Miniature Digital Sun Sensor for Application in Nano- and Picosatellites

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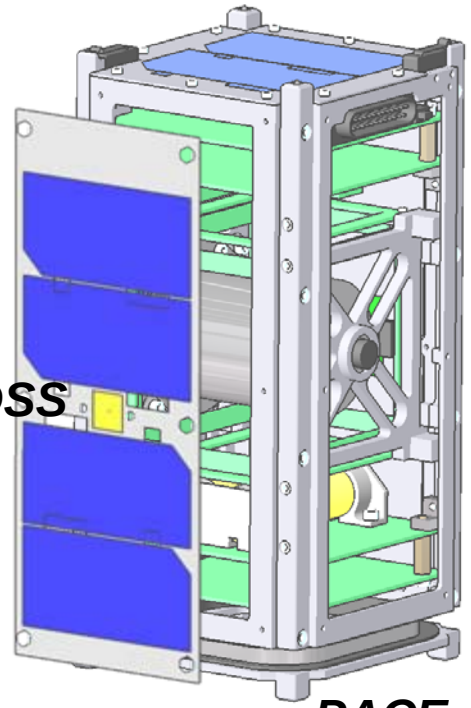
Research Objectives

- Development of a precise digital sun sensor
- Suitable for CubeSats and Nanosatellites
- Realize large field of view
- Accuracy in the order of 1 deg

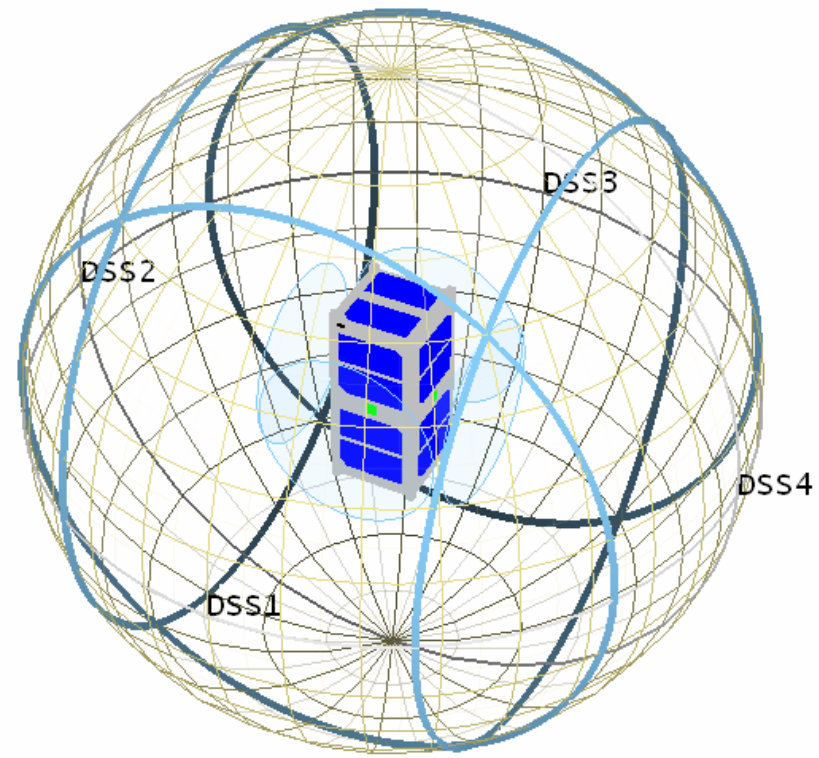
Motivation and Purpose

- To be used on PACE (2kg) and LEAP (30kg) satellites, both being developed at National Cheng Kung University.



Specification of Digital Sun Sensor

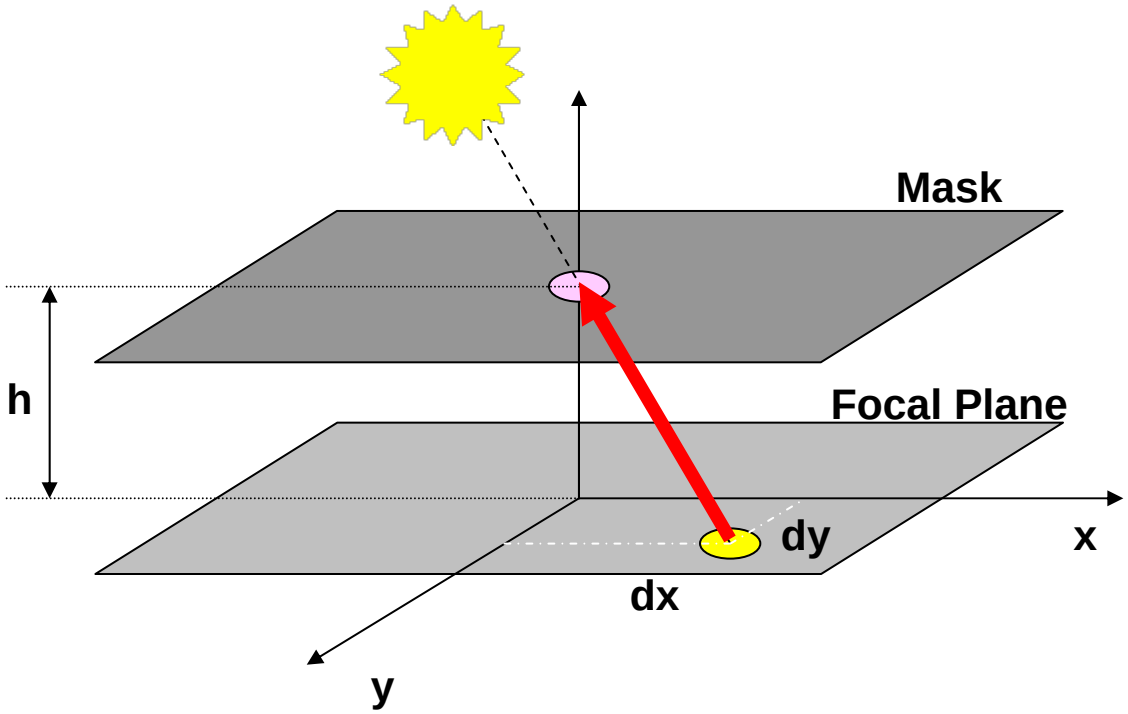
- 120° x 120° Field of View
- 1 Hz update rate
- <0.5° resolution (TBC)
- <1° accuracy (TBC)
- 20 grams total mass
- 3.3 Volt supply, max. 0.2W
- 42mm x 29mm x 5mm

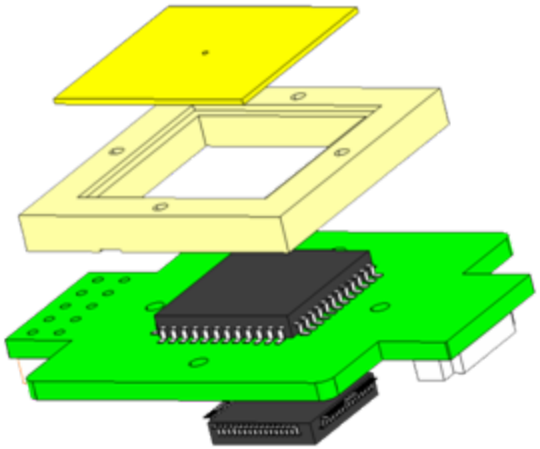


Coverage of 4 DSS (one per side)

Measurement Principle

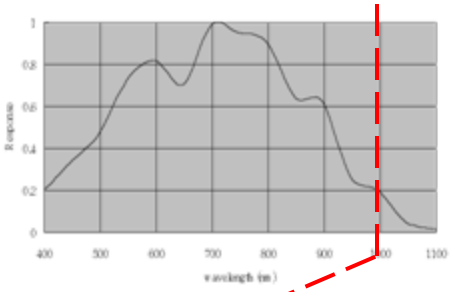
- A pinhole mask is placed in front of an image sensor.
- The sun light will form a sun spot on the focal plane.
- Determination of the spot center yields a sun pointing vector.

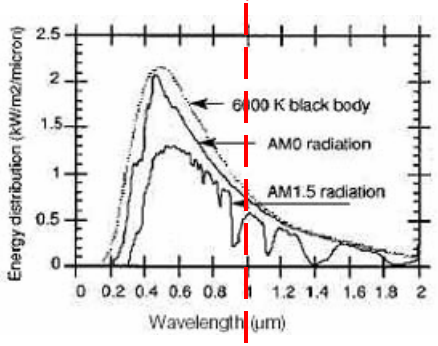




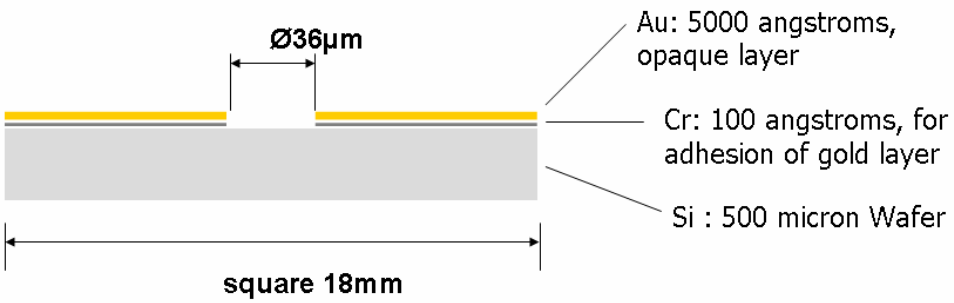
Hardware (1/2)

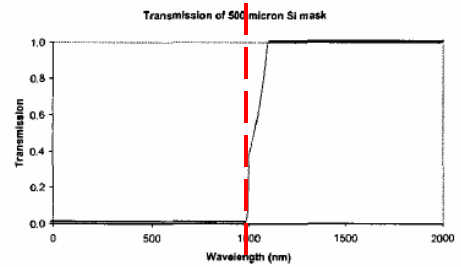
- **Image Sensor**
  - CMOS B/W image sensor
  - 512 x 512 pixels (8 bit), 12µm pixel size
  - On-chip in-pixel analog frame-buffer (200 ms)
  - Clock-less and X-Y addressed image readout
  - On-chip 8-bit A/ D converter





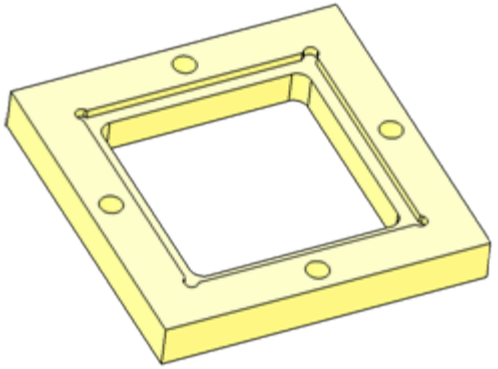
- **Mask**
  - MEMS technology, Si wafer



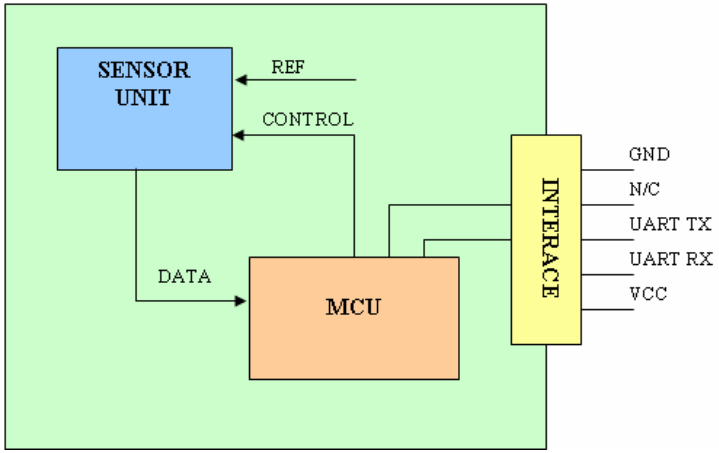


Hardware (2/2)

- **Mask Spacer**
  - Placing the mask at a certain distance in front of the image sensor has impact on the FOV.
  - Made of Teflon to achieve thermal decoupling from the panel it is mounted to.



- **Microcontroller**
  - C8051F123 MCU
  - Provides 9600/38400 bps UART I/F
  - Controls Sensor and runs filter and detection algorithms



Software

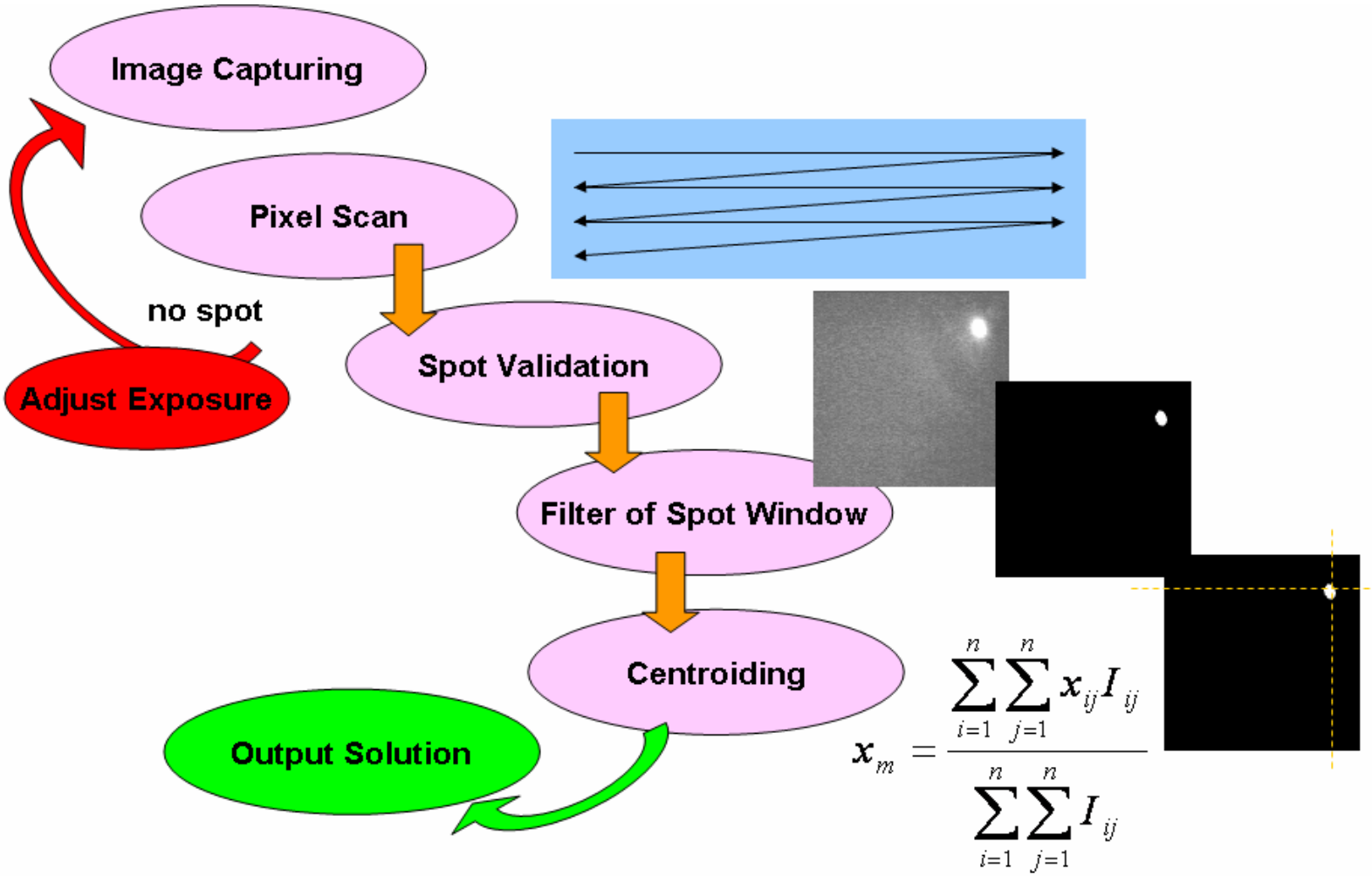
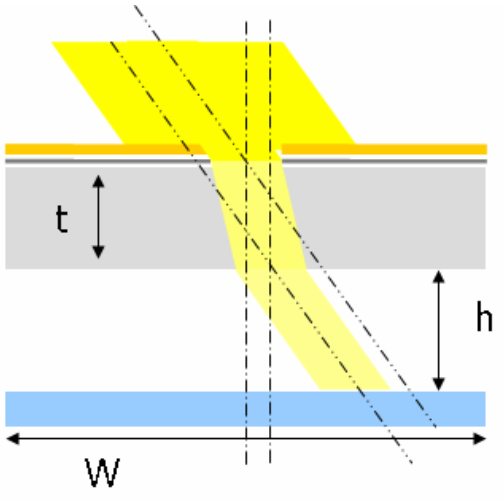


Image Capturing
Pixel Scan
no spot
Adjust Exposure
Spot Validation
Filter of Spot Window
Centroiding
Output Solution
$x_m = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} x_{ij} I_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} I_{ij}}$

Performance Assessment (1/2)

- **Resolution**

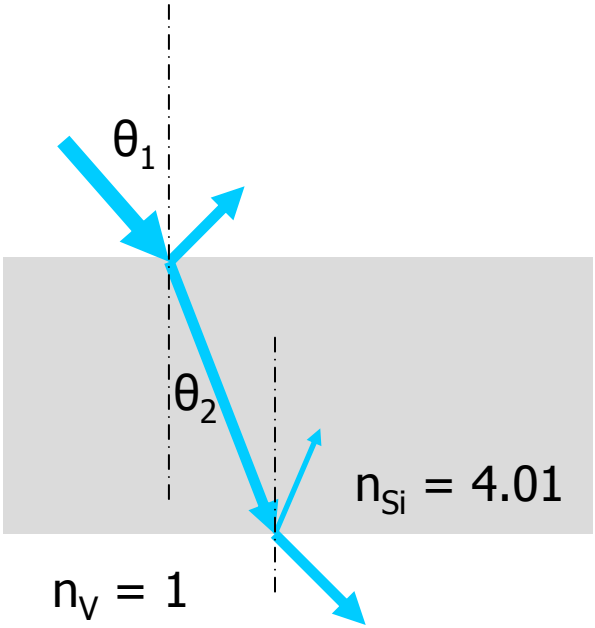
  With a distance of h = 1500µm:
  - FOV = ±63.3°
  - Resolution @ nadir = 0.46 °
  - Resolution @ 45° = 0.23°
  - Resolution @ 60° = 0.16°



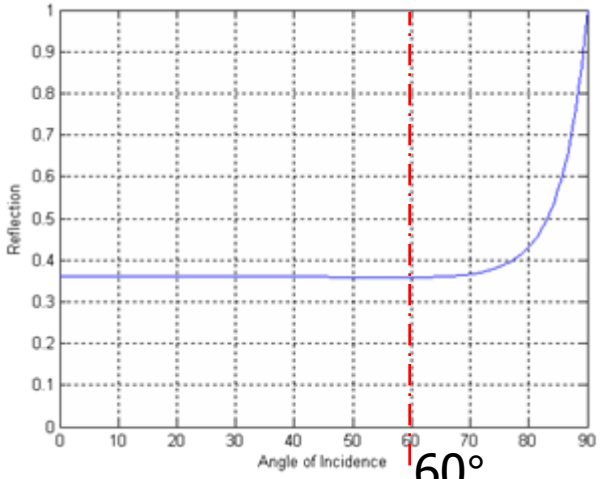
- **Disturbances and Noise**
  - Si wafer filters out IR sources and most of the noise
  - Thresholding and spot detection cancels out the effects of Albedo and Moon reflection

Performance Assessment (2/2)

- **Reflection and Refraction in the Mask**

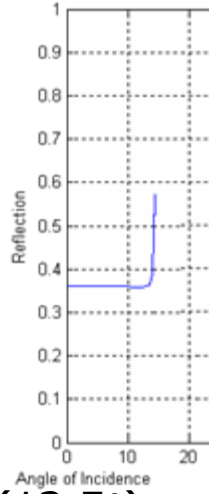


Reflection Vacuum-Si



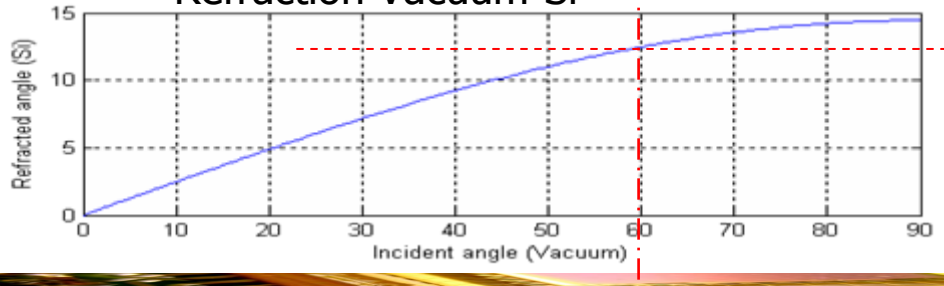
60°

Reflection Si-Vacuum



R(12.5°) = 0.36

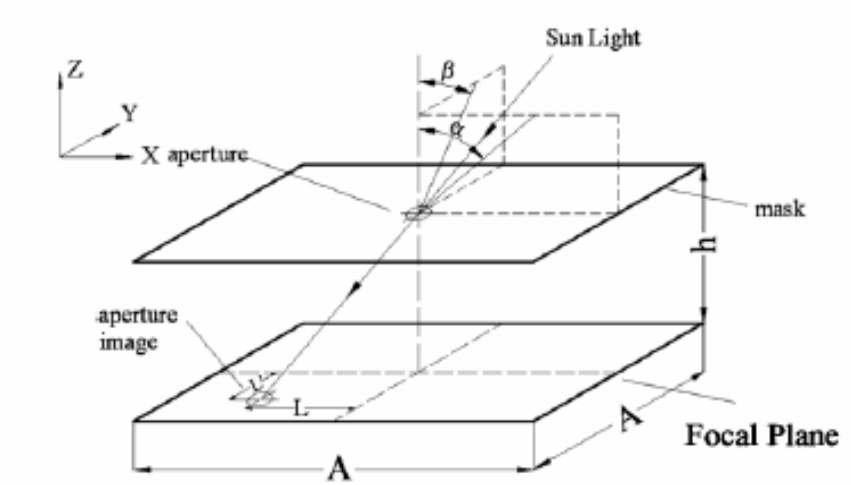
Refraction Vacuum-Si

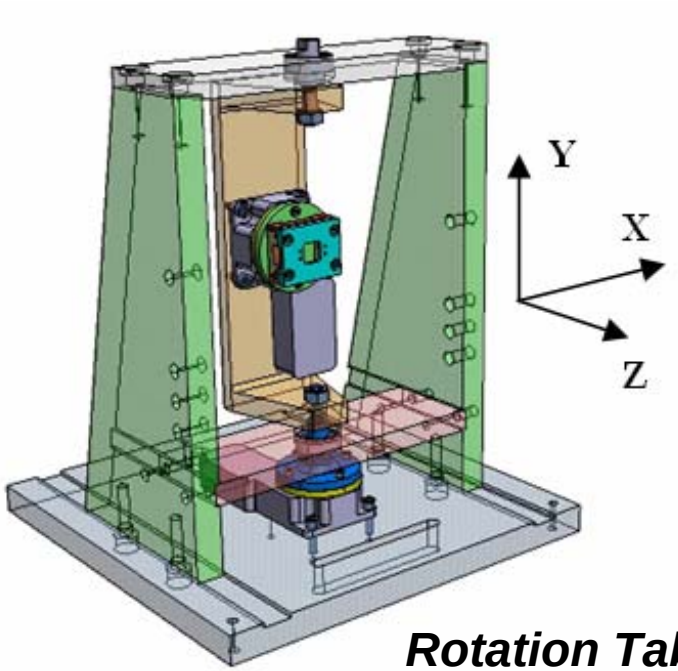


12.5°

Calibration Procedure (Planned)

- Rotation table and sun simulator aperture for determination of:
  - Field of View
  - Parameters h, x_0, y_0
  - Accuracy over entire FOV





Rotation Table

$$\begin{bmatrix} x_p \\ y_p \end{bmatrix} = \begin{bmatrix} -h \cdot \cos\varphi \tan\theta + x_0 \\ h \cdot \sin\varphi \tan\theta + y_0 \end{bmatrix}$$

Thank you for your attention!

...Questions ?

please email to:

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more at:

www.nspo.org.tw/ASC2008

Backup Slides

Functional Testing of Prototype