SWEET CubeSat

–

The Open-source Satellite Mission for Worldwide Water-quality Assessment

Presenters: Kelly Antonini and Florian Schummer

Co-authors: Martin Langer, Kim Steinkirchner, David Messmann, Sebastian Rückerl, Nicolas Appel and Ulrich Walter

WARR Satellitentechnik

ARTEMIS Cubesat Constellation [1]

Introduction

- SWEET (Sweet Water Earth Education Technologies)
- 2U CubeSat (precursor mission and constellation)
- Mission Objective: Water level and water quality monitoring of medium-to-large sweet water reservoirs in Africa
- Payload: VTT Fabry-Perot interferometer based hyperspectral imager[4]
- Education[al] [stu]dents in CubeSat d[esign] and water ma[nage]ment

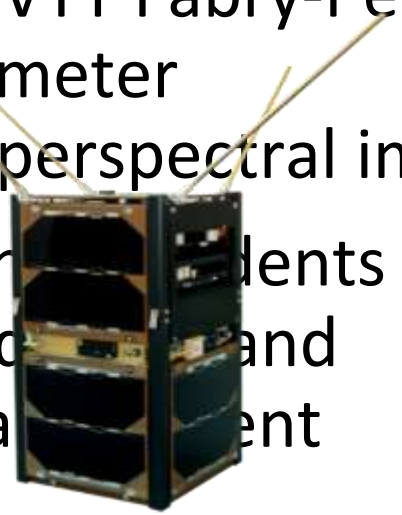


Image 2: NanoRacks-GOMX-2 [2]

Image 4: VTT Hyperspectral Imager [4]

Image 3: A woman carries water to her home [3]

Motivation (1/2)

- Major challenge of the 21st century: contamination of fresh water
- Major causes of sickness and mortality in Africa
- Sub-Saharan Africa: 40% of the 783 million people[5]
- 2 causes of water pollution:
  - Lack of sanitati
  - Cyanobacteria
- Mission goal: F
  everywhere to
  water quality i
  major african v

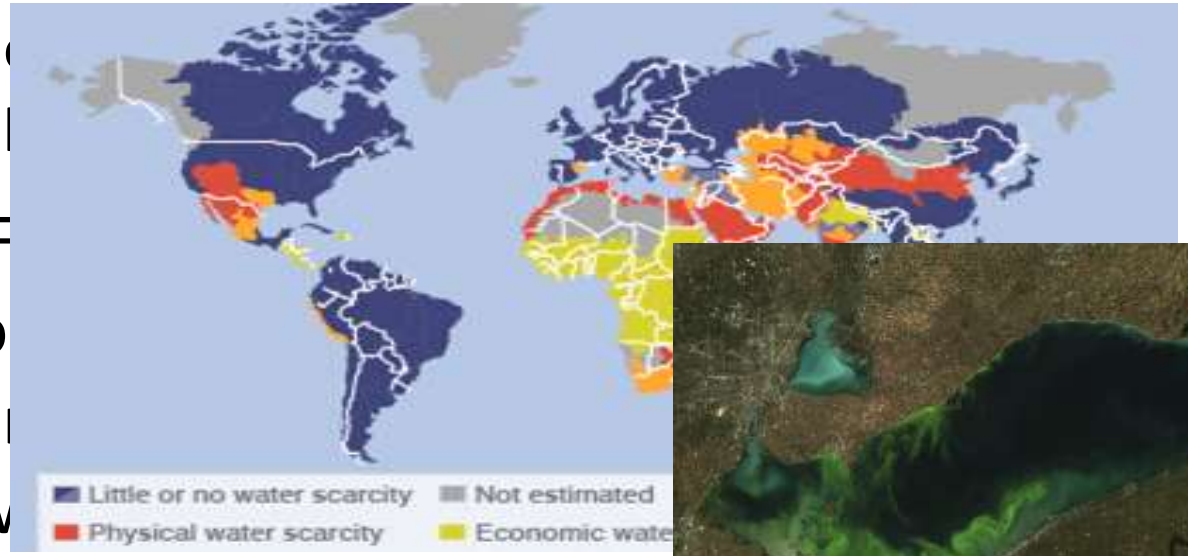


Image 5: International Water Manag

Image 6: Cyanobacteria Bloom [7]

Image 7: Algae Blooms in Lake [8]

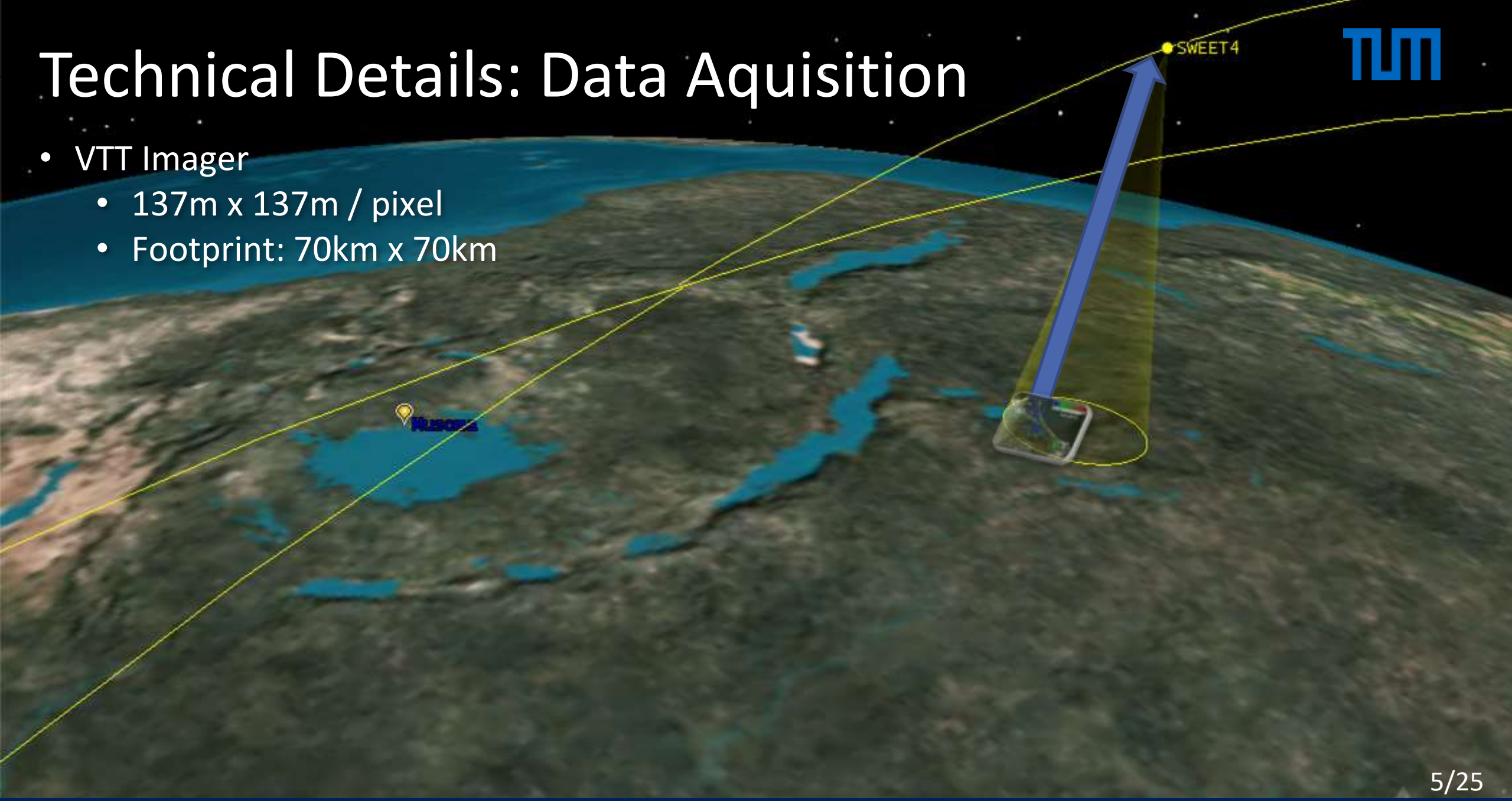
Motivation (2/2)

- Current in-situ water monitoring techniques are sparse, and often difficult to execute
- Remote sensing offers a solution to routinely measure water level and quality for large areas
  - MODIS on Terra and Aqua (NASA)
  - MERIS on Envisat (ESA)

Image 8: Lake Tanganyika [9]

Technical Details: Data Aquisition

- VTT Imager
  - 137m x 137m / pixel
  - Footprint: 70km x 70km



Technical Details: Data

- MEdium Resolution Imaging Spectrometer (MERIS) – Envisat (ESA)

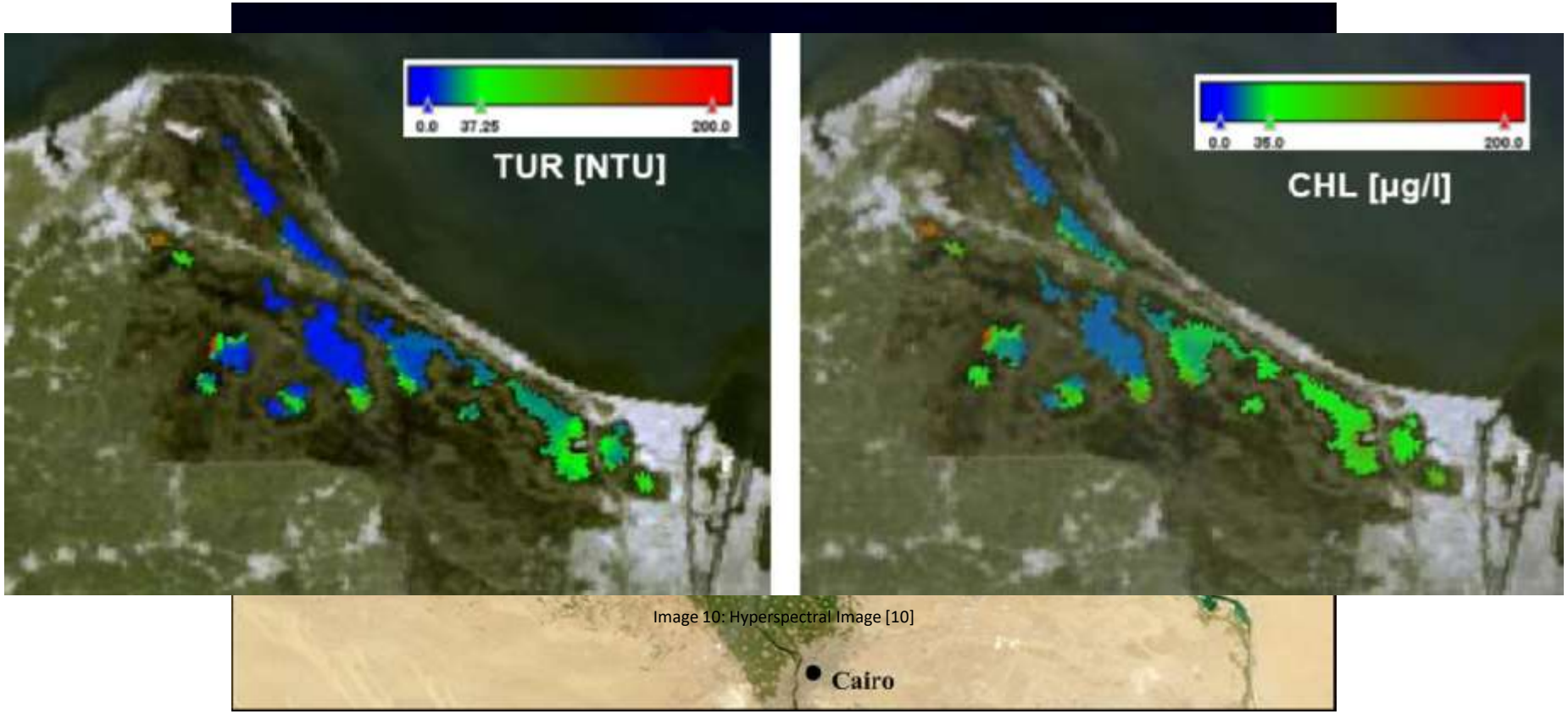
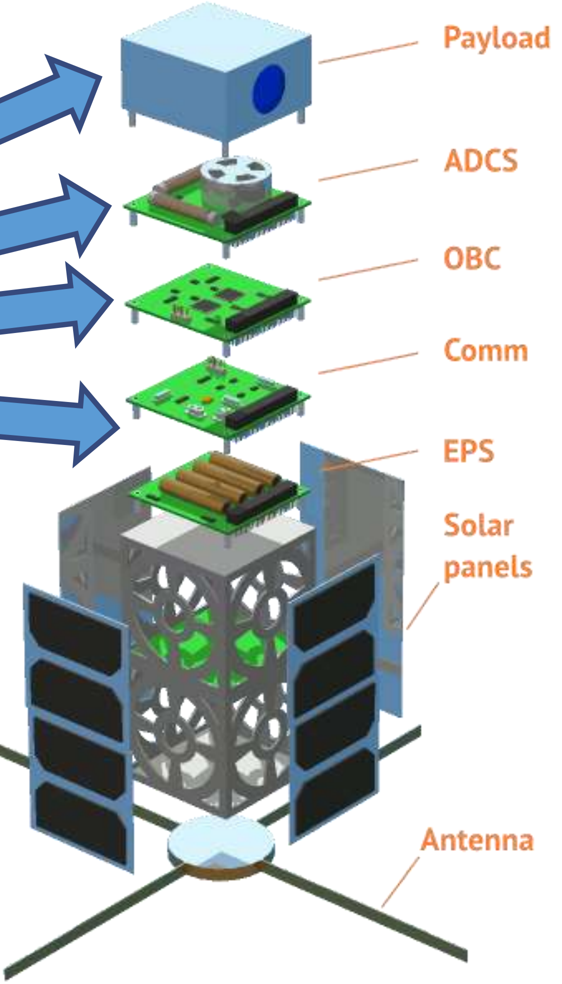


Image 10: Hyperspectral Image [10]

Image 9: Study region in Egypt [10]

Technical Details: Subsystems

- UHF/VHF transceiver [illegible]
  - [illegible] ARM-9
  - [illegible] 70km
- S-Band [illegible] Determination
  - [illegible] OS, SD cards [illegible] images
  - [illegible] images
  accelerometer



Technical Details: Power

- 24 solar panels
- Generate on average 6.5 W or 10.1 Wh per orbit
- GomSpace BP4 38.5 Wh battery
- 5 images only using VHF per day
- 11 images using both VHF and S Band per day

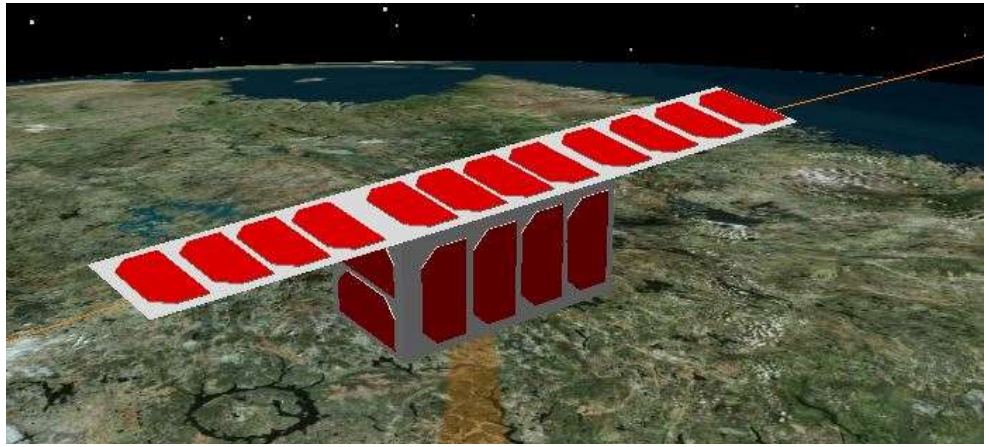


Image 11: SketchUp 3D Model of SWEET's Solar Panels [11, 12]

Technical Details: Orbit

- Launch from ISS
- Initial altitude: 400 km
- Inclination: 51.6°
- Period: 92.56 min
- Footprint: 4900 km^2
- Imager resolution: 137 x 137 m^2 / pixel

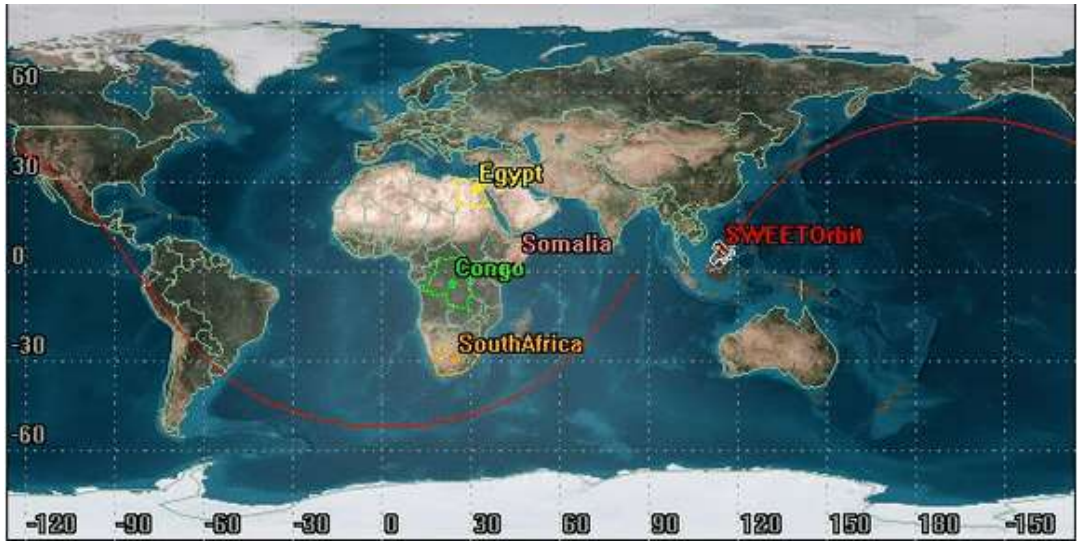
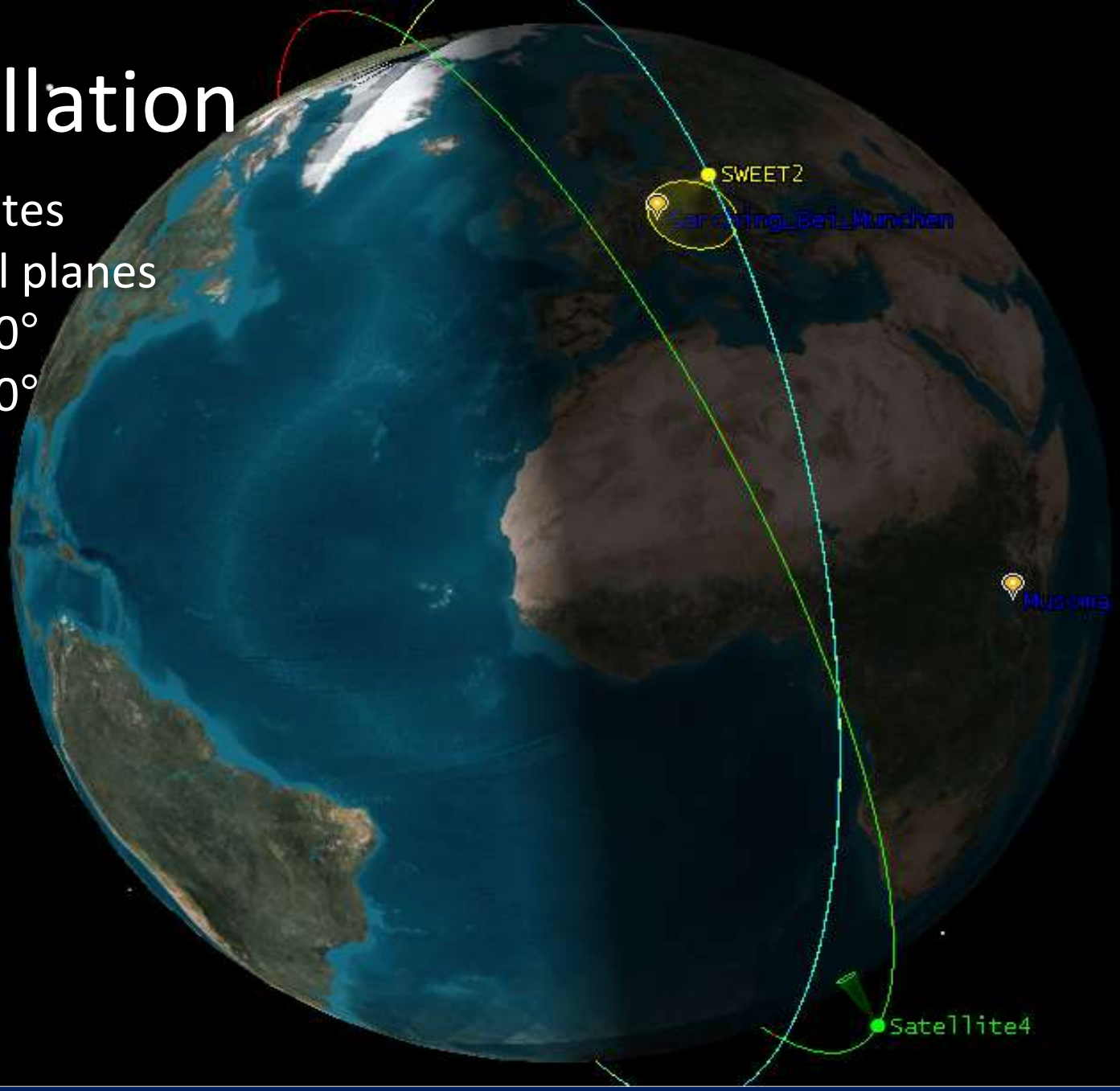


Image 12: SWEET Precursor Mission ISS Orbit [11]

	Yearly average flybys	Average revisit time
3 biggest lakes	99	3 to 4 days
30 biggest lakes	41	9 days
Total analyzed lakes (62)	31	11.8 days
Smallest lake	17	21 days

Constellation

- Four satellites
- Two orbital planes
  - SSO 100°
  - SSO 280°



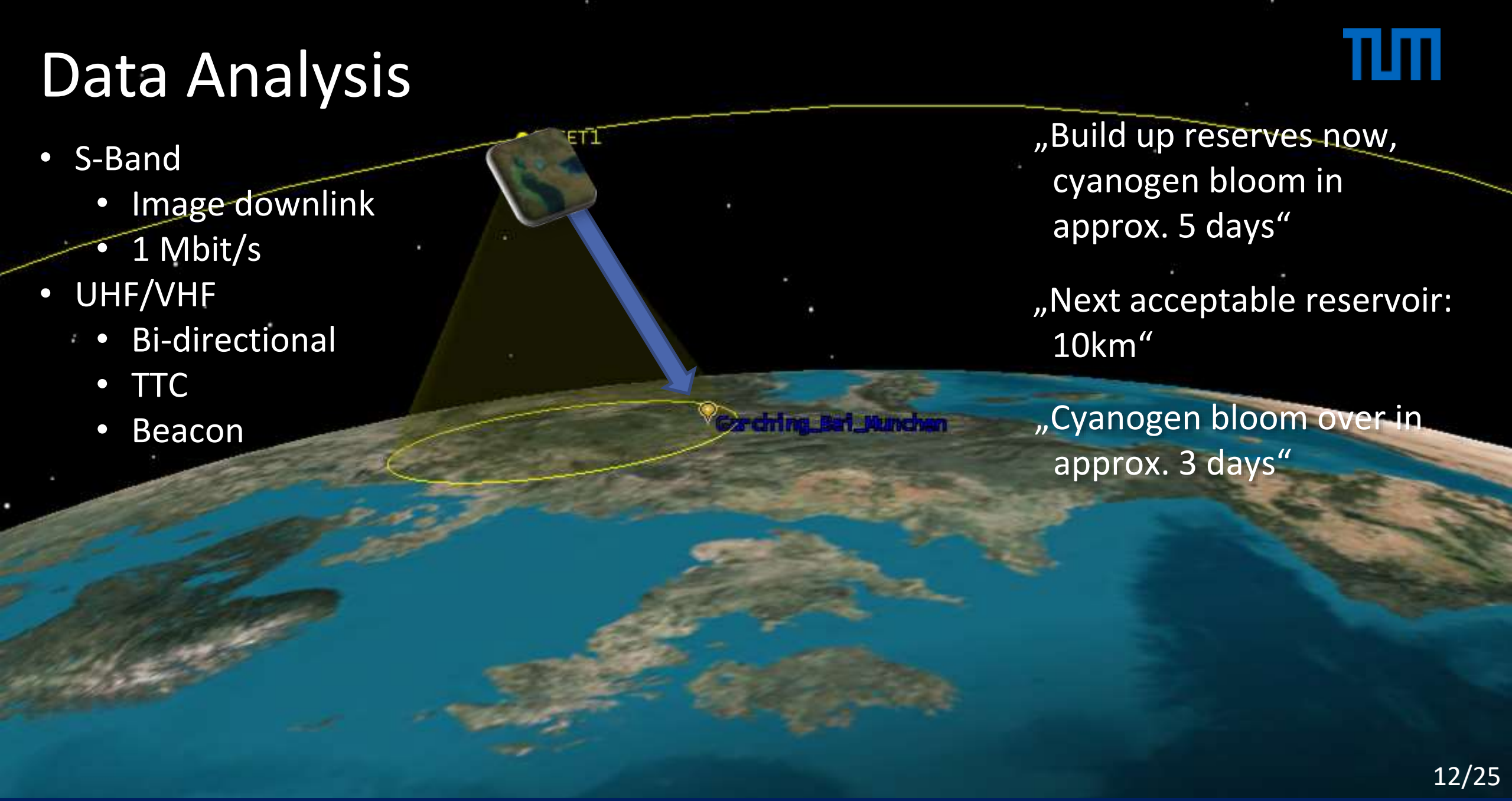
Results

- Constellation of 4 SSO (initial altitude 650km) CubeSats, RAAN 100° and 280°
- Hardware Cost: 206,000€ (excluding launch)
- Precursor mission (ISS) expected lifetime: 4.2 months
- Constellation natural orbit decay: 21.63 years

	Yearly average flybys	Average revisit time
3 biggest lakes	218	1.5 days
30 biggest lakes	128	2.8 days
Total analyzed lakes (62)	103	3.5 days
Smallest lake	68	5.3 days

Data Analysis

- S-Band
  - Image downlink
  - 1 Mbit/s
- UHF/VHF
  - Bi-directional
  - TTC
  - Beacon



„Build up reserves now, cyanogen bloom in approx. 5 days“

„Next acceptable reservoir: 10km“

„Cyanogen bloom over in approx. 3 days“

Communications

- 3 stations: Munich, South Africa and Nigeria
- African ground stations for educational purposes
- UHF to upload
- VHF to download: 9.6 Kbit/s (FOV: 80° elevation half angle)
- S Band to download: 1 Mbit/s (FOV: 15° elevation half angle)

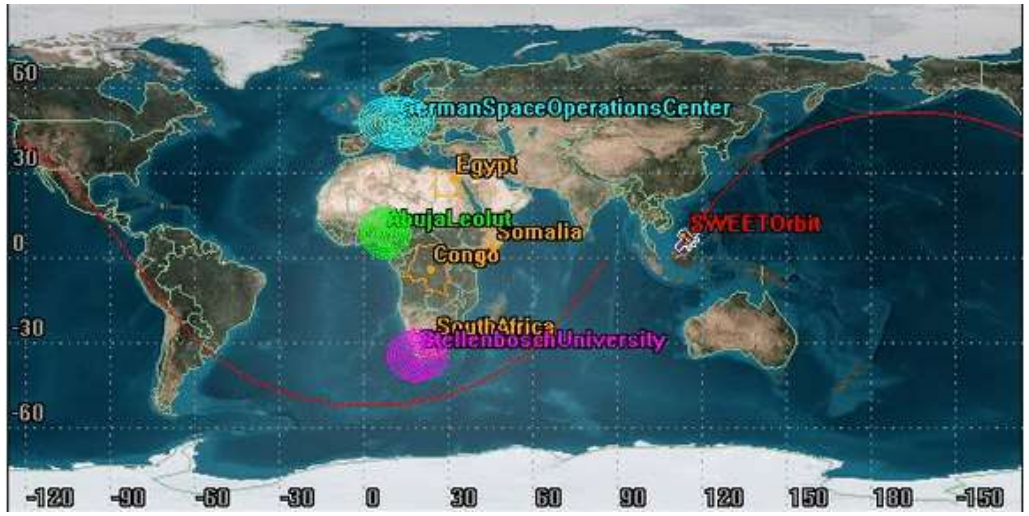


Image 13: SWEET's Ground Stations [11]

Data Distribution

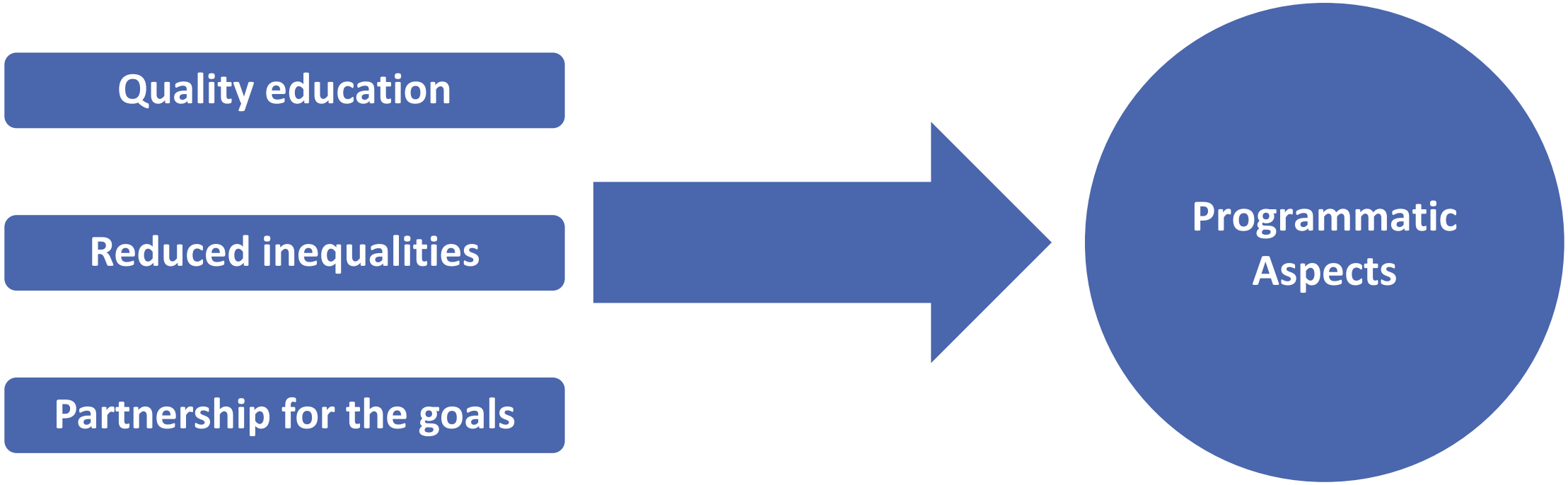
Sustainable Development Goals

- No poverty
- Zero hunger
- Good health and well being
- Quality education
- Clean water and sanitation
- Reduced inequalities
- Life on land
- Partnership for the goals

Sustainable Development Goals

- No poverty
- Zero hunger
- Good health and well being
- Quality education
- Clean water and sanitation
- Reduced inequalities
- Life on land
- Partnership for the goals

Sustainable Development Goals



Programmatic Aspects

Flatsat [13]

Design and first integration

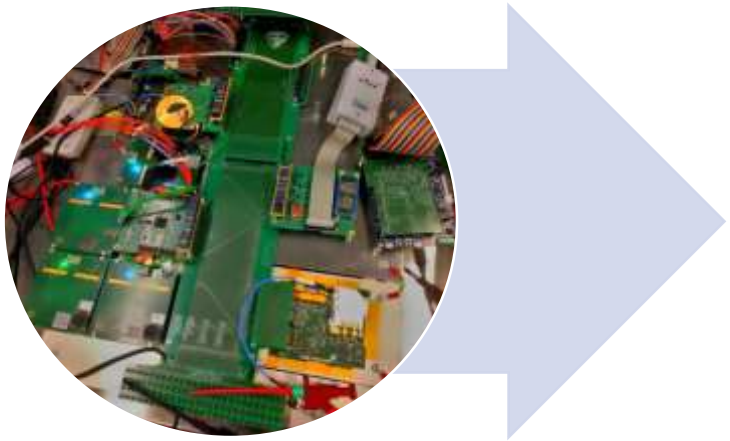
High Altitude Balloon [14]

First flight on high altitude balloon

ISS [15]

Precursor mission deployed from ISS

Programmatic Aspects



Design and First Integration

- Open Design Hardware
- Open Source Software
- ITAR Free

Reduced inequalities

Development and Review Process

- Invitation to public formal reviews
- Contribution in the software development process (open-source)
- Active global search for specialists in water analysis
- Usage of open design standards

Partnership for the goals

From Listener to Active Contributor

- SDR ground station to listen for beacons
- In-depth use of ground station software to analyze complete beacons
- Contribute in reuploading most recent data from SWEET1 to SWEET2, SWEET3, SWEET4

Quality Education

Current Fields of Work

- Use of additional bands (in use: 3, VTT-imager: 20 channels, 500nm-900nm, resolution 10nm)
- Cost effective data distribution
- Review of 1st Phase 0 study, conduction of 2nd Phase 0
- Search collaboration with water analysis institutes/experts
- On-Board analysis possible?
- **Looking for investors**

Conclusions

- It is possible to measure water quality with a 2U CubeSat with an unmatched cost per pixel ratio
- Integrated mass, volume and power into a 2U CubeSat
- A constellation of four 2U-CubeSats enables an update rate of once every 3.5 days
- SWEET enables African countries to educate and to monitor drinking water quality
- A precursor mission is deployed from the ISS to prove the concept

Image 16: Children of Africa [16]

References

Journal Paper: Kelly Antonini, Martin Langer, Ahmed Farid, Ulrich Walter, SWEET CubeSat – Water detection and water quality monitoring for the 21st century, In Acta Astronautica, Volume 140, 2017, Pages 10-17, ISSN 0094-5765, https://doi.org/10.1016/j.actaastro.2017.07.046.

[1]:https://universechallenge.wordpress.com/artemis-constellation-cubesat-programme/

[2]:http://www.nasa.gov/mission_pages/station/research/experiments/1328.html

[3]:http://www.dailymail.co.uk/sciencetech/article-2132064/Not-just-good-cocktails-The-secret-safe-drinking-water-twist-lime-bit-sun.html

[4]:http://www.vttresearch.com/

[5]:http://www.un.org/waterforlifedecade/africa.shtml

[6]:http://www1.american.edu/ted/ice/uganda-climate.htm

[7]:http://waterboards.ca.gov/

[8]:http://civileats.com/2012/09/17/green-slime-algae-blooms-in-nation%E2%80%99s-freshwater-causes-health-risks/

[9]:http://bingwallpaper.anerg.com/au/201311

[10]:M. F. Mohamed, "Satellite data and real time stations to improve water quality of Lake Manzalah," Water Science, vol. 29, pp. 68-76, 4// 2015

[11]:http://www.agi.com/products/stk/

[12]:http://www.sketchup.com/

[13]:http://spacebillboard.com/press-during-embargoMOVE-II

[14]:https://www.nasa.gov/sites/default/files/styles/full_width_feature/public/ballooninflation_0_0.jpg (balloon)

[15]:http://www.boeing.com/space/international-space-station/ (ISS)

[16]:https://journals.worldnomads.com/although_poverty/photo/43385/974118/Uganda/there-is-no-water-in-the-houses-children-filling-bottles-of-water-water-pipe

Thanks for your attention!

”Where you are in the world should not determine whether you are in the world..”

Florian Schummer, B.Sc.
Florian.schummer@tum.de
+49 89 289 16017

Kelly Antonini, M.Sc.
kelly.antonini7@gmail.com

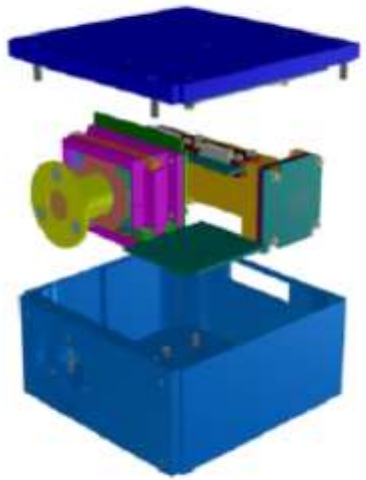
WARR
Satellite Technology

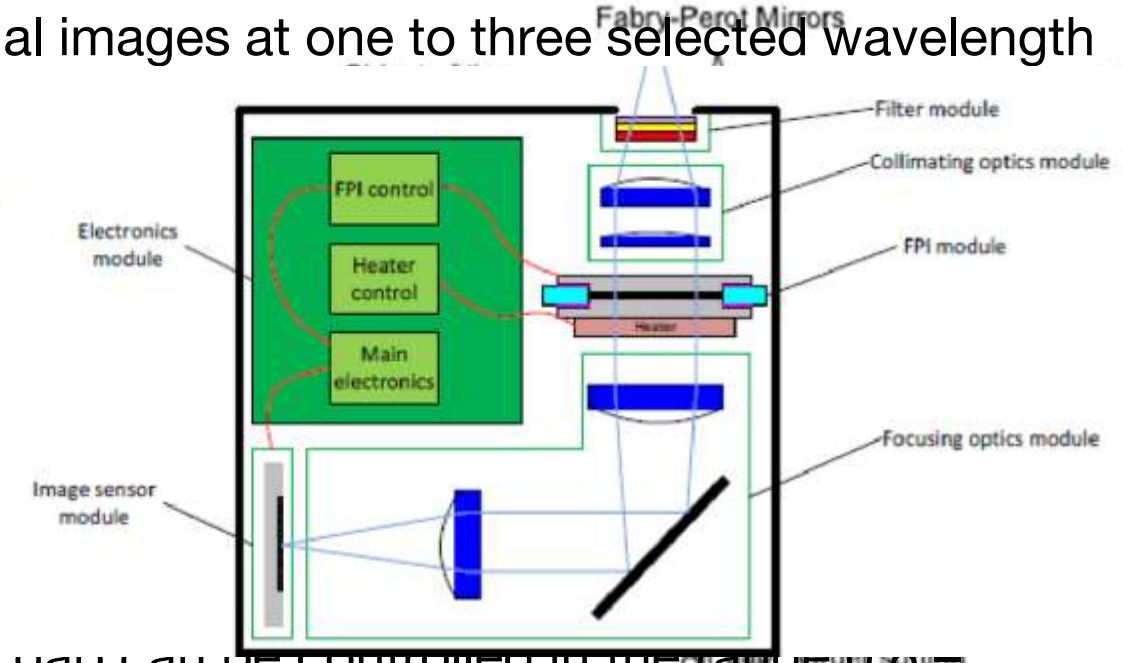
Current Fields of Work

- Use of additional bands (in use: 3, VTT-imager: 20 channels, 500nm-900nm, resolution 10nm)
- Cost effective data distribution
- Review of 1st Phase 0 study, conduction of 2nd Phase 0
- Search collaboration with water analysis institutes/experts
- On-Board analysis possible?
- **Looking for investors**

Appendix: VTT Imager

- Can record 2D spatial images at one to three selected wavelength





diameter and the air gap can be controlled in the range 0.5–
3.5nm enabling the erferometer orders
- Mirrors are made w dioxide protective layer
- *To be flown on Cub*

Precursor Mission

- One satellite
- ISS deployment
- Lifetime <5 months
- Prove space segment to work
- Verify data aquisition, analysis, and distribution concept
- Measure against space debris in 650 km orbit
- Measure against infant mortality

Constellation

Average revisit times

	One satellite option	Four satellites option
3 biggest lakes	3 to 4 days	1.5 days
30 biggest lakes	9 days	2.8 days
Total analyzed lakes (62)	**11.8 days**	**3.5 days**
Smallest lake	**21 days**	**5.3 days**