CAMERAS

Consumer digital CCD cameras

Aerial Cameras

Leica RC-30

Zeiss RMK

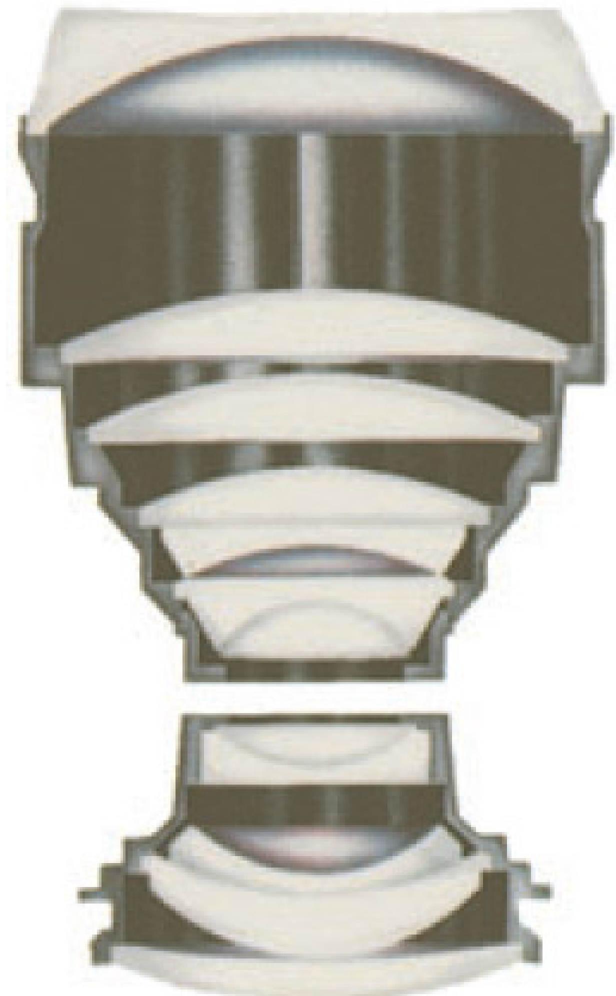
Zeiss RMK in aircraft

Vexcel UltraCam Digital (note multiple apertures

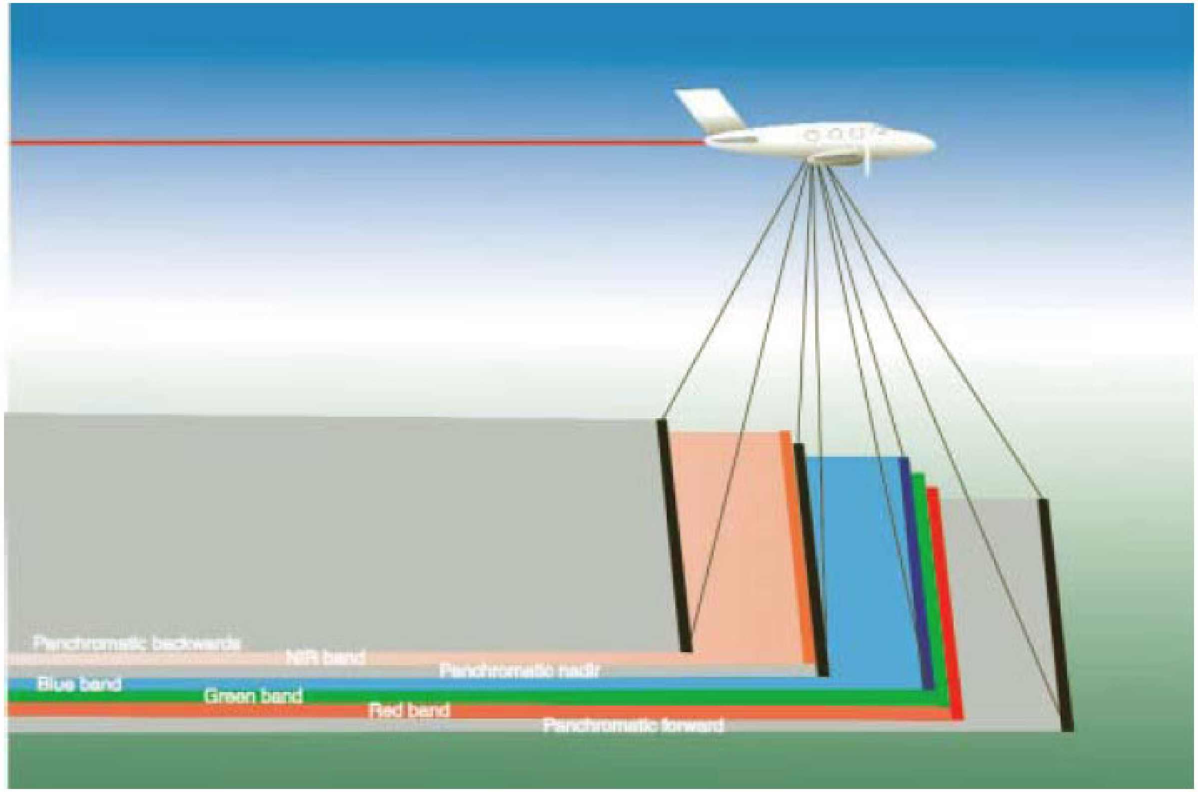
Lenses for Leica RC-30. Many elements needed to minimize distortion and other aberrations

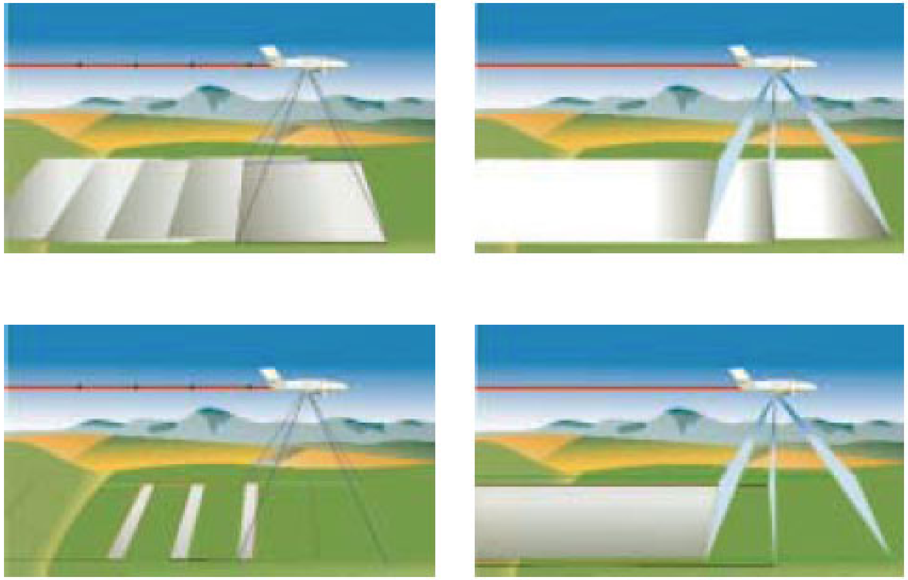
Wide angle lens cone

Normal angle lens cone

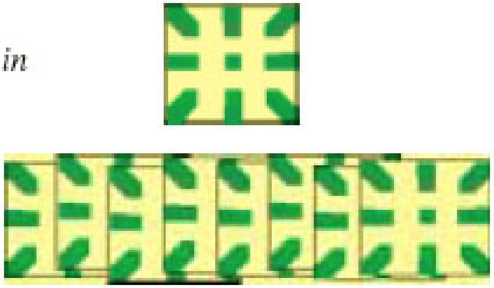


Leica digital aerial camera ADS40, “3-line scanner”

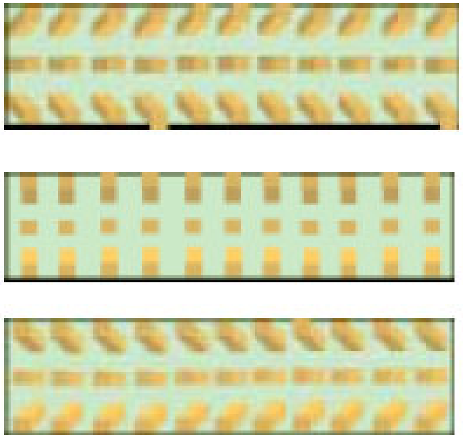


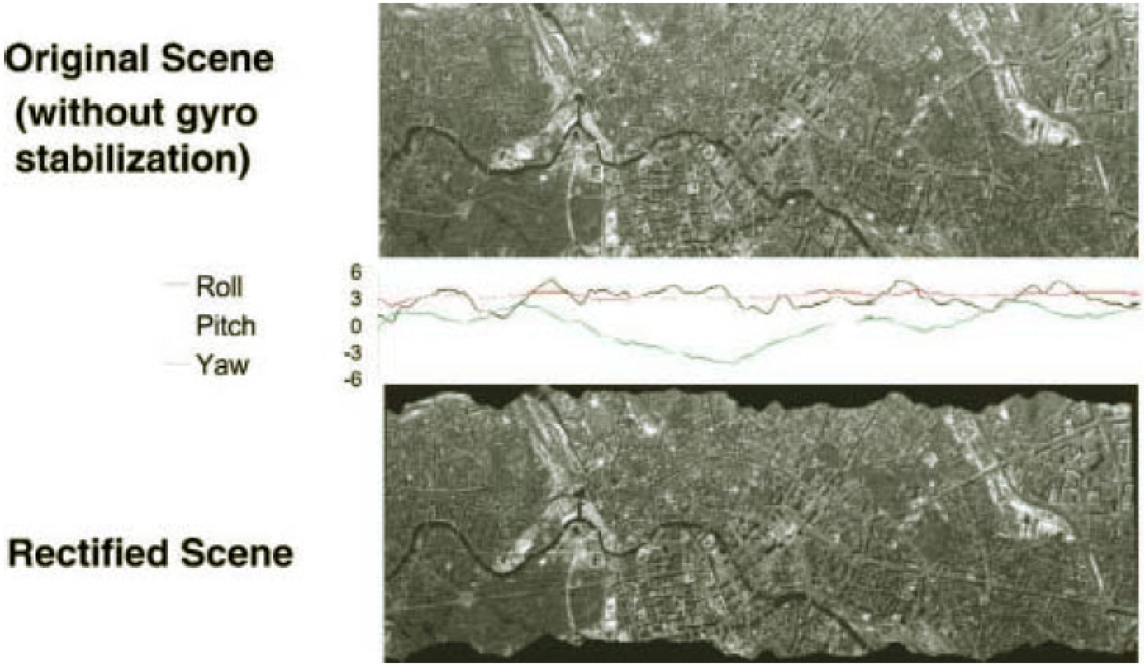


Relief displacement in frame imagery.



Relief of displacement in three-line-scanner imagery.





Linear array scanning from aircraft platform (ADS40)

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?

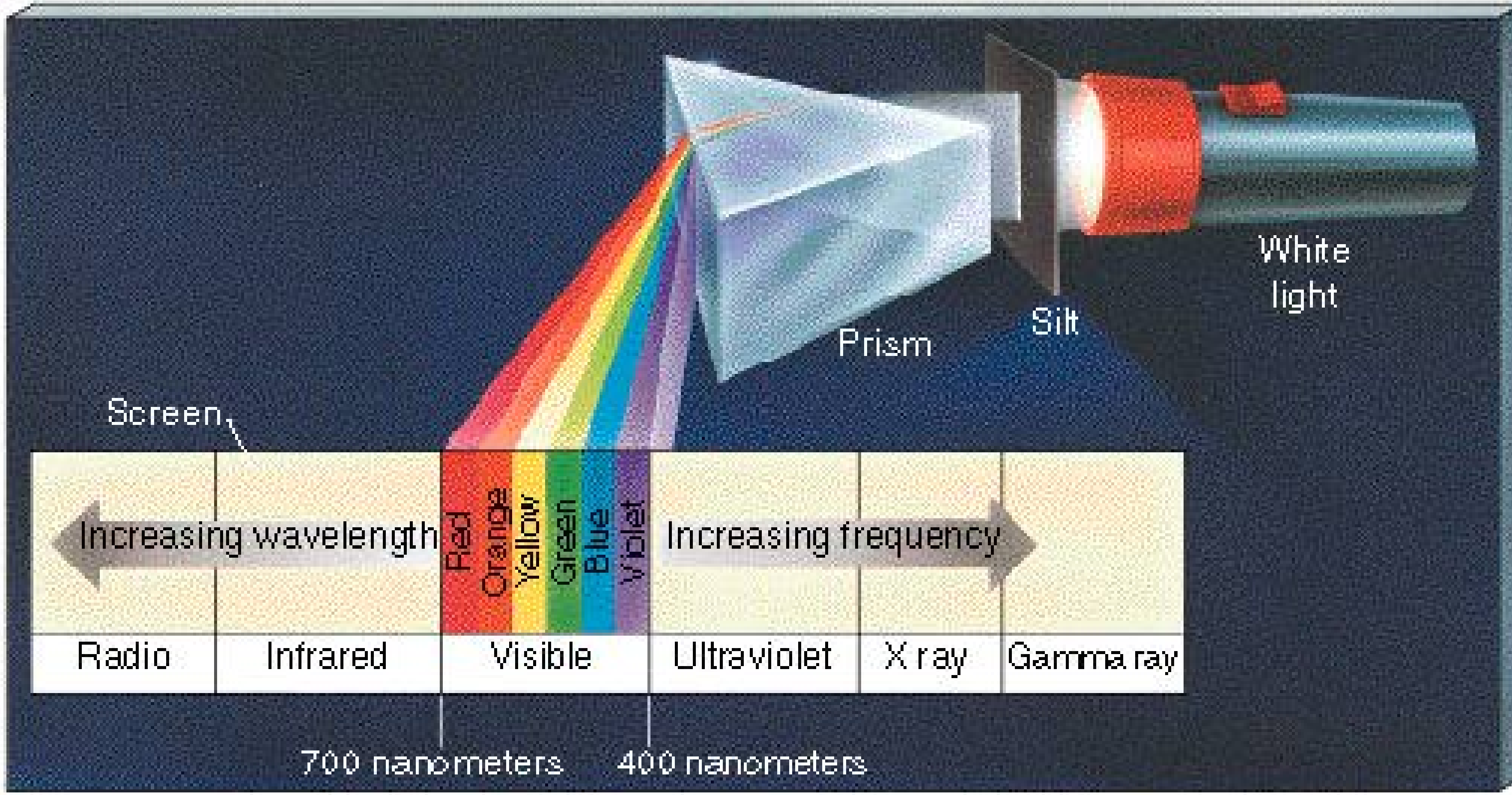
What about a telephoto (long focal length) lens ?

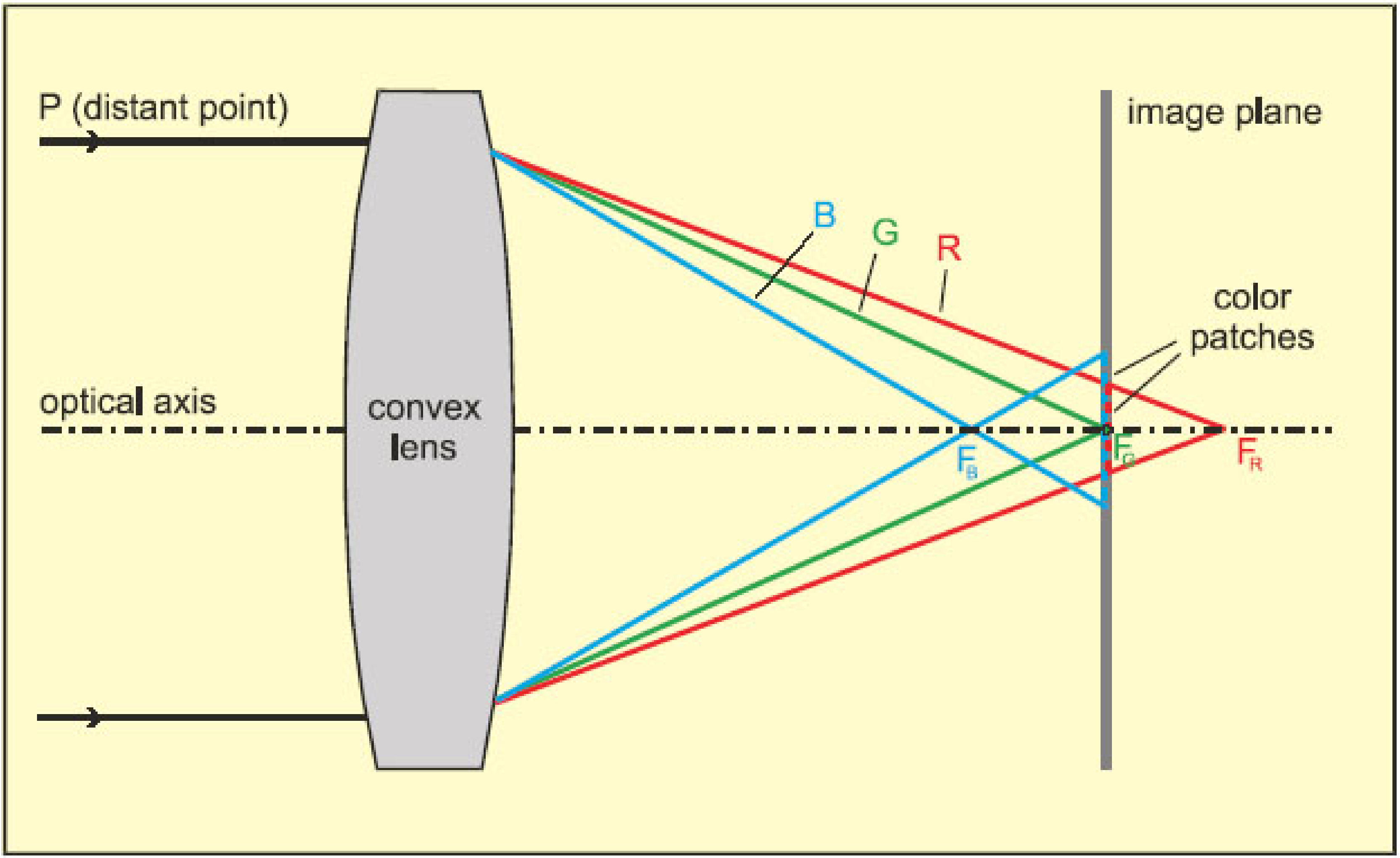
Canon EF 500mm F/4


Canon EF LENS
EF300mm F2.8L IS USM

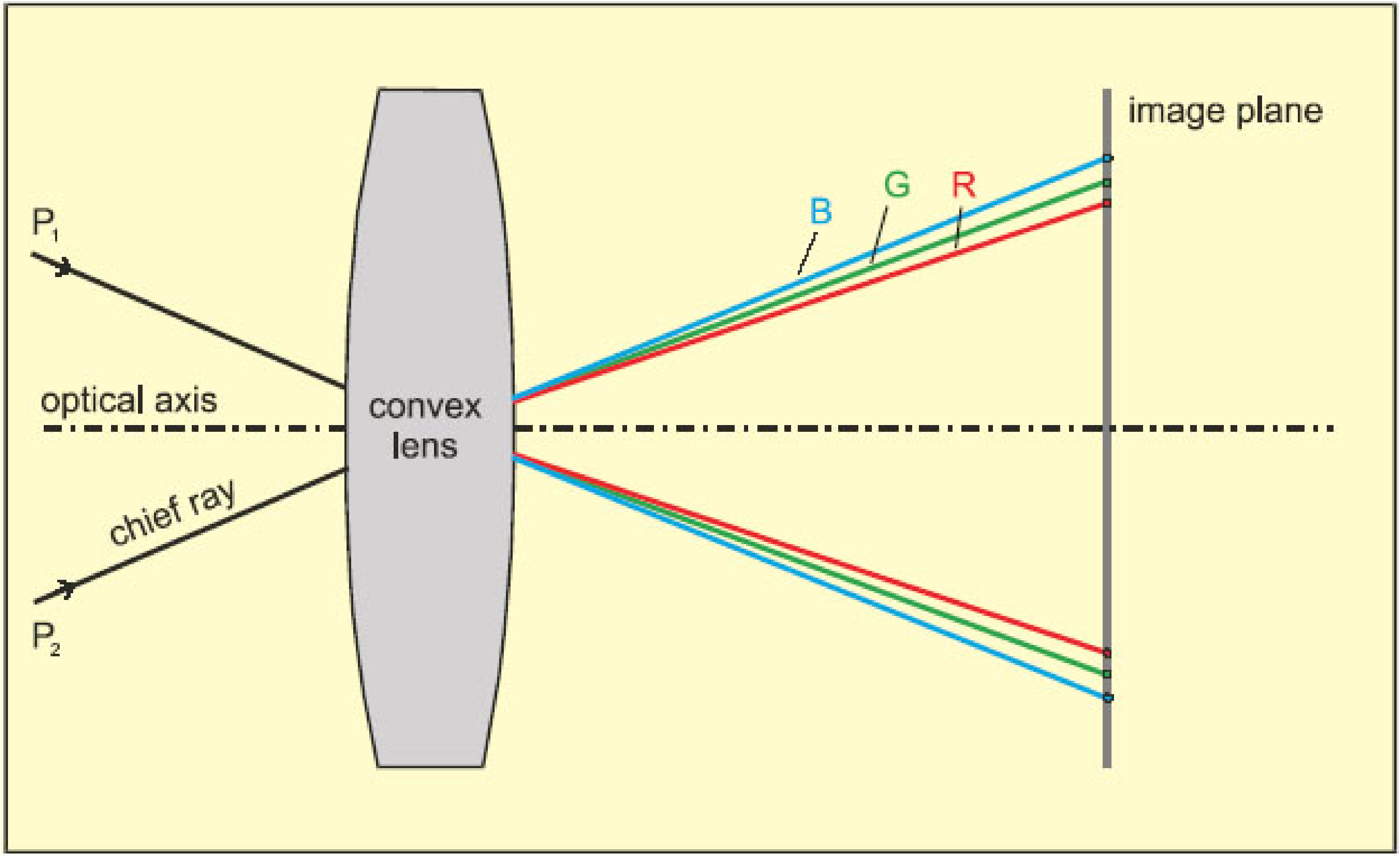
For a RS camera, there are two big problems with this approach.

- **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
Silt
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

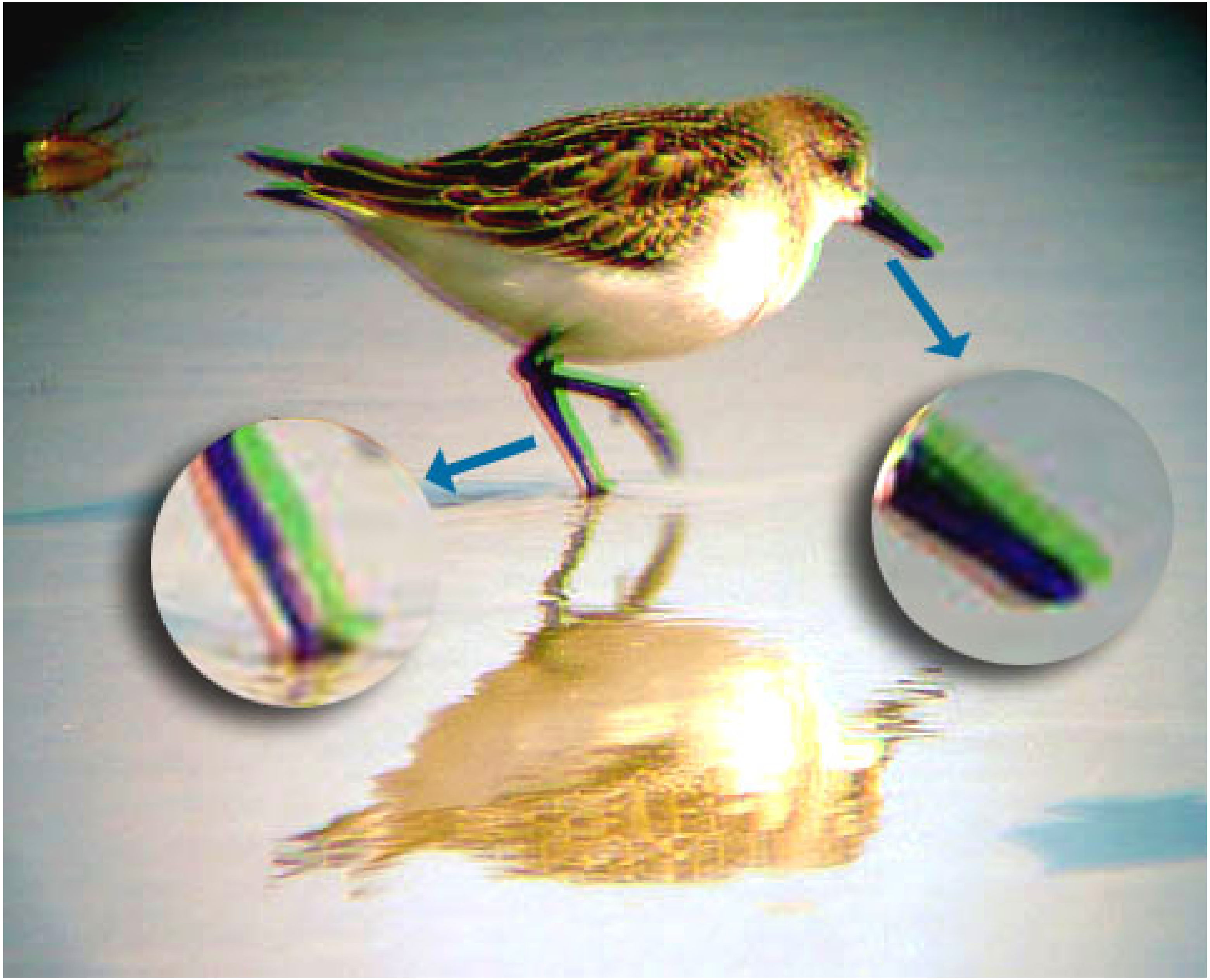
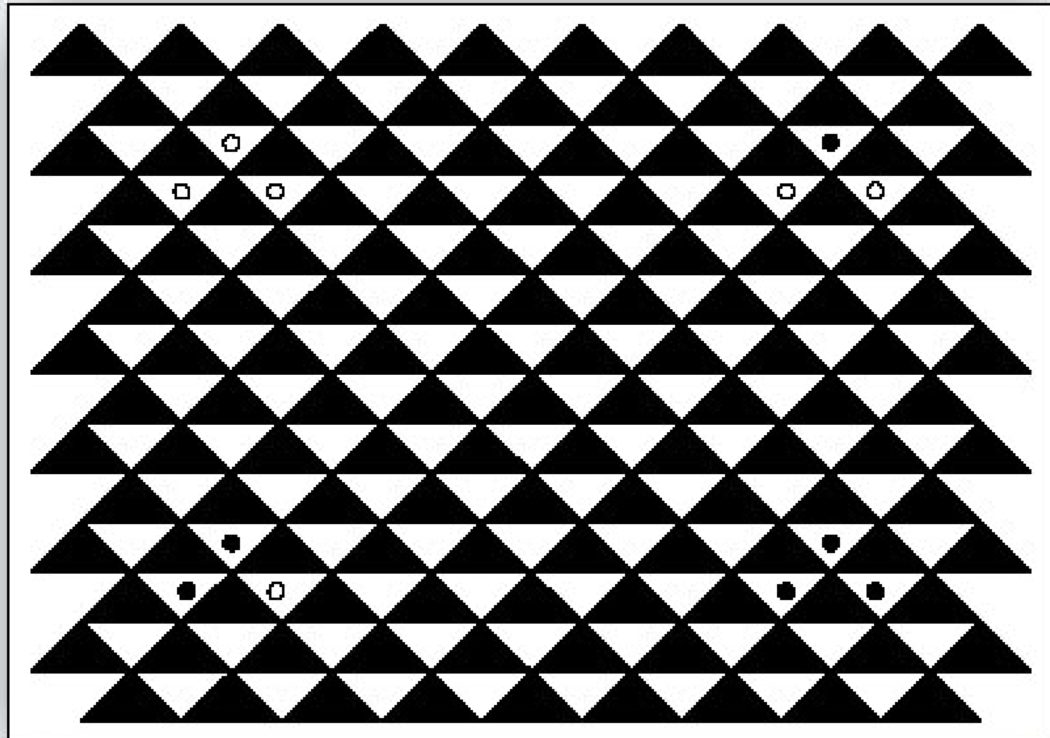


Image obtained from test pattern



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

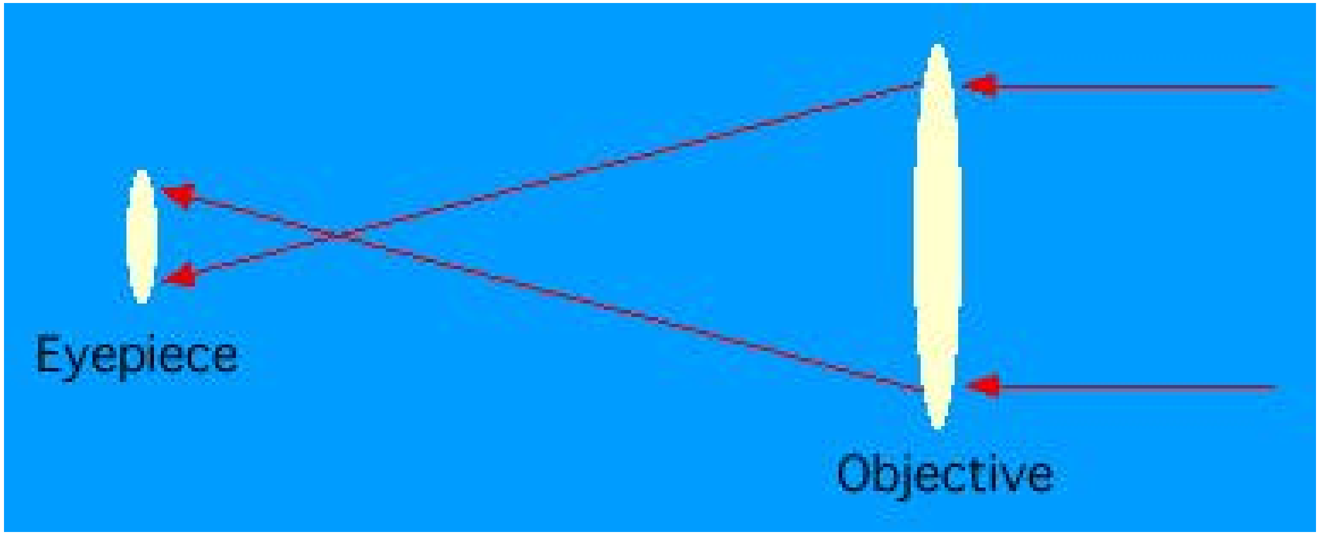
← Measuring of corresponding p(
channels by means of LSM

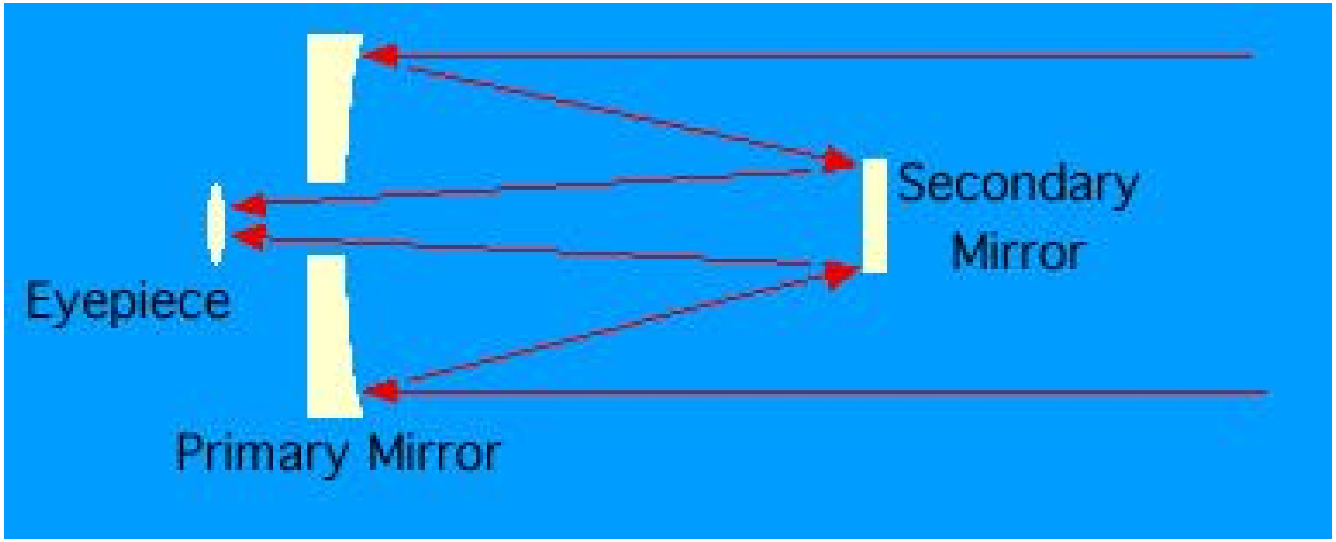
- The color photo
into their single

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

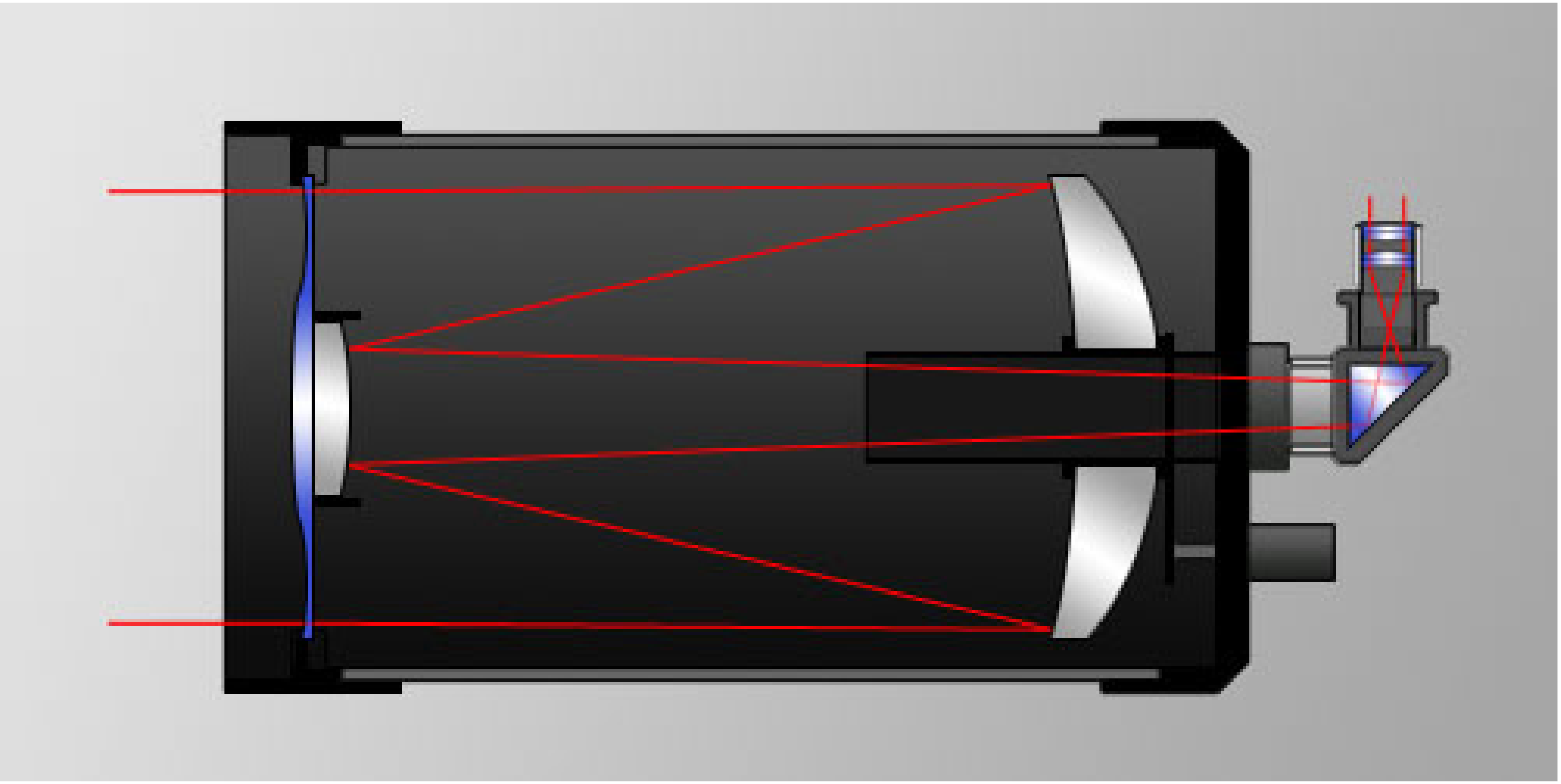
Again, note the purple fringes around the bright patches in the zoomed in view

Refractive versus reflective optical elements

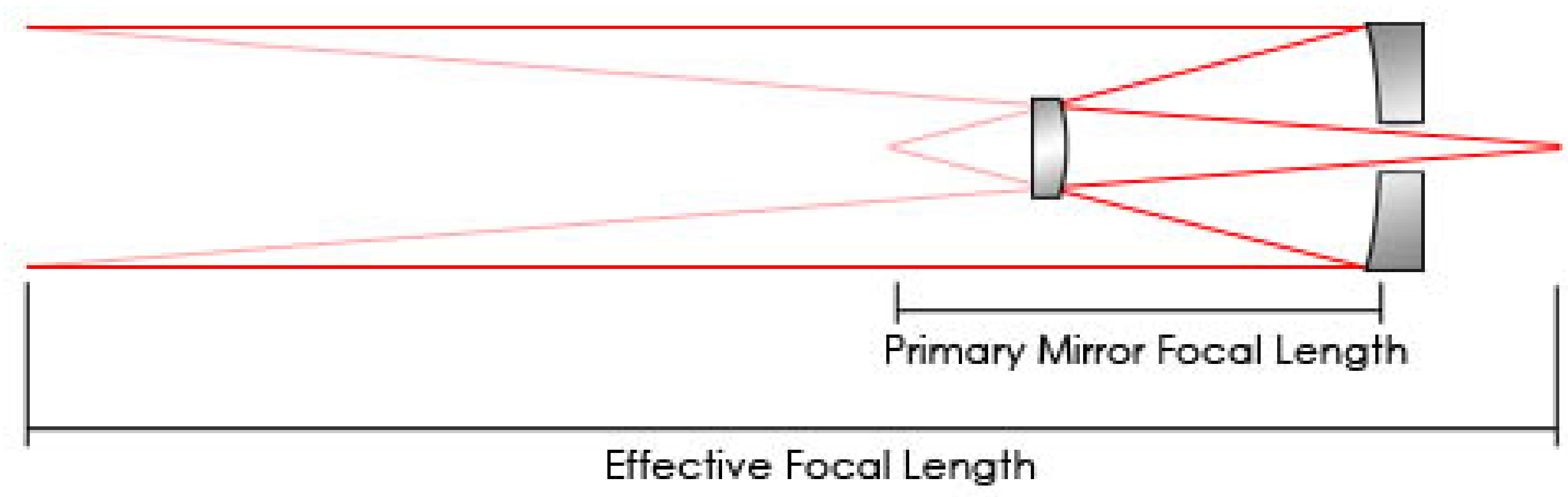




Schmidt-Cassegrain Telescope

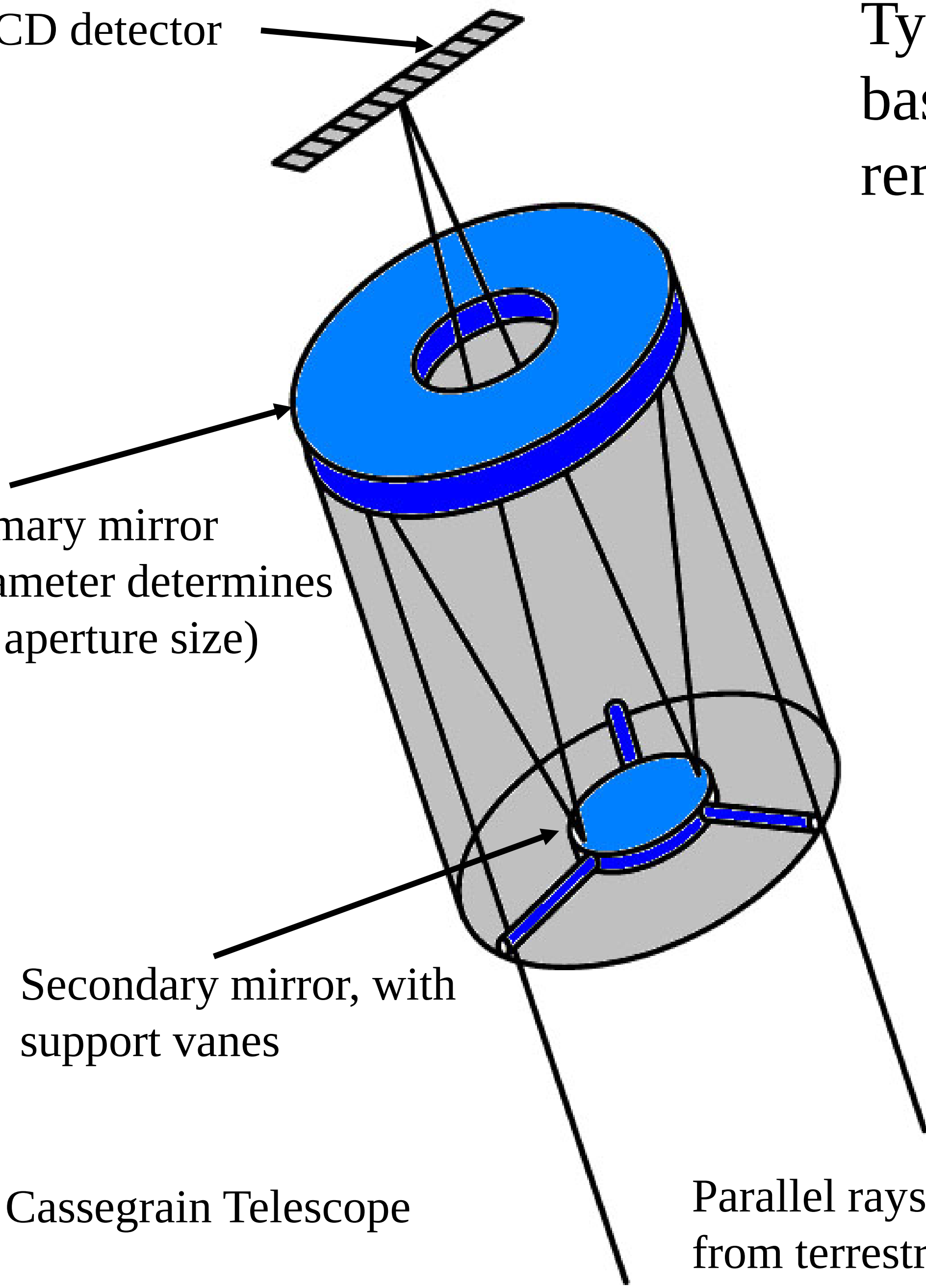


Another advantage of reflective optical elements – “folded” light path allows long focal length within a package that is much shorter



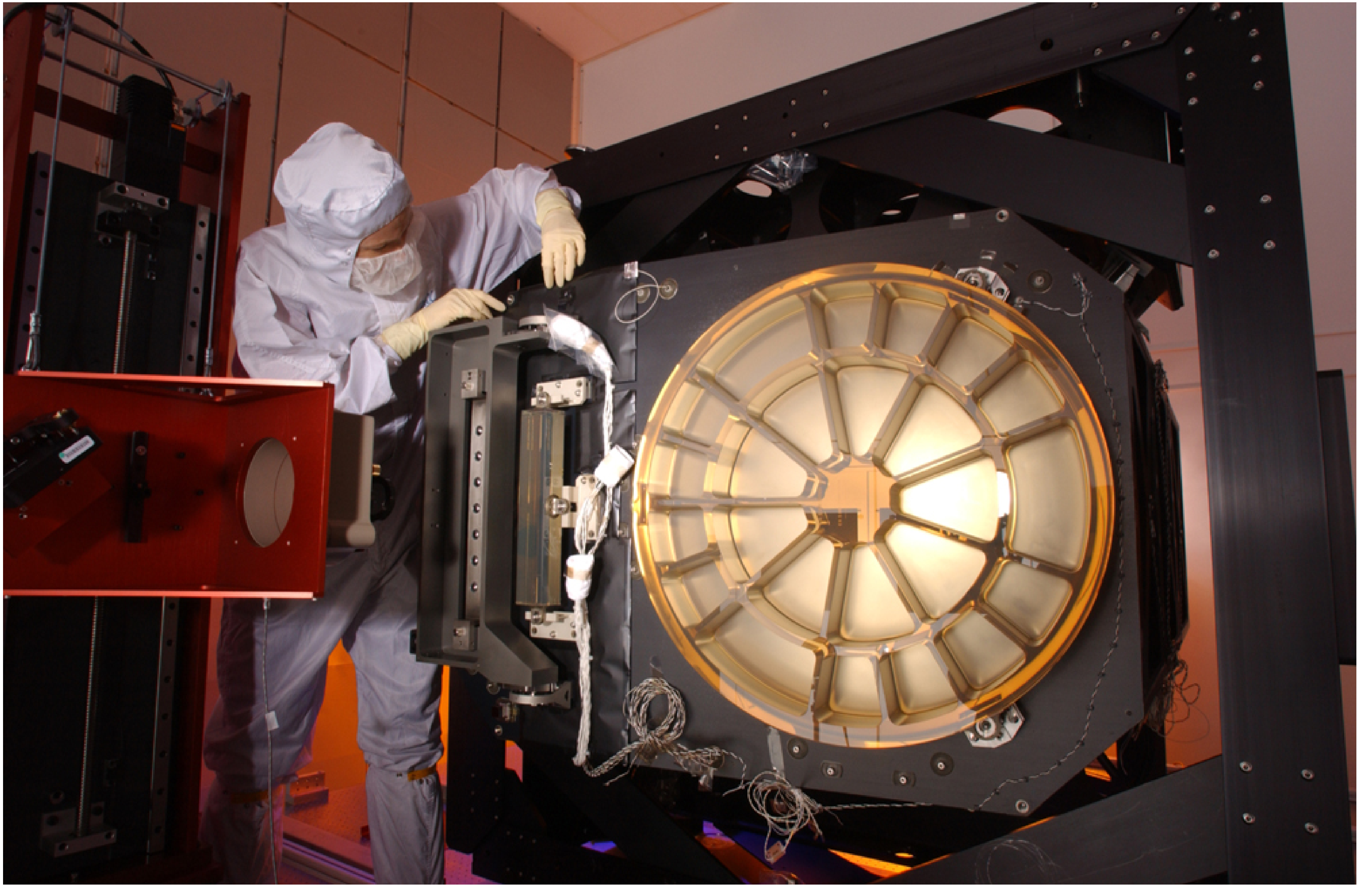
Scmidt-Cassegrain 500 mm optics for handheld camera – compare size and bulk to earlier shown lens

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

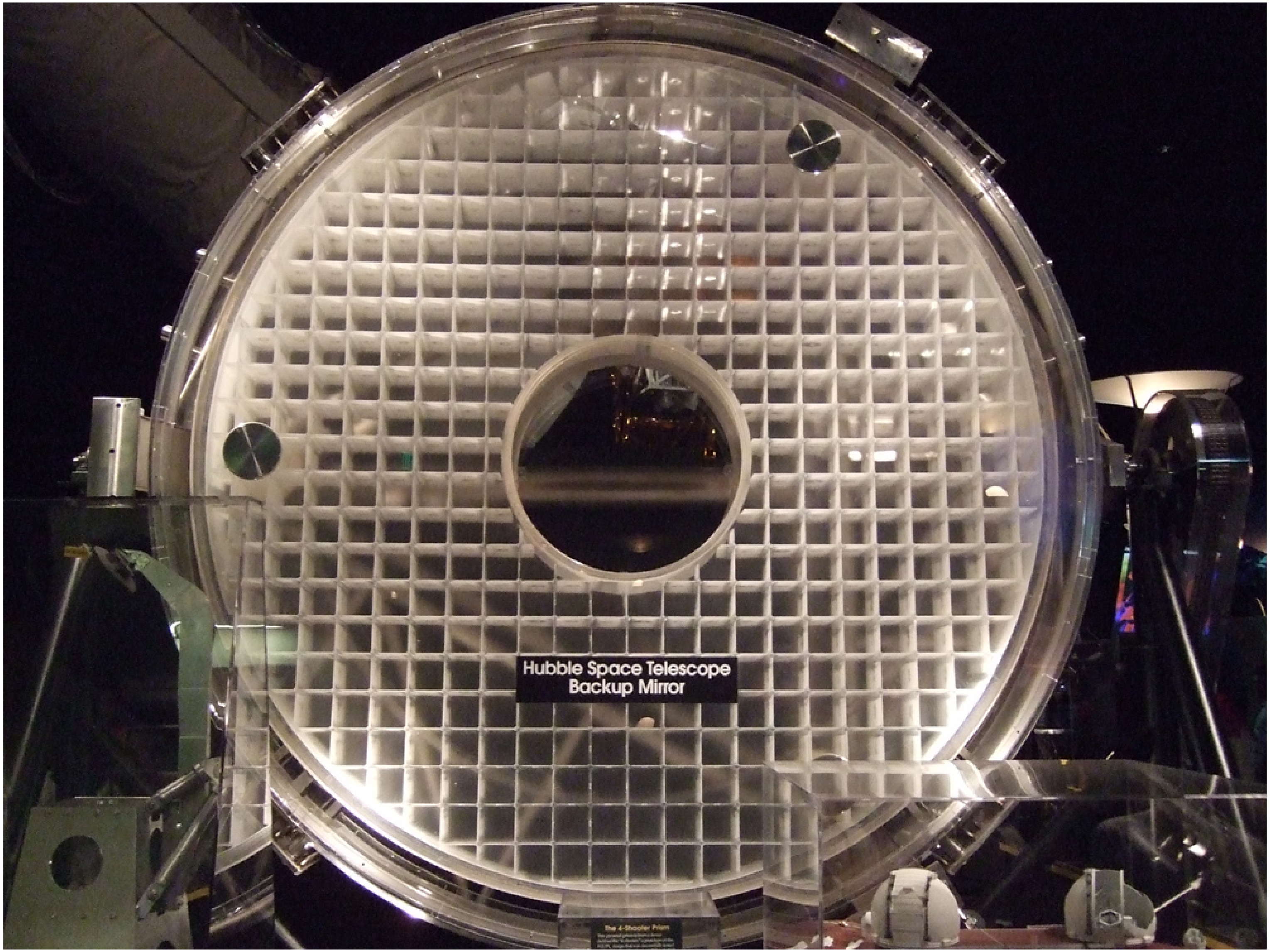


Primary and secondary mirrors are “powered” (curved) and do the focusing, like a lens. There can be more than 2 elements. Sometimes there are flat mirrors to just “fold” the optical path for a needed long focal length. Area CCD arrays are not big enough for practical use. Dimension of linear array determines 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



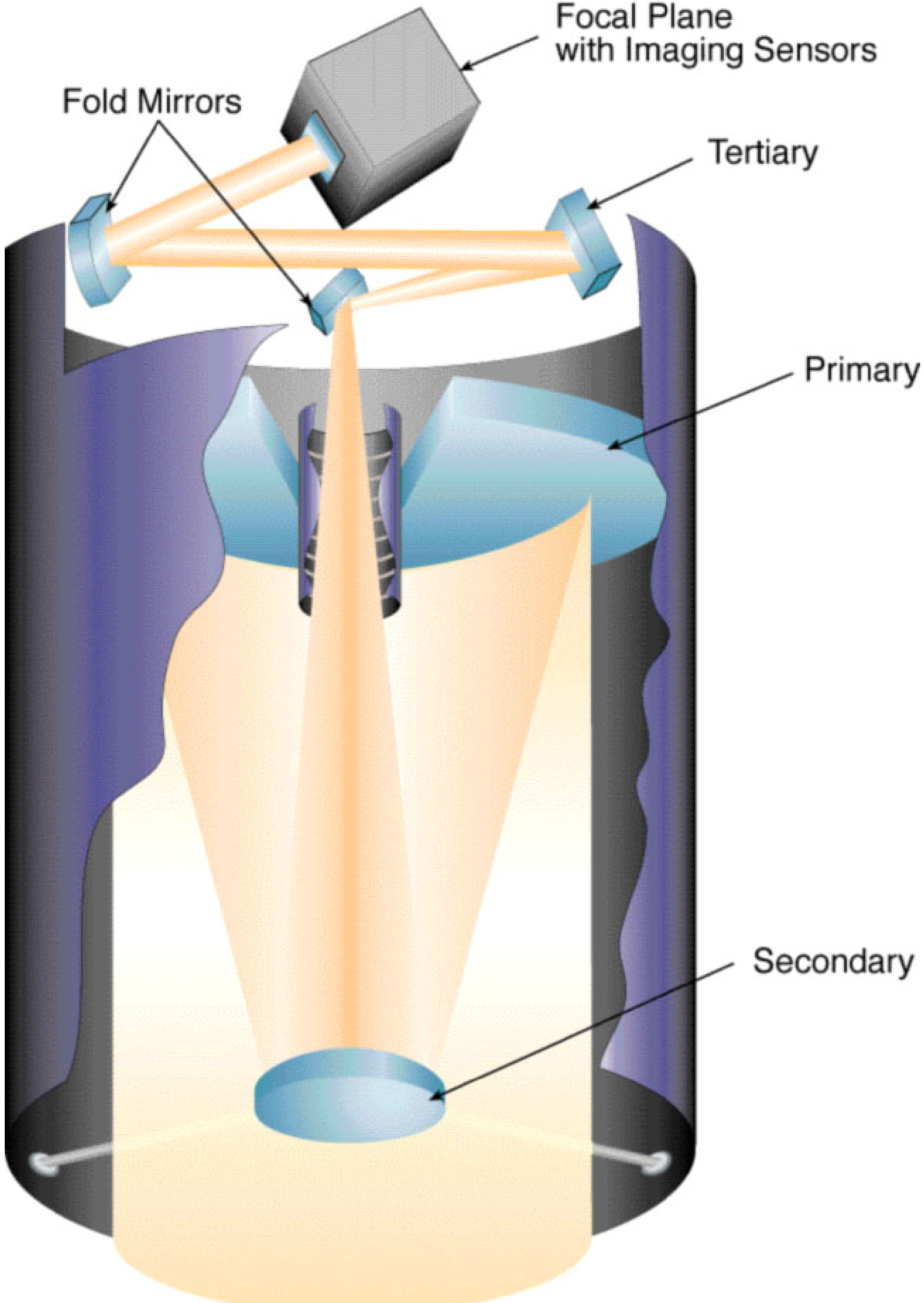
Hubble backup mirror made by kodak, this one did not have defects as did the one from Perkin Elmer



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.



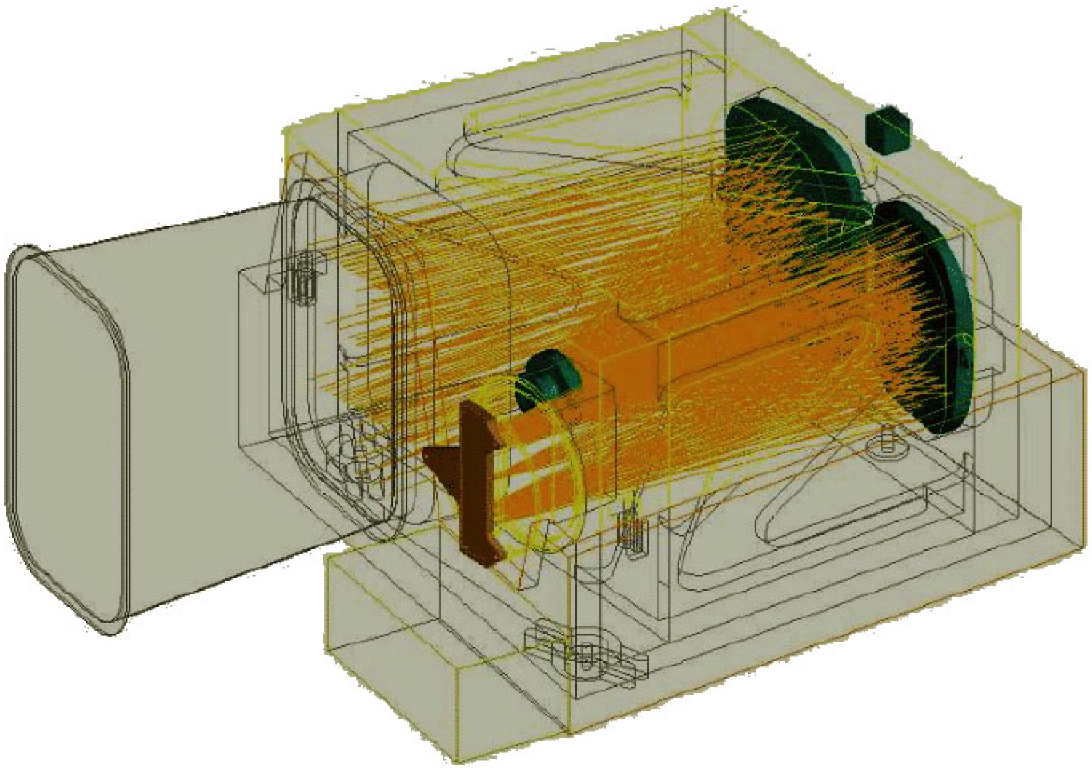
Schematic of IKONOS camera

- •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

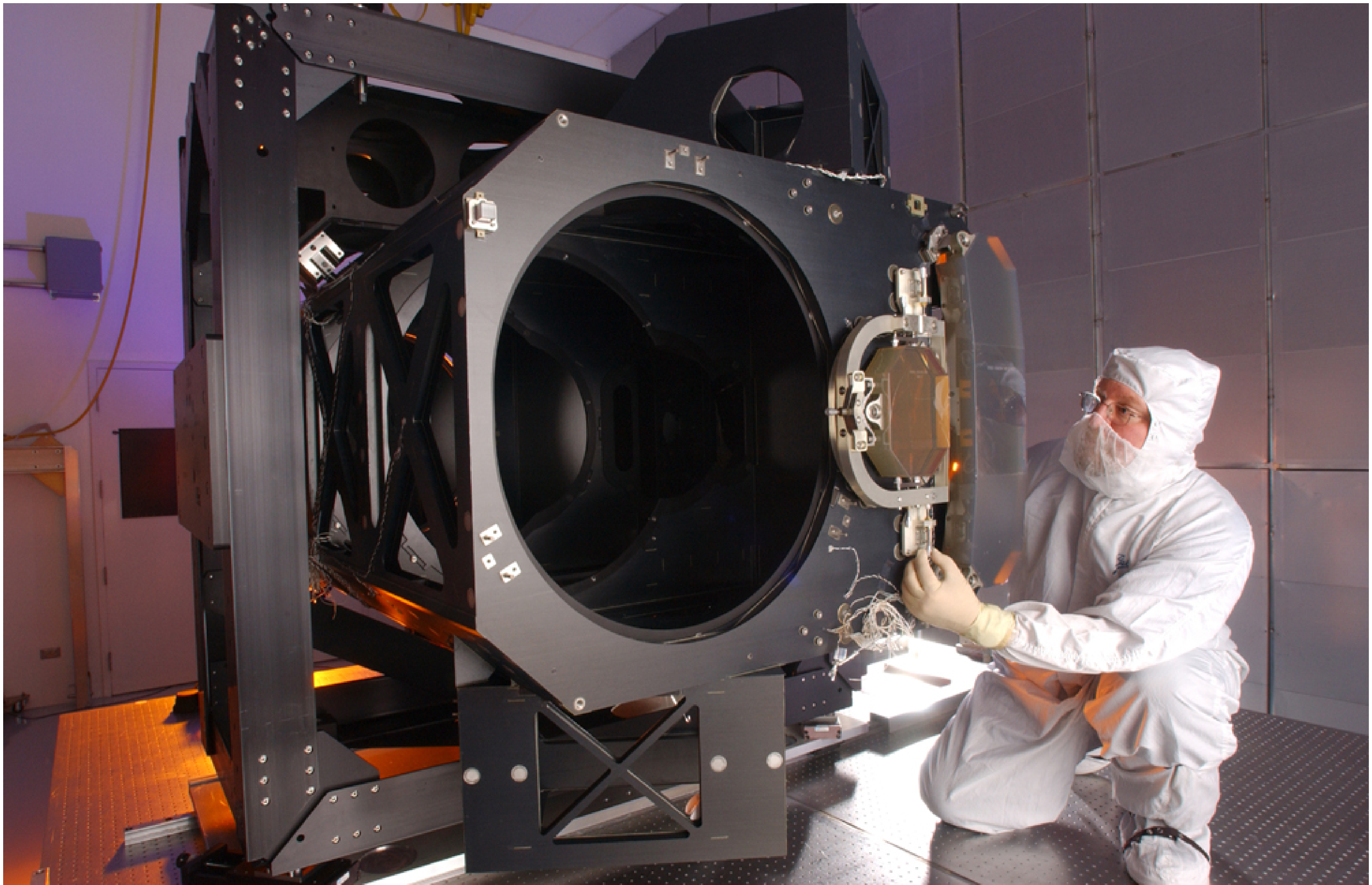
- Reduced size and mass for fitting into mini-satellites
- ~$ 1M
- ~ 2 year delivery time

Optical Camera Payload
Three Mirror Anastigmat (TMA)

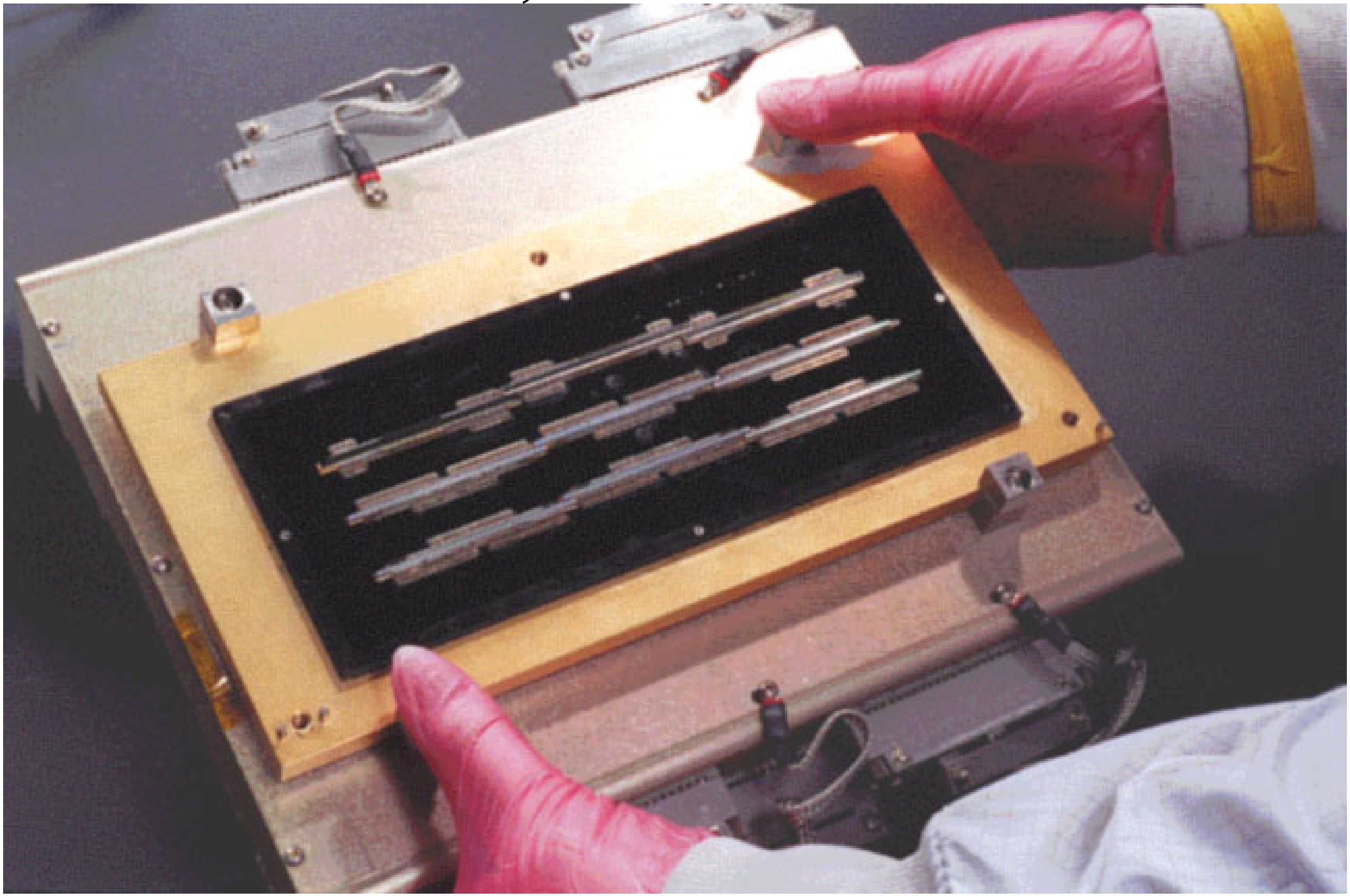


Off-axis design to eliminate the obstruction of the secondary mirror, from Jena Optik Rapideye

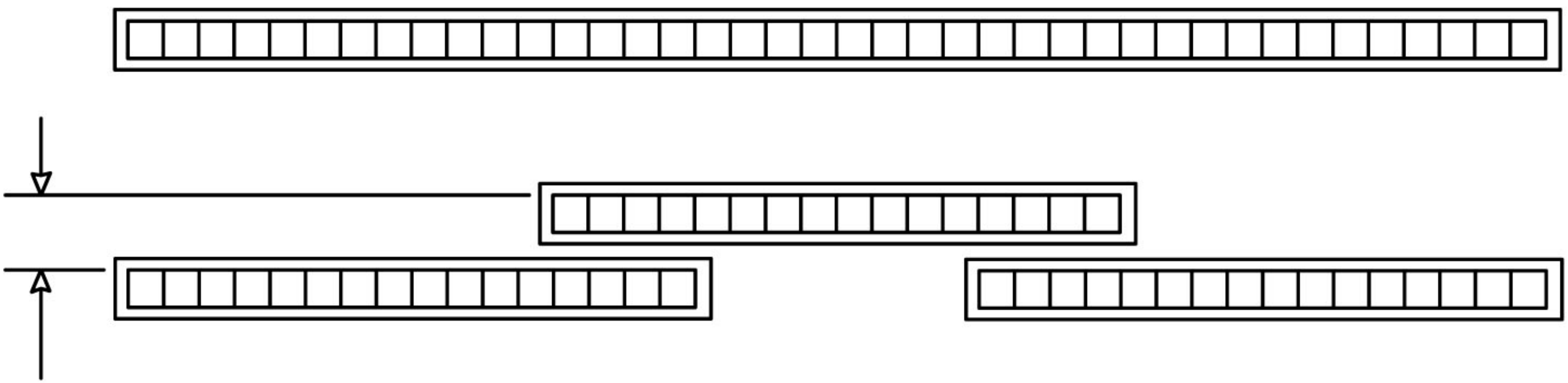
Worldview 1 also has Off-axis TMA design for unobstructed aperture



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



Integer number
of line widths

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.

Quickbird Focal Plane Layout

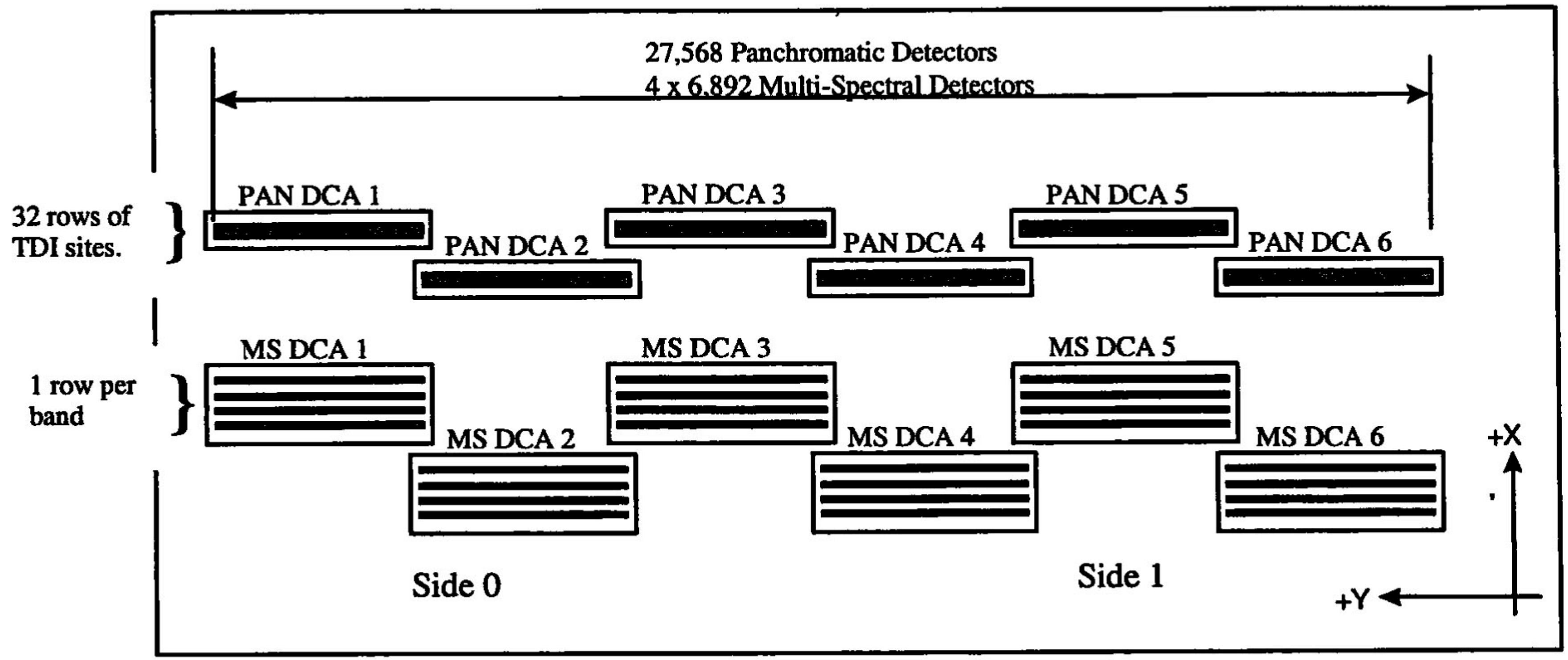
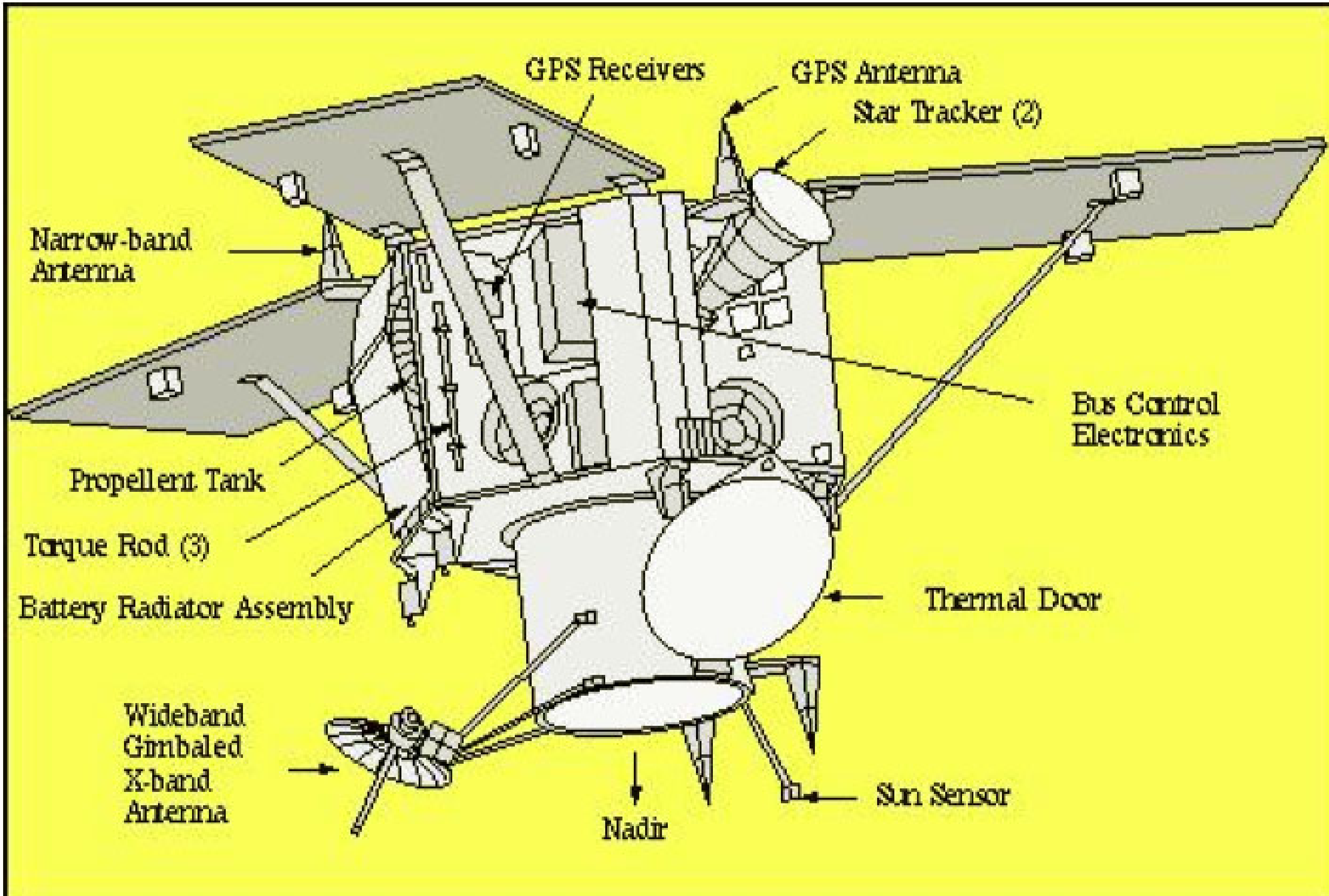


Figure 1: The QuickBird Focal Plane Layout (not drawn to scale)

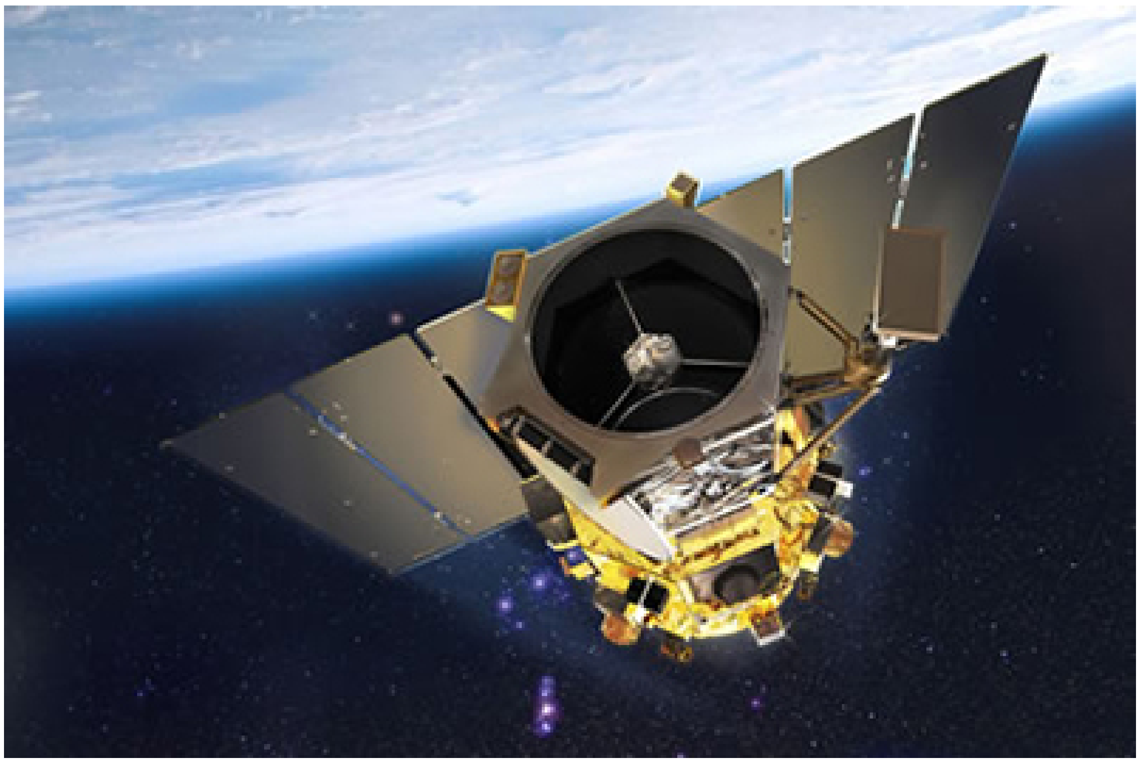
Schematic of auxiliary components for the IKONOS sensor



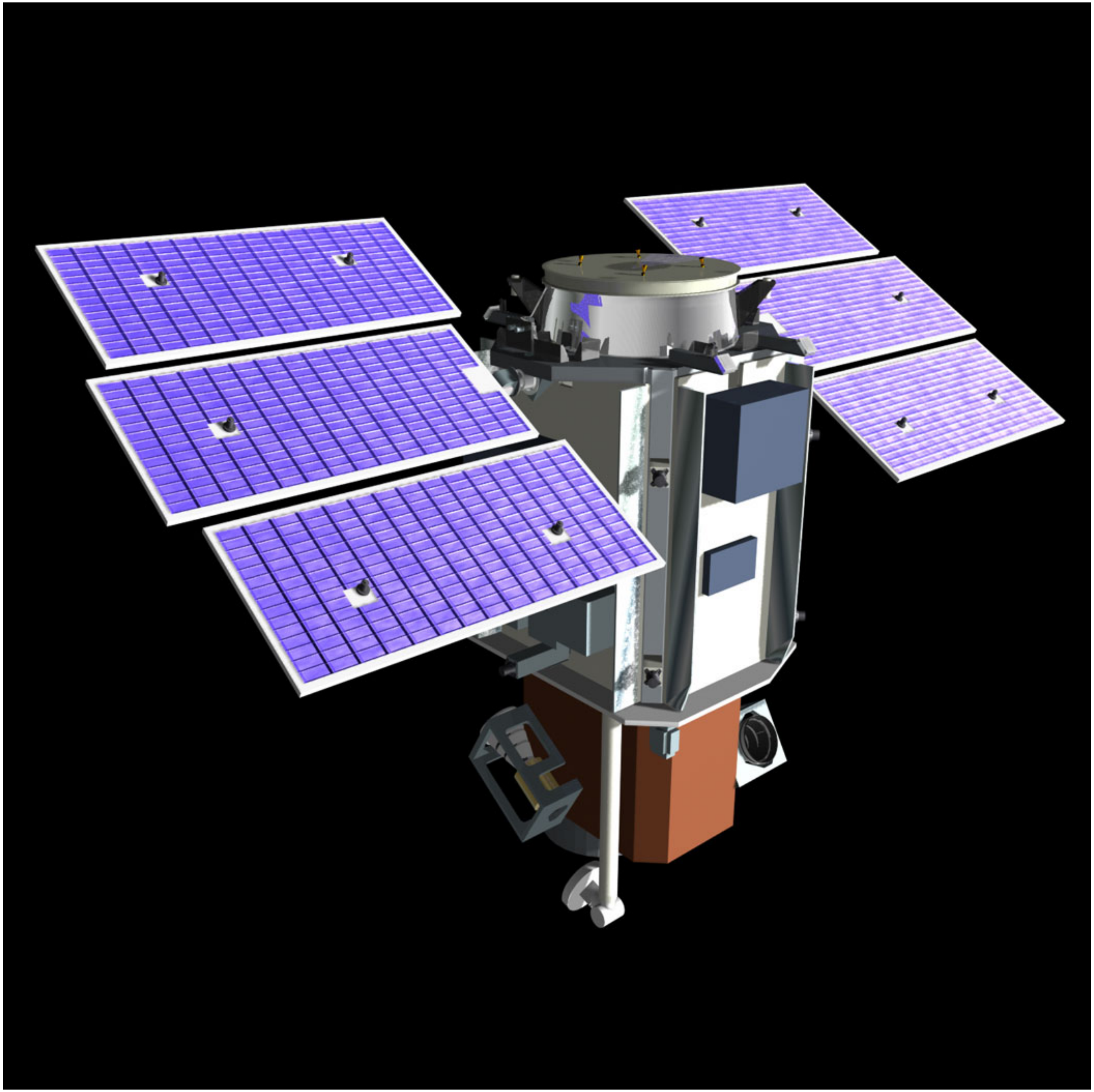
IKONOS – Space Imaging (GSD=0.82m)

GeoEye 1 - GeoEye
(GSD=0.46m)

Orbview 3 -Orbimage

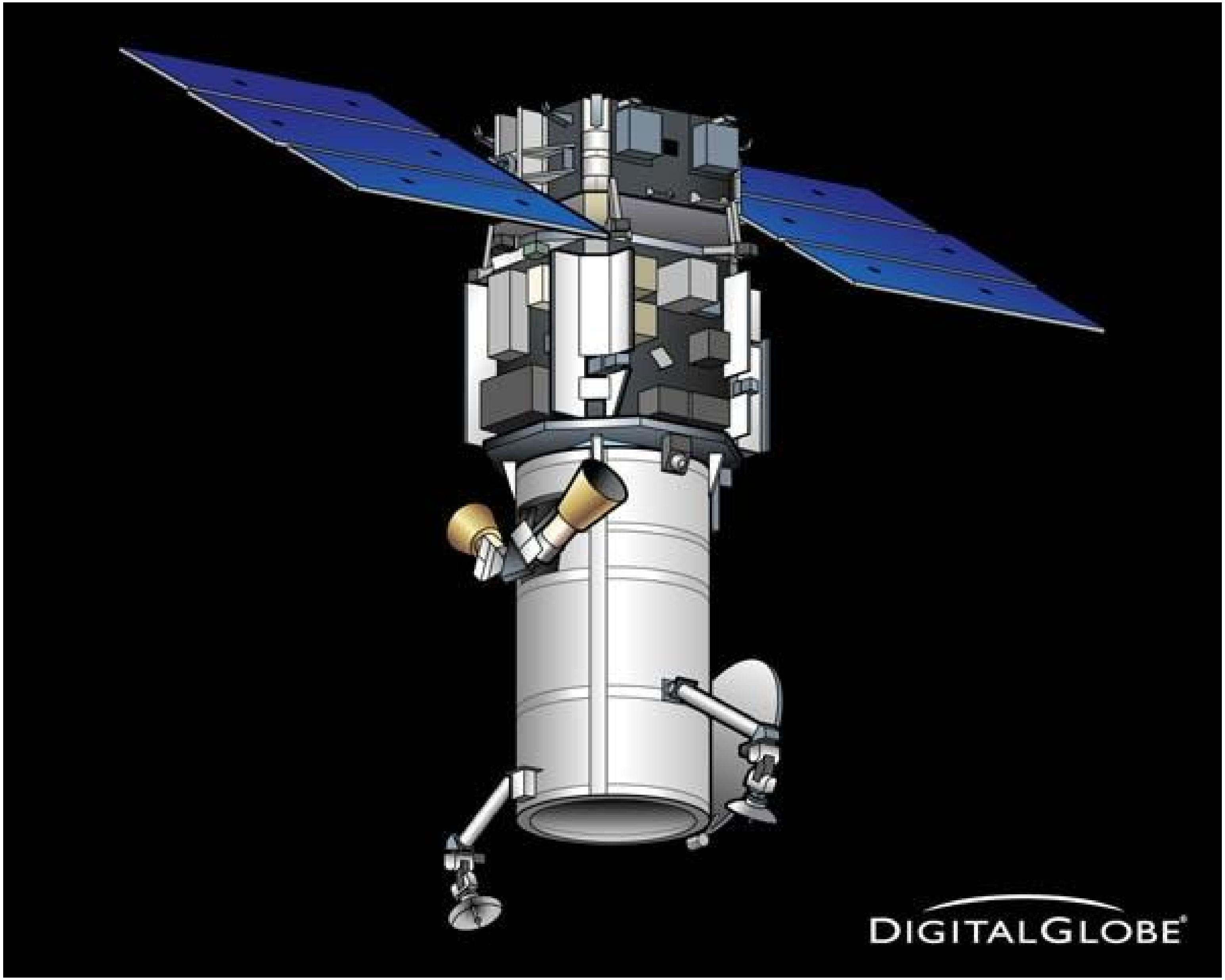


Space Imaging + Orbimage = GeoEye
Digital Globe + GeoEye = Digital Globe

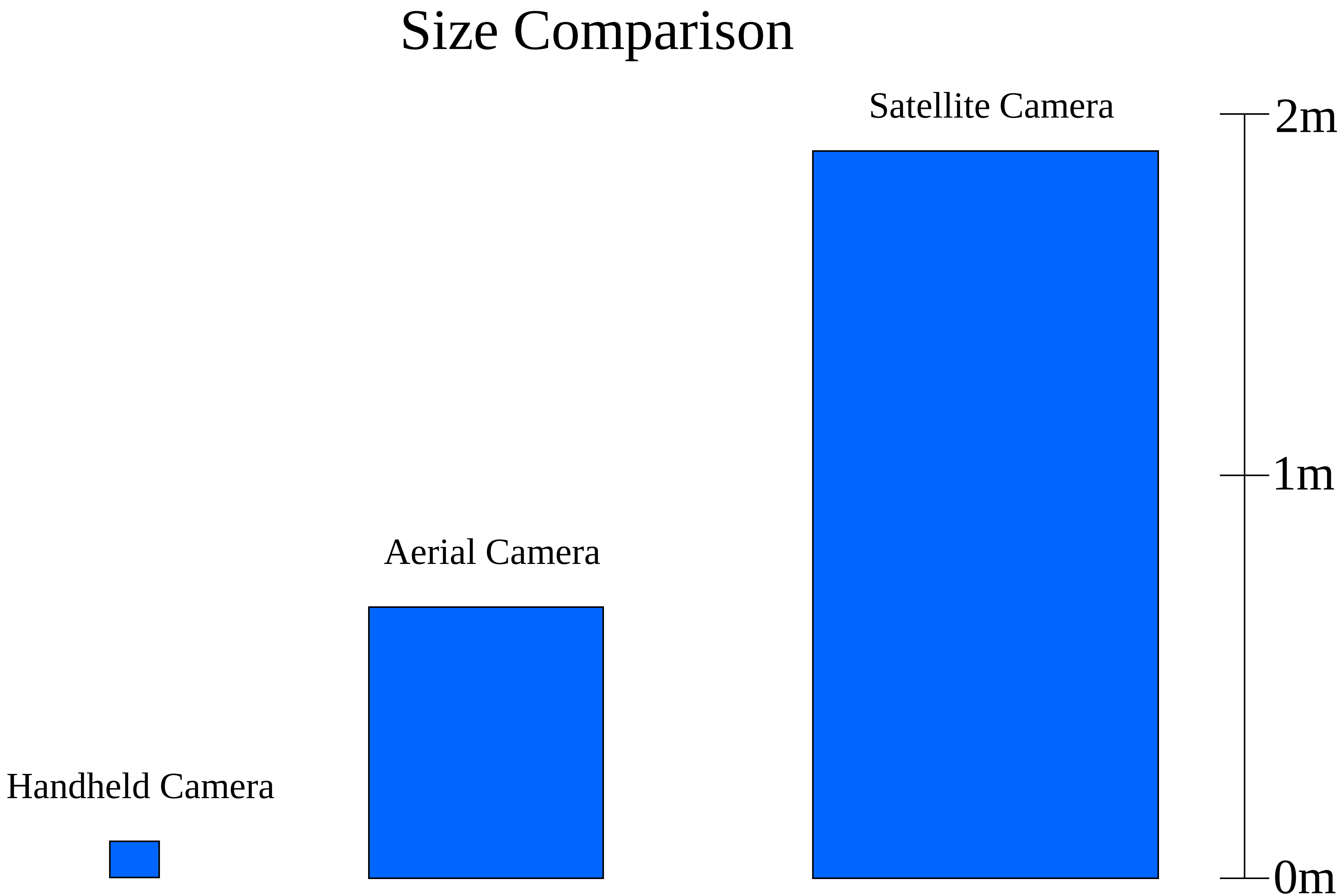


Quickbird Spacecraft and camera yielding 0.65m panchromatic imagery (operated by Digital Globe)

Worldview 2 - Digital Globe (GSD=0.46m)



Worldview 3
Digital Globe
(GSD=0.31m)


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