# Space Based Remote Sensing
# - Geometric Design of a Space Camera -

# Geometric Design of a 3-line CCD Camera for Mars Observation

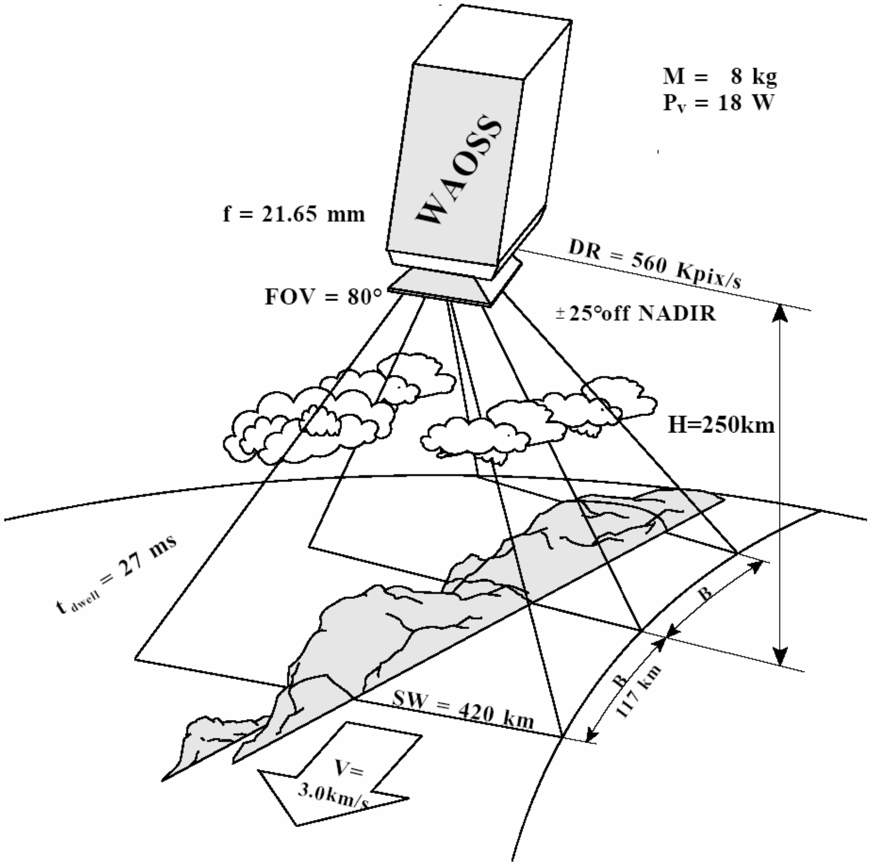
The geometric design aspects of a three line scanner are strongly related to the scientific requirements.

They have influence on

- the CCD array selection,
- the design of the focal plate module,
- the lens design, and
- the electronics design.

**Major design steps:**

1. CCD selection
2. Parameters for optics and focal plate design
3. Parameters for electronics design




Stereo imaging scenario at Mars [San94]

# 1. CCD Selection

A lot of factors determine the CCD selection. Most important factors are:

- small pixel size - to allow as high as possible ground resolutions
- large pixel number to allow a large field of view FOV
- High quantum efficiency
- High saturation electron numbers
- other, e.g. no blooming, ….

**Selection:**

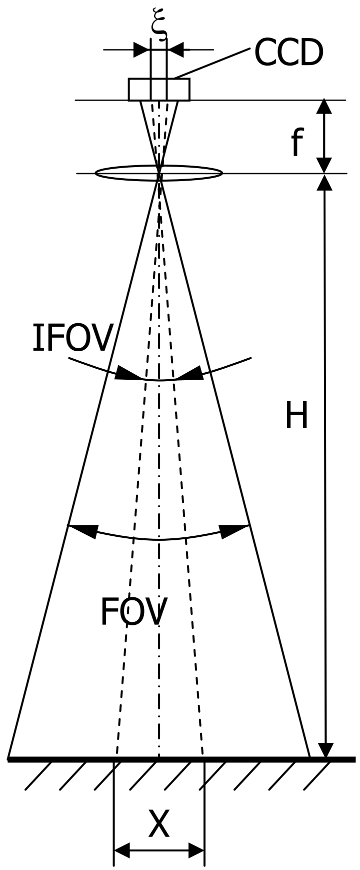
The Thomson THX 7808B is a good compromise with

- a pixel size = 7 µm x 7 µm
- pitch (pixel distance) $\xi = 7\ \mu m$
- number of active pixels $n_{pix} = 5184$

The active line length of $d = n_{pix} \cdot \xi = 36.288$ mm allows to select a lens from usual picture size camera lenses.

# 2. Parameters for Optics and Focal Plane Design

To determine the focal length f, we can use either
the necessary field of view FOV or
the ground pixel size X as the input parameter.




Using as input parameters:

| | |
|---|---|
| the ground pixel size | X = 80 m |
| the pericenter altitude | H = 240…250 km |
| and the convergence angles | $\gamma = \pm 25°$ |

some geometrical optics parameters can be derived:

- **Focal Length** (H=250km)

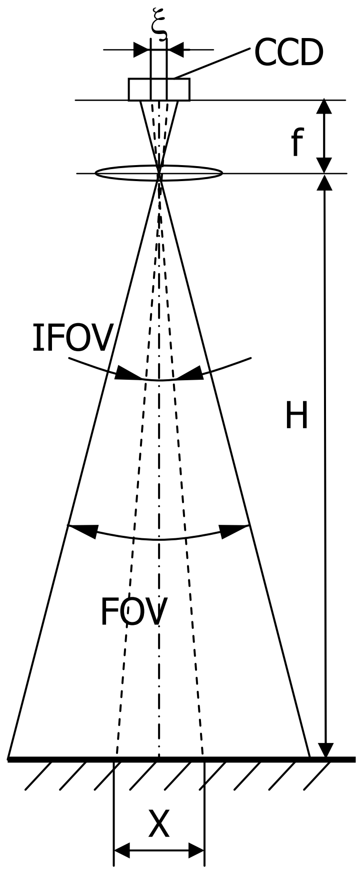
$$f = \zeta \cdot \frac{H}{X} = 21.875\,\text{mm}$$

Definition: f = 21.65 mm

# 2. Parameters for Optics and Focal Plate Design

## Instantaneous Field Of View IFOV

$$IFOV = 2\arctan\left(\frac{X}{2H}\right) = 0.32\,\text{mrad}$$




## Field Of View FOV

$d = n_{pix} \cdot \xi = 36.288$ mm

$$FOV = 2\arctan\left(\frac{d}{2f}\right) = 80\,\text{deg}$$

## Total Field Of View TFOV

$$TFOV = 2\arctan\sqrt{\tan^2\gamma + \tan^2\left(\frac{FOV}{2}\right)}$$

$$TFOV = 87.7\,\text{deg}$$

# Focal Plane

Related to the Focal plane module we obtain:

**Distance of the stereo CCD lines D** from the nadir looking CCD line

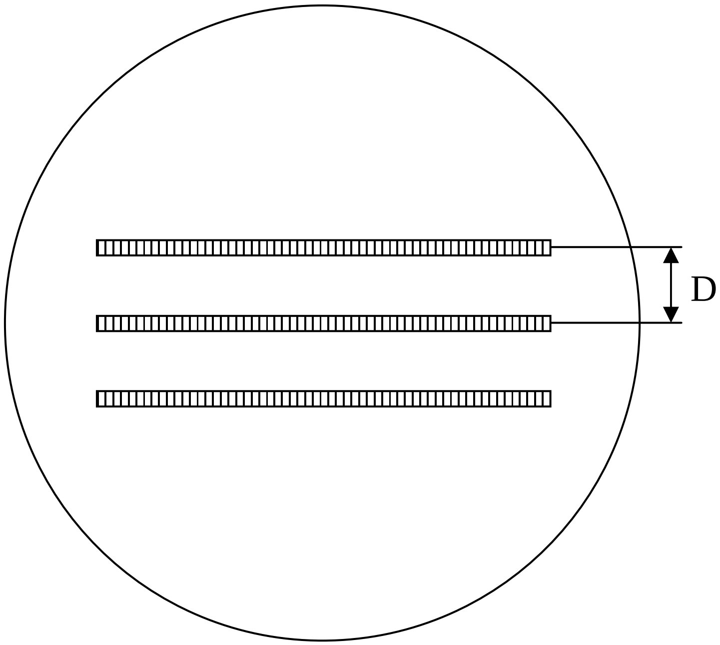
$$D = f \cdot \tan\gamma = 10.1\text{mm}$$

which leads to the photo active area (image field) of

2D x d = 20.2 mm x 36.3 mm

**Total Field Of View TFOV**

$$\text{TFOV} = 2\arctan\left(\frac{1}{f}\sqrt{D^2 + \left(\frac{d}{2}\right)^2}\right) = 87.7\ \text{deg}$$




Focal plane module with 3 CCD lines

# Swath Width and Basis Length

the ground related parameters are

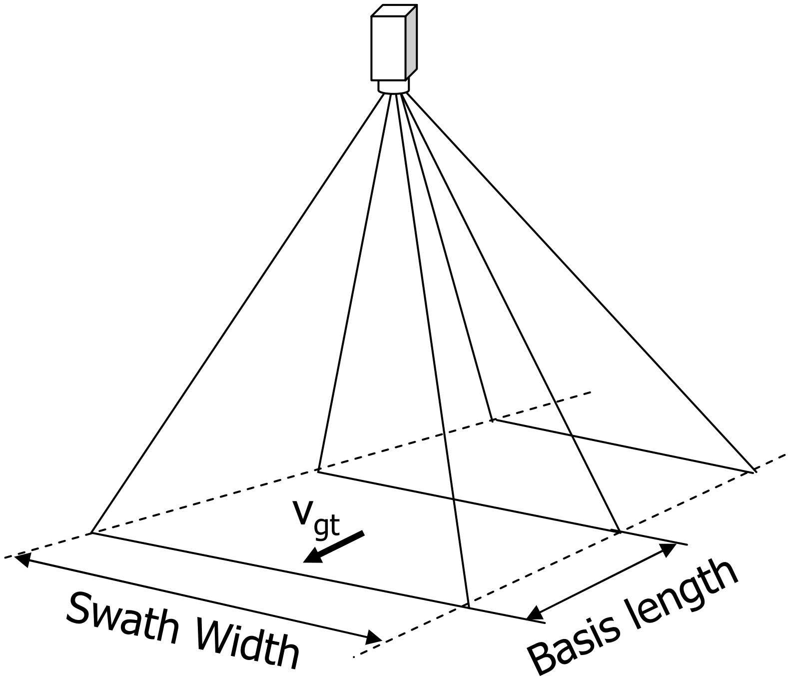
**swath width SW**

$$SW = H \cdot \frac{d}{f} = 420\,km$$

- **basis length BL**

= distance of two successive CCD line projections on the ground

$$BL = H \cdot \frac{D}{f} = 117\,km$$




- **achievable height resolution**

$$\Delta Z \approx \frac{1}{C} \cdot X \cdot \frac{f}{2D} \geq 1.1 \cdot X$$

with $0 \leq C \leq 1$ - scene dependent correlation factor

# 3. Parameters for Electronics Design

Basic parameters for the electronics design are:

- Data rate from the focal plane (in kpix/sec)
- Data volume for one stereo image (Mpix)
  (one pixel can contain 8…12 bits)

For the calculation the following ground sampling parameters are needed:

- ground track velocity $v_{gt}$
- dwell time $t_{dwell}$

# Mars Ground Track Velocity and Dwell time

Given

- Mars radius $R_M = 3394$ km
- Mars mass $M_M = 0.64\ 10^{24}$ kg
- gravitational constant $G = 6.67\ 10^{-11}\ m^2kg^{-1}s^{-2}$

**Orbit period**

$$T = 2\pi\sqrt{\frac{(R_M + H)^3}{G \cdot M_M}} \approx 1.9\ \text{hrs}$$

**Ground track velocity**

$$v = \frac{2\pi \cdot R_M}{T} = 3.1\frac{\text{km}}{\text{s}}$$

**Dwell time**

$$t_{dwell} = \frac{X}{v_{gt}} = 25.8\ \text{ms}$$

# Data Rate and Data Volume

**Data Rate** from the focal plane with n = 3 lines:

$$DR = \frac{n_{CCD} \cdot n_{pix}}{t_{dwell}} \approx 600\ \text{Kpix/s}$$

Minimum **observation time** for one basis length **for 3D**:

$$T_{3D} = 3 \cdot T_B = 3 \cdot \frac{BL}{v_{gt}} = 113\ \text{s}$$

**Data Volume for the 3D** information of one basis length:

$$V_{3D} = DR \cdot T_B = 67.8\ \text{Mpix}$$