# CAMERAS

# Consumer digital CCD cameras


# Aerial Cameras

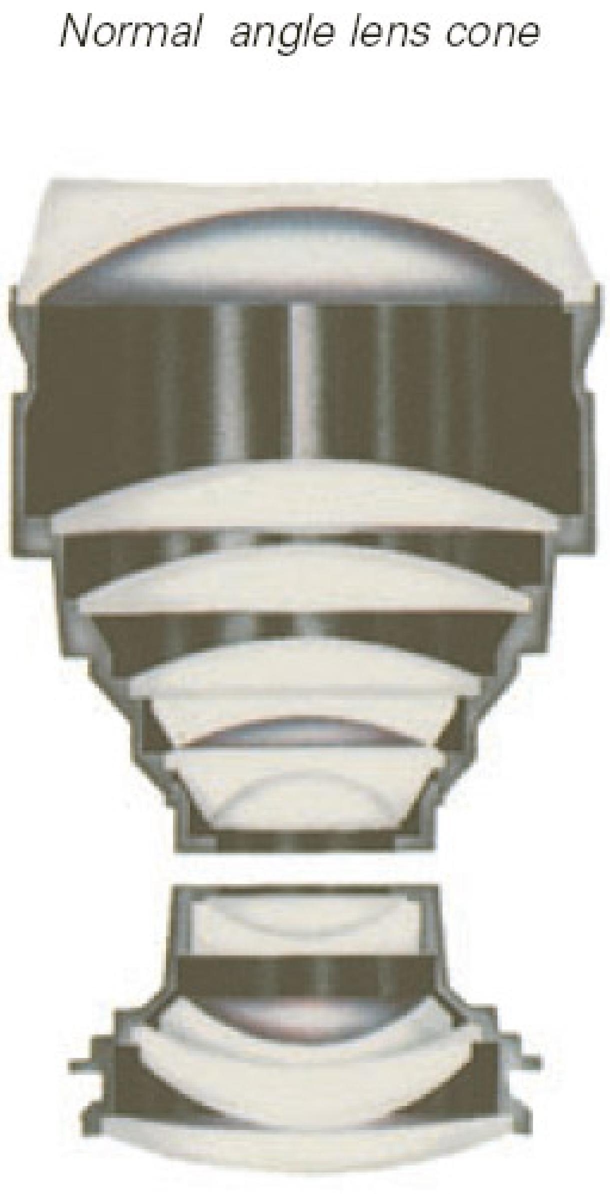
Leica RC-30

Zeiss RMK

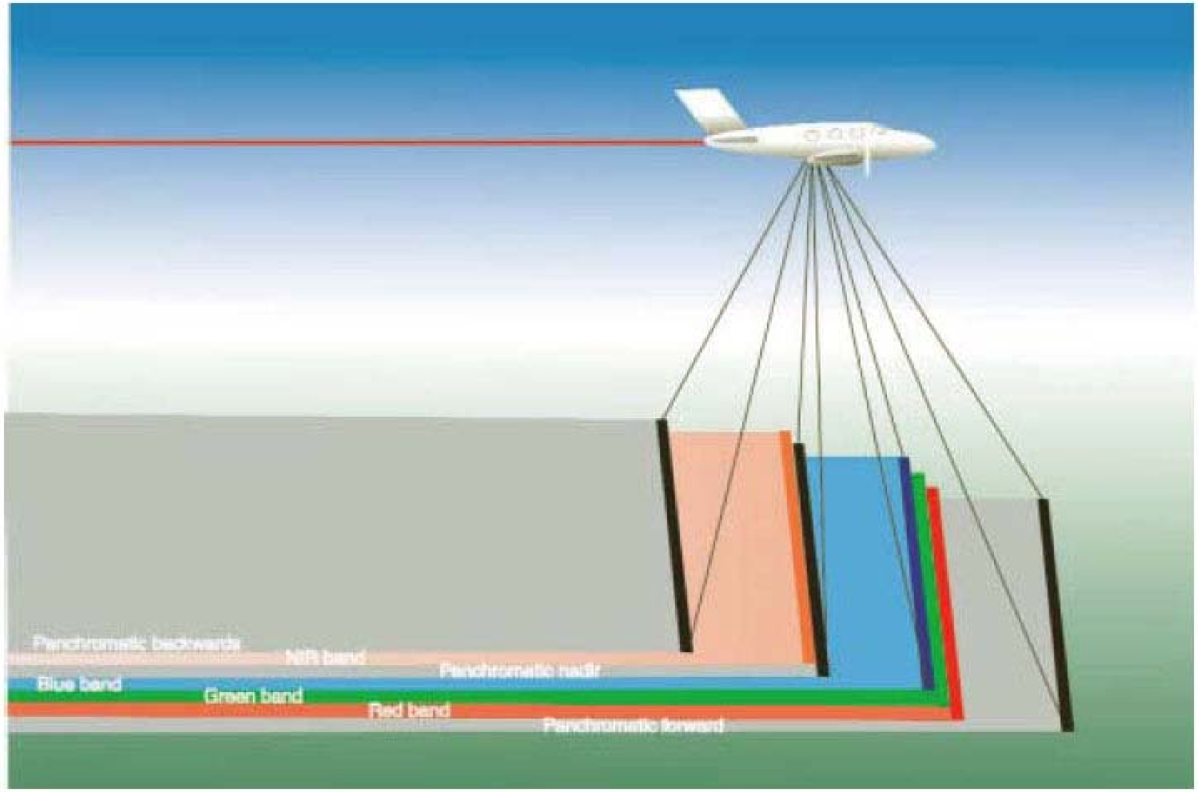

Zeiss RMK in aircraft

Vexcel UltraCam Digital (note multiple apertures

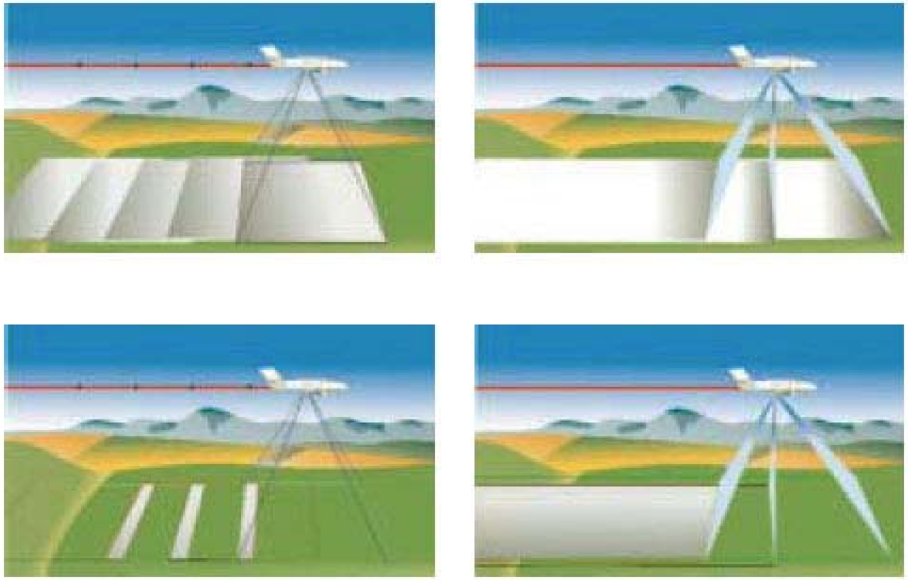
# Lenses for Leica RC-30. Many elements needed to minimize distortion and other aberrations

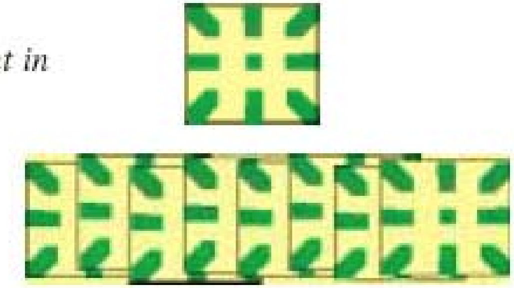
# Leica digital aerial camera ADS40, “3-line scanner”



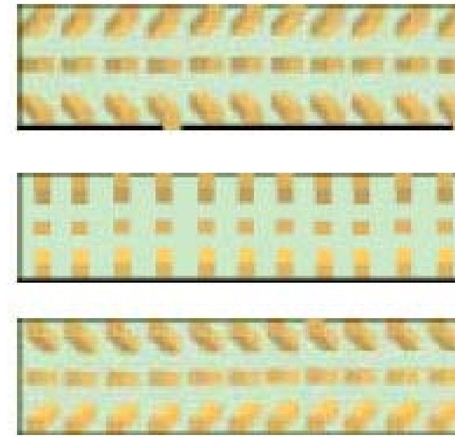
# Linear array scanning from aircraft platform (ADS40)

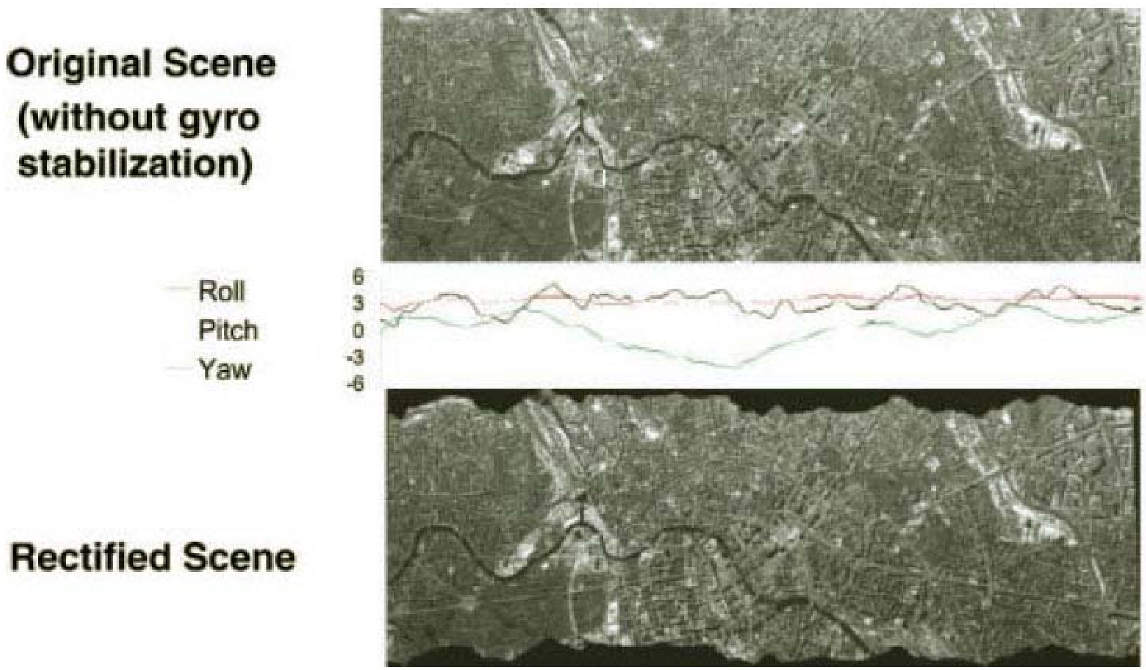


*Relief displacement in frame imagery.*



*Relief of displacement in three-line-scanner imagery.*





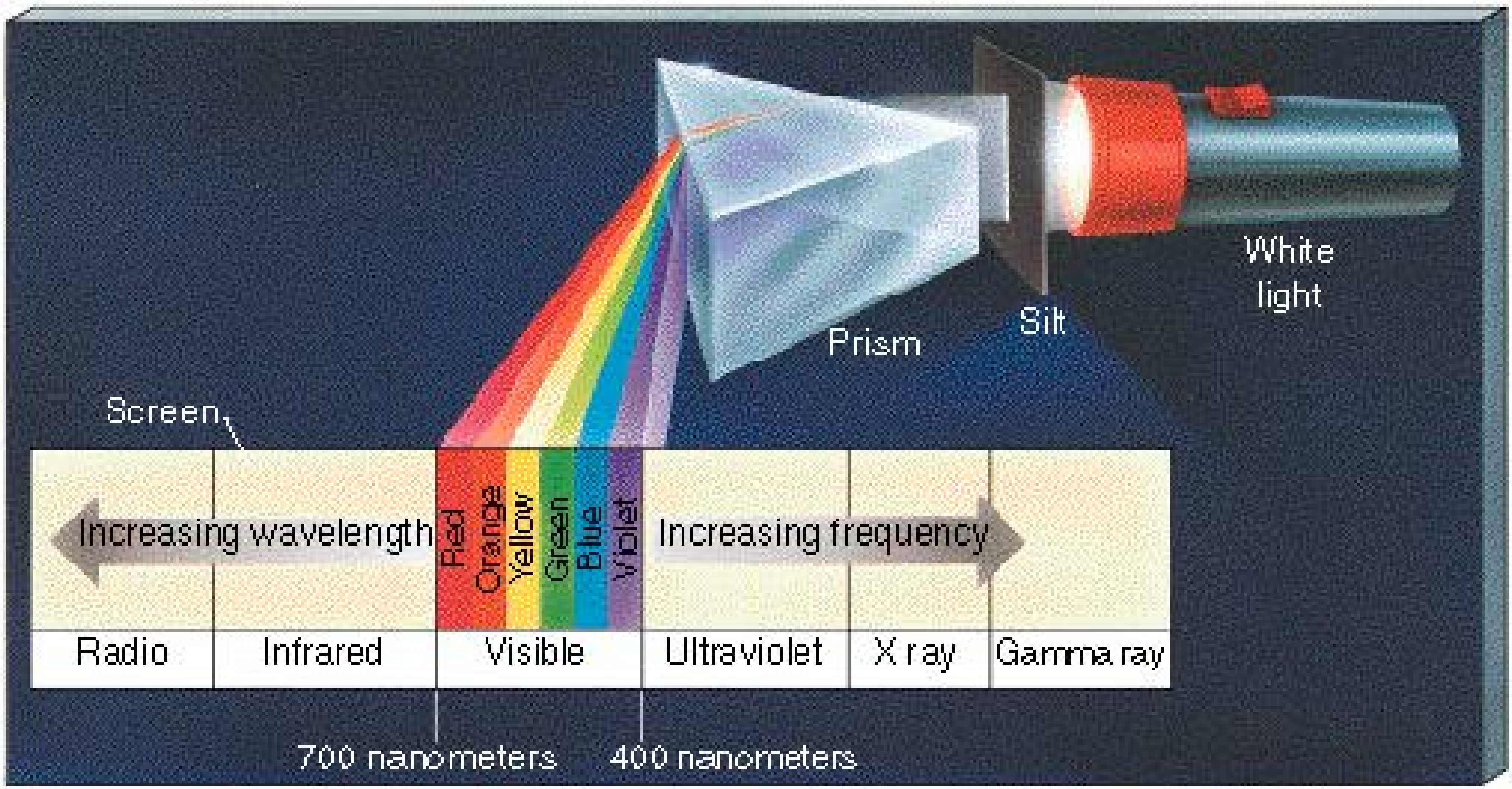
What if you are very far away (RS satellites in LEO are 400-800 km) and you want to see lots of detail in the scene?

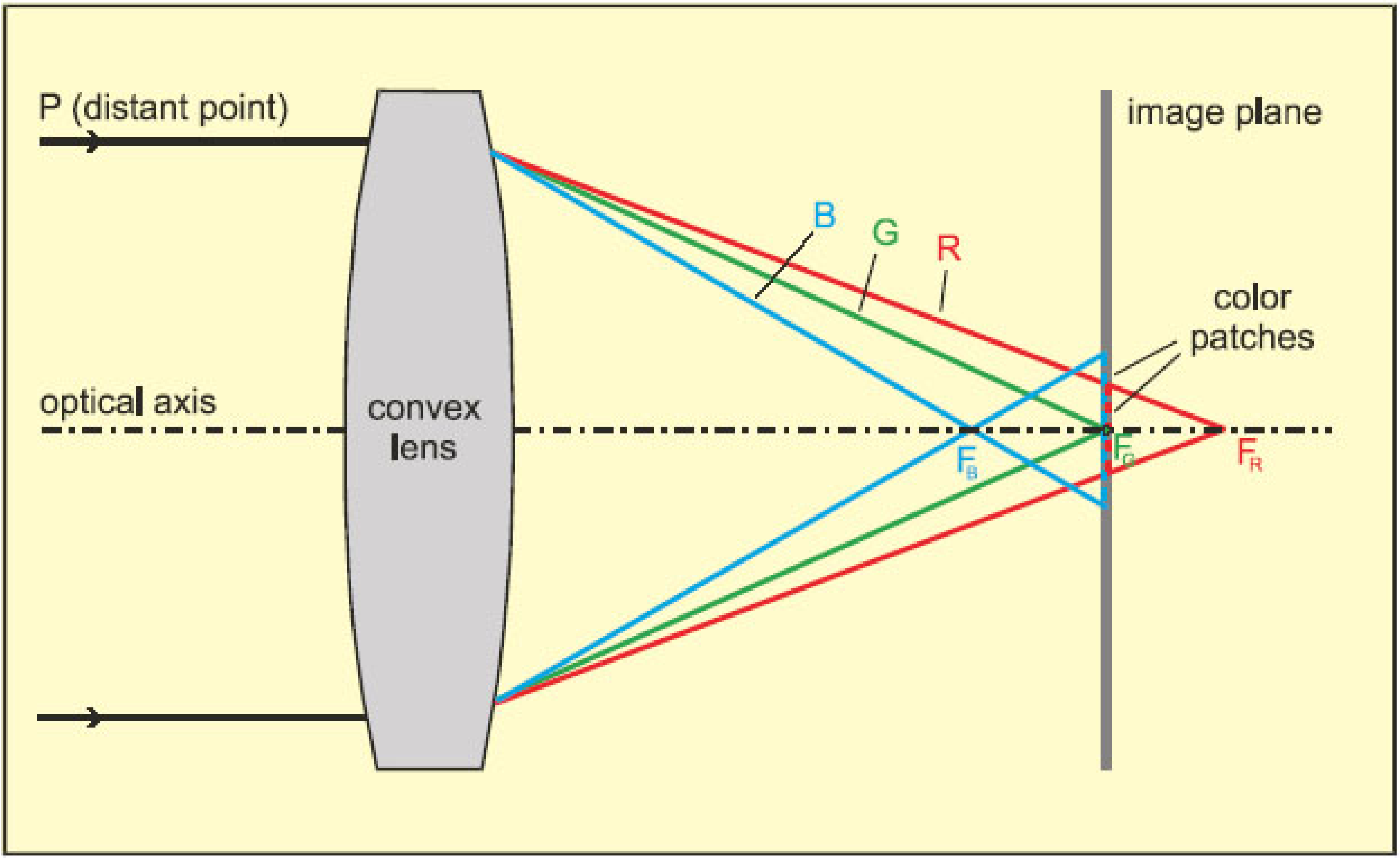
What about a telephoto (long focal length) lens ?

# Canon EF 500mm F/4

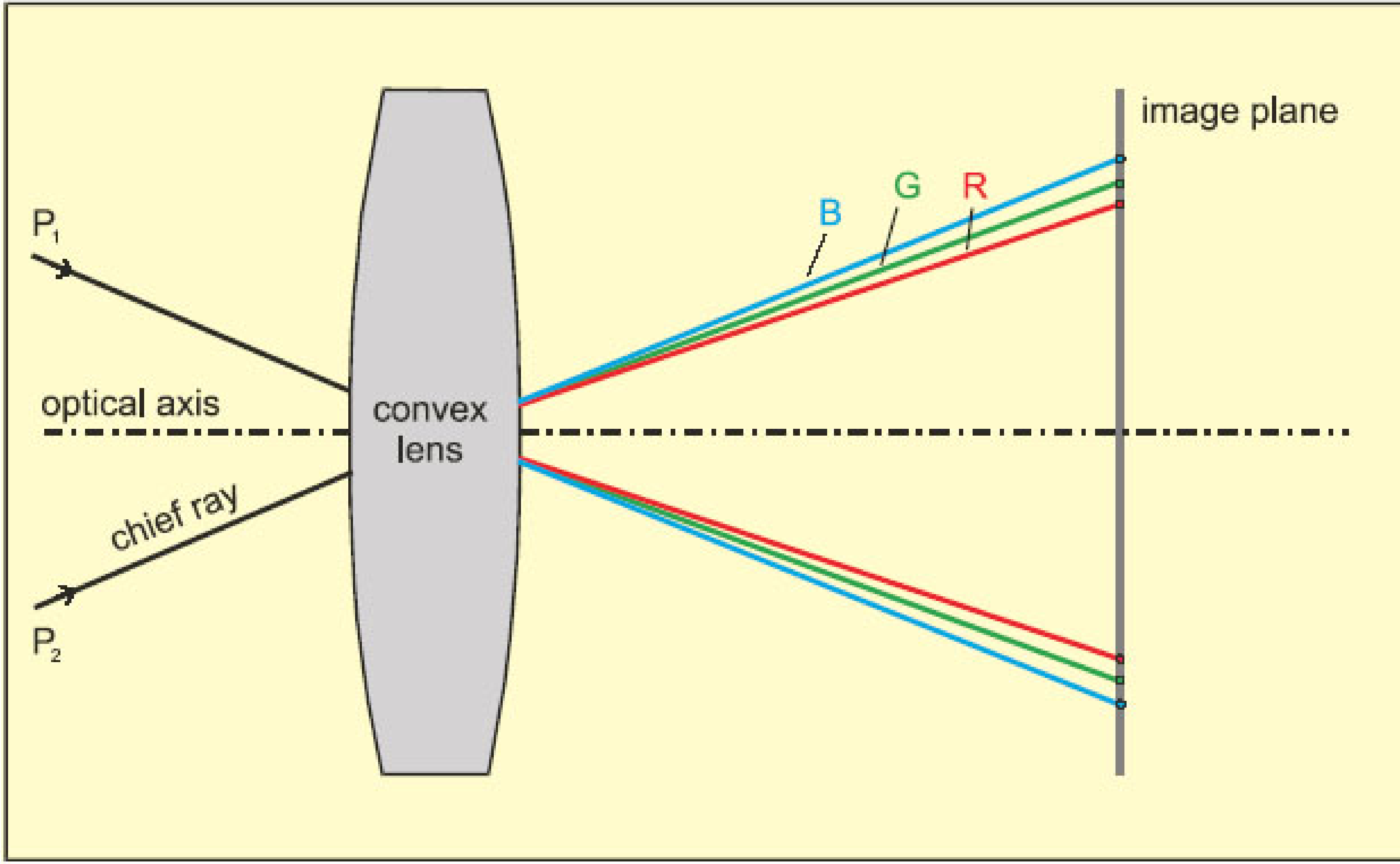
For a RS camera, there are two big problems with this approach.

- **Speed / Aperture / Weight,** need small f# (f/d). f fixed by scale requirements, therefore diameter must be large. Glass is heavy. Satellite payloads must minimize weight.
- **Chromatic Aberration,** refractive elements (lenses) affect different wavelengths differently. Produces color fringes. Reflective elements (mirrors) do not. In addition, RS cameras usually have RGBI not just RGB channels, that makes it even worse.


White light
Slit
Prism
Screen
Increasing wavelength
Red
Orange
Yellow
Green
Blue
Violet
Increasing frequency
Radio
Infrared
Visible
Ultraviolet
X ray
Gamma ray
700 nanometers
400 nanometers



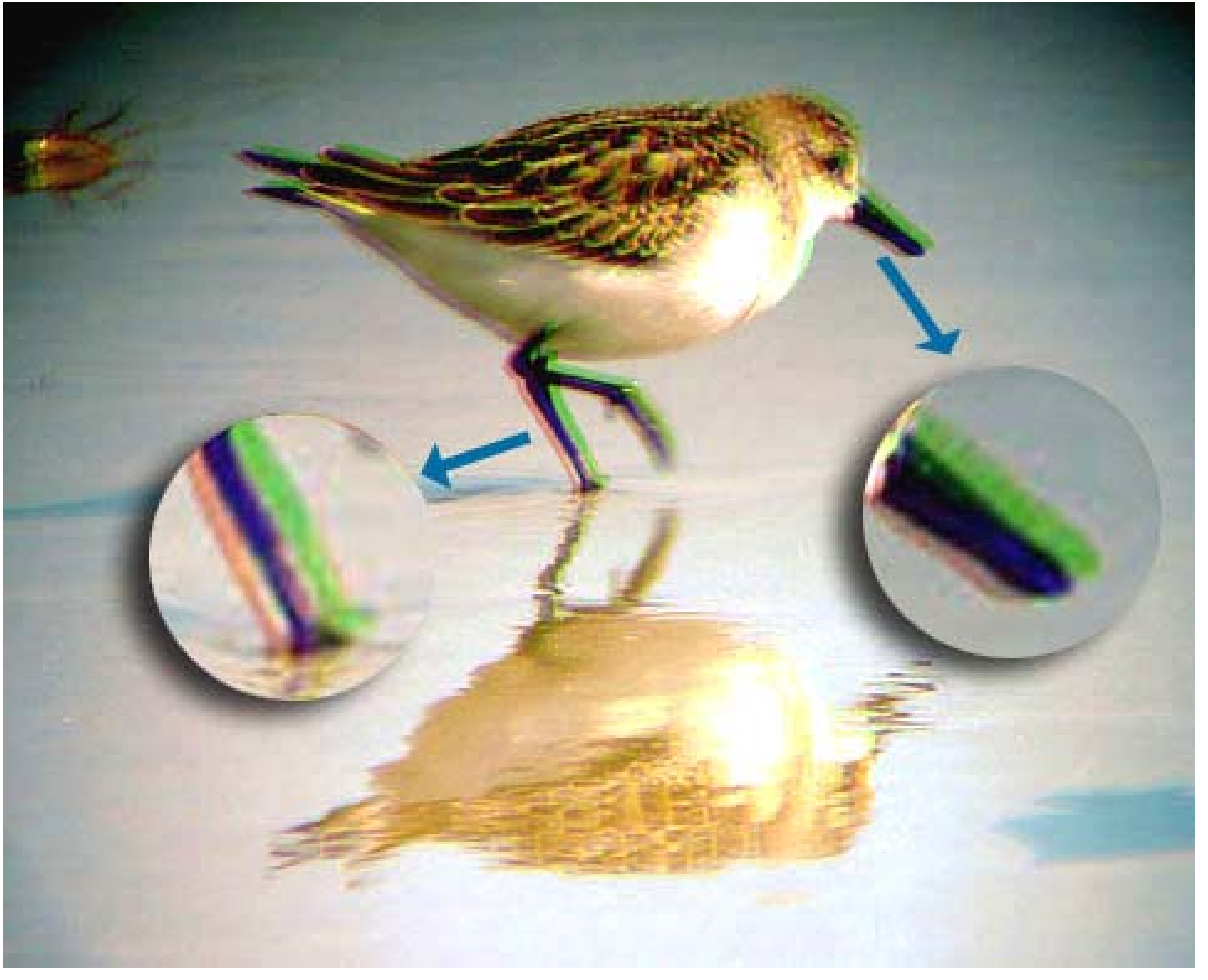

Longitudinal (axial) chromatic aberration



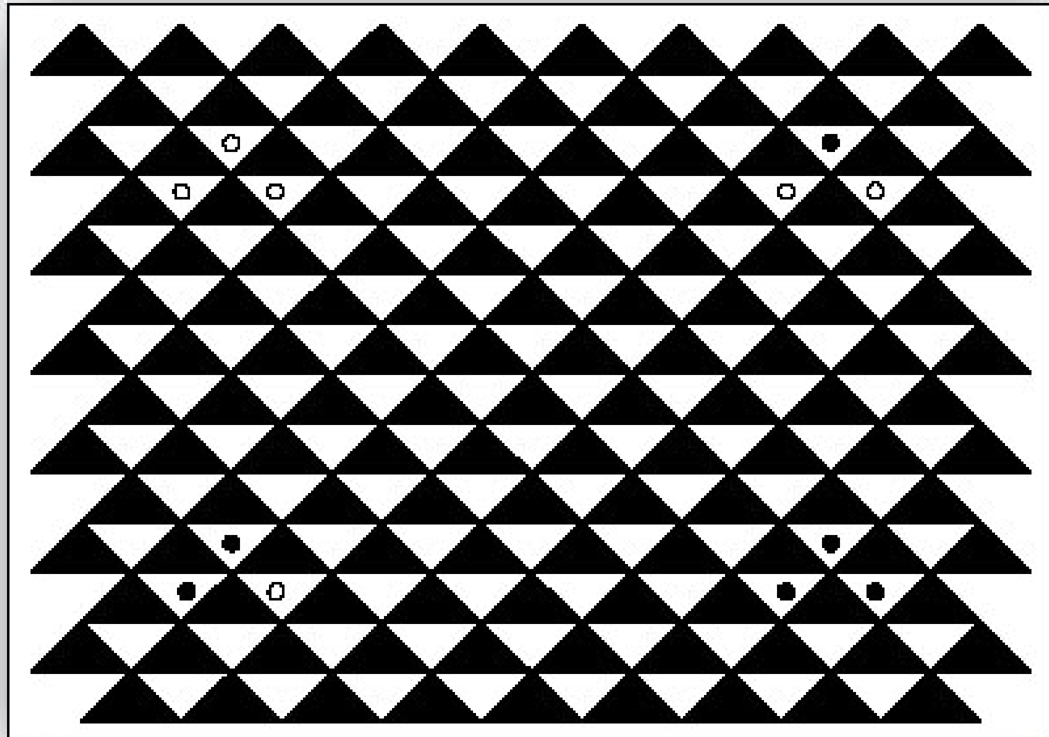

Lateral (oblique) chromatic aberration

# Some examples of chromatic aberration

# Chromatic aberration from poor quality optics



# Image obtained from test pattern



Planar calibration field of PhotoModeler 4.0


| | |
|---|---|
| Camera: | digital SLR c |
| Sensor: | CCD array |
| Resolution: | 3008 x 200 |
| Pixel size: | 7.8 x 7.8 mi |
| Color: | Bayer patte |

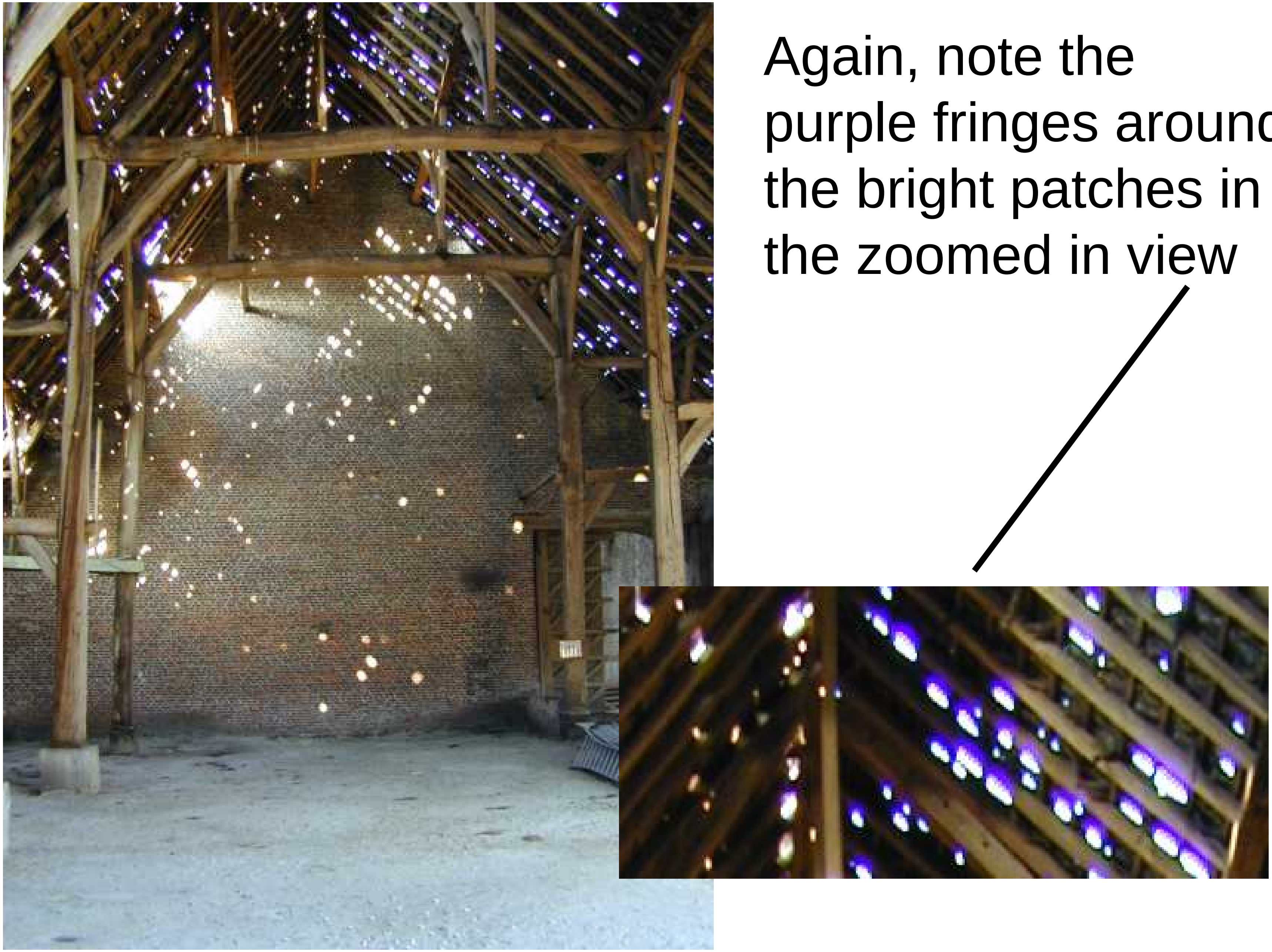
window size
70 x 70

← Measuring of corresponding p
channels by means of LSM

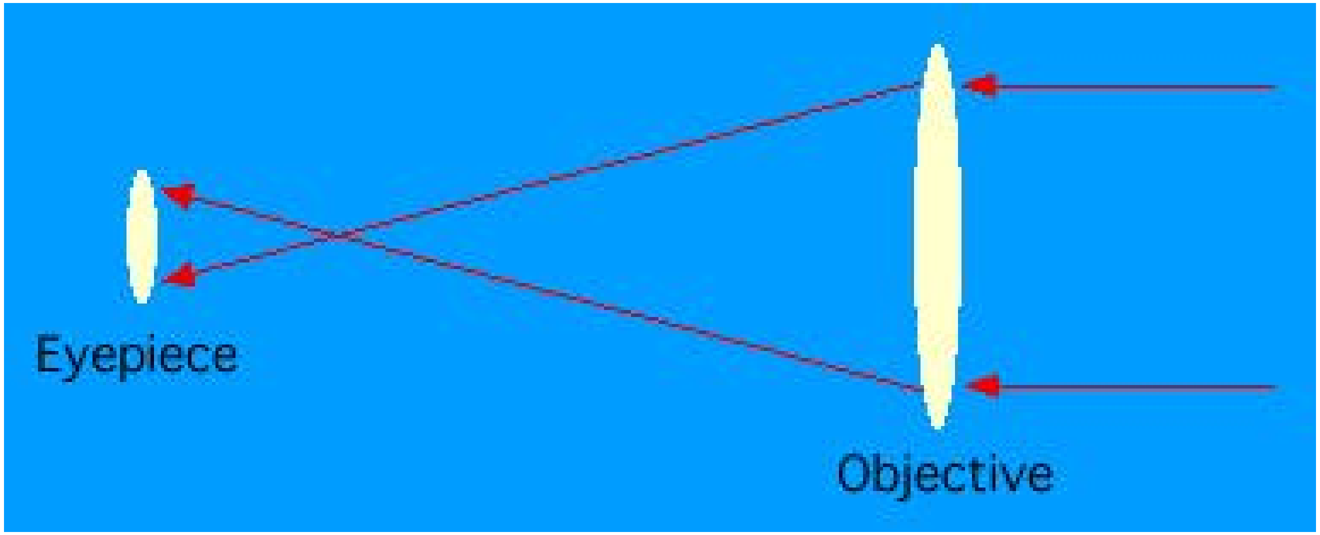
- The color photo
into their single

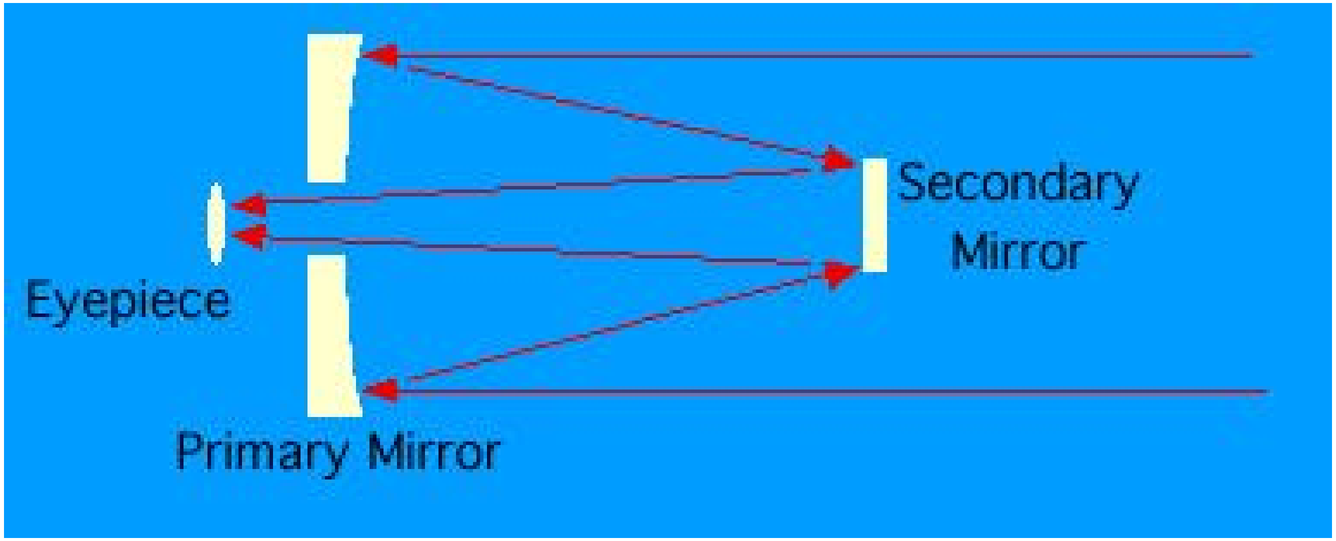
Note the famous purple fringe around the zoomed in images of the bright lights

Again, note the purple fringes around the bright patches in the zoomed in view

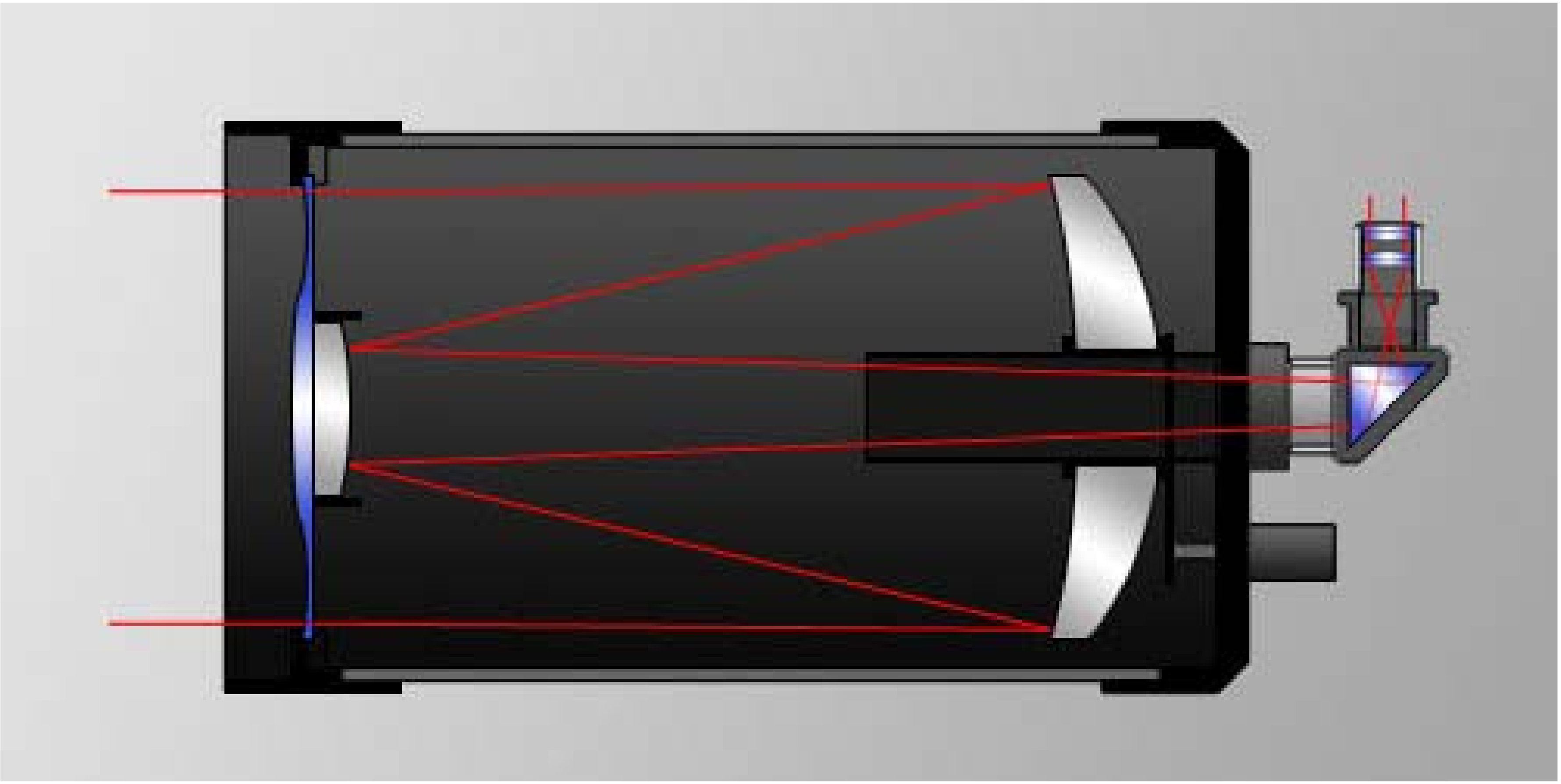


# Refractive versus reflective optical elements

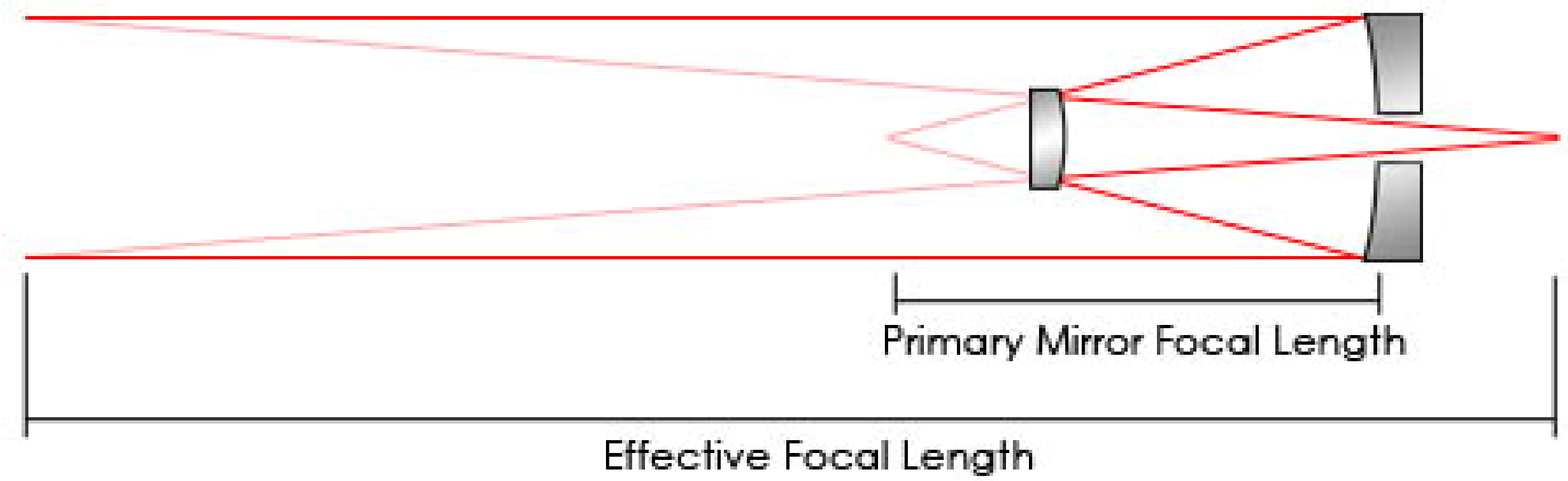


# Schmidt-Cassegrain Telescope

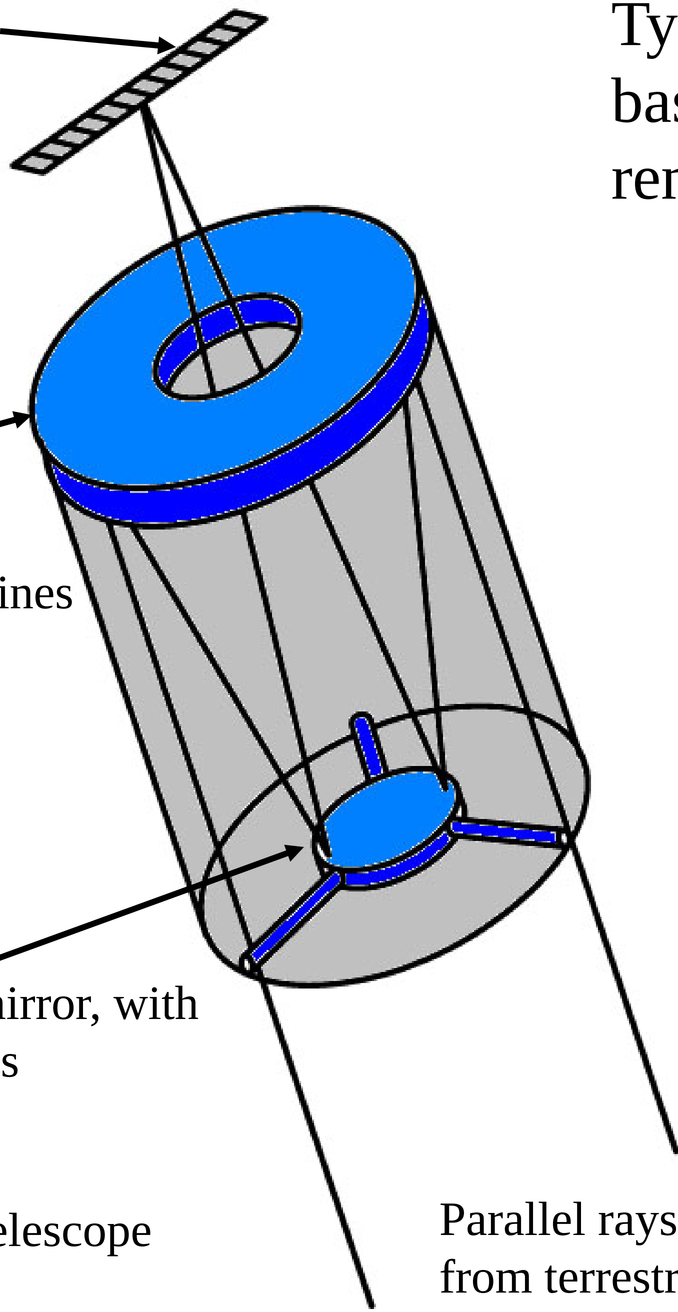


Another advantage of reflective optical elements – “folded” light path allows long focal length within a package that is much shorter



# Scmidt-Cassegrain 500 mm optics for handheld camera – compare size and bulk to earlier shown lens

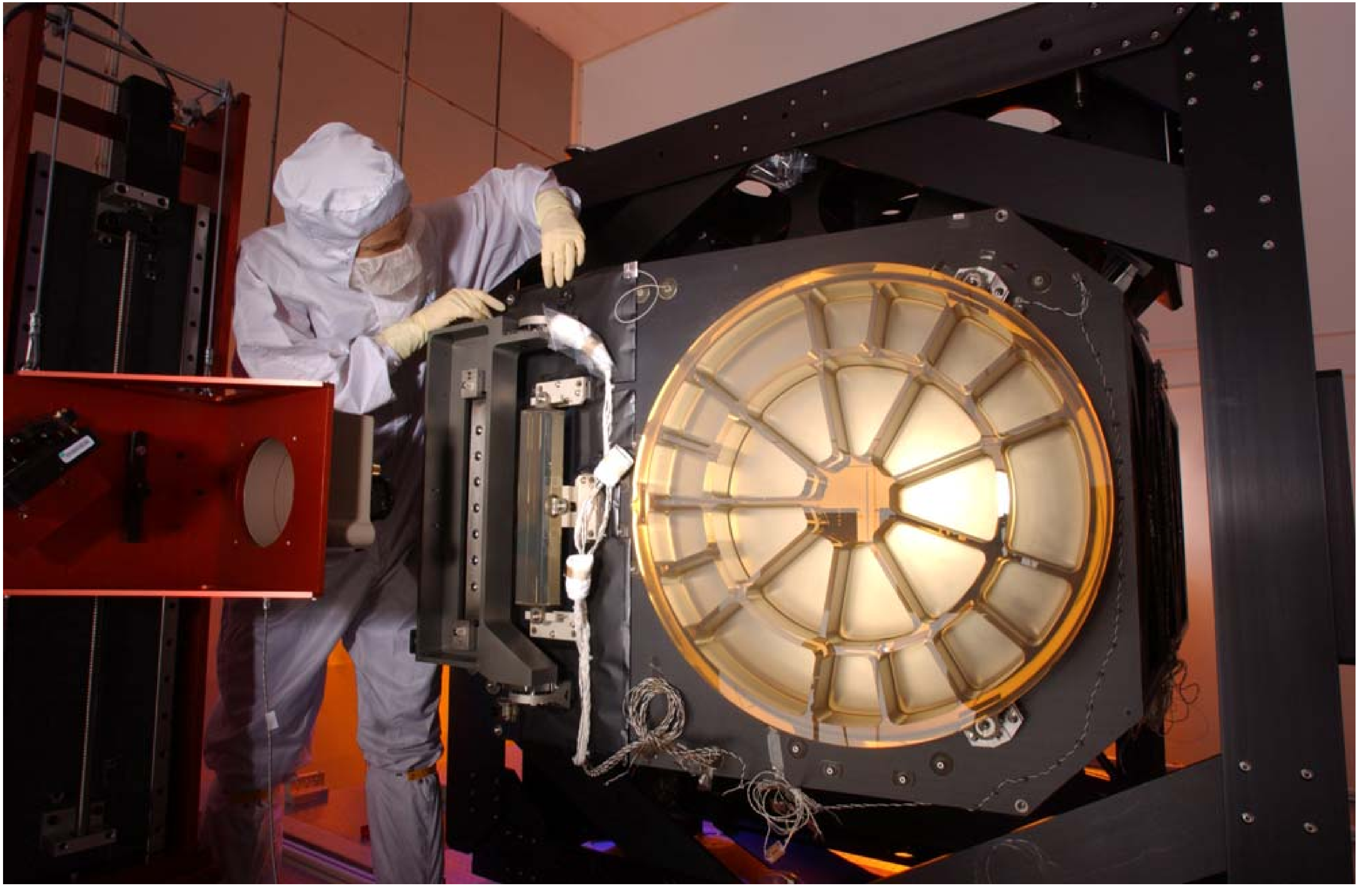
# Typical layout of linear sensor based telescope “camera” used for remote sensing from space.



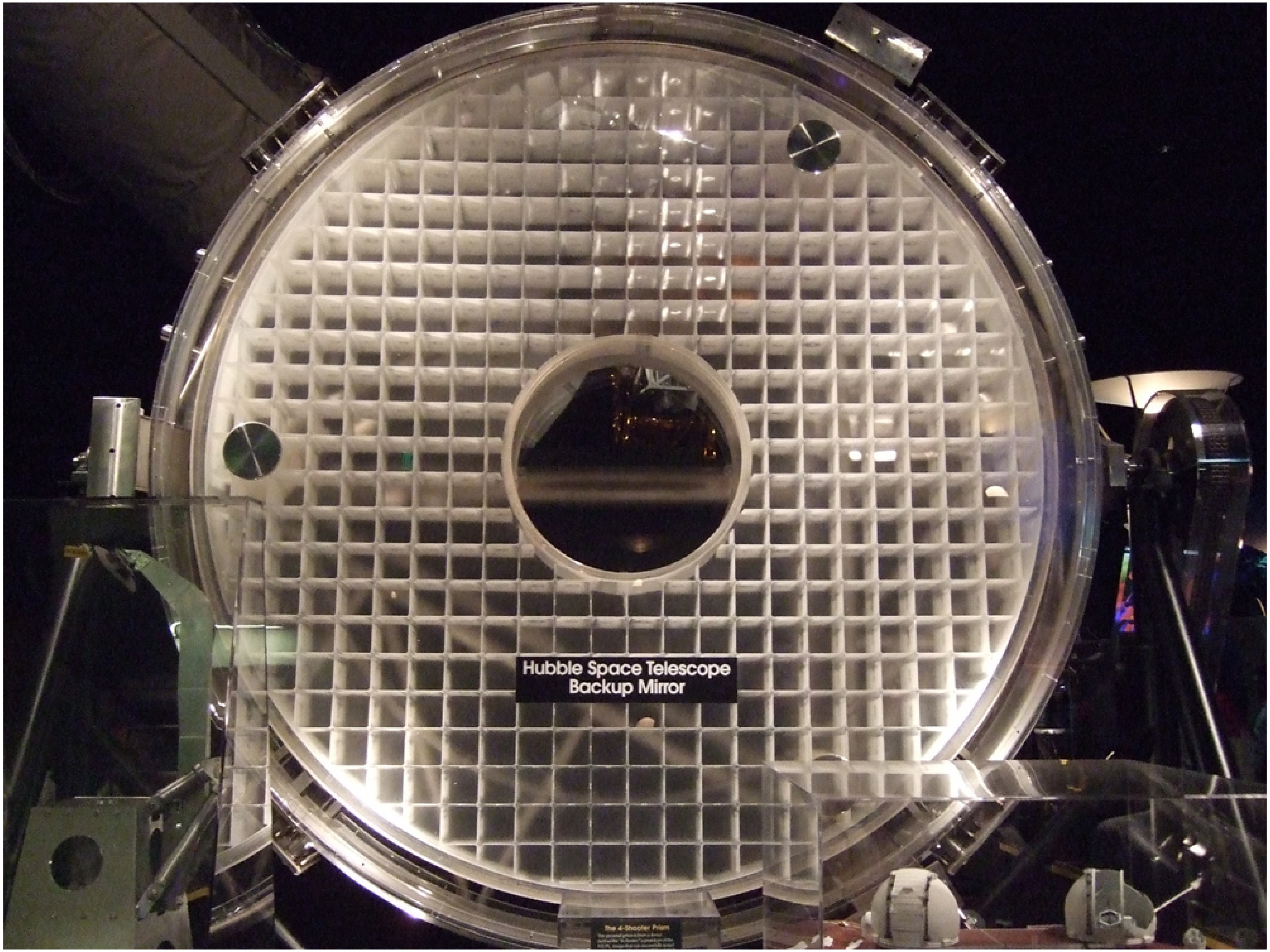

Cassegrain Telescope

Primary and secondary mirrors are “powered” (curved) and do the focusing, like a lens. There can be more than 2 elements. Sometimes there are flat mirrors to just “fold” the optical path for a needed long focal length. Area CCD arrays are not big enough for practical use. Dimension of linear array determines image “width” and cross-track GSD, orbit motion or “body scanning” plus sampling in time produce the image “length”, and determine the along-track GSD (usually these two GSD’s are approximately the same)

# Worldview 1 Primary Mirror from the back, note material removal to reduce mass



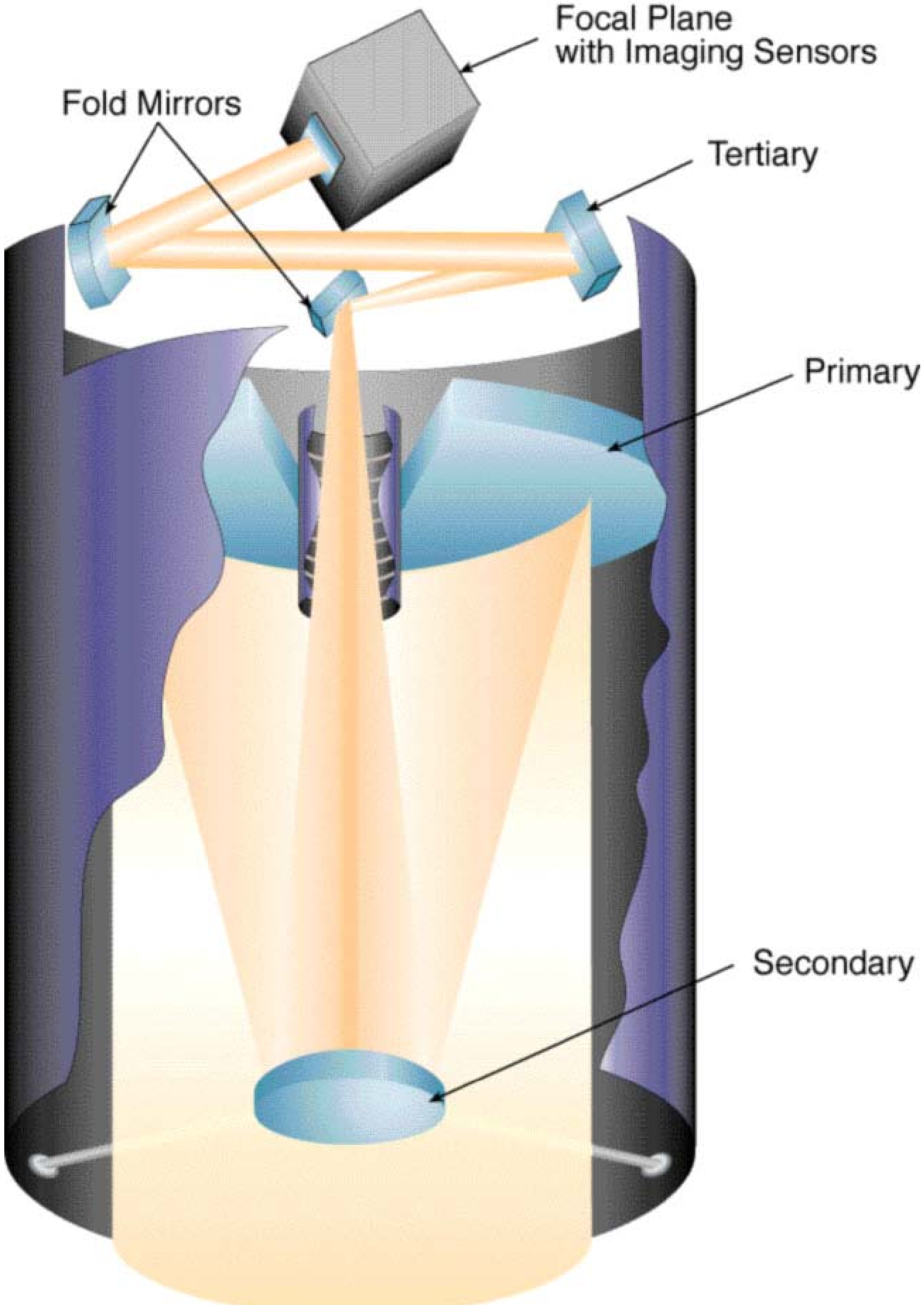
# Hubble backup mirror made by kodak, this one did not have defects as did the one from Perkin Elmer



# Geoeye 1 Primary Mirror

# Satellite camera resembles an astronomical telescope more than the conventional notion of a camera

**Meade 16" LX200GPS with Permanent Altazimuth Pier.** As shown, the telescope fits comfortably inside a 2-meter (7 ft.) dome.



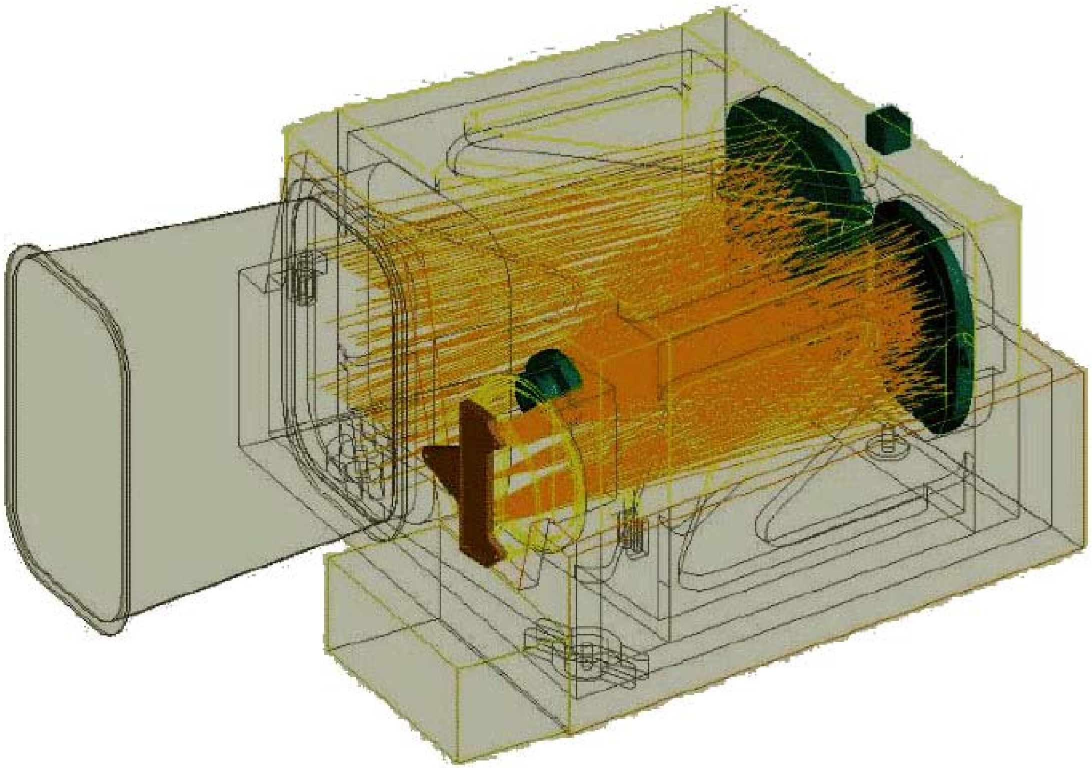

# Schematic of IKONOS camera

- Camera made by Kodak
- Cassegrain (Korsch TMA) telescope
- 10 meter focal length
- 12 micrometer detector size
- TDI: 10-32 stages
- 11 bit quantization with APCM compression
- Aperture size 0.7m
- +/- 30 degree pointing
- 13,500 panchromatic pixels (1m), 3375 multispectral pixels (4m)
- 6500 lines / second
- 11-13 km swath width at 680km alt.

# Kodak Model 1000TM commercial version of the IKONOS camera

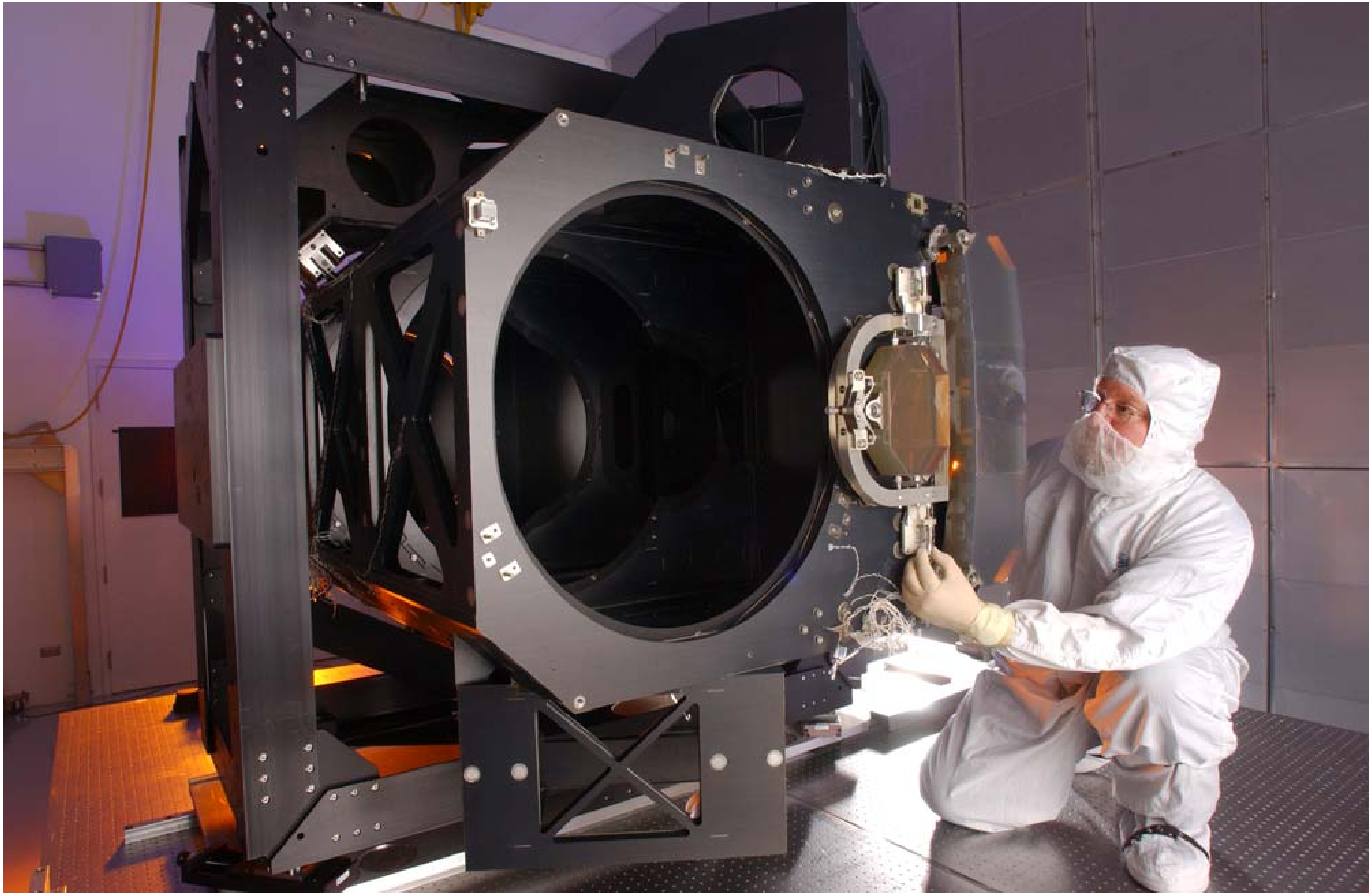
- Reduced size and mass for fitting into mini-satellites
- ~$ 1M
- ~ 2 year delivery time

# Optical Camera Payload
## Three Mirror Anastigmat (TMA)

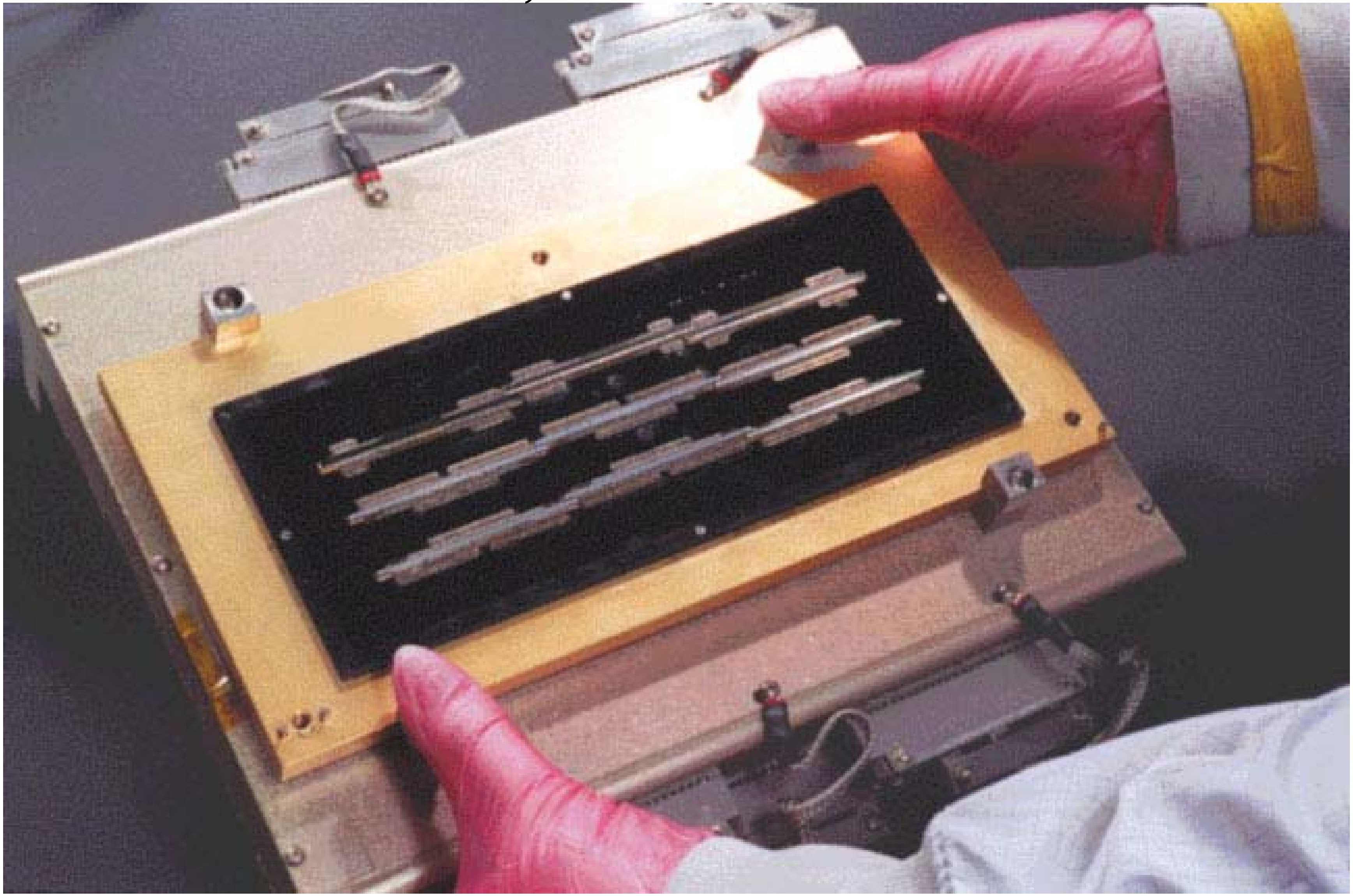


Off-axis design to eliminate the obstruction of the secondary mirror, from Jena Optik Rapideye

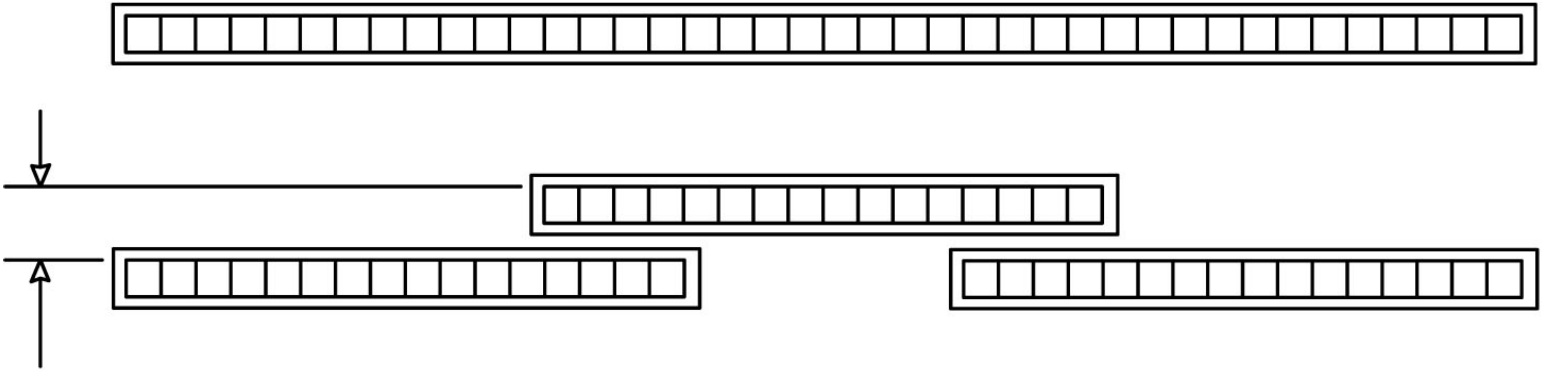
# Worldview 1 also has Off-axis TMA design for unobstructed aperture



# IKONOS focal plane with mechanically displaced linear arrays to simulate 13,500 length, panchromatic, RGB, and near infrared

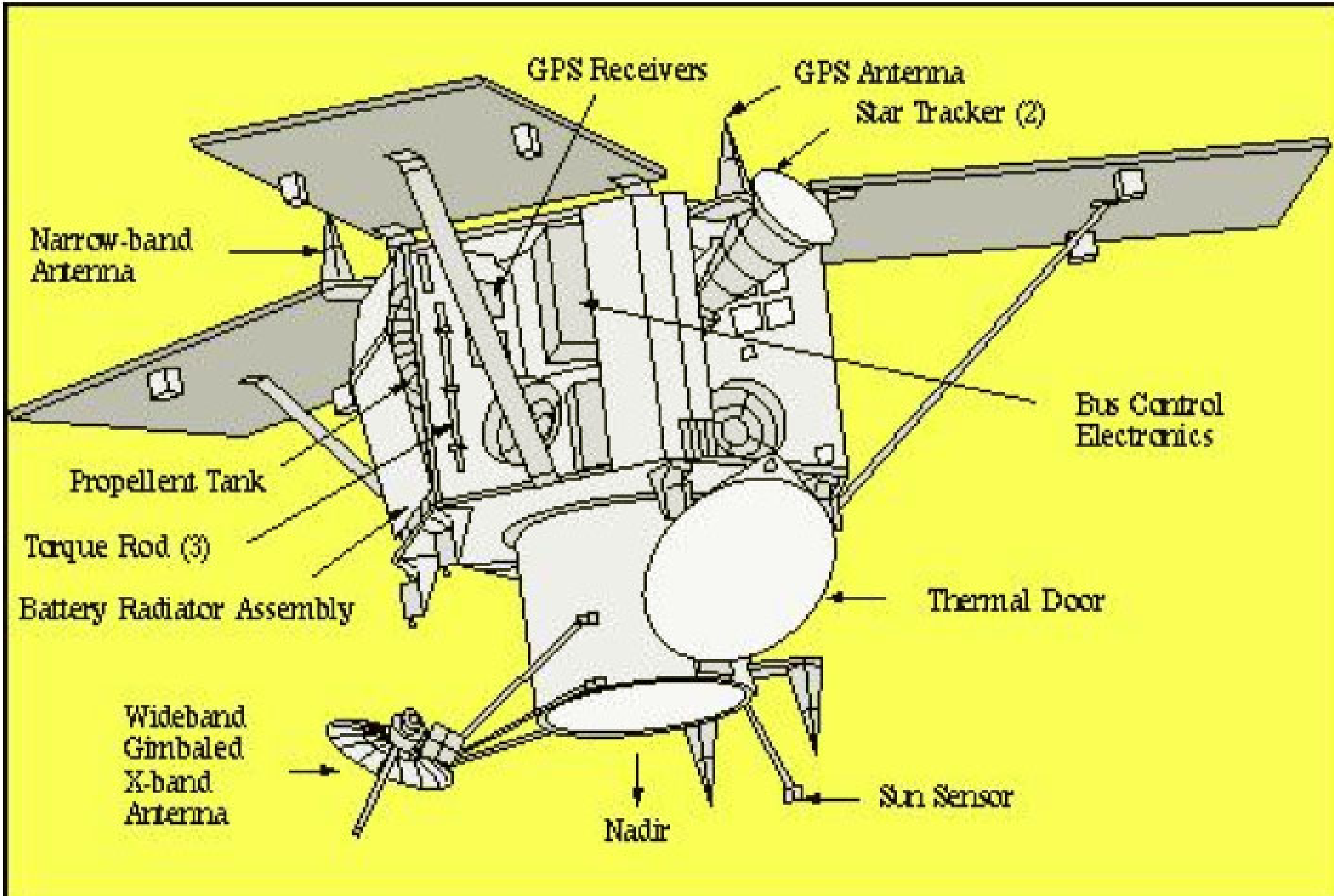


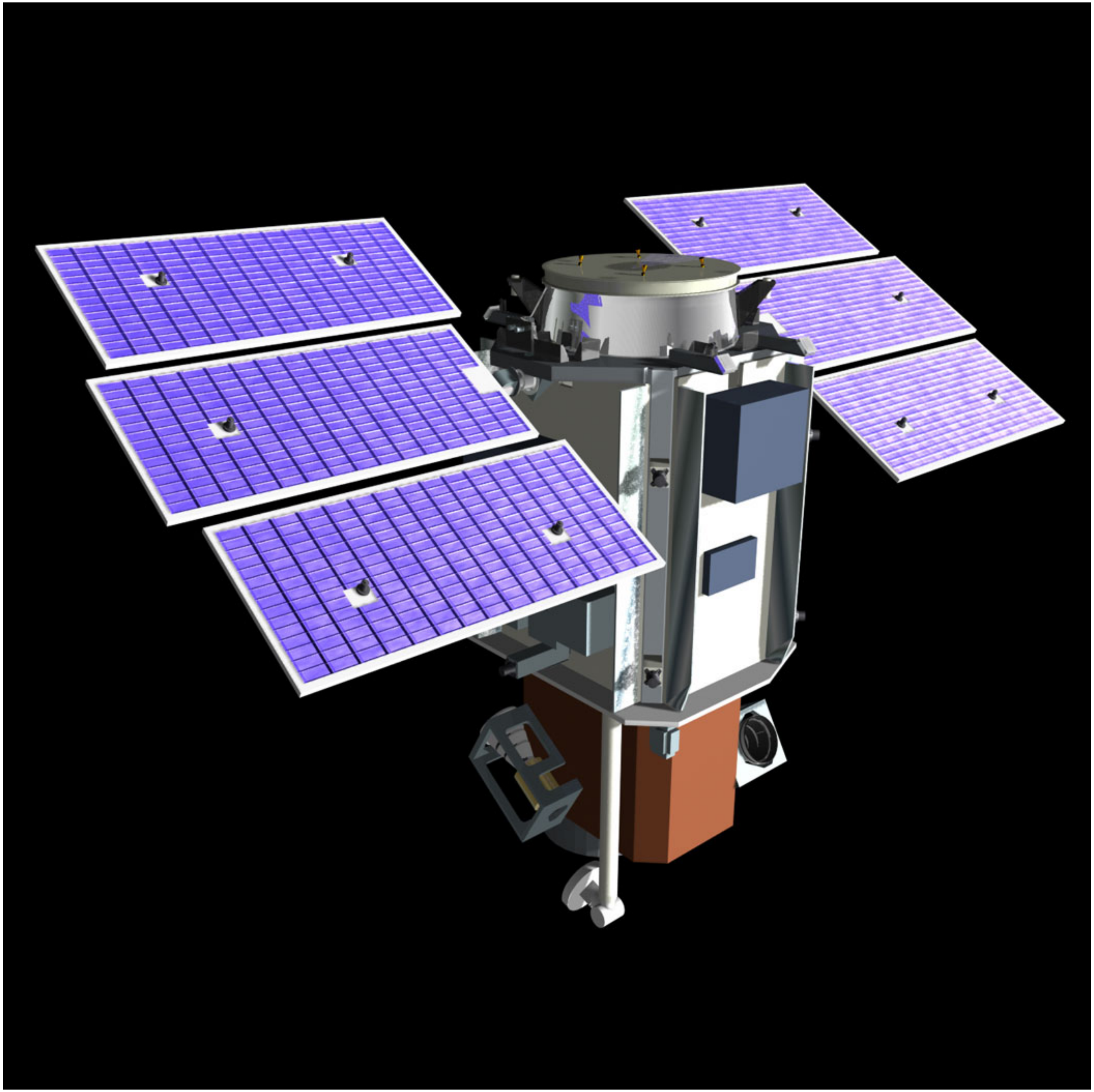
# Emulate a continuous 40-pixel linear array with 3 16-pixel arrays, align left-right and displace by integer number of pixel dimensions




Displacement in the focal plane for nadir scanning between linear array segments. $V_{gs}$ is the ground velocity of the viewpoint. n is any integer, for off nadir scanning, may adjust timing.

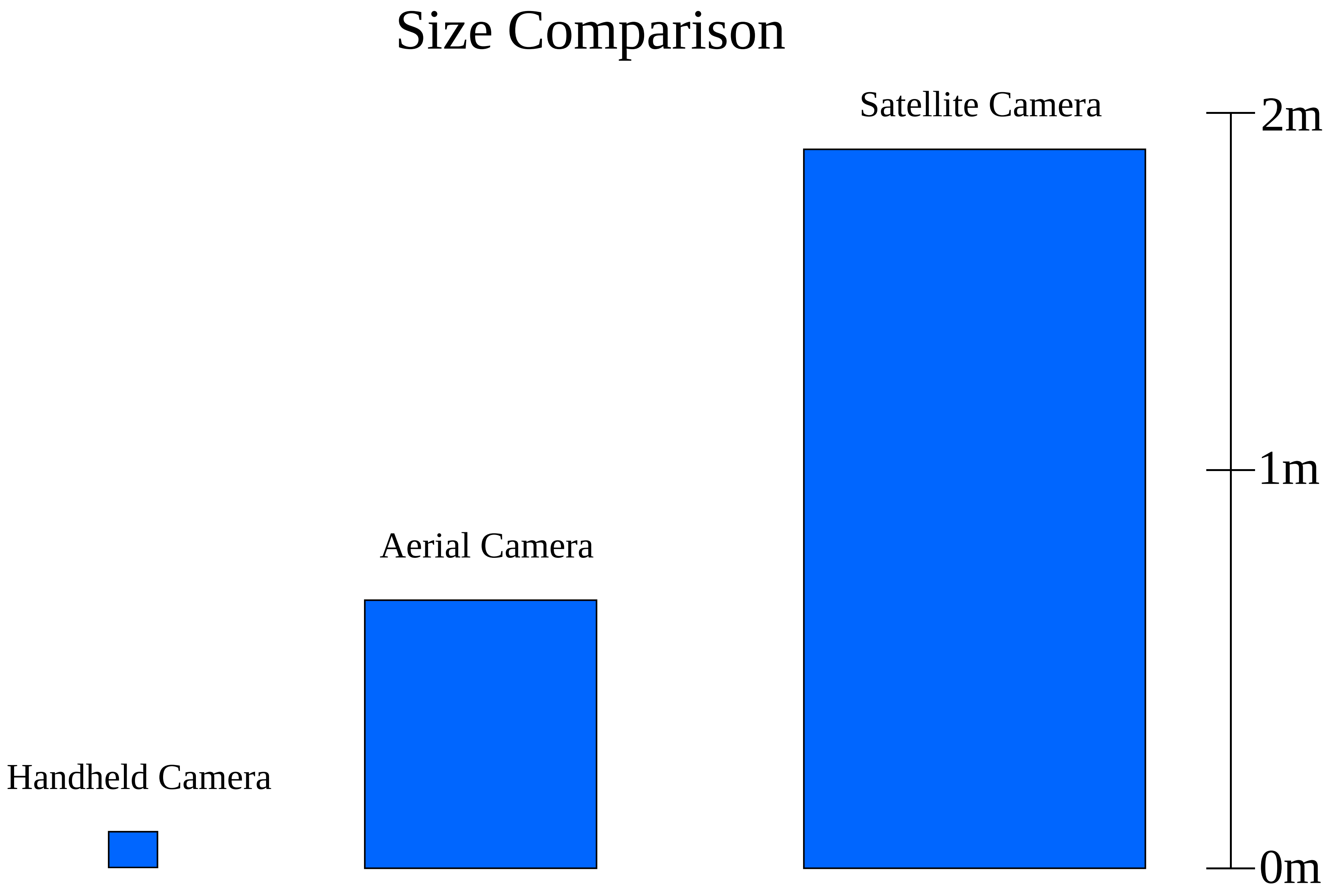
# Schematic of auxiliary components for the IKONOS sensor





Quickbird Spacecraft and camera yielding 0.6m panchromatic imagery (operated by Digital Globe)

# Orbview-3, ~1m panchromatic imager, note Orbimage & Space Imaging merge to form GeoEye (?)



Size Comparison
Satellite Camera
Aerial Camera
Handheld Camera
2m
1m
0m