Scarab, First Calibration Results
SCARAB first result

On-ground:
- Long wave calibration
- Short wave calibration

In-orbit:
- Radiometric noise
- Thermal leak
- Gain
- A’ factor
- Location
- Registration
- LA/LA2 comparison
Long wave calibration

Intespace facility
SCARAB / on ground calibration
Two high performance Black Bodies (HGH)

Theorical emissivity
>0.9993

Hot BB temperature :
223° / 323°K

Cold BB filled with
Liquid nitrogen
SCARAB / on ground calibration

- Short wave calibration
- CNES facility
Method:

Uniform data: use of « space » pixels

Standard deviation of 3 pixels x 500 scans

MS mode only (channel 2&3 with solar filter), once per month

Results:

<table>
<thead>
<tr>
<th></th>
<th>Channel 1 visible</th>
<th>Channel 2 solar</th>
<th>Channel 3 total</th>
<th>Channel 4 IR window</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max radiometric noise</td>
<td>LSB</td>
<td>6 LSB</td>
<td>2.5 LSB</td>
<td>2.1 LSB</td>
</tr>
<tr>
<td>Max radiometric noise</td>
<td>W/m²/sr</td>
<td>0.2 W/m²/sr</td>
<td>0.09 W/m²/sr</td>
<td>0.07 W/m²/sr</td>
</tr>
<tr>
<td>Noise requirements</td>
<td>W/m²/sr</td>
<td>1 W/m²/sr</td>
<td>0.5 W/m²/sr</td>
<td>0.5 W/m²/sr</td>
</tr>
</tbody>
</table>

SCARAB first result / noise
Thermal leak:

Channel 2
=> Solar radiance

Thermal leak
=> Thermal radiance

Thermal leak must be evaluated and subtracted to deliver Channel 2 solar radiance.

Thermal leak is estimated from Channel 4
### SCARAB first result / thermal leak

<table>
<thead>
<tr>
<th>Channel 2</th>
<th>Night area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Channel 4</td>
<td></td>
</tr>
<tr>
<td>Level 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Channel 2</td>
<td>STD value : 0.13 W/m²/sr</td>
</tr>
<tr>
<td>Level 1</td>
<td>(not corrected)</td>
</tr>
<tr>
<td></td>
<td>Mean value : 0.03 W/m²/sr</td>
</tr>
<tr>
<td></td>
<td>STD value : 0.06 W/m²/sr</td>
</tr>
<tr>
<td></td>
<td>≈ 2 LSB</td>
</tr>
</tbody>
</table>

\[
L_{2\_SW} = \frac{N_2}{G_{2\_sw}} - \left\{ a_2 \cdot (L_{4\_IRW})^2 + a_1 \cdot L_{4\_IRW} + a_0 \right\}
\]
SCARAB first result / thermal leak

Thermal leak – Evaluation of the efficiency

Night area of 300 scans
Calculation of the mean

Mean < 0.05 W/m²/sr
Thermal leak – Evaluation of the efficiency

Night area of 300 scans
Calculation of the standard deviation

Channel 2, Radiometric noise after thermal correction, night area

STD < 0.11 W/m²/sr < 3 LSB
Gain
Measured with the CALibration Module (CALM)

- 1 lamp for channel 1
- 3 black bodies for channel 2-3-4
- No solar filter on channel 2 (filter wheel)
- CALM mode once per month
SCARAB first result / gain

Channel 1 gain

LSB/W·m²·sr

G1 lamp
G1 on ground
SCARAB first result / gain

LW Gain for Scarab channels 2&3

-32.5
-32.55
-32.6
-32.65
-32.7
-32.75
-32.8
-32.85
-32.9
-32.95
-33
-31.5
-31.55
-31.6
-31.65
-31.7
-31.75
-31.8
-31.85
-31.9
-31.95
-32

G2 LW
G2 LW on ground
G2 stability+0.1%
G2 stability-0.1%
G3 LW
G3 LW on ground
G3 stability+0.1%
G3 stability-0.1%

LSB/ W * m² * sr
SCARAB first result / gain

LW Gain for Scarab channel 4

-206
-206,5
-207
-207,5
-208
-208,5
-209
-209,5
-210


LSB/ W * m² * sr

G4
G4 on ground

+/-0,1%
Gain

Difference between last ground value and in-orbit value ≈ 0.2%

Gain stability is better than +/-2% for channel 1, mainly due to lamp instability.

Gain stability is better than +/-0.1% for channels 2&3.

Gain stability is better than +/-0.2% for channel 4.
SCARAB first result / A’ factor

Channel 2: Solar channel 0.2-4µm Short wave radiance \( L_{sw} \)

Channel 3: Total channel 0.2-200µm Total radiance \( L_{total} \)

Channel 5: Infrared channel 4-200µm long wave radiance \( L_{lw} \)

Channel 5 is computed with:

\[
L_{lw} = L_{total} - A' \times L_{sw}
\]

When channels 2&3 observe a same pure SW source, A’ can be evaluated by:

\[
A' = \frac{L_{total}}{L_{sw}} = \frac{L_3}{L_2}
\]

A’ represents the difference of sensibility in the SW domain, between channel 2 and channel 3.
SCARAB first result / A’ factor

**MS Mode:**

Channel 2 AND Channel 3 have an identical silica filter

=> Both observe the same pure SW source

=> $A_{ms} = \frac{N_3}{N_2}$

=> $A' = A_{ms} \times \frac{G_{2_{sw}}}{G_3} / T_{filter}$

$T_{filter}$ must be known accurately with on-ground measurements!
SCARAB first result / A’ factor

MS Mode:

The difference between the in orbit value and the sphere value is less than 0.2%.
The stability of the A’ms factor is about +/-0.05% for this first year.
SCARAB first result / A’ factor

Nominal Mode:

Selection of bright clouds:
\[ L_{sw} > 250 \text{ W/m}^2/\text{sr} \]
\[ L_{ir\_window} < 5\text{ W/m}^2/\text{sr} \ (223K) \]

Selection of homogenous area:
10%

Evaluation of LW radiance with Channel 4, with a polynomial P:
\[ L_{LW\_estimated} = P(L_{ir\_window}) \]

Evaluation of A’:
\[ A' = \frac{L_{3\_total} - L_{lw\_estimated}}{L_{2\_sw}} \]
Nominal Mode:

A’ value on clouds (nominal image)
SCARAB first result / A’ factor

Comparison for the first three months

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A’ from MS mode</td>
<td>0.9159</td>
</tr>
<tr>
<td>A’ nominal</td>
<td>0.9180</td>
</tr>
</tbody>
</table>

The difference is around 0.2%
Absolute pointing location

Comparison by massive correlation between Scarab and VeGeTation images.

VGT images: geolocation accuracy of less than 1km
resolution is 1 km
VGT Band 2 is used
cloud free images
Absolute pointing location

Figure 1: Orbit 666 extract from scan 1 to scan 221,
Resampled VGT on the top, SCARAB C2 below
### SCARAB first result / Absolute pointing location

#### Absolute pointing location

<table>
<thead>
<tr>
<th></th>
<th>Nadir</th>
<th>Swath border</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>across track</td>
<td>along track</td>
</tr>
<tr>
<td></td>
<td>across track</td>
<td>along track</td>
</tr>
<tr>
<td>Maximum bias measured</td>
<td>0.4 km</td>
<td>1.3 km</td>
</tr>
<tr>
<td></td>
<td>1.5 km</td>
<td>2.3 km</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>1 km</td>
<td>1 km</td>
</tr>
<tr>
<td></td>
<td>1 km</td>
<td>1 km</td>
</tr>
<tr>
<td>VGT geolocation accuracy less than 1 km</td>
<td>1 km</td>
<td>1 km</td>
</tr>
<tr>
<td></td>
<td>1 km</td>
<td>1 km</td>
</tr>
<tr>
<td>Total</td>
<td>2.4 km</td>
<td>3.4 km</td>
</tr>
<tr>
<td>Requirement</td>
<td>5 km</td>
<td>5 km</td>
</tr>
</tbody>
</table>
Registration

Massive correlation between channels

Nominal mode and MT mode

Across track and along track shifts histograms between C3 and C2 respectively in red and white for MT mode products
## SCARAB first result / Registration

### Registration for level 1A

<table>
<thead>
<tr>
<th></th>
<th>C1/C2</th>
<th>C3/C2</th>
<th>C4/C3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anticipated surface registration (on-ground measurement)</td>
<td>89 %</td>
<td>97.4 %</td>
<td>93 %</td>
</tr>
<tr>
<td>In orbit measured value</td>
<td>92.1 %</td>
<td>97.3-97.8%</td>
<td>98 %</td>
</tr>
<tr>
<td>Level 1A</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Level 1A2 : All channels are resampled on channel 2

<table>
<thead>
<tr>
<th></th>
<th>C1/C2</th>
<th>C3/C2</th>
<th>C4/C3</th>
</tr>
</thead>
<tbody>
<tr>
<td>In orbit measured value</td>
<td>98.2 %</td>
<td>99.3 %</td>
<td>99.4 %</td>
</tr>
<tr>
<td>Level 1A2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
To compute synthetic channel 5:

\[ L_{lw} = L_{tot} - A'L_{sw} \]

Channel 3 \( (L_{tot}) \) and Channel 2 \( (L_{sw}) \) must aim at the same location.

At level 1A, the covering of channel 2 by channel 3 is around 98% \( (0.05^\circ) \)

As Scarab respects Shannon theorem, it is possible to resample channel 3 on channel 2 with a low level of artifacts, to generate L1A2 products

How to compare the 2 products?

=> With MS mode, Channel 2 and Channel 3 are identical!
=> \( C5 \) should be equal to 0
SCARAB first result / L1A-L1A2 comparison

MS mode 3775

Ch 2

Ch 3

Ch 5
L1A

CH5
L1A2
SCARAB first result / L1A-L1A2 comparison

Ch 2

Lake Malawi / Tanganika

Ch 5
L1A

CH5
L1A2

Madagascar

Madagascar coast

Madagascar coast
<table>
<thead>
<tr>
<th></th>
<th>Standart deviation W/m²/sr</th>
<th>Min W/m²/sr</th>
<th>Max W/m²/sr</th>
<th>Mean W/m²/sr</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2</td>
<td></td>
<td></td>
<td></td>
<td>48</td>
</tr>
<tr>
<td>C5_A</td>
<td>0.57</td>
<td>-3.8</td>
<td>7.8</td>
<td></td>
</tr>
<tr>
<td>C5_A2</td>
<td>0.41</td>
<td>-2.9</td>
<td>7.6</td>
<td></td>
</tr>
</tbody>
</table>

=> No artifacts on level A2  
=> Better performances on level A2
Estimation of the absolute calibration error for Channel 5 (LW channel), function of the short wave radiance:

\[ e_{A1}(L_{2\_sw}) = \frac{\sigma_{C5\_A1}(L_{2\_sw})}{L_{2\_sw}} \]
This value is calculated for the MS mode orbit 3775 for each interval of SW radiance.

For L1A:
- 0.4% at 220 W/m²/sr to 1.2% at 20 W/m²/sr

For L1A2:
- 0.3% at 220 W/m²/sr to 0.9% at 20 W/m²/sr
The absolute calibration budget can be established:

<table>
<thead>
<tr>
<th>L1A2</th>
<th>Bright clouds</th>
<th>Hot / bright scene</th>
<th>Night scene</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>250 SW + 50 LW</td>
<td>210 SW + 130 LW (20°)</td>
<td>0 SW + 80 LW</td>
</tr>
<tr>
<td>Instrumental noise</td>
<td>Random</td>
<td>0.21%</td>
<td>0.11%</td>
</tr>
<tr>
<td>Calibration CALM</td>
<td>Bias</td>
<td>0.12%</td>
<td>0.12%</td>
</tr>
<tr>
<td><strong>A’ factor (0.2%)</strong></td>
<td>Random</td>
<td>1%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Registration and spectral effects</td>
<td>Random</td>
<td>1.5%</td>
<td>0.55%</td>
</tr>
<tr>
<td>Location</td>
<td>Random</td>
<td>0.4%</td>
<td>0.40%</td>
</tr>
<tr>
<td>Budget @1σ %</td>
<td></td>
<td>1.9%</td>
<td>0.8%</td>
</tr>
<tr>
<td>Budget @1σ W/m²/sr</td>
<td></td>
<td>0.95</td>
<td>1.0</td>
</tr>
<tr>
<td>Requirement</td>
<td></td>
<td></td>
<td>1%</td>
</tr>
</tbody>
</table>
Absolute calibration of channel 2 was made in front of an integrating sphere at CNES facilities.

<table>
<thead>
<tr>
<th>Items</th>
<th>Value</th>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short wave calibration (sphere)</td>
<td>3% @2σ</td>
<td>Biais</td>
<td>1.5%</td>
</tr>
<tr>
<td>Error on spectral response</td>
<td></td>
<td>Biais</td>
<td>0.4%</td>
</tr>
<tr>
<td>Thermal gain correction</td>
<td>0.08%/°</td>
<td>Random</td>
<td>0.03%</td>
</tr>
<tr>
<td>dT= 0.04° @1σ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20% of the thermal leak @1σ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal leak correction</td>
<td>20% of the thermal leak @1σ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>0.06°@1σ</td>
<td>Random</td>
<td>0.4%</td>
</tr>
<tr>
<td>Budget at 1 sigma</td>
<td></td>
<td></td>
<td>1.6%</td>
</tr>
</tbody>
</table>
### SCARAB first result / Conclusion

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Status</th>
<th>Coherence with on-ground value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiometric noise</td>
<td>=&gt; Very low</td>
<td></td>
</tr>
<tr>
<td>Thermal leak</td>
<td>=&gt; Coherent with on-ground value</td>
<td></td>
</tr>
<tr>
<td>Gain value</td>
<td>=&gt; Very stable</td>
<td>0.2%</td>
</tr>
<tr>
<td></td>
<td>=&gt; Coherence with on-ground value</td>
<td></td>
</tr>
<tr>
<td>A’ factor</td>
<td>=&gt; Very stable</td>
<td>0.2%</td>
</tr>
<tr>
<td></td>
<td>=&gt; Coherence with on-ground value</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>&lt;5 km as required</td>
<td></td>
</tr>
<tr>
<td>Registration</td>
<td>=&gt; Coherent with on-ground value</td>
<td></td>
</tr>
<tr>
<td></td>
<td>=&gt; Very good for L1A2 product</td>
<td></td>
</tr>
</tbody>
</table>