

On-orbit MTF and defocus assessment methods applied to SPOT5 cameras

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Objective

- To maintain the best image sharpness during satellite life
 - Periodic assessment of the Modulation Transfer Function (MTF) of SPOT5 HRG cameras
 - » To verify cameras requirements
 - Assessment of possible defocusing
 - » To propose refocusing, if any
 - MTF assessment after refocusing
 - » To verify MTF increase

Main features of SPOT 5

- Two cameras (HRG)
 - Pointing mirrors to set viewing angle
- THR (2.5m), HM (5m) B1, B2, B3 (10m), B4 (20m)
 - HM used for MTF quality control
- Pan mode HM : two linear arrays
 - HMA and HMB shifted 0.5 pixel (CT) and 3.5 pixels (AT)

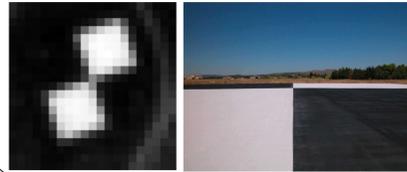
MTF Assessment Methods

□ Absolute MTF

- Slanted edge method
- Due to inclination angle
 - 3 lines needed for oversampling
- Due to the PSF width
 - Only 2 lines available without side effect
- One point out of three is missing in ESF
 - Missing points obtained by interpolation
- MTF obtained by calculating the ratio of FFT of ESF to FFT of Heaviside function
- Mean of upward and downward edges
- Mean of HMA and HMB results

Checkerboard target

- Salon de Provence (south of France)
- 60m x 60m
- White: $\rho = 0.50$ - Dark: $\rho = 0.05$
- Inclination versus satellite track: $\sim 18^\circ$



□ Relative MTF

- Comparison of two HRG cameras
 - Both cameras image the same landscape
 - Frequency content comparison between homologous areas



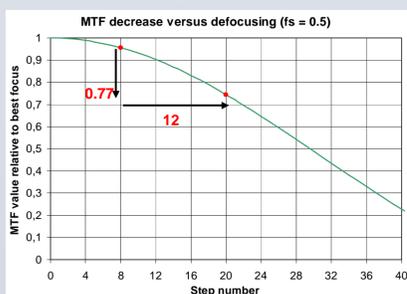
- Integration of image spectra near $0.3 f_s$ ($0.25 f_s$ to $0.35 f_s$)
- Calculation of MTF ratio HRG2/HRG1

Defocusing Assessment Methods

□ Assessment methods without refocusing mechanism activation

- Use of an onboard periodic test target (HRG2 "autotest")
 - Evolution of target image contrast
- Use of a defocusing model by a combination of initial **absolute MTF** and defocusing measurements, and observed **MTF decrease**
- Use of a defocusing model by a combination of initial **relative MTF** and defocusing measurements, and observed **relative MTF evolution**

□ Defocusing assessment using HRG2 absolute MTF



Best focus after initial focusing		
Field area	Center	Right
Cross-track	-2	-8
Along-track	2	0

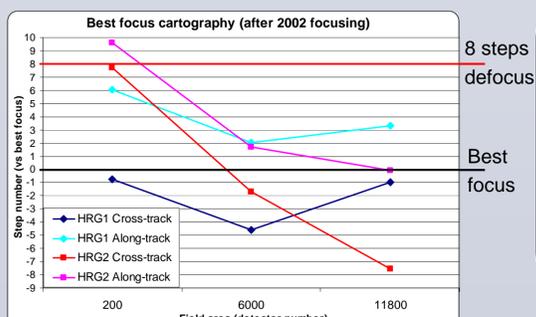
Best focus evolution		
Field area	Center	Right
Cross-track	-15	-12
Along-track	-16	-4

MTF evolution (2002 – 2010)		
Field area	Center	Right
Cross-track	0.81	0.77
Along-track	0.86	0.99

Mean evolution: -12
Some discrepancies

□ Defocusing assessment using Relative MTF

- Best focus versus field area with respect to mean best focus after 2002 focusing



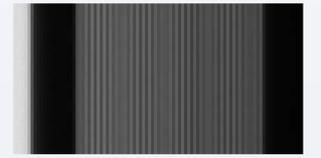
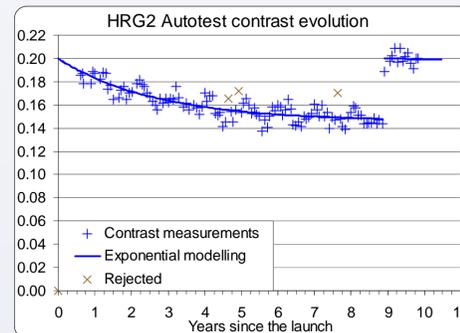
□ Evaluation algorithm

- Supposing mean defocus of p steps (similar for both instruments)
- Calculating defocusing for each field area
- Calculating MTF evolution using defocus modelling (Steel, W. H., *Optica Acta*, 1956)
- Calculating relative MTF
- Searching p for best fitting between calculated relative MTF and measured relative MTF

□ Result of assessment: $p = -10$

Refocusing results

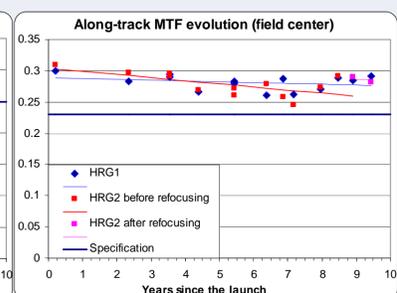
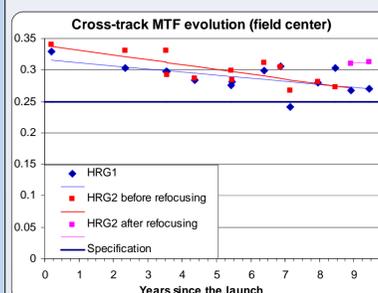
□ Evolution of "autotest" contrast



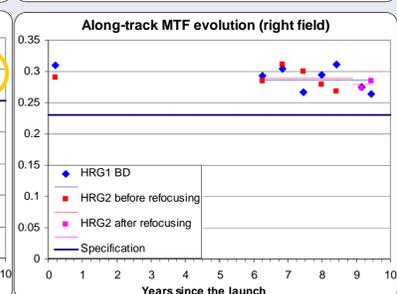
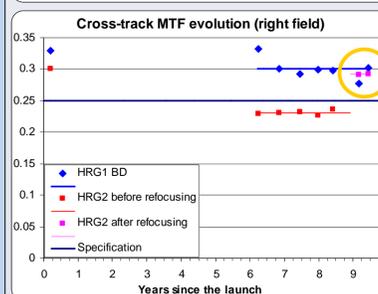
"Autotest" target image

Increase 0.05 after refocusing → Return to initial level

□ Absolute MTF – field center and right field

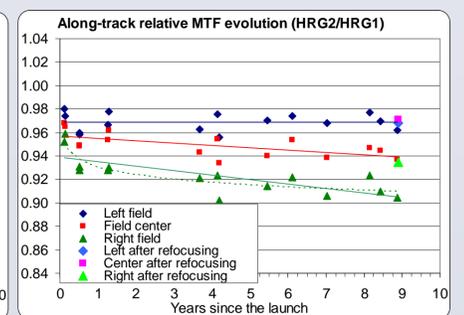
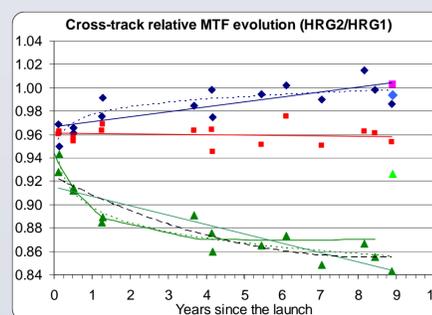


Increase of field center MTF value



Return to initial level for cross-track right field MTF value
→ above specification

□ Relative MTF – field center and two field edges



- Increase of right field value (mainly cross-track direction)
- Similar values to initial values
- Also increase of field center values

Summary

- Periodic cameras MTF assessment showed a slight defocusing for HRG2 (2002 - 2010)
- Defocusing value assessed by combining several methods
 - without refocusing mechanism activation
- MTF assessment after refocusing shows refocusing is sufficient
 - HRG2 MTF requirement is again met in the whole field
- HRG1 MTF requirement is met, therefore no refocusing is needed
- "Autotest" method is specific to SPOT 5 satellite
- Relative MTF measurement is easy to use because of two cameras
- Relative MTF method could also be applied with nimble satellites, e.g. Pleiades

Contract

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References

- On-orbit MTF assessment of satellite cameras
D. Leger, F. Viallefont, Ph. Deliot, and C. Valorge
Post-Launch Calibration of Satellite Sensors, ISPRS 2004
- In-flight refocusing and MTF assessment of SPOT5 HRG and HRS cameras
D. Leger, F. Viallefont, E. Hillairet, and A. Meygret
Proc. SPIE 4881, 224 (2003)

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