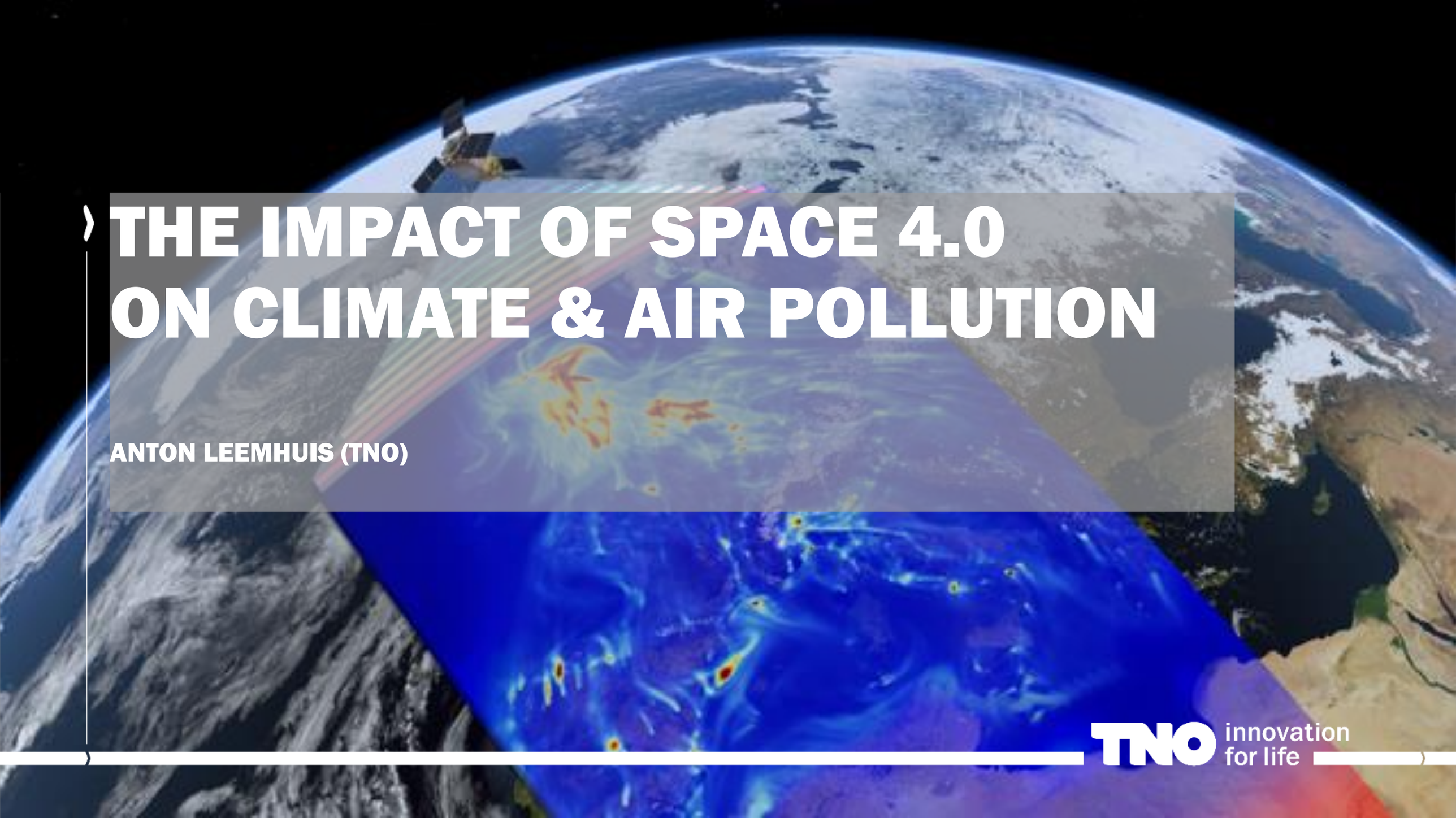
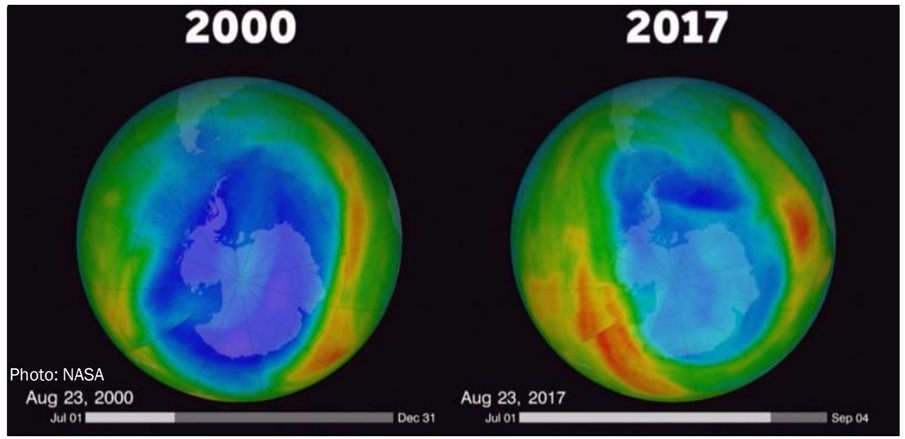


THE IMPACT OF SPACE 4.0 ON CLIMATE & AIR POLLUTION

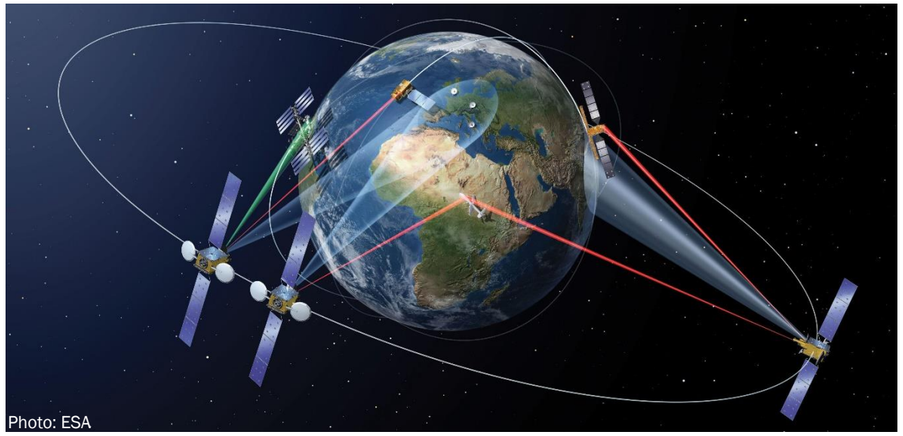
ANTON LEEMHUIS (TNO)

TNO innovation for life

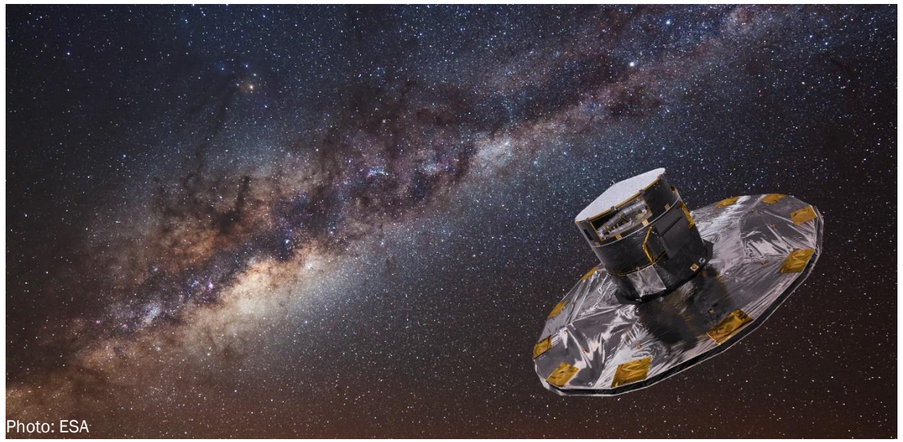
MISSION: WHY TNO SPACE & SCIENTIFIC INSTRUMENTATION?



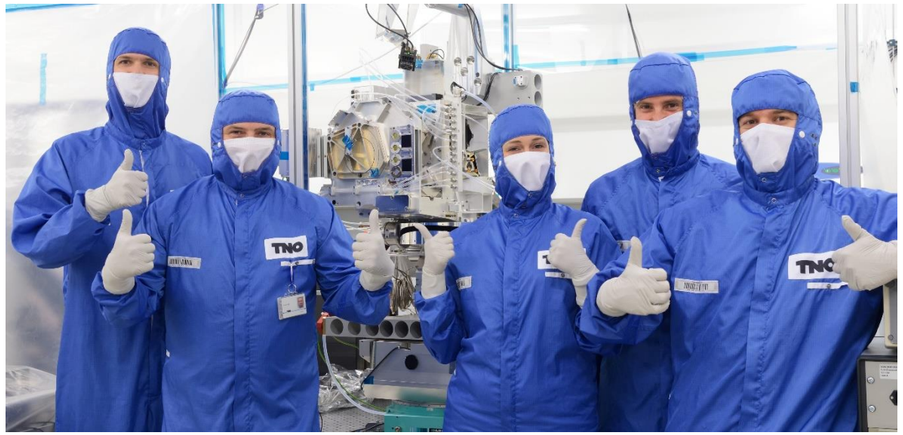
Preventing Climate Change & Air Pollution



Enabling Secure Broadband Connectivity



Understanding the Universe



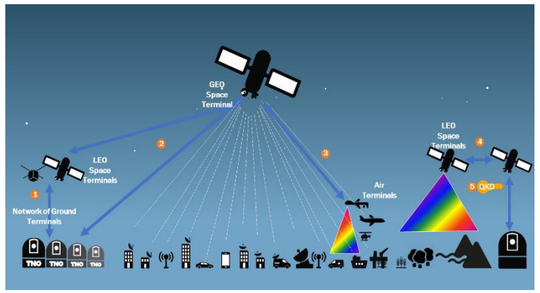
Stimulating Economic Growth in NL and EU

TNO innovation for life

OUR PORTFOLIO

Instruments for Earth Observation

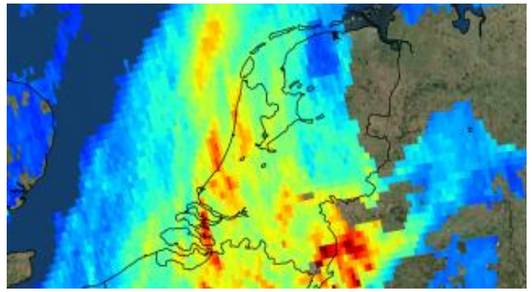
Satellite Communication: Laser & RF



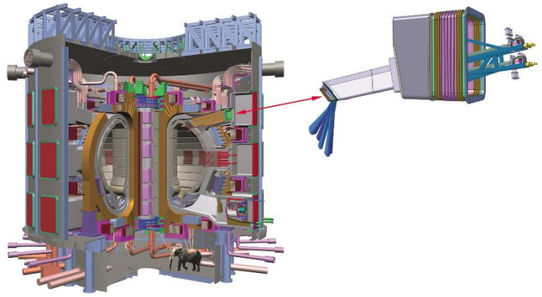
Instruments for Ground based Astronomy

Instruments for Space based Astronomy

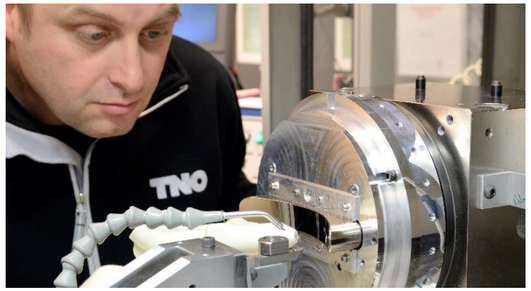
Space Data Utilization: Air Quality Modelling



Scientific Instrumentation



High End Optics Manufacturing



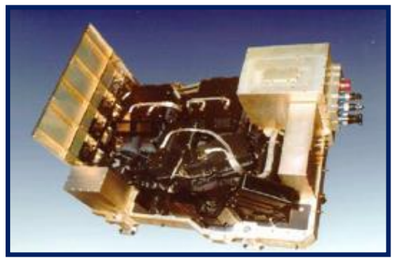
CLIMATE & AIR POLLUTION

AIRBUS DEFENCE & SPACE NL

Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Verkeer en Waterstaat

SRON Netherlands Institute for Space Research

esa



GOME / GOME-2
1995 ERS-2
2006-2020+ METOP1, 2, 3

esa

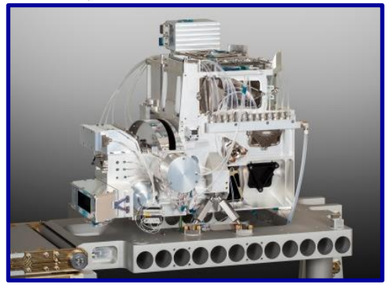
SCIAMACHY
2002

NASA

OMI
2004

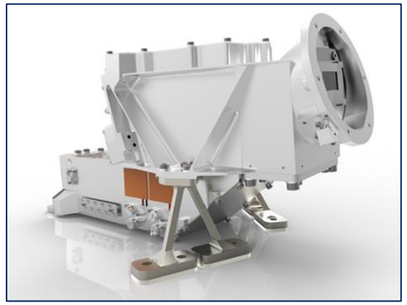
Netherlands Space Office

esa



TROPOMI
2017

esa



Sentinel 5
2021

1995

2020+

Satellite instruments to monitor our atmosphere

TNO innovation for life

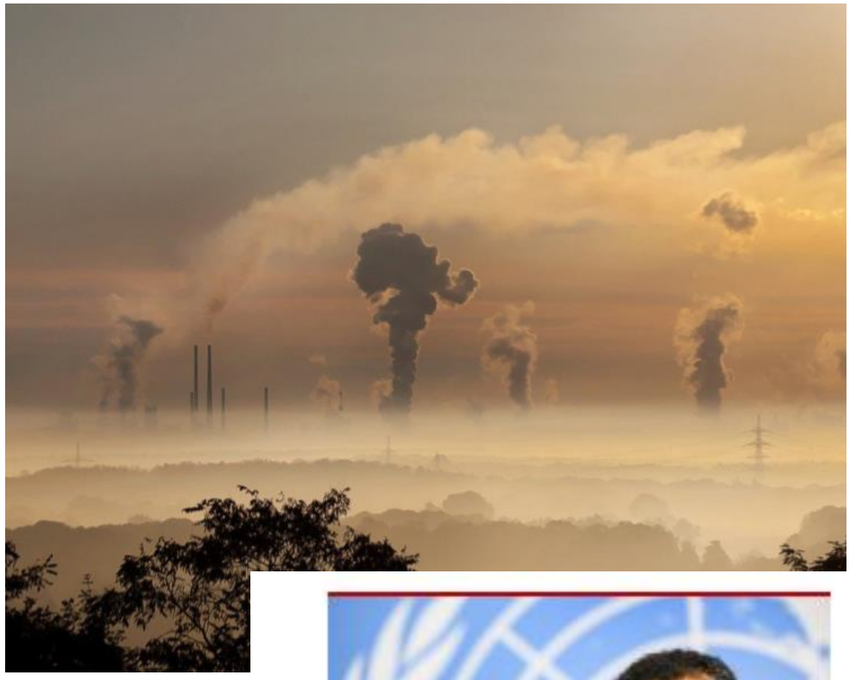
THE PROBLEM

Green house gas emissions

- Global temperature rise
- Results in shifting weather patterns, threatens food production, rising sea levels and increases the risk of catastrophic flooding
- CO2, CH4, N2)

Air pollution emissions

- Health risk due to toxic chemicals or compounds in the air
- 7 million premature deaths in 2017 according to WHO
- 91% world population lives in areas above WHO limits
- Pollution levels globally are growing
- Nitrogen dioxide (NO2), Ozon (O3), Aerosols (particles), ammonia (NH3), SO2 and CO



Air pollution is the 'new tobacco', warns WHO head

TNO innovation for life

IMPORTANCE OF ATMOSPHERIC MONITORING

Satellite instruments have unique capabilities to monitoring green house gas emissions and air pollution

- **Provide independent measurement**
  - Currently there is a lack of reliable figures (provided by individual countries, organization and industry)
  - Most emission numbers not based on measurements
- **At a global scale**
  - Atmospheric measurement sites are few (dozens in NL)
  - Many countries hardly have them at all
- **Frequent reporting & action**
  - Currently emission are reported annually, not when issues occur or action is needed

Science & Environment

Polluters exposed by new eye in the sky satellite

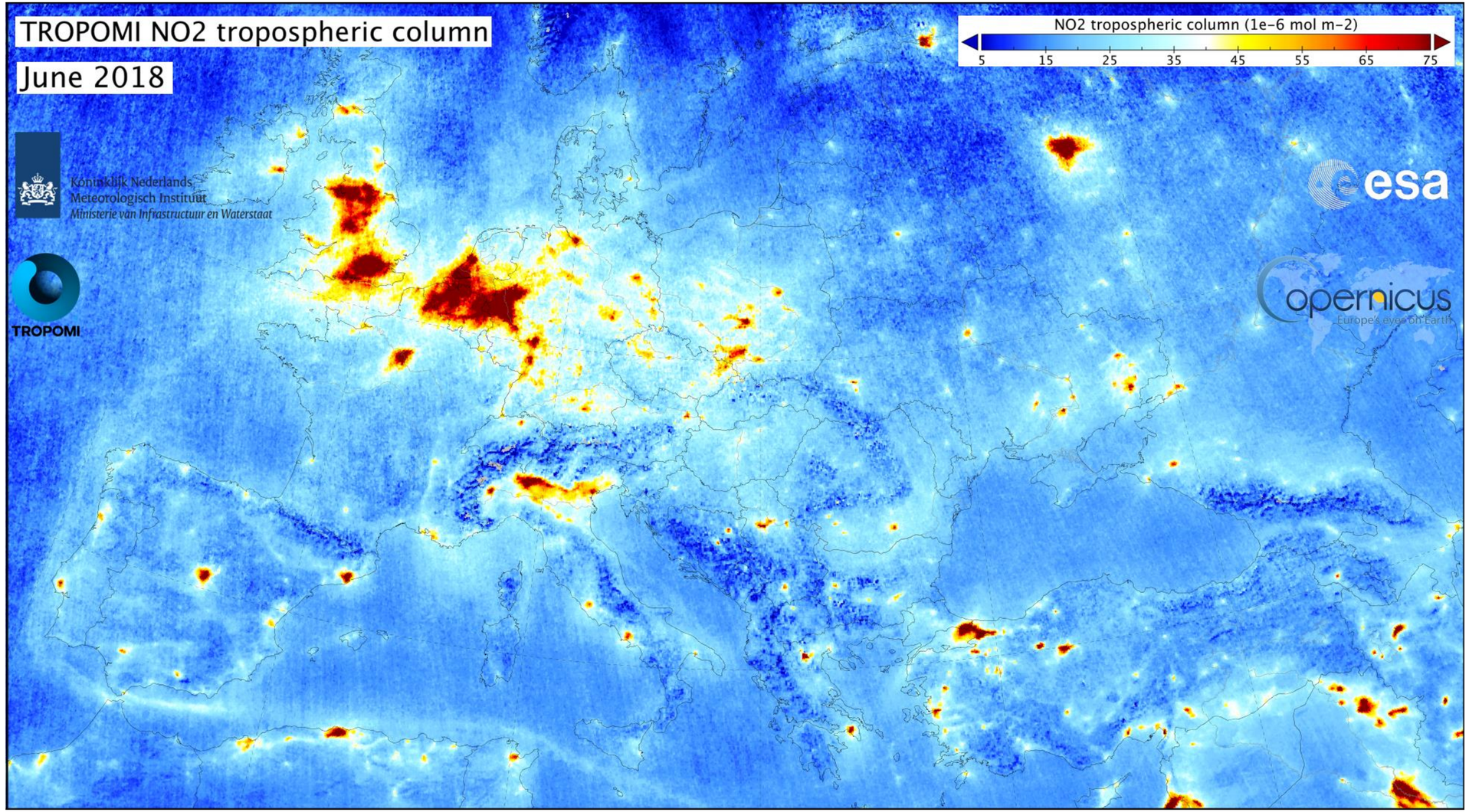
By Jonathan Amos
BBC Science Correspondent

5 July 2018

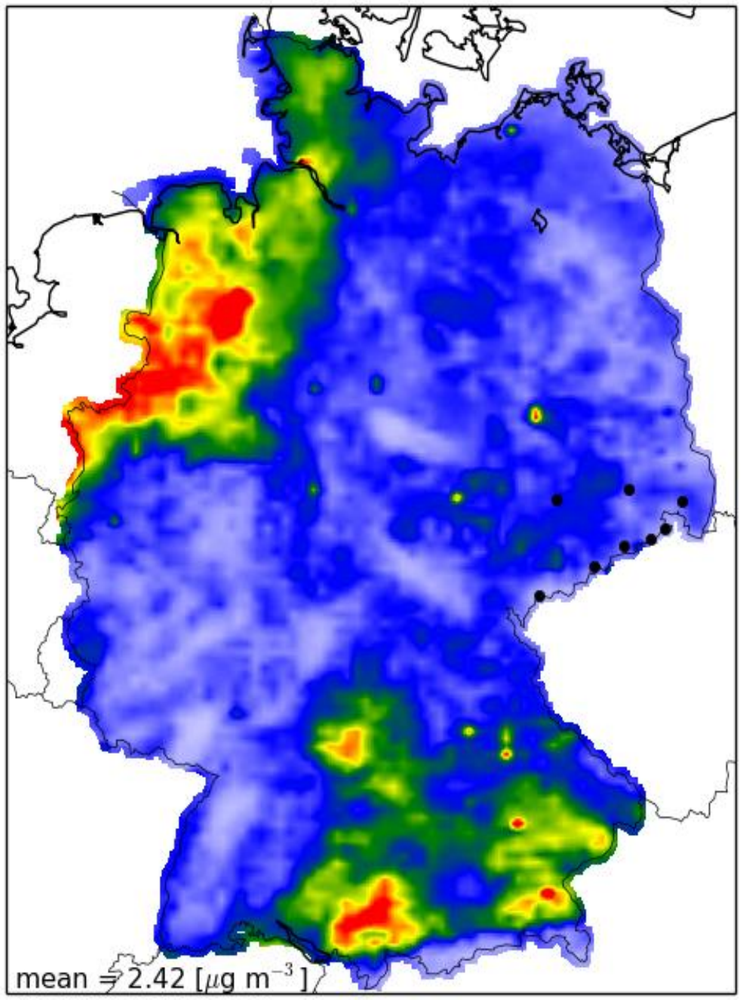
Artwork: It will be the autumn before S5P-Tropomi is fully operational for all the gases it monitors

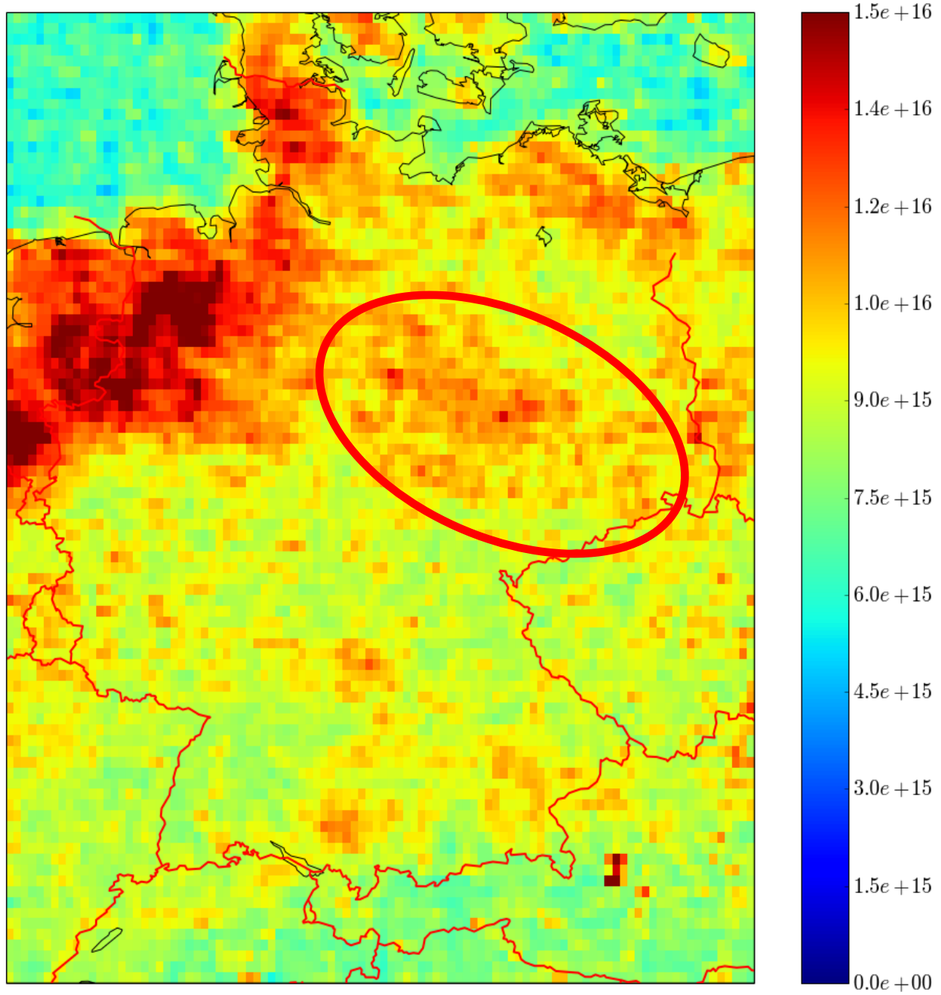
International attention for the Dutch instrument TROPOMI

MONITORING


TROPOMI NO2 tropospheric column
June 2018
NO2 tropospheric column (1e-6 mol m-2)
5
15
25
35
45
55
65
75
Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat
TROPOMI
esa
opernicus
Europe's eyes on Earth

VERIFICATION





TNO comparison of atmospheric NH3 concertation based on report emissions to satellite 8 year average (IASI)

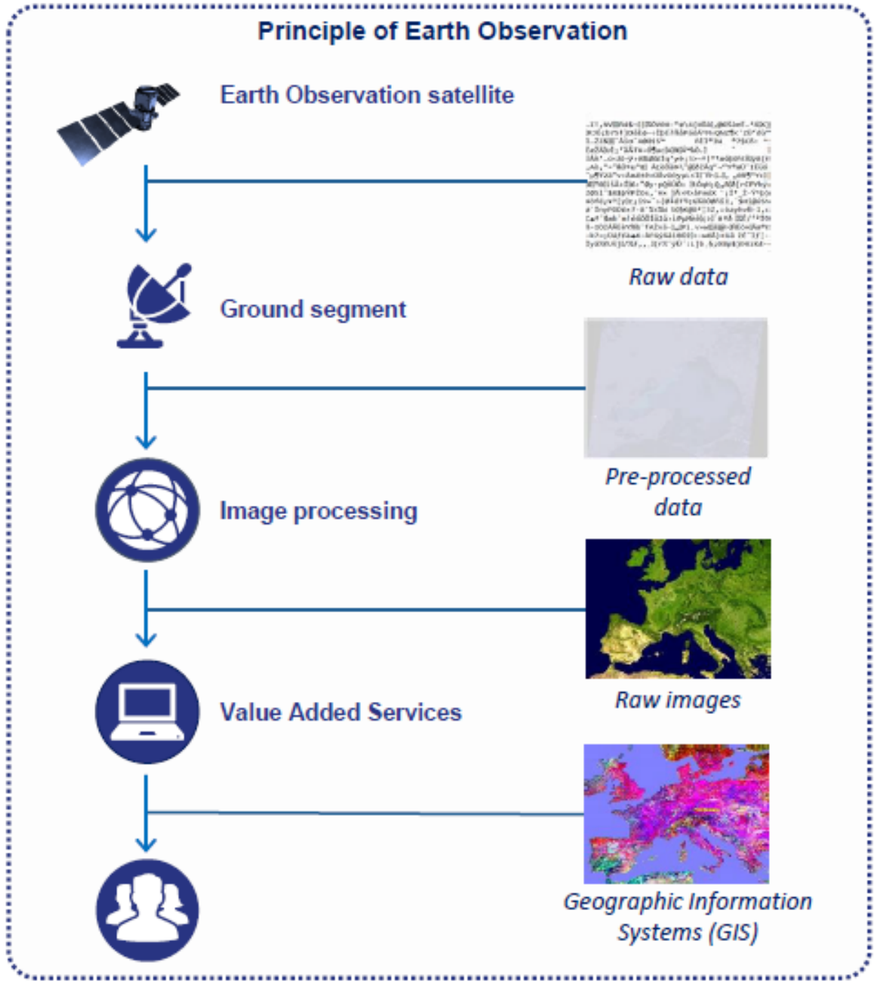
CHALLENGES: CAN SPACE 4.0 HELP?

Challenges

- Green house gas emissions and air pollution are on a fast rise
- Atmospheric concentrations can be monitored, emission sources often not yet
- Monitoring technologies become more complex
- Technology & mission development takes long
- Budgets needed are large (billions)

How could Space 4.0 contribute?

- New players like e.g. private enterprise
- End-to-end solutions
- New technologies like small sats



SMALL SATELLITE

Current satellites:

- Measuring global levels of pollutions
- Can measure only very large source, few in EU and US
- Single overpass/ day
- Price ~100’s millions

Small satellite/ Nano sat

- Measure in smaller areas at higher resolution (e.g. < 1km)
- Increase revisit frequency by flying multiple satellites
- Price ~1-10’s millions

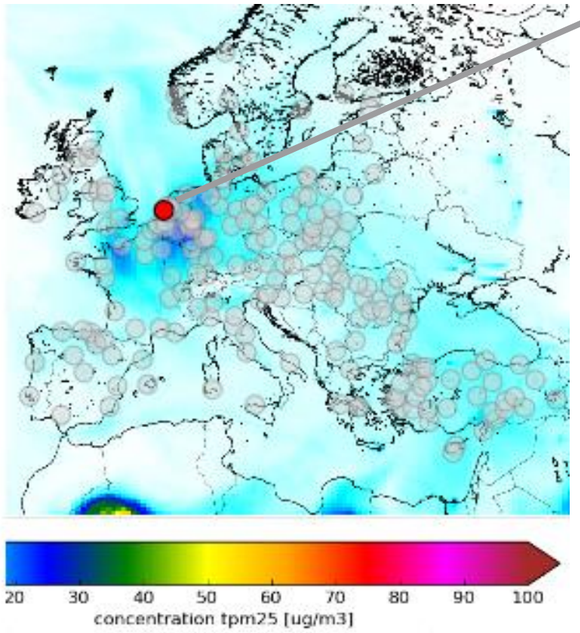
Good position Netherlands

- TNO small instruments based on TROPOMI heritage
- Industrial cooperation ISIS Space Solutions, Airbus DS Netherlands, S&T

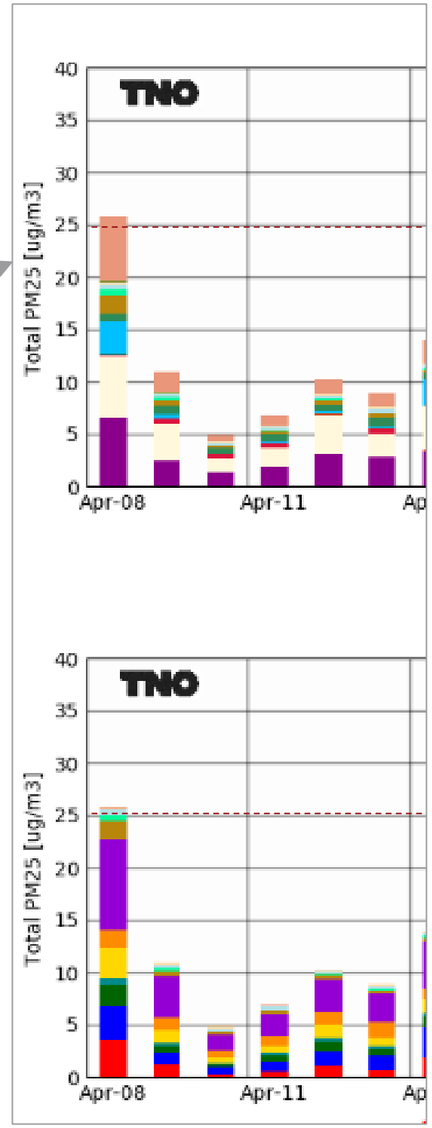
AIRBUS DEFENCE & SPACE ISIS s[&]t TNO innovation for life

INFORMATION PRODUCTS

TNO's innovative TOPAS system: identification location and origin of pollution.



https://topas.tno.nl/

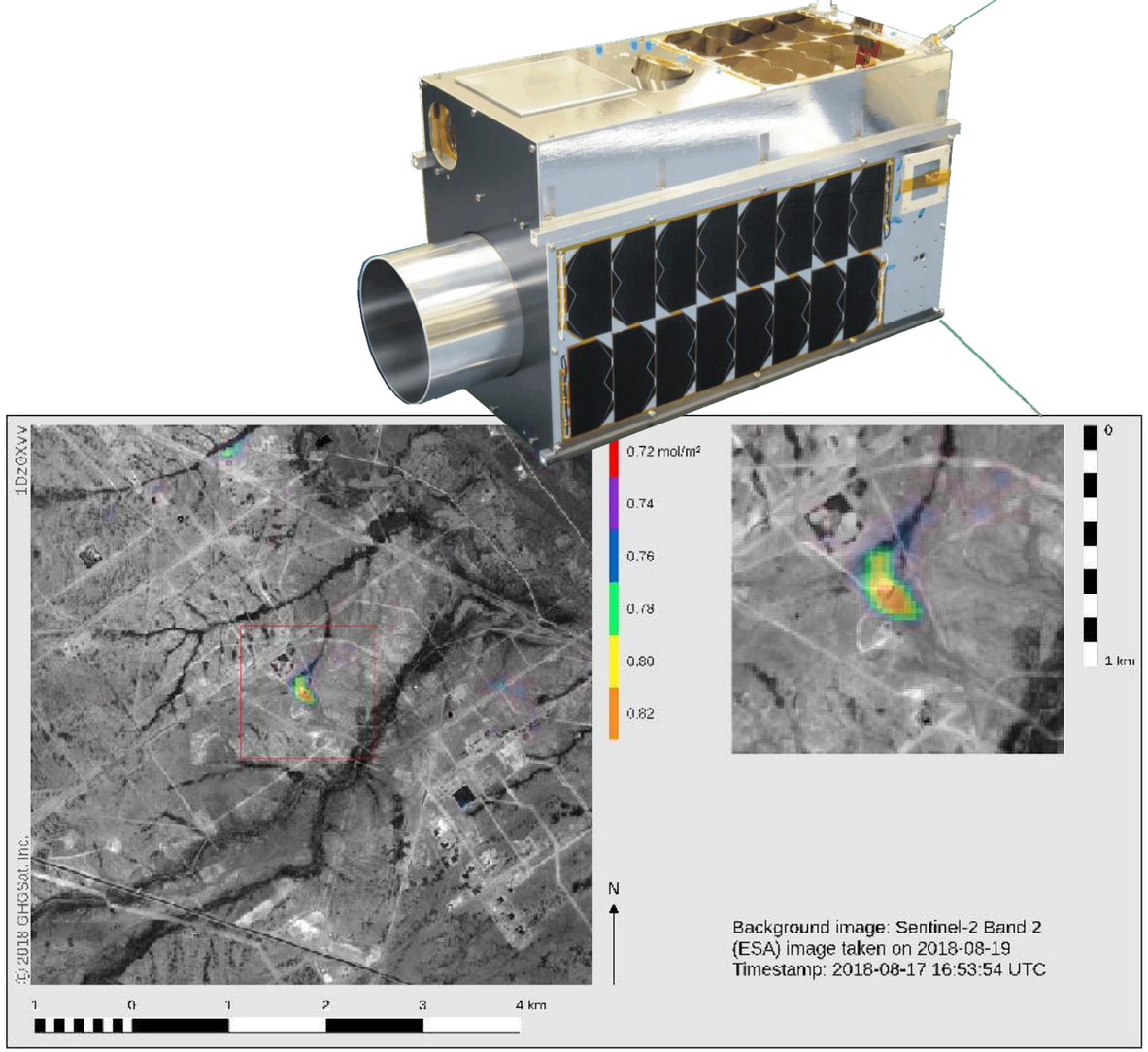


Country Contribution to Air Quality The Hague (aerosol/ PM25)

Sector Contribution to Air Quality The Hague (aerosol/ PM25)

NL annual average treshold 20 ug/ m3

TNO innovation for life



GHGSat-D CH_4 column measurement in Permian TX, USA, on 17 August 2018 (image credit: GHGSat

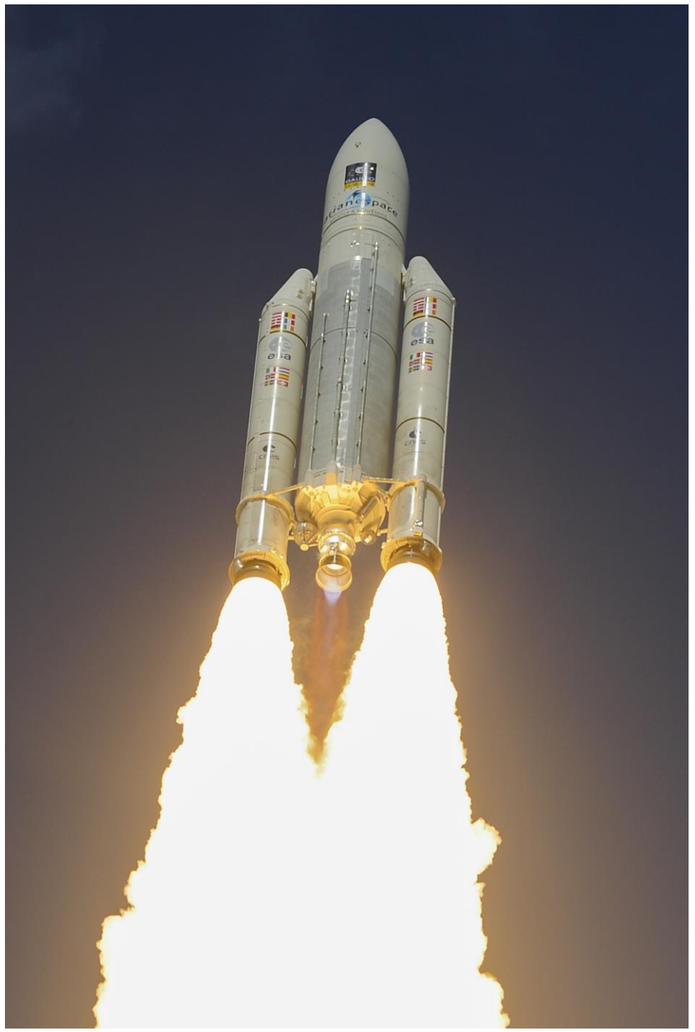
The new MethaneSAT methane-detecting satellite

ARE WE THERE?

Some early success!

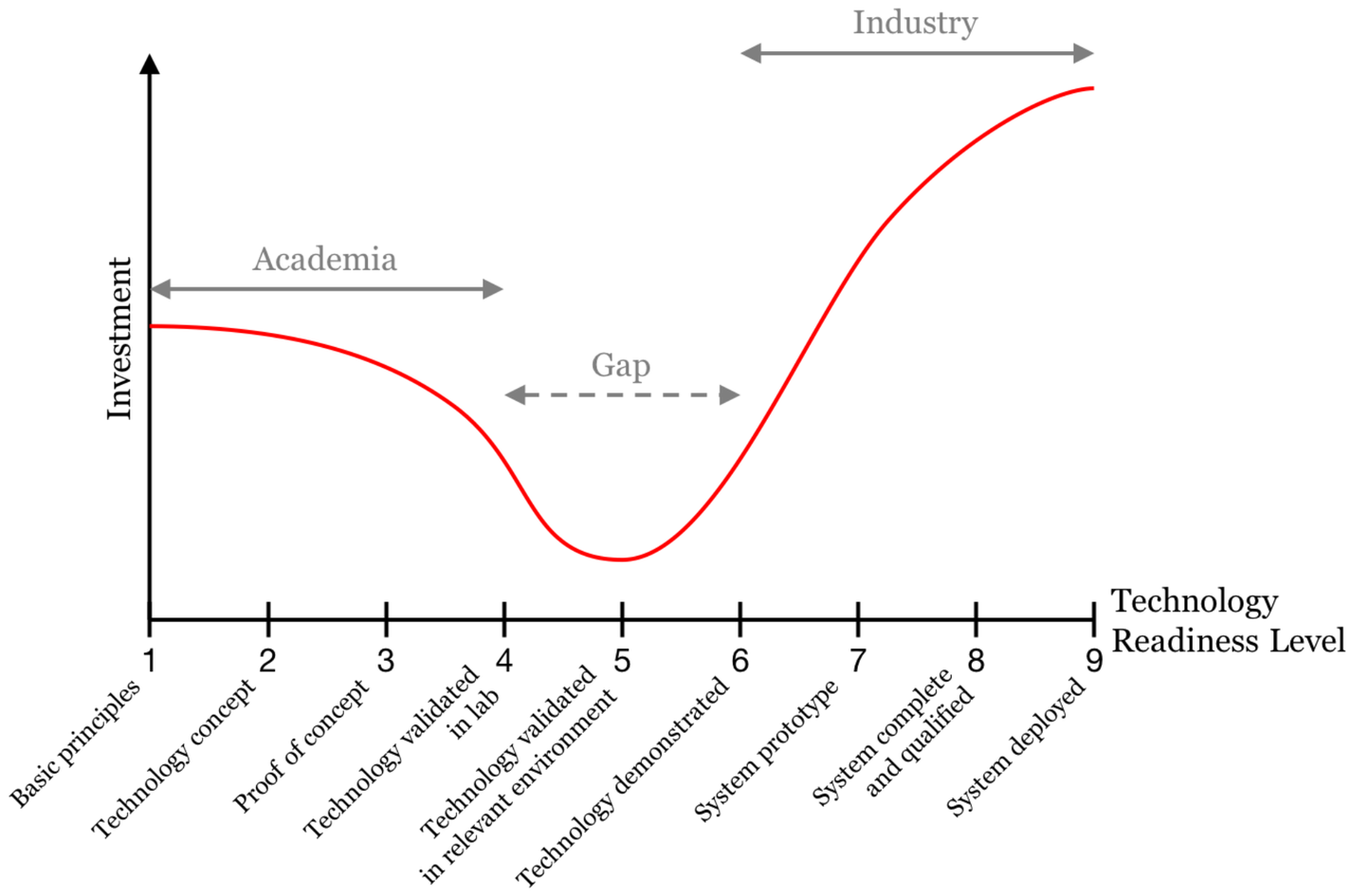
But, a faster uptake is needed to realize a significant new monitoring capability for independent verification of emissions

- Multi-trace gas measurement: primary species + atmospheric correction needed
- Important species overlooked: NH3, aerosols, NO2, N2O
- Quality data still an issue
- Some in the US, but non in Europe



BOTTLENECKS

- This is largely a non-commercial market: lack legislation & treaties on some species prevent solid business cases for private sector
- Funding in valley of death
- Most know-how is with scientists and engineers who worked in Space 2.0 or 3.0 mindset
- No EU alternatives: missed opportunity for global level playing field and world class EU know-how



WHAT CAN WE DO AS EU SECTOR?

- Prioritize Space 4.0 missions for climate:
  - Modest budget
  - Truly accept the idea of “Try fast fail fast”
- Public-Private cooperation
- New ways of working needed for traditional institutional players that have top know-how
- Keep pushing the boundaries of technology
- New talent: young people, outsiders

Thank you for your attention! anton.leemhuis@tno.nl