a stepping stone for Global Troposphere Monitoring

L. Maresi – European Space Agency
W. Van Der Meulen – Netherland Space Office
J. de Vries – Dutch Space
TROPOMI, a stepping stone for Global Troposphere Monitoring

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Two layers of communication

- Engineers ➔ Technology solutions & innovations
- Project & Line Managers ➔ Tailoring project and resources
TROPOMI = Troposphere and Ozone Monitoring Instrument
TROPOMI, mission objectives

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TROPOMI, mission objectives

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Spatial & Temporal Evolution of Trace Gases & aerosols
**TROPOMI, mission objectives**

Spatial & Temporal Evolution of **Trace Gases & aerosols**

*Air quality*: Air quality forecasts & enforcement of international protocols

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TROPOMI, mission objectives

Spatial & Temporal Evolution of Trace Gases & aerosols

**Air quality:** Air quality forecasts & enforcement of international protocols

**Climate:** Heat forcing generated by green houses gases (among which methane)
Spatial & Temporal Evolution of *Trace Gases & aerosols*

**Air quality:** Air quality forecasts & enforcement of international protocols

**Climate:** Heat forcing generated by green houses gases (among which methane)

**Weather Forecasts:** Effects of chemical processes on the weather
**TROPOMI, mission objectives**

**Spatial & Temporal Evolution of Trace Gases & aerosols**

- **Climate:** Heat forcing generated by greenhouse gases (among which methane).
- **Air quality:** Air quality forecasts & enforcement of international protocols.
- **Weather Forecasts:** Effects of chemical processes on the weather.

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- Nitrogen: 78%
- Oxygen: 29%
- Argon: 1%
- 'All others', i.e. "Trace Gases" < 2%

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## Level 2 Data Products

<table>
<thead>
<tr>
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<th>Concentration</th>
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<tbody>
<tr>
<td>Sulphur Dioxide (SO2)</td>
<td>20 ppb</td>
</tr>
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<td>Nitrogen Dioxide (NO2)</td>
<td>30 ppb</td>
</tr>
<tr>
<td>Carbon Monoxide (CO)</td>
<td>0.1 ppm</td>
</tr>
<tr>
<td>Methane (CH4)</td>
<td>1.8 ppm</td>
</tr>
<tr>
<td>Glyoxal (CHOCHO)</td>
<td>1 ppb</td>
</tr>
<tr>
<td>Formaldehyde (HCHO)</td>
<td>1 ppb</td>
</tr>
<tr>
<td>Bromine Monoxide (BrO)</td>
<td>10 ppt</td>
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1 ppm: 1 Gallon in an Olympic swimming pool
## TROPOMI, mission objectives

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TROPOMI, instrument overview

What's new?

• 100 times better spatial resolution wrt to OMI/SCHIAMACHY
• Xy times more spectral bands
• SWIR channel

What are the innovations

• Optics Manufacturing (SPDT)
• Large (and fast) CCDs
• Large Format SWIR
TROPOMI, instrument overview

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SCHIAMACHY – CO
GOME2 – NO2

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TROPOMI, instrument overview
Measurement Method: Differential Optical Absorption Spectroradiometry
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Instrument Configuration:
- Four grating spectrometers ranging from UV to SWIR
- A common telescope with a Field of view 108 degrees
**TROPOMI, instrument overview**

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<th>Spectrometer</th>
<th>Band</th>
<th>Spectral properties (nm)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Range</td>
</tr>
<tr>
<td>UV</td>
<td>1</td>
<td>270–300</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>300–320</td>
</tr>
<tr>
<td>UVIS</td>
<td>3</td>
<td>310–405</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>405–500</td>
</tr>
<tr>
<td>NIR</td>
<td>5</td>
<td>675–725</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>725–775</td>
</tr>
<tr>
<td>SWIR</td>
<td>7</td>
<td>2305–2385</td>
</tr>
</tbody>
</table>
**TROPOMI, instrument overview**

**Reference Radiance**

$log_{10}(\text{ph}(\text{scm}^2\cdot\text{sr}\cdot\text{nm}))$

$265 \quad 270 \quad 275 \quad 280 \quad 285 \quad 290 \quad 295 \quad 3$

**reflectance $r = 1/F_o$, $A = 5\%$, SZA = 70°**
TROPOMI, on Sentinel 5 Precursor

The Astrium AstroBus 250 on a 820 Km Polar Orbit
PROTFLIGHT Approach

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**Scientific Objectives**

**Mission Definition**

**Payload**

**Thermal Control & Str.**

**Telescope**

**SWIR**

**UV/VIS/NIR**

**Electronics**

**Electronics**

**I/F Control Unit**

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Universal Gantt Chart

1. Analyze
2. Plan
3. Execute
4. Re-baseline
5. Execute
6. Re-baseline
7. Execute
8. Cold Slap of Reality
9. Switch to "Agile" Method
10. Finish Project Very, Very Late
11. Pretend You Can Avoid This Next Time

rashnull.com
Project Jumpstarting: lessons learned from TROPOMI

The NTCP Reference Frame

Technology

Pace

Complexity

Novelty

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Project Jumpstarting: lessons learned from TROPOMI - The NTCP Reference Frame

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Project Jumpstarting: lessons learned from TROPOMI

The NTCP Reference Frame

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“Life is really simple, but we insist on making it complicated.” — Confucius
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“Atmospheric Chemistry is really complicated, but we insist in making it simple”
- Harry Foerster
“Life is really simple, but we insist on making it complicated.” — Confucius

“Atmospheric Chemistry is really complicated, but we insist in making it simple”
- Harry Foerster

“This project has only two speed: forward and fast forward” – Kevin McMullan
Technology Platform & Technology Evolution.
TROPOMI, a technology platform

Technology Platform & Technology Evolution.
Dinosaurs went extinct 31,000 years after a meteorites impacted the Earth 65 million years ago.
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Palm went out of business 31 months after its peak market success.
Q#1: What is our competitive advantage?
Q#2: What can we reuse for the next generation?
Q#3: What technologies may will make the design obsolete?

What is our Technology Platform?
The Technology Platform of TROPOMI is a stepping stone for future atmospheric chemistry missions.
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OMI was launched on 2004, first data on SO$_2$ were released in 2008.

Atmospheric Chemistry is still in his infancy.
Which direction to go?
Which direction to go?

Bigger & Better

Smaller & Smarter
Which direction to go?

Bigger & Better

Smaller & Smarter

“It’s too complicated, too different, you won't have any users. Come back with something standard” - comment of an app developer to the new Palm OS
Which direction to go?

Bigger & Better

Smaller & Smarter

A simplified ‘entry level’ version of TROPOMI will have a larger user base and will to ensure continuity to the cluster of expertise.
Stakeholder analysis

Industry will have less margin

Engineers don’t see it challenging

National Agencies & ESA won’t break the news with a simpler instrument.

The Scientist not interested in an instrument with similar performance.

→ nobody is interested in supporting a more affordable instrument:

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Smaller and simpler?

Convincing arguments WANTED!!

Hey, I really don’t get it!
“If you're not confused, you were not paying attention.” — Tom Peters,
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“The real discovery is not in finding new lands but in seeing with new eyes.” – Marcel Proust
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Technology

Freeform Telescope
Immerse Grating (SWIR)
Detectors (UV/VIS & SWIR)

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Complexity

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Freeform Telescope Immerse Grating (SWIR) 
Detectors (UV/VIS & SWIR)

Novel product retrieval, not yet used in NWP, first instrument to retrieve CH4

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Freeform Telescope Immerse Grating (SWIR) Detectors (UV/VIS & SWIR)

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Procurement Constraints

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Complexity
European Space Agency

Novelty

Freeform Telescope Immerse Grating (SWIR) Detectors (UV/VIS & SWIR)

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Precursor Mission

Procurement Constraints

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Novel product retrieval, not yet used in NWP, first instrument to retrieve CH4

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Delegation, Operative autonomy

Define overall objectives, check and re-assess

"Skunk works" full team – full time

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Technology

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