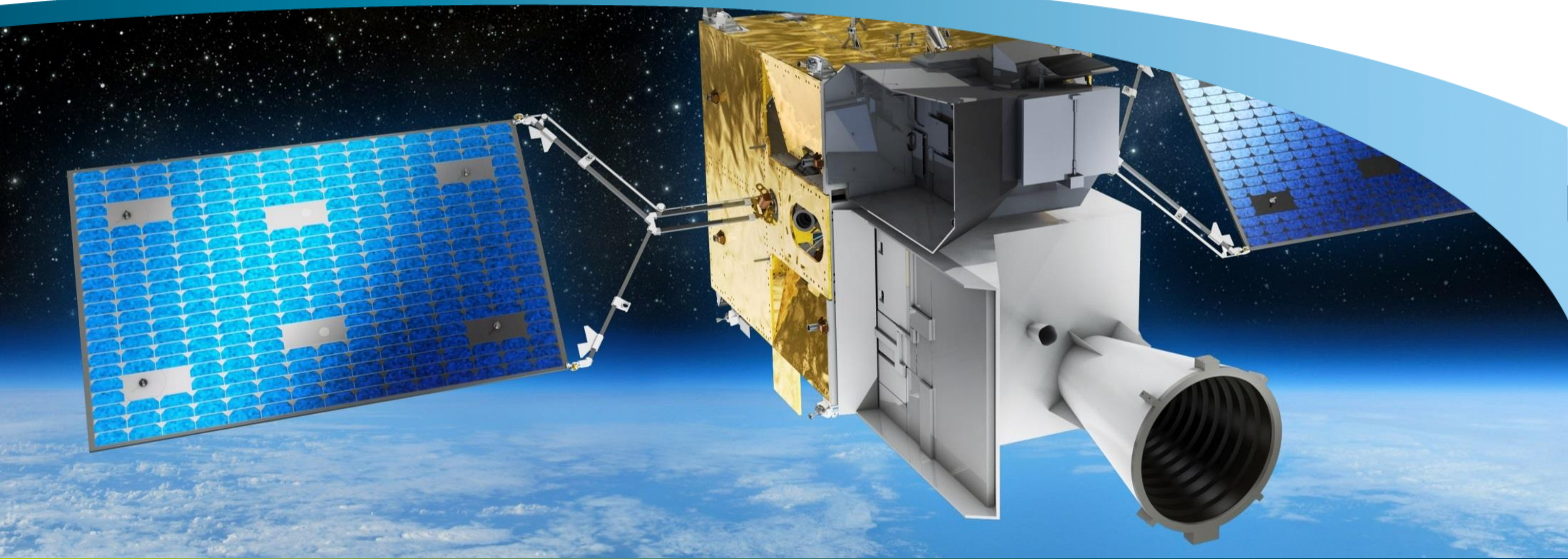
OHB System AG
Kathrina Weiß
23.03.2019, GAFOE Symposium
Hamburg

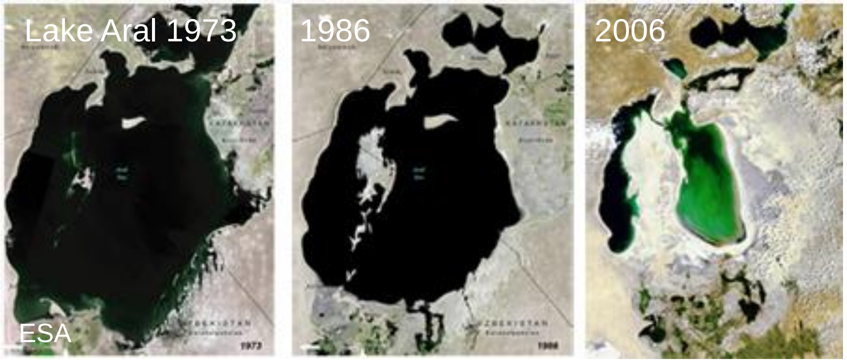


SPACE SYSTEMS

Observing the earth beat from space with high performance optical instruments

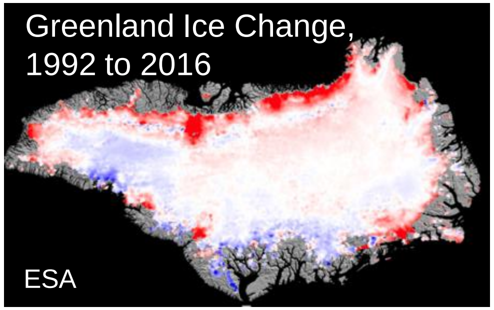
We. Create. Space.

Earth observation – what for?



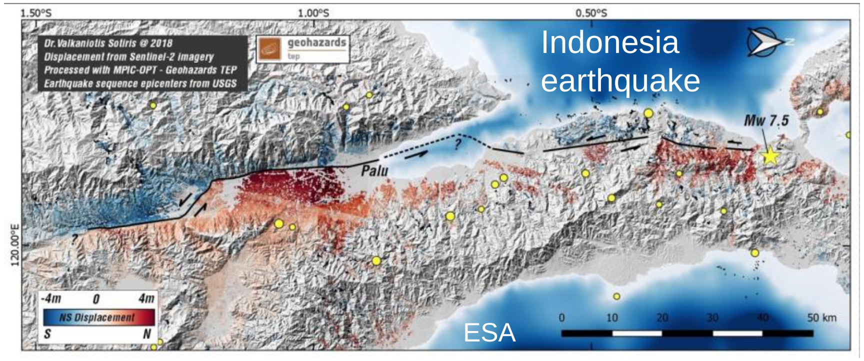
- Water and Resources monitoring
- Ecosystem monitoring

- Climate modeling & monitoring



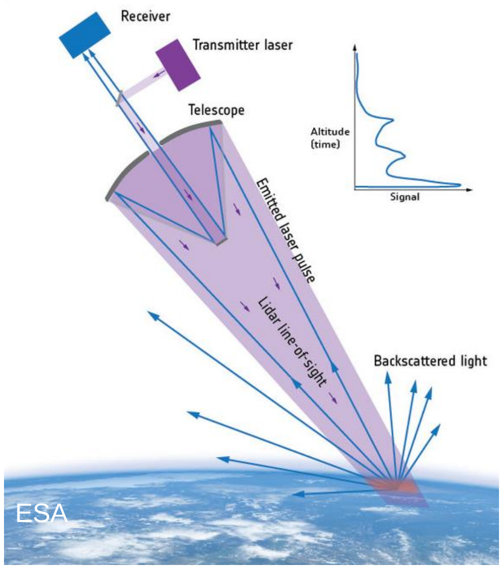
- Weather forecast
- Agricultural practices
- Air traffic optimization

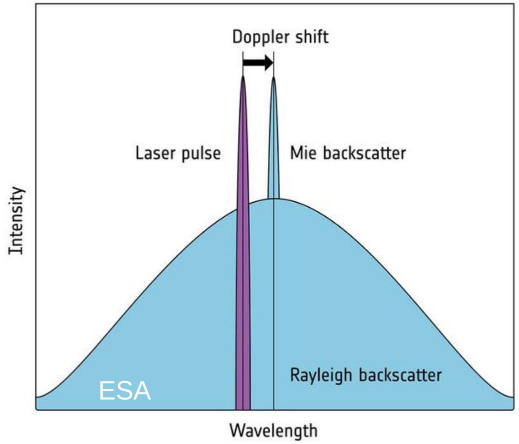
- Disaster monitoring and management
- Wildfires, earthquakes, flooding, hurricanes, droughts, volcanic eruptions, …
- Supporting emergency aid

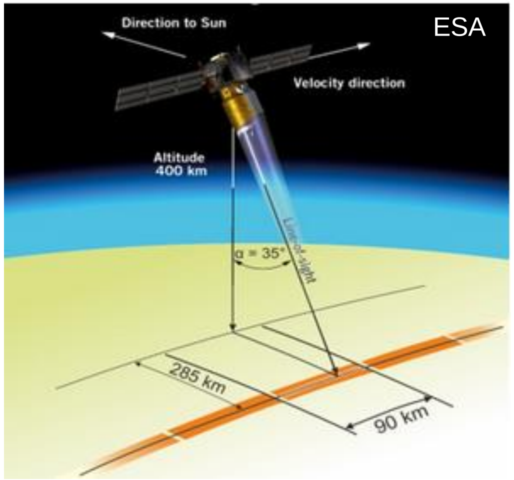


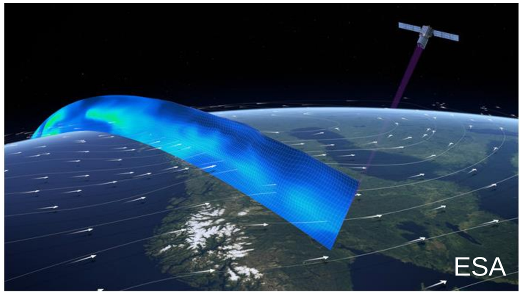
LIDAR

- LIDAR
- Time of flight measurement
  - Altitude measurements
- Wind velocity: Doppler LIDAR
- Mission example **ADM Aeolus**
- Data usage
  - Weather forecast
  - Climate models
- Instrument parameters
  - Vertical resolution: 0.5- 2km
  - Accuracy 1-3 m/s averaged over 90 km
- Main technological challenge
- High power lasers in space



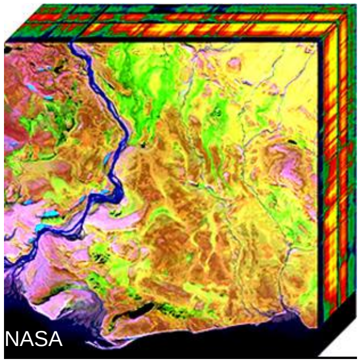


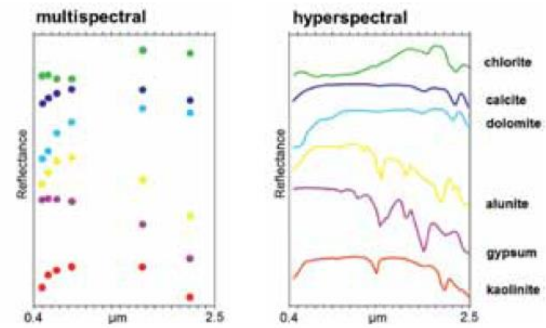




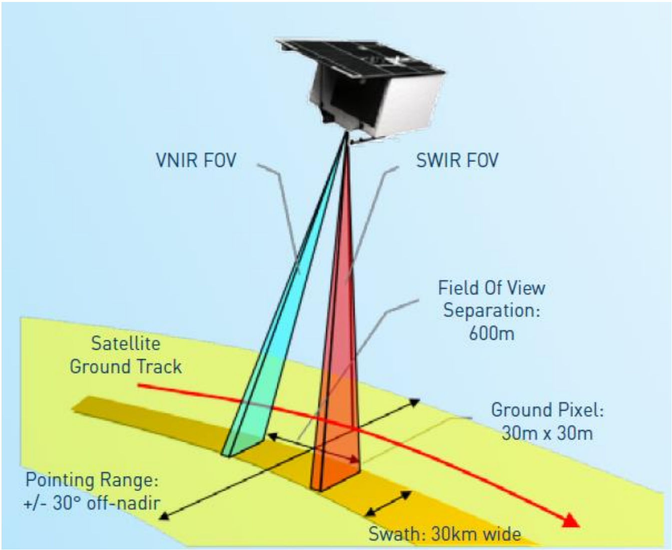
Hyperspectral Instruments

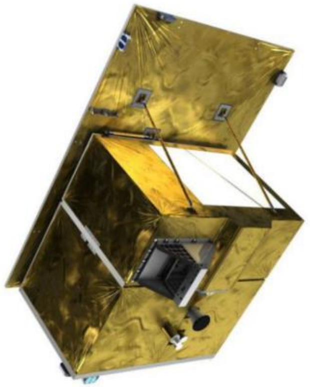
- Hyperspectral Imagers
- Quasi continuous wavelength bands
- Mission example: **EnMap**
- Data usage:
    - Land cover changes/ land use
    - Ecosystem monitoring
    - Resource and water monitoring
    - Climate change
- Instrument parameters:
    - Low orbit
    - Spatial scanning
    - Ground Resolution: 30m
    - 244 spectral channels between 420nm and 2450 nm
- Main technological challenge
- Highly sensitive infrared detector
- Thermal stability of optical payload





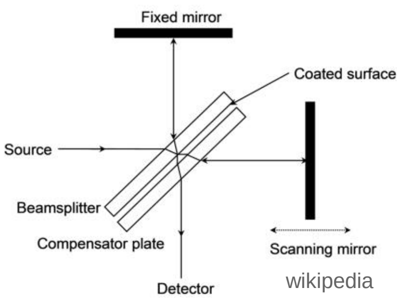
EnMap: Environmental Mapping





Infra-red Fourier transform spectrometers

- Infra-red Fourier-transform spectrometers
- Wavelength dependent absorption
- Mission example: **MTG Sounder**
- Dynamic of atmospheric temperature and humidity
- Data usage
  - Early warnings of thunderstorms
  - Input to climate modeling
- Instrument parameters:
  - Geostationary orbit
  - Scan earth disc every hour
  - On-ground sampling: 4km x 4 km
- Main technological challenge
  - High precision optical scanner
  - Micro-vibrations
  - Sun Intrusion management



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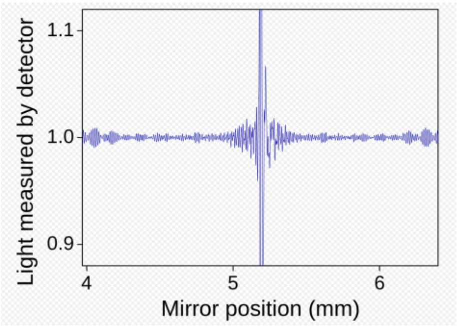
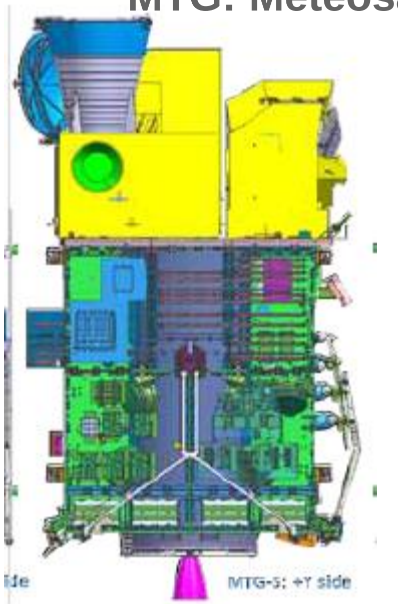
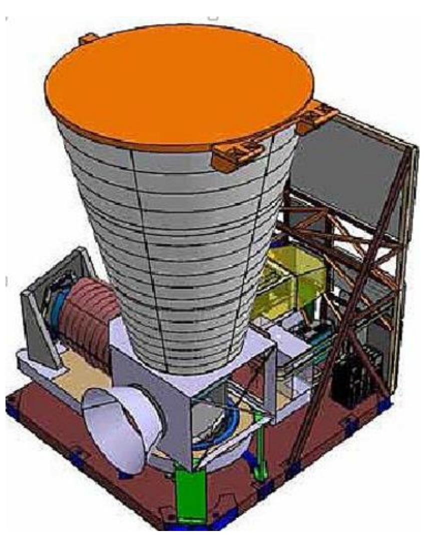
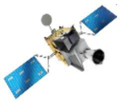


MTG: Meteosat Third Generation



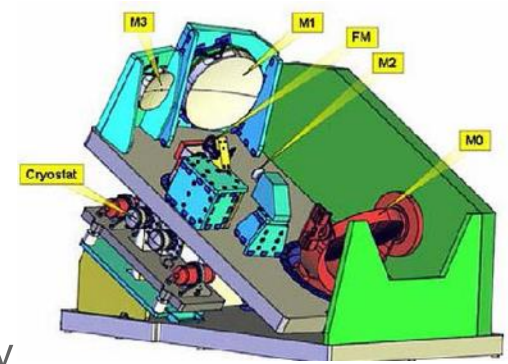




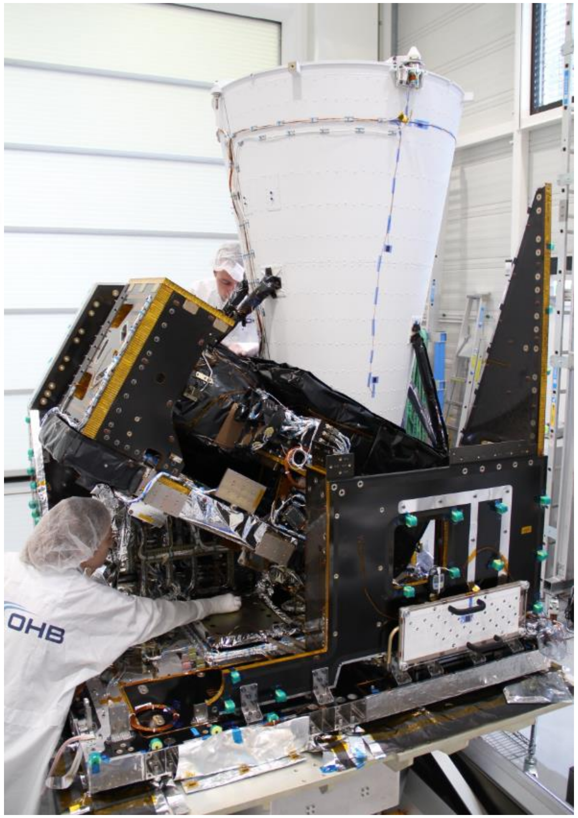
Imagers

- Images in wavelength bands
- Mission example: **MTG Imager**
- Data usage
  - Weather forecast
  - Forest fire detection
- Instrument parameters:
  - Geostationary orbit
  - Scans quarter of earth disc every 2.5 minutes with 1 km resolution
  - Full earth disk every 10 minutes with 2 km resolution
  - Wavelength: 400nm to 16µm
- Main technological challenge
- High precision optical scanner
- Optical alignment/ shimming technology
- Sun Intrusion management

MTG: Meteosat Third Generation

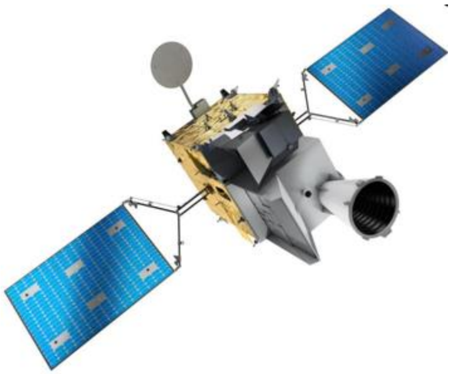


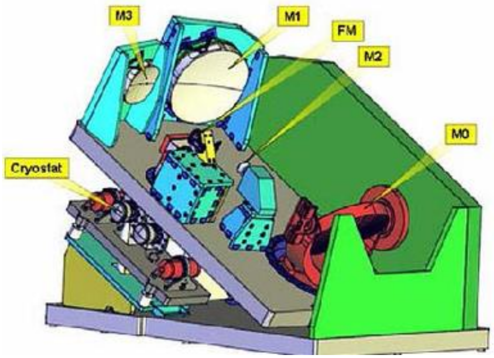
Thales

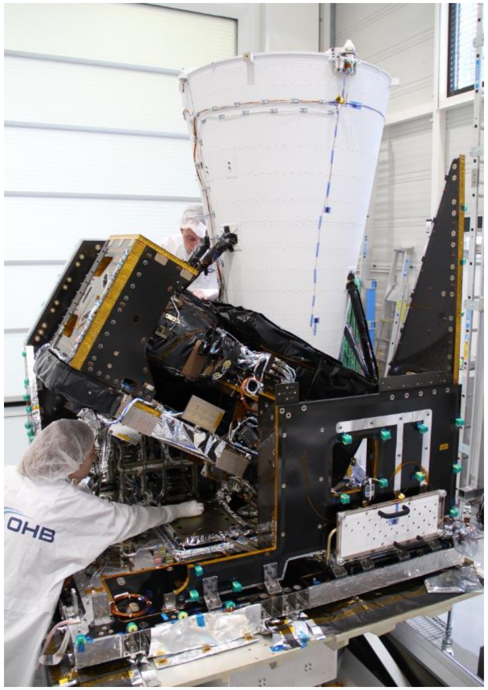


MTG – Imager: Performance Requirements

- Wide spectral range: 414nm to 13.6µm
- Spatial sampling ~1km
- High pointing stability
  - 1µrad over 0.3s
  - 4µrad over 10min
- Mass limit
  - Front telescope assembly 300 Kg
- High repeat cycle
  - Scans earth disc every 10 minutes







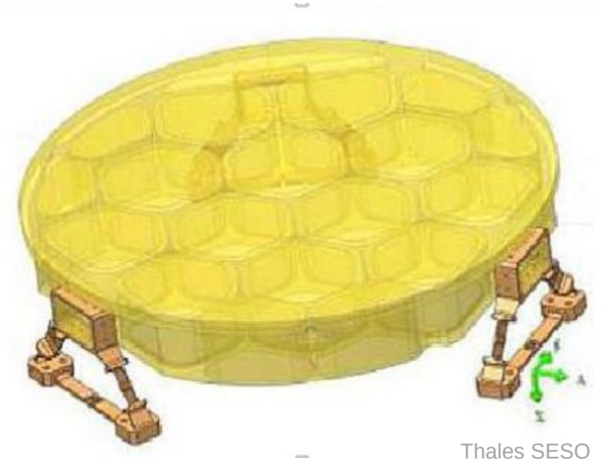
MTG – Mission Contraints

- Geostationary orbit
- Sun Illumination and cold space
- Launch loads

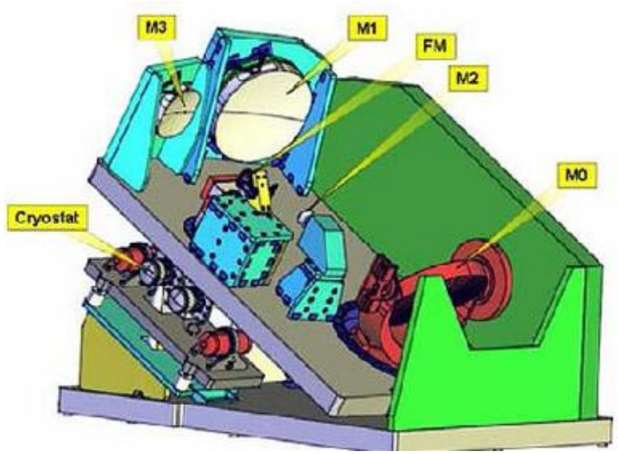
- Zero gravity
- Vacuum
- Radiation

MTG – Imager Design choices

- Wide spectral range
  - Mirror telescope
- Spatial sampling
  - Surface form error of front-telescope ~ 50 nm
  - Accurate placement of mirrors (~5µm)
- High pointing stability
  - Iso-static mounting
- Mass limit
  - Mirror light weighing
- High repeat cycle - Geostationary orbit
  - Straylight control

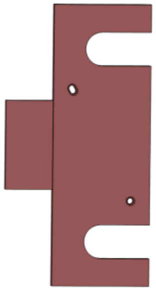


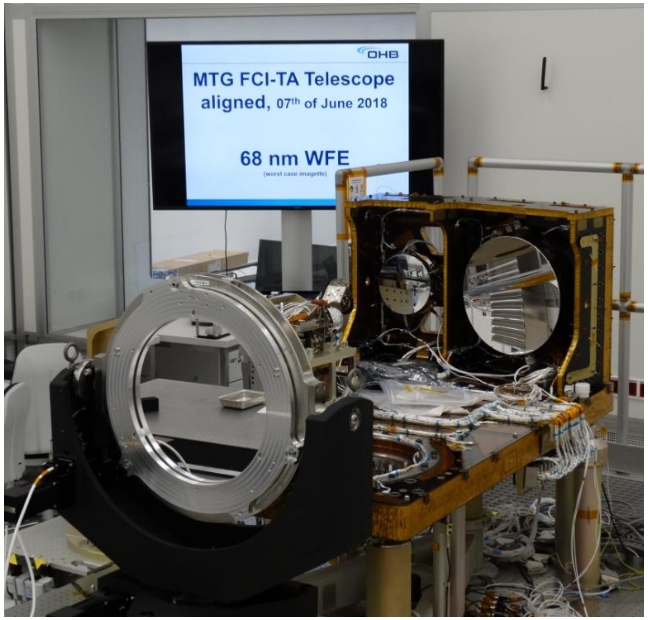
Thales SESO



MTG – Alignment

- Requirements
  - **Accurate** (5µm) and **stable** mounting
  - Fast and **safe** integration
- Mounting concept
  - 3 dimensional wedged shims and pins
- Pre-calculate shim properties
  - Accurate opto-mechanical characterization
  - Data processing of > 40 Coordinate systems





Measure M1 – M4 surface error → Calculate mirror positions (minimze WFE and LOS) → Calculate shim wedge angle thickness and pinhole locations

Measure M1 – M4 optical axis location versus mechanical interface location → Calculate shim wedge angle thickness and pinhole locations

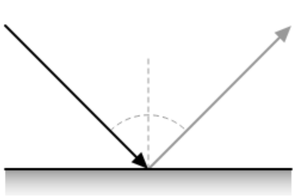
Measure location and flatness of interfaces on structure → Calculate shim wedge angle thickness and pinhole locations

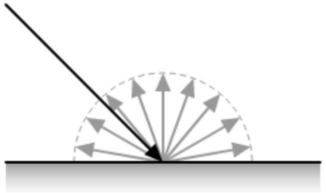
Calculate shim wedge angle thickness and pinhole locations → Manufacture shims and Integrate mirrors with shims on structure

Definition and drivers

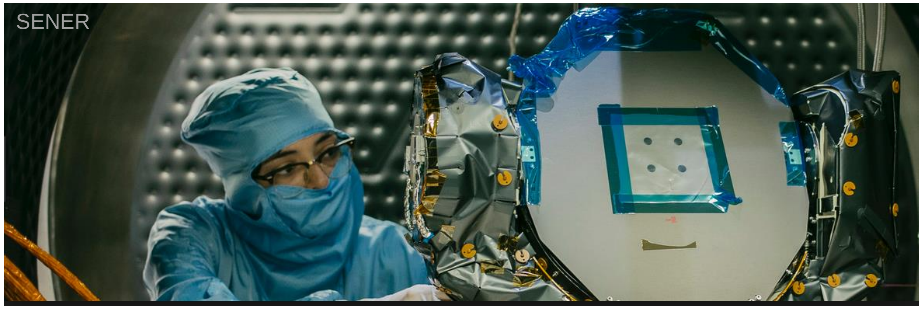
Light scattered to detector, which does not contribute to the intended image.

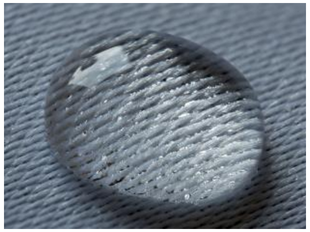
Becomes more and more important with increasing sensitivity of optical sensors.

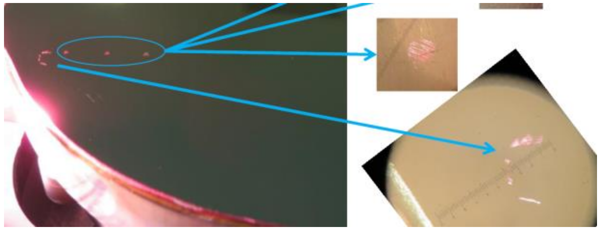




- Reflection from diffractive optics surfaces (e.g. lenses)
- Contamination
- Integration activity
- Surface roughness and defects
- Manufacturing process and scratches







Straylight prediction

- High accuracy modelling needed
- Contamination and high clean room requirements
- Manufacturing process selection and optimization
- Coating selection (anti-reflective coatings, black paint)
- Straylight correction algorithm

Straylight modeling (MTG)

Mirrors: Contamination scatter function

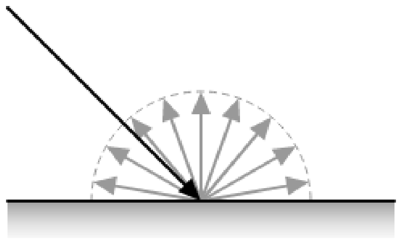
Extract Harvey Shack Parameters

Mirrors: Surface roughness scatter function

Extract Harvey Shack Parameters

Structure: Black paint scatter function

Extract Harvey Shack Parameters



Straylight model of instrument

- **Surface scatter behavior**
- Instrument design (from CAD)
- Light source (earth, sun)
- Ray tracing

Straylight model correlation (MTG)

Mirrors: Contamination scatter function

Extract Harvey Shack Parameters

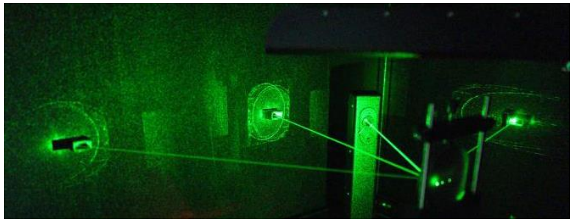
Mirrors: Surface roughness scatter function

Extract Harvey Shack Parameters

Structure: Black paint scatter (baffles) function

Extract Harvey Shack Parameters

Measure samples
- Contamination
- Roughness
- Paint



Straylight model of instrument

- **Surface scatter behavior**
- Instrument design (from CAD)
- Light source (earth, sun)
- Ray tracing

Instrument Straylight test

Use AI/ machine learning to simplify straylight modeling?

Mirrors: Contamination scatter function

Mirrors: Surface roughness scatter function

Structure: Black paint scatter (baffles) function

Measure samples
- Contamination
- Roughness
- Paint

Extract Harvey Shack Parameters

Extract Harvey Shack Parameters

Extract Harvey Shack Parameters

Straylight model of instrument

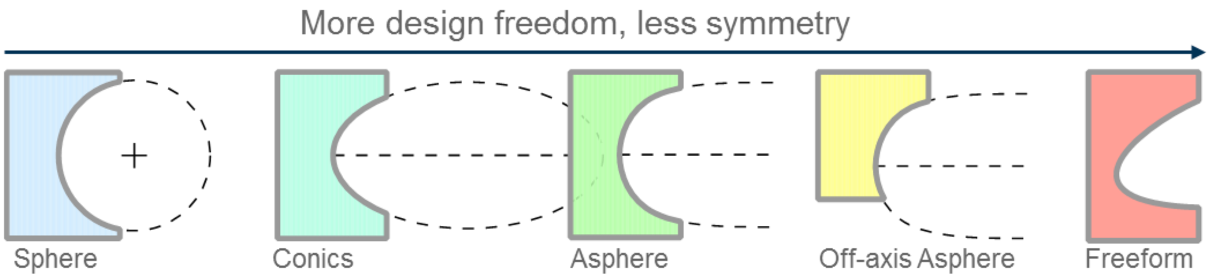
- **Surface scatter behavior**
- Instrument design (from CAD)
- Light source (earth, sun)
- Ray tracing

Instrument Straylight test

Free form optics opportunities

Freeform optics involve optical designs with at least one freeform surface which has no translational or rotational symmetry about axes normal to the mean plane.

- **Boosts performance with reduced size, weight and cost**
- Larger FoV, higher image quality (better aberration correction)
- Reduced number of optical components
- Technological challenges
- High number of degrees of freedom to be handled during design and optimizations
- Classical metrology cannot be applied
- Requires high sophisticated ultraprecision machining



Conclusion

- Earth observation is key to understand our eco-system
- Earth observation data is present in our daily lives
- Earth observation is enabled by challenging optical technologies
- Earth observation technologies are and need to be mastered by multidisciplinary highly skilled engineering teams
- Earth observation application and developments are and will be more and more multi-national
- Crossing and even eliminating the frontiers between engineering disciplines and national engineering communities will be key for our future