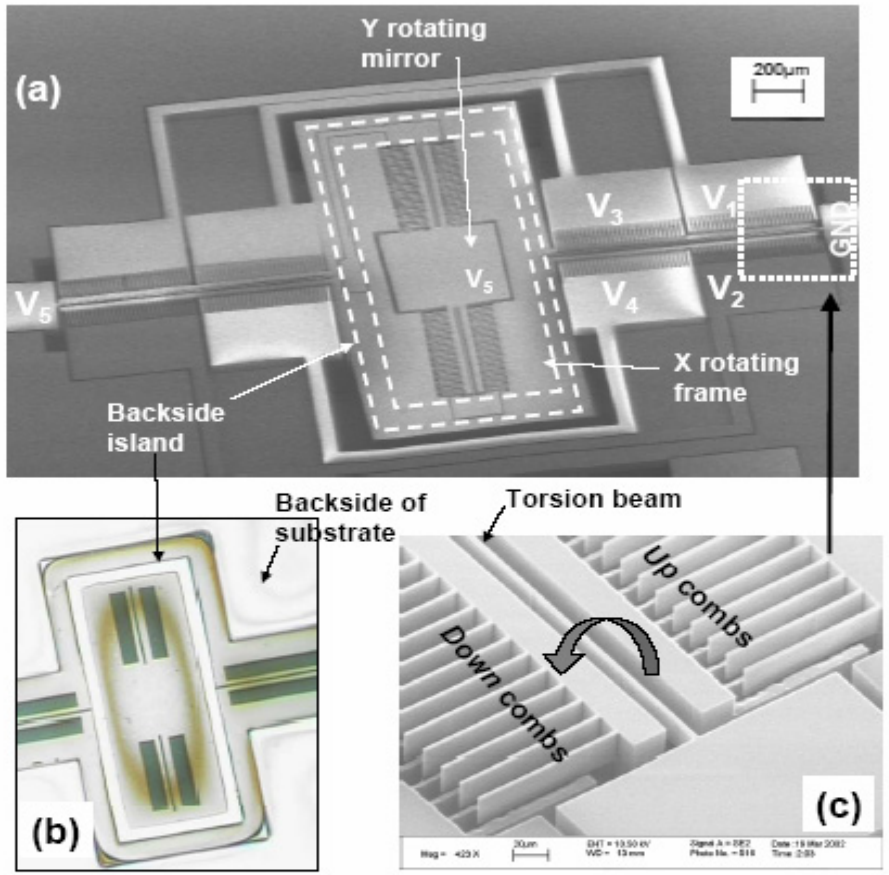


(a) The SEM of 2DoF gimbaled micromirror using SOI (Topview), (b) The microscope picture of backside island (Bottom view), and (c) Vertical combdrives with torsion beam

Proposal to 3rd Korean Science Payload
EVENT

- Science
  - 1st goal: UHECR, dust grain, meteor
  - 2nd goal: Atmospheric science: ionosphere related, solar activity related science (solar max in 2008), Blue Jets, Aurora, Thunderstorm discharge, earthquake related, …

- Technology
  - Public attention like "ARTIFICIAL MOON"
    - Turning mirror
    - Folding segments
  - Digital MEMS application in space
    - Try of multi-detector (multi-frequency) system: UV & IR measurement in one platform
  - Try of ground supervision like mountain fire, large scale explosion, etc.

Meteor

Brightness, direction, occurance -> source of meteor

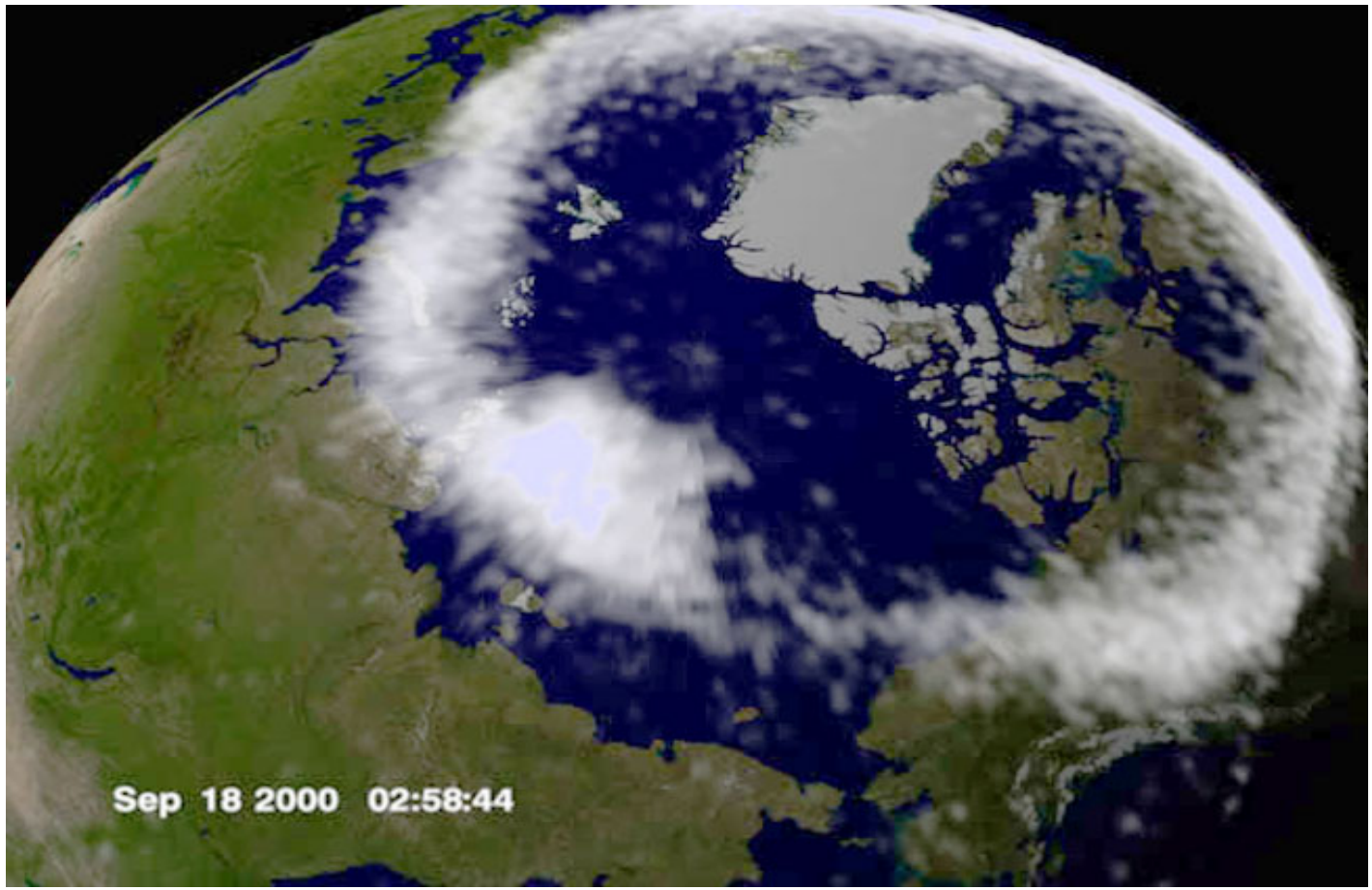
- 1~10 events/revolution
- Kinetic energy ~ 100 J (size ~ 0.5 mm)
- Horizontal meteors (zenith angle > 60 degree) recorded in several pixels

EVENT

TUS

Aurora belts (Northern and Southern)

are the main features of the average UV flux measurements



Artistic view of the Aurora belts in UV as they were measured by the NASA

EVENT

Fire

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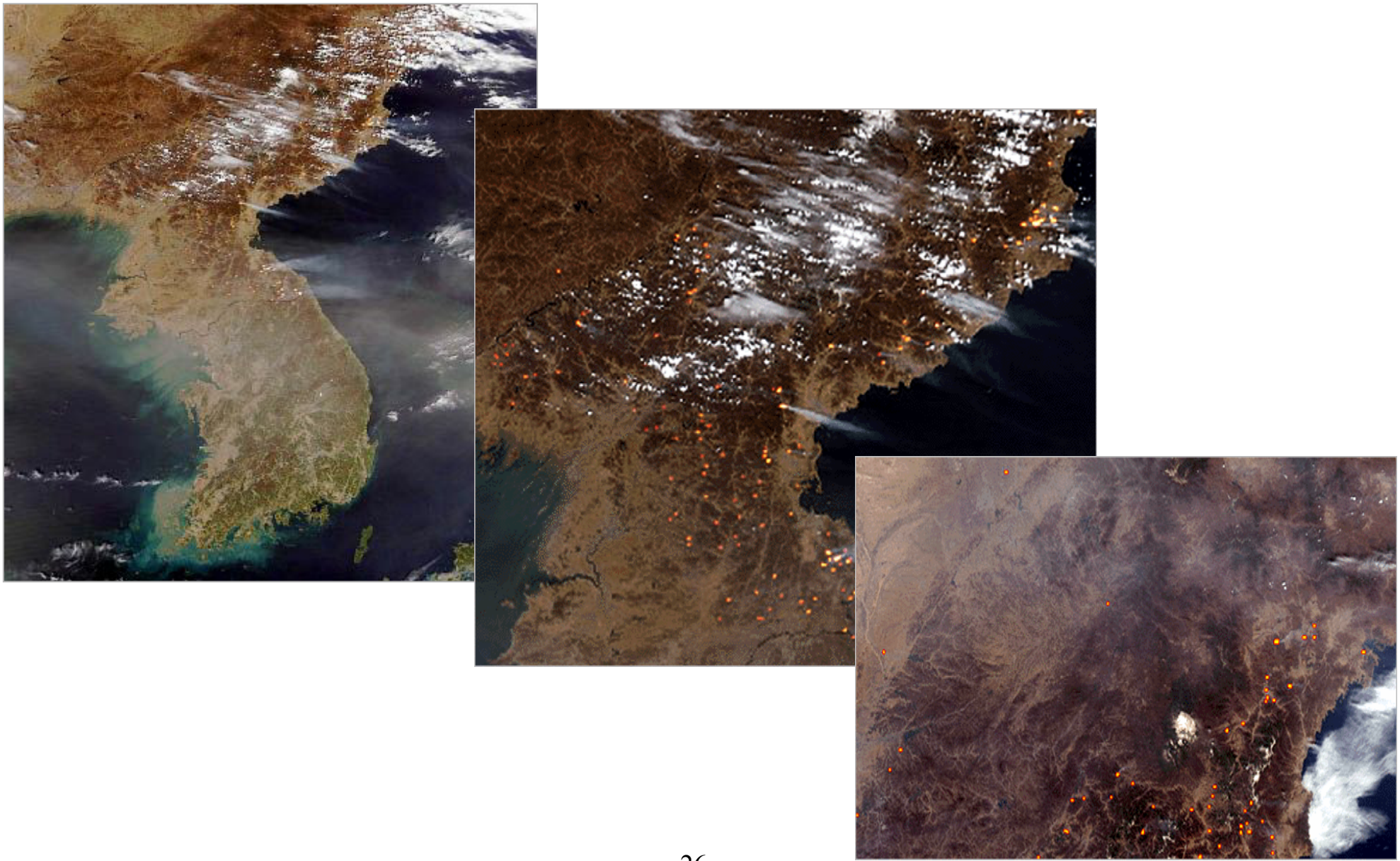

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Night View of the Earth :

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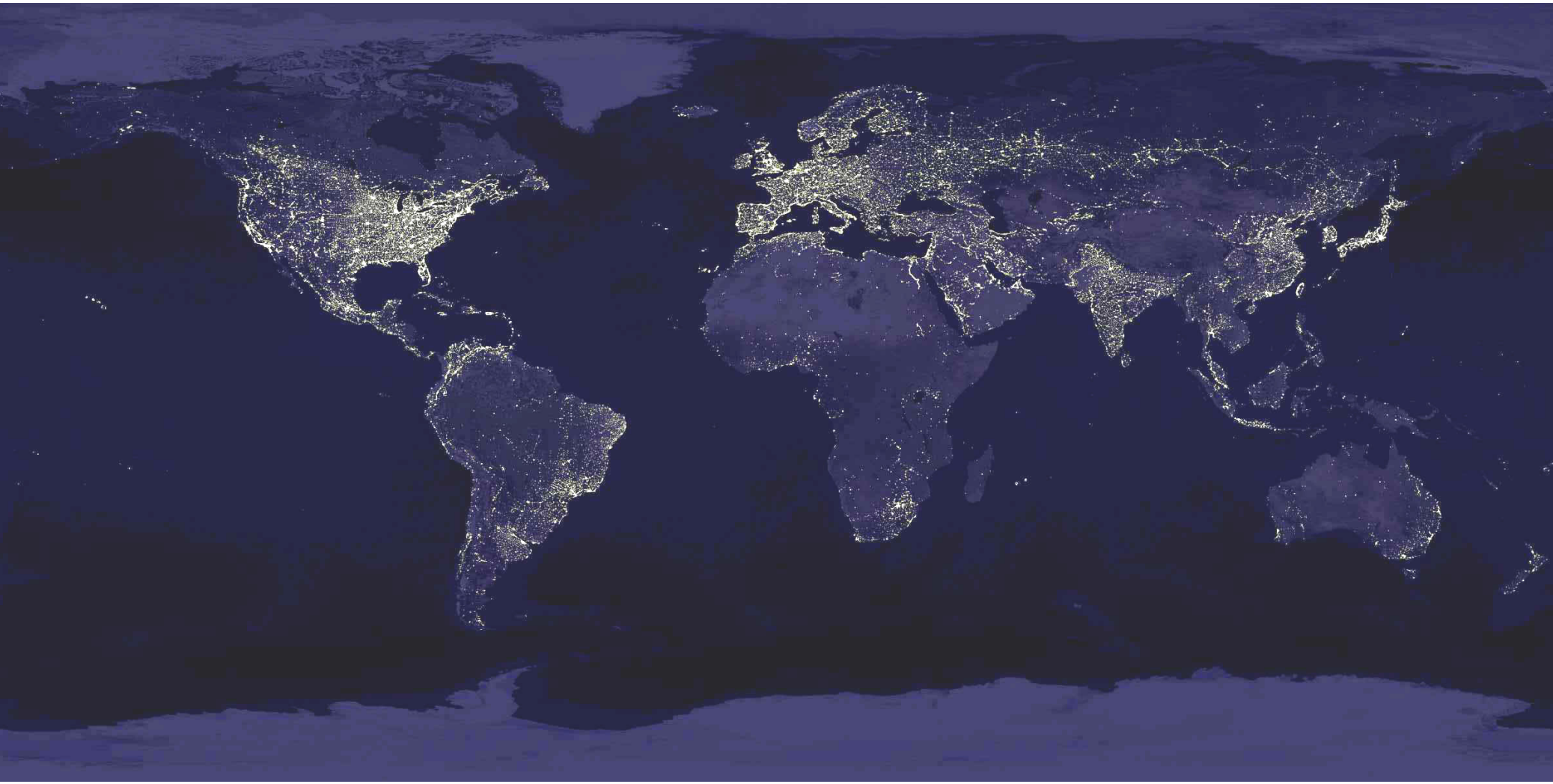
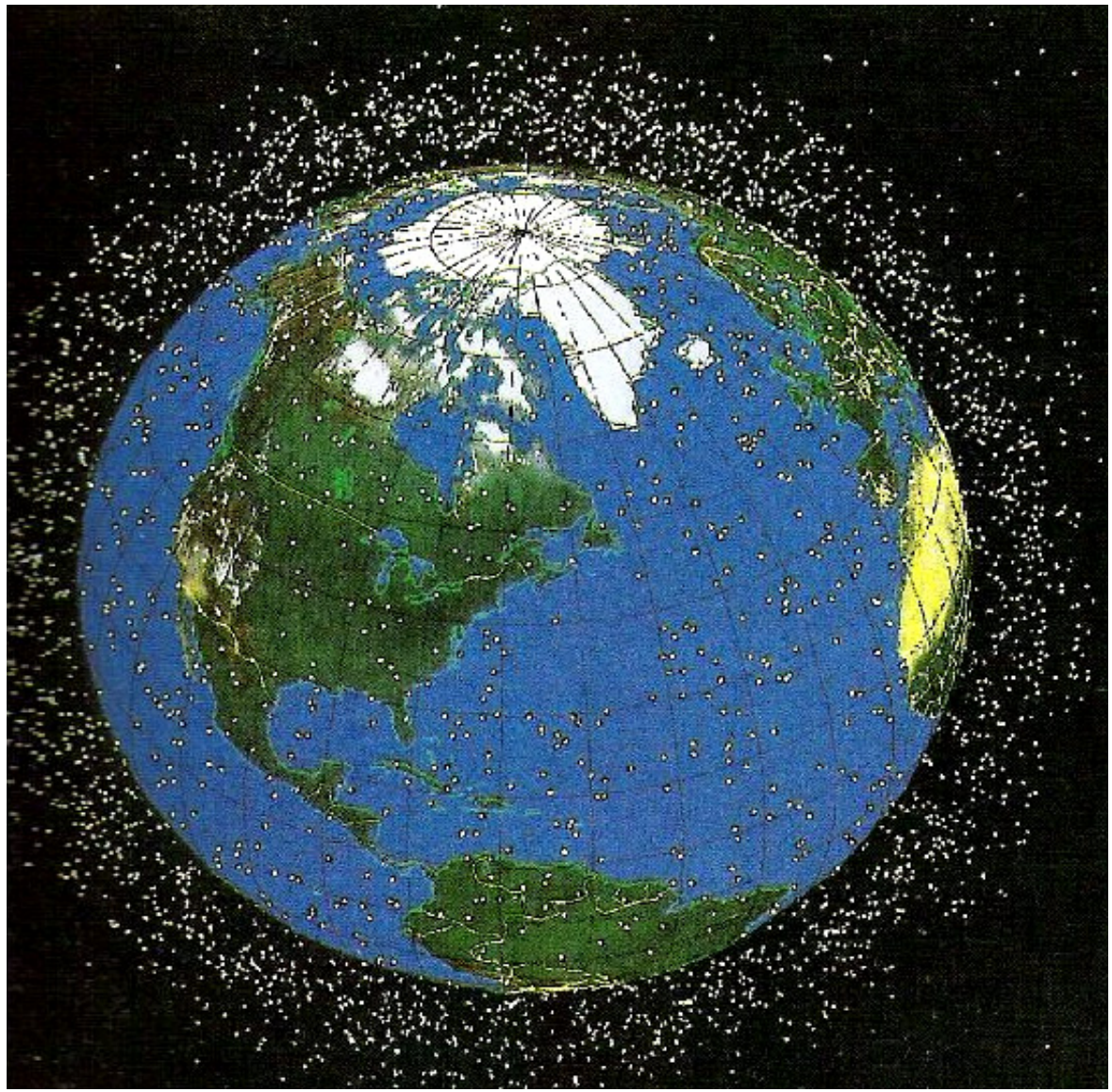
We will measure the real background



Debris



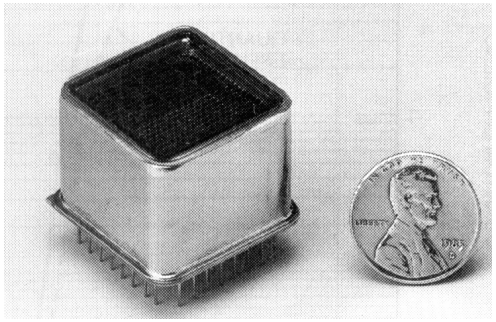
Proposal to 3rd Korean Science Payload
EVENT

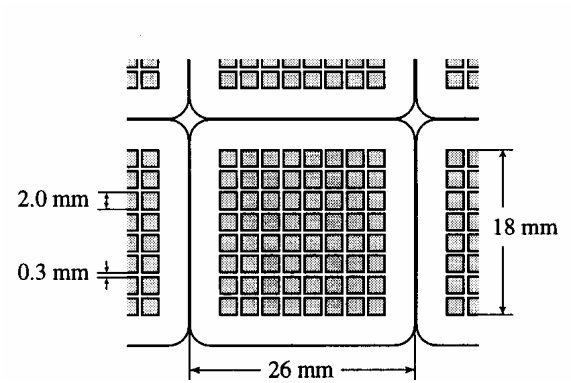
- Payload
  - Weight: ~100 kg
  - 3m diameter mirror built from mirror segments of two or three ring structure, unfolded in space, Fresnel or spherical mirror
  - FOV: 15 degree ?
  - Aperture: ?
  - No of channel: ~2000 PMT channel foreseen
  - Other small detectors for atmospheric science or solar physics can be added if possible
  - Preliminary conceptual, but as detailed as we can, design should be made soon
  - Thinking a bit ambitiously
    - May try "multi-detector" system
      - Lights delivered to UV photo detector and IR detector (or to solar cells) by using digital MEMS micromirror
      - Optics is then off-axis, bit complicated, but certainly possible
    - May try to rotation of mirror to look up and down using an engine built in

Mirror segment and Photodetector

- Fresnel mirror or Carbon plastic spherical mirror
- MultiAnode PMT

Carbon plastic spherical mirror

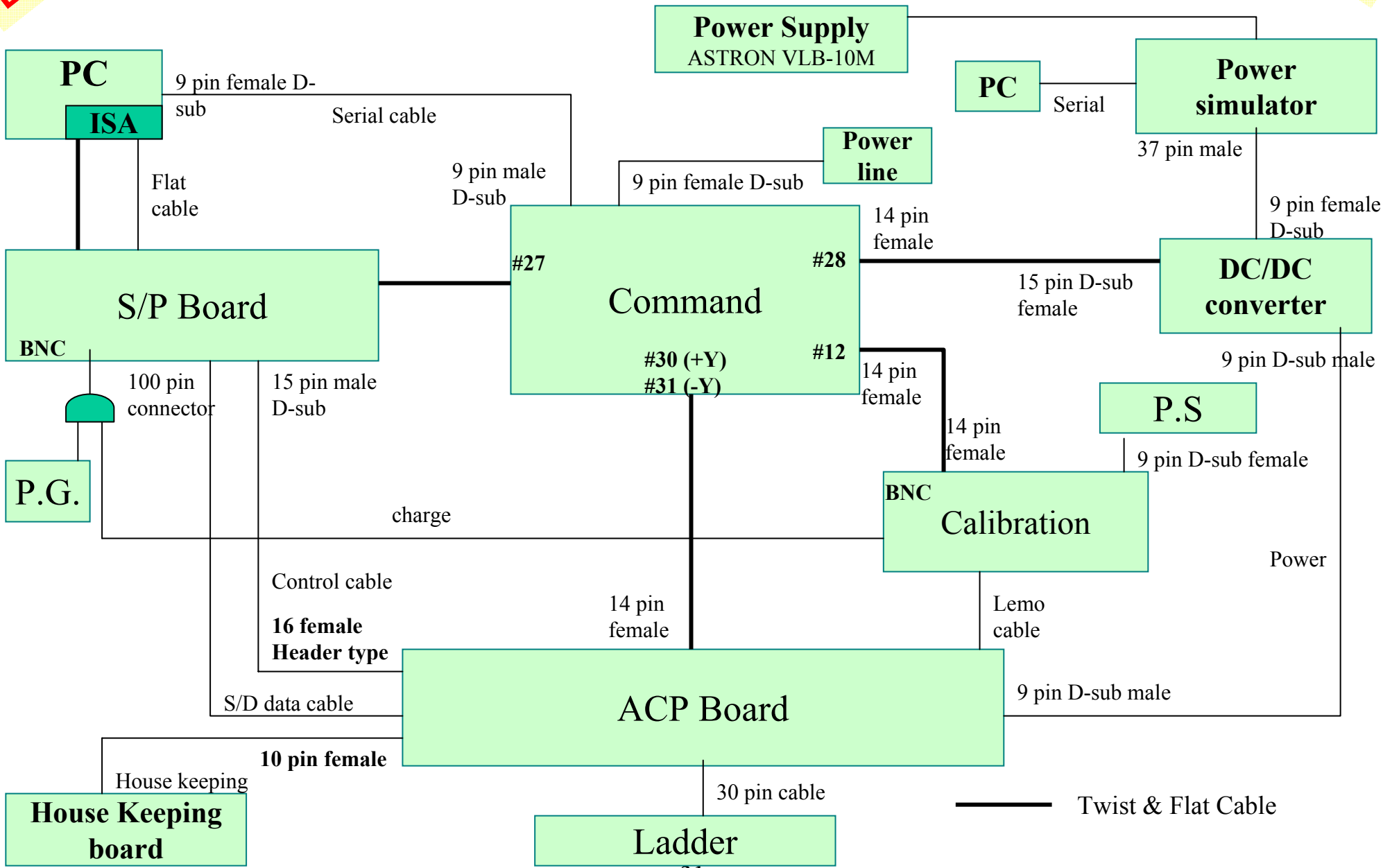




Hamamatsu R5900 M64

- 8x8 channels
- Size: 26x26 mm^2
- Bialkali PC: Q.E. ~ 22% at lmax = 400 nm. Gain ≈ 10^6
  - Quartz lenses to increase active area
  - Single photon sensitivity
  - Precision < 1mm
  - 3 ns falling time (300 MHz readout)
- Active area fraction 38%. Increased by lenses (≈78%)

Electronics/DAQ Architecture



EVENT

- Launch
  - Using same as MSU-Tatiana, using Military satellite
  - Energia and Samara using PROGRESS
  - Submarine launching

- Ground control
  - 3 years of mission
  - ?

EVENT

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Proposal

To be clearly stated with concrete plan

- Payload name
- Mission
  - minimal:
  - Maximal:
  - If we are lucky:
- Results and spinoff
- Risks
- Platform
- Launch
- Organization and Collaboration (?)
  - Korea: [Ewha, KAIST, Yonsei, KAO], [KARI, Satrek]
  - Russia: [MSU, DUBNA, …], [Energia, …], […]
- MOU or agreement letters, etc

EVENT

Discussion in this "CR in Space" community

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- EVENT can be considered as a "pilot experiment" for future EUSO or KLYPVE
- You can try to test any what we have on mind with EVENT
- Our CR community is quite small, so I need your support and collaboration to win the AO this year