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Evaluation of a New Tool for Heliostat Field Flux Mapping

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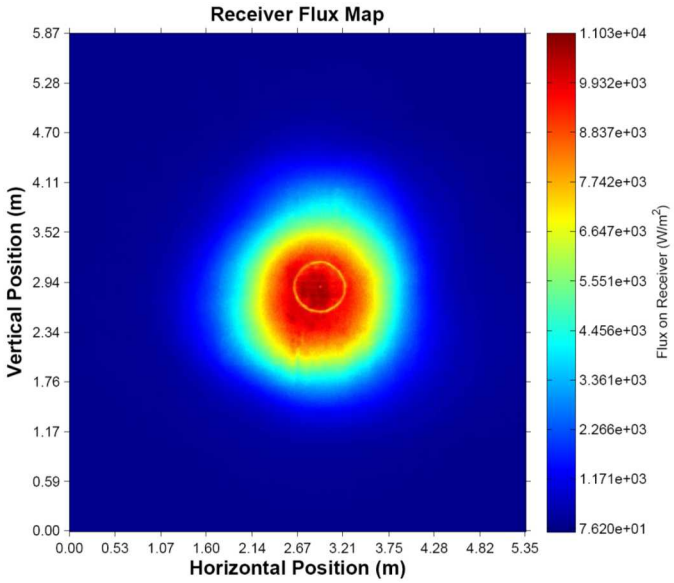
Objective

- **Develop accurate flux-mapping tool that is less expensive and simpler than existing methods**
- **PHLUX Method***
  - Photographic Flux Mapping Tools

*Details in ASME ES2011 paper

PHLUX Method

- **PHLUX Tool consist of:**
  - A digital SLR camera
    - Photo of the illuminated diffuse receiver or target
    - Photo of the sun and DNI
      - Scaling (power, size)
  - Algorithms/Software
    - Calculates irradiance distribution on the receiver
    - Determines length scales and angles



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PHLUX Procedure

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Testing and Validation

- **Applied PHLUX method to heliostat beams projected onto face of tower**
  - National Solar Thermal Test Facility, Sandia National Labs, Albuquerque, NM

Receiver and Sun Images

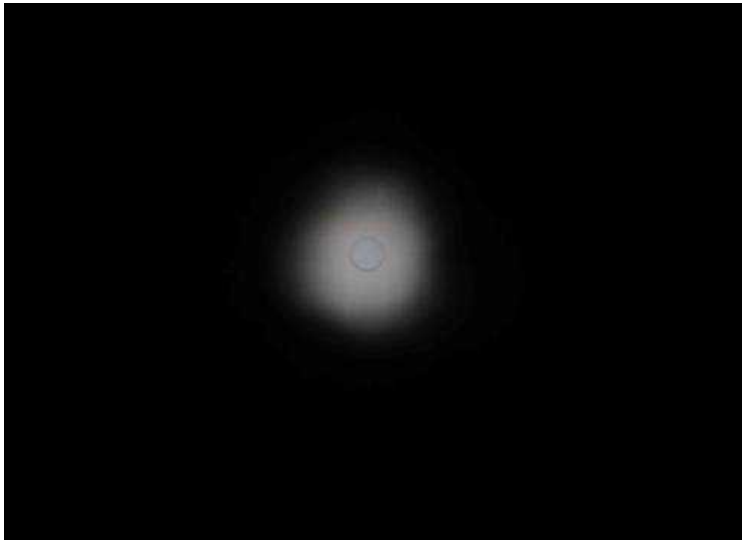


Image of beam on tower

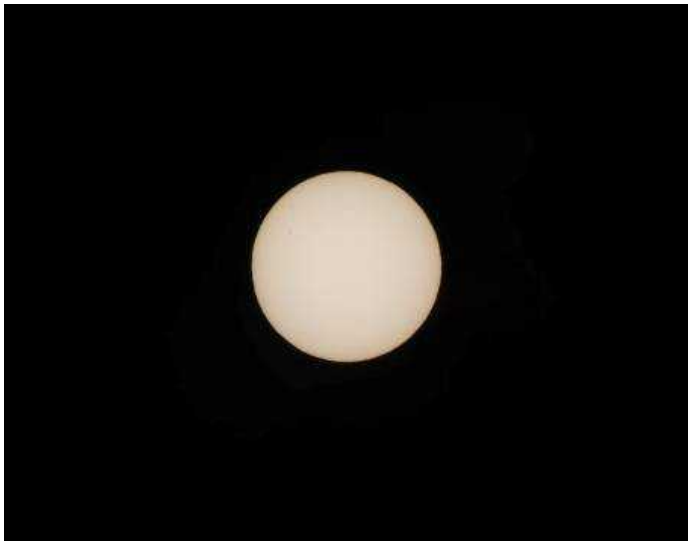
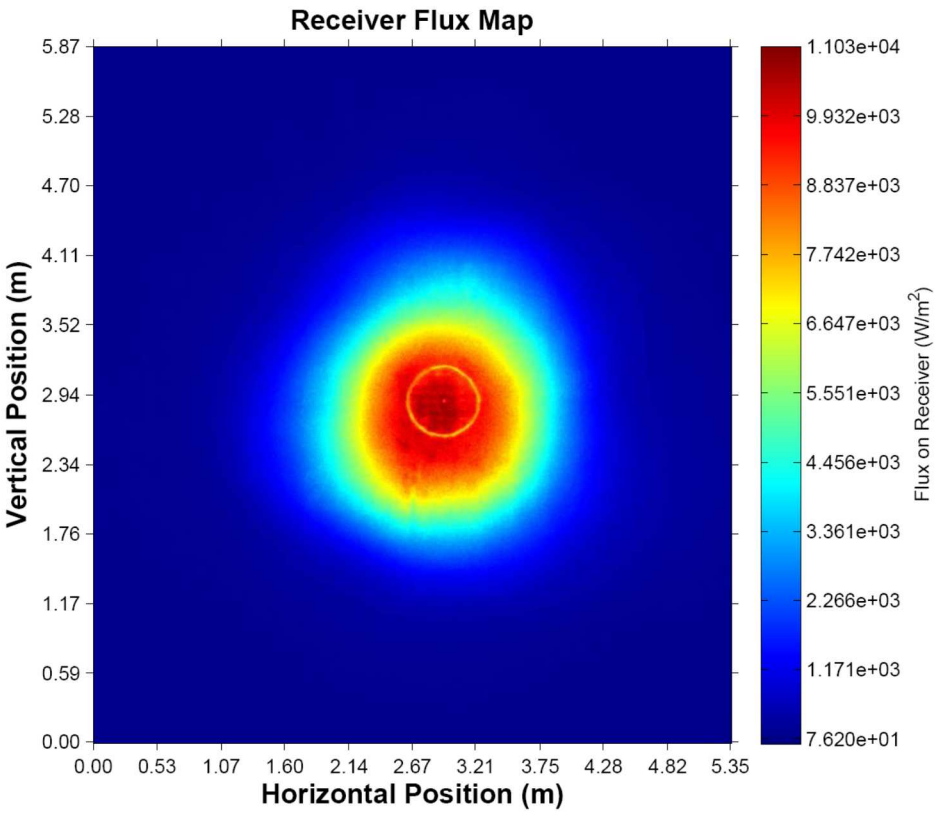
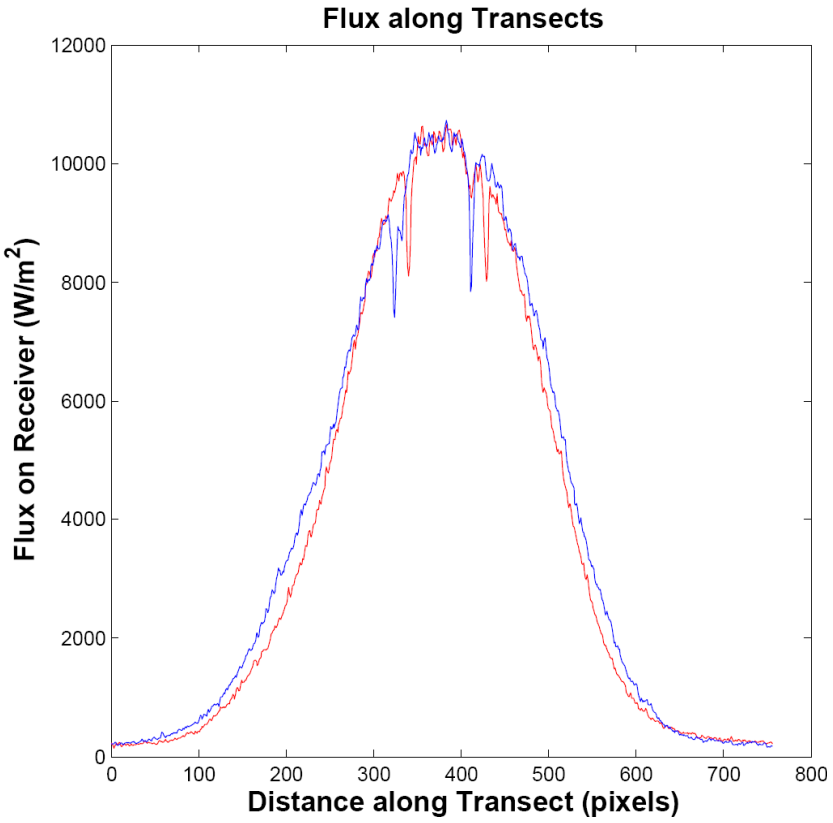


Image of sun

PHLUX Map





- **Peak flux using PHLUX method was within 2% of that measured by flux gauge**
- **Additional tests using multiple heliostats showed that the PHLUX method yielded results that were within 10% of that measured by flux gauge**

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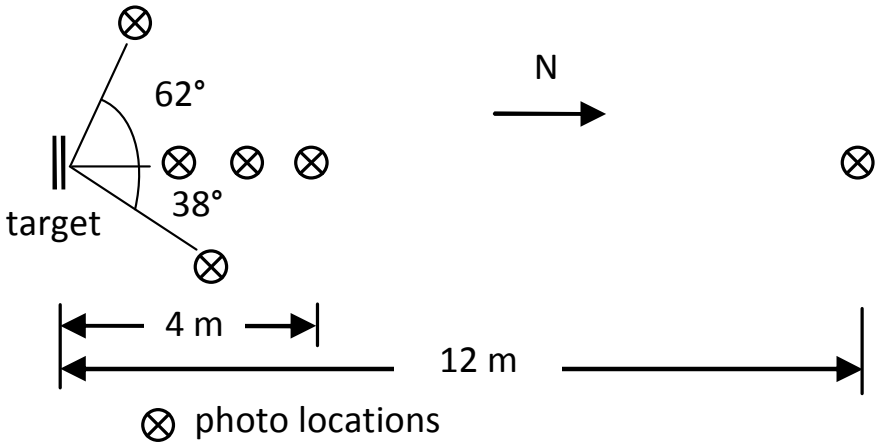
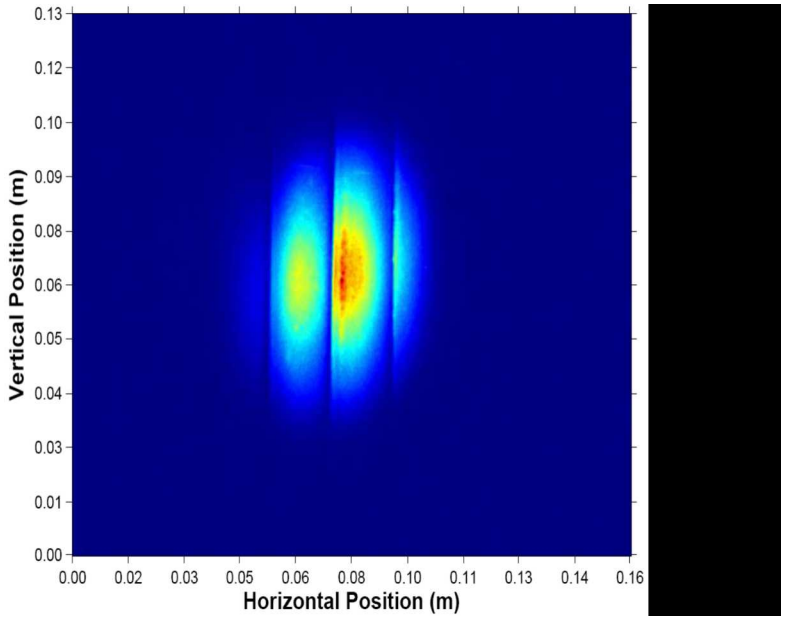
Distance and Angle Independence

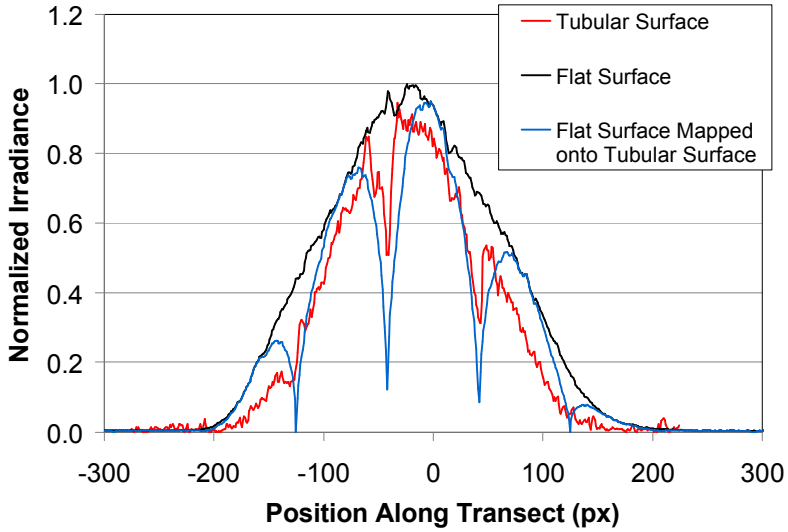


∴ **PHLUX results shown to be independent of angle and distance between camera and target**

Non-Planar Receiver Surfaces



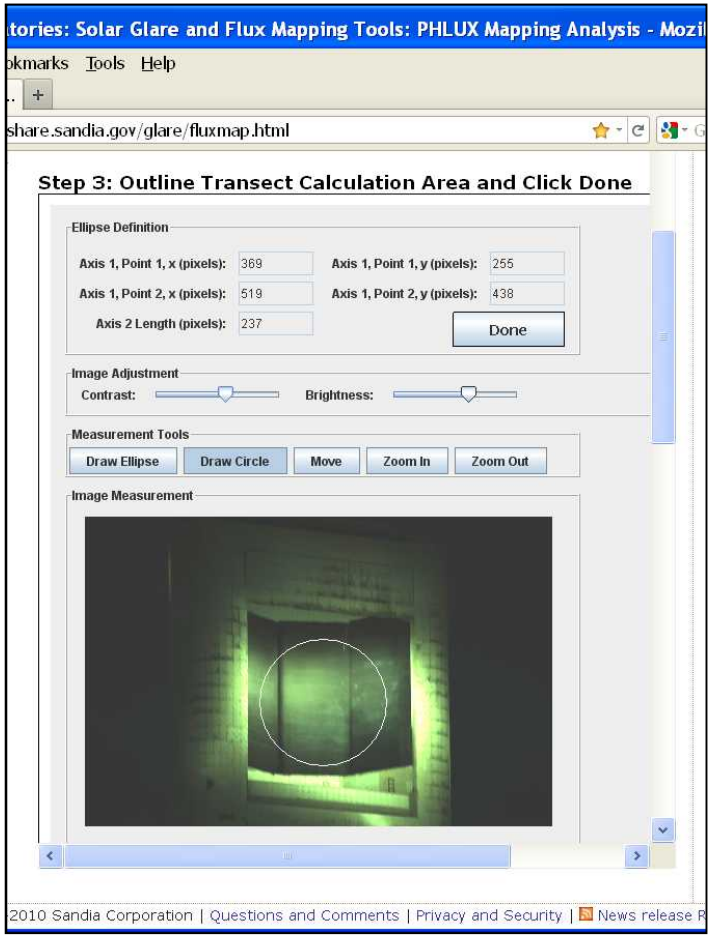
∴ **PHLUX method can be applied to non-planar surfaces**



Summary

- **PHLUX method provides simple and inexpensive flux mapping tool**
  - Only requires digital camera and reflectivity of receiver
  - Uses image of sun (and DNI) to scale power and size
- **PHLUX method evaluated with testing**
  - Accurate to within ~2 – 10% of flux gauge readings
  - Irradiance independent of distance and angle between camera and target
  - Applicable to non-planar (tubular) surfaces
- **Web-based tool developed**
  - Seeking beta testers

Web-Based PHLUX Tool



Looking for beta testers for web site

Backup Slides

Next Steps

- **Continue testing PHLUX method**
  - Evaluate impact of camera settings and filters
  - Evaluate impact of different receiver geometries
- **Resolve security issues for website before public release**
- **Demonstrate calculation of reflectivity map for receivers with non-uniform reflectivity**
- **Develop stand-alone software for PHLUX method**
  - Apply to video camera recordings

PHLUX Theory

Pixel value

DNI value at time sun image was recorded

Average pixel value in sun image

$$E_{R,i} = \frac{V_{CCD,i} E_{DNI}}{\rho_{R,i} \tan^2(\gamma/2)} \frac{\pi r_{sun\_pixels}^2}{\sum_{sun} V_{CCD\_sun,i}}$$

Receiver irradiance corresponding to each pixel value

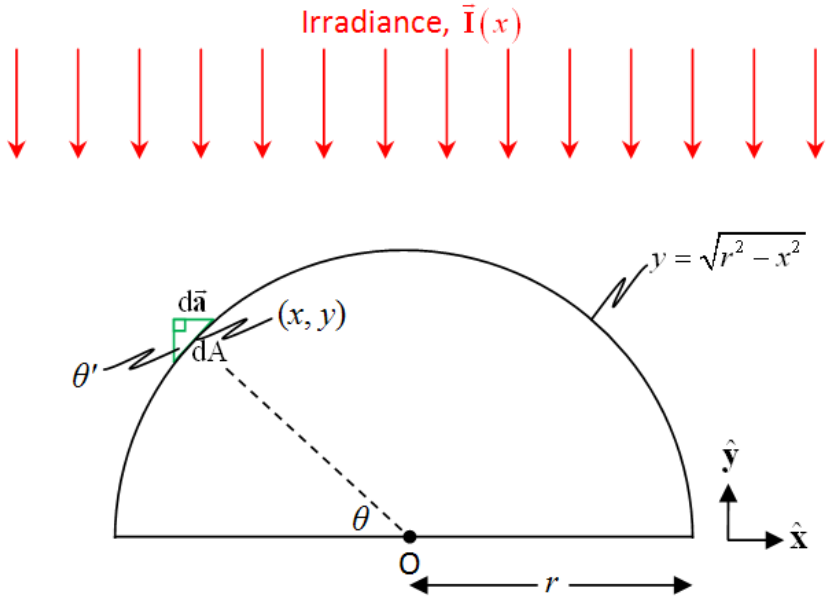
Reflectivity of receiver element corresponding to pixel *i**

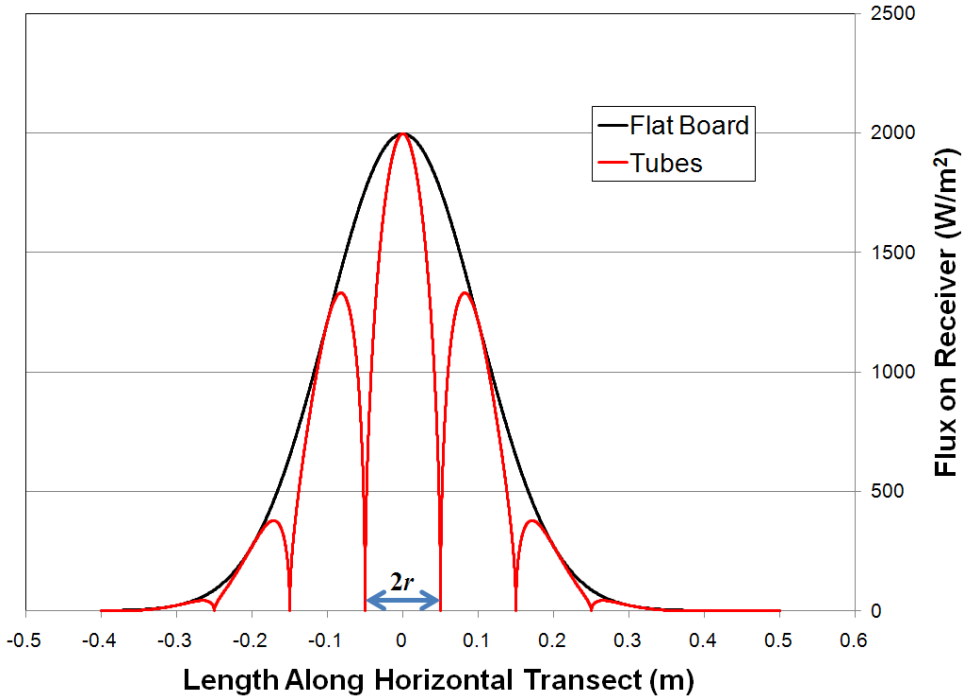
Subtended angle of the sun (~9.3 mrad)

Measurement of irradiance is independent of receiver geometry and camera angle/distance

*Paper describes methods to determine an effective reflectivity or a reflectivity map using digital images

Irradiance on Non-Planar Surface





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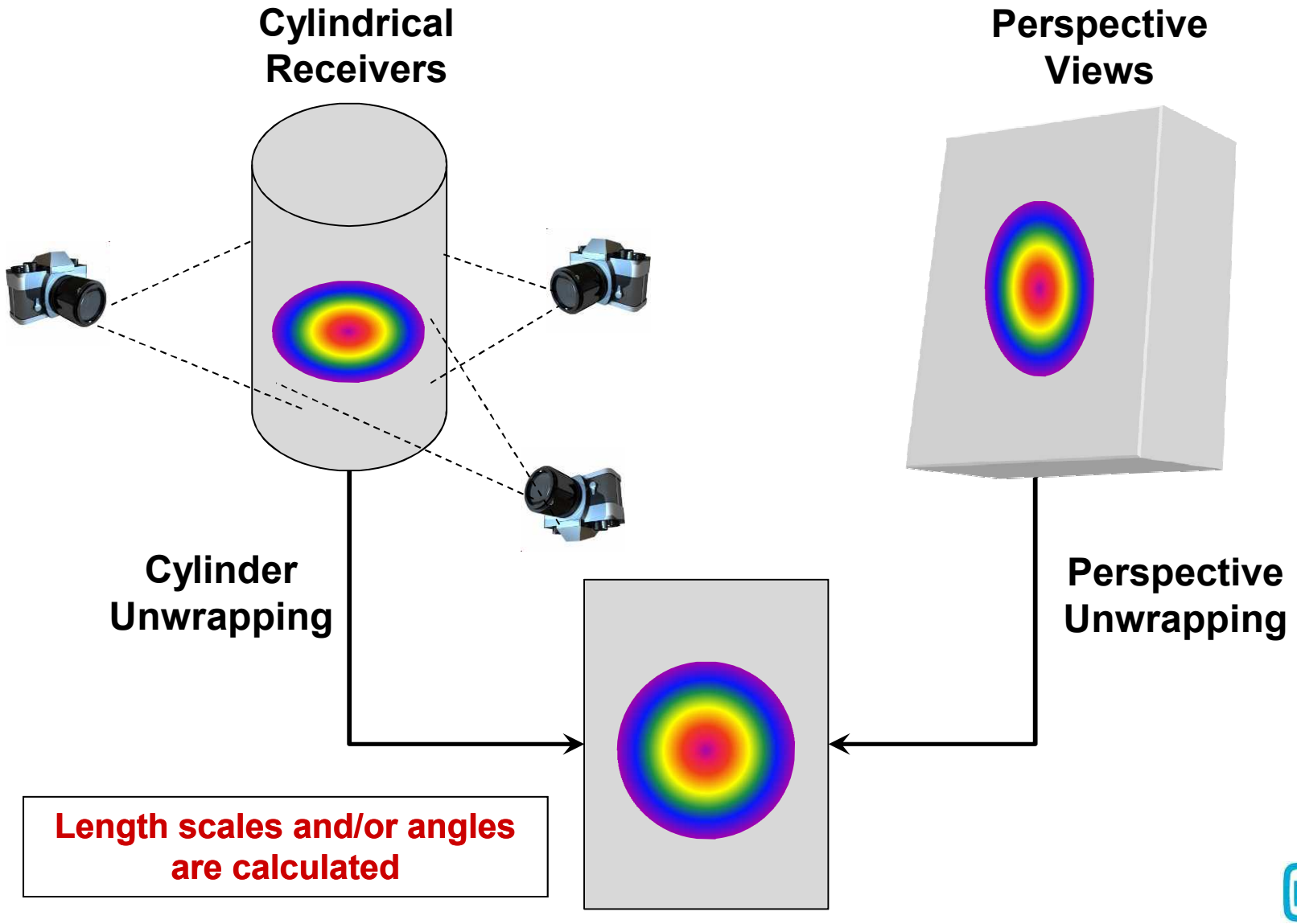
Additional Considerations



Length scales and/or angles are calculated