Surface Biology and Geology
An Observing System for Climate Impacts and Earth System Dynamics

David Schimel¹, Ryan Pavlick¹, Kerry Cawse-Nicholson¹, and the SBG team
Jet Propulsion Laboratory, California Institute for Technology

THE SURFACE BIOLOGY AND GEOLOGY DO IS DEFINED WITH CONSIDERABLE DETAIL IN THE DECADAL SURVEY

SBG is key to understanding in five research and applications focus areas:
- Terrestrial and aquatic ecosystems
- Hydrology
- Weather
- Climate
- Solid Earth

The Decadal Survey defines the implementation as two sensors “Hyperspectral imagery in the visible and shortwave infrared; multi- or hyperspectral imagery in the thermal IR”:

1. “….a moderate spatial resolution (30-45 m GSD), hyperspectral resolution (10 nm; 400-2500 nm), high fidelity (SNR = 400:1 VNIR/250:1 SWIR) imaging spectrometer is needed for characterizing land, inland aquatic, coastal zone, and shallow coral reef ecosystems”

2. “….30-60 m TIR observations in the 10.5-11.5 μm and 11.5-12.5 μm spectral regions are needed with a 2-4 day revisit frequency”

1) Note, this specification was updated based on recent work and community engagement to optimize for the DS-specified science and applications.
SBG: MOST AND VERY IMPORTANT RESEARCH AND APPLICATIONS
OBJECTIVES ACROSS ALL FIVE DS FOCUS AREAS

HYDROLOGY

H-1. How is the water cycle changing?

H-2. How do anthropogenic changes in climate, land use, water use, and water storage, interact and modify the water and energy cycles locally, regionally and globally.

H-4. Hazards, extremes, and sea level rise. How does the water cycle interact with other Earth system processes to change the predictability and impacts of hazardous events.

WEATHER

W-3. How do special variations in surface characteristics (influencing ocean and atmospheric dynamics, thermal inertia and water) modify transfer between domains?

ECOSYSTEMS AND NATURAL RESOURCES

E-1. What are the structure, function, and biodiversity of Earth’s ecosystems, and how and why are they changing in time and space?

E-2. What are the fluxes of carbon, water, nutrients, and energy between ecosystems and the atmosphere, the ocean, and the solid Earth, and how and why are they changing?

E-3. Fluxes within ecosystems. What are the within ecosystems, and how and why are they changing?

CLIMATE

C-3. How large are the variations in the global carbon cycle and what are the associated climate and ecosystem impacts?

SOLID EARTH

S-1. How can large-scale geological hazards be accurately forecast in a socially relevant time frame?

S-2. How do geological disasters directly impact the Earth system and society following an event?
Agriculture, Food Security and Surface Water Management

Improve “crop per drop” by assessing vegetation water stress over irrigated agriculture.

Improve water supply management through better characterization of snow properties and estimated reservoir inflows.

Reduce the impacts of drought, such as crop loss and famine, on global scales.

Water Quality and Coastal Zones

Support early detection of and response to harmful algal bloom formation.

Protect sensitive aquatic habitats by monitoring/reducing water pollutant loading, particularly in coral reefs and other sensitive ecosystems.

Water surface temperature and impacts on marine biodiversity.

Conservation

Support biodiversity understanding and protections by mapping invasive species composition, structure, distribution; support removal and restoration efforts.

Monitoring of endangered species habitat; provide alerts of disease mortality of impacted vegetation, including insect infestation.

Biodiversity hotspots and priority conservation areas, 30 x 30 plans.

Wildfire Risk and Recovery

Fuel mapping (cover type, extent, status) for wildfire danger management.

Post fire severity assessment and recovery, including prediction of areas with higher likelihood of debris flows.

Disasters and Natural Hazards

Detect and track oil spill events and support active fire mapping and response.

Improve mitigation of heat wave events for vulnerable populations.

Geology Applications

Mineral mapping for exploration efforts and reduction of environmental hazards.

Forecast aviation hazards and support emergency response for volcanic eruptions.

Landslide risk assessment with improved substrate map land cover maps.
SBG: KEY RESEARCH AND APPLICATIONS REQUIREMENTS

**COVERAGE:** The system must provide **global coverage** to address the global scope of the science including the coastal ocean and inland waters.

**STABILITY AND DURATION:** Measurements must be able to detect **long term changes** for addressing dynamics of the Earth System.

**GEOMETRY:** The system’s orbit must allow for **consistent sun-sensor geometry** for consistency in retrievals and for calibration and validation, and provide for global coverage, as above (polar orbit).

**RANGE, RESOLUTION AND SENSITIVITY:** Visible to Shortwave Infrared (VSWIR; 400-2500 nm) imaging spectroscopy and multi-spectral thermal infrared (TIR; 4 - 12 \(\mu m\)) measurements to observe “diversity” in ecosystem function. Radiometric performance driven by aquatic targets.

**SPATIAL RESOLUTION:** The observing system must provide **high spatial resolution** (30 and 60 m for VSWIR and TIR)

**REVISIT:** The SBG observing system temporal resolution must be adequate to capture **synoptic and seasonal variation** as well as observe **rapid or transient changes** related to Earth system events such as fires, landslides, volcanic activity and anthropogenic incidents.

**LATENCY:** Low latency, the time between an event and data access, must be low enough to support time-sensitive applications, \(\leq 24\) hours.
SBG Architecture

SBG Constellation Pathfinder

SBG Light
Wide-swath VSWIR spectrometer
Sun-sync orbit (late AM)
185 km swath
16 day revisit
10 nm, 200+ bands
30 meter GSD
High SNR and radiometric performance

SBG Heat
Wide-swath TIR imager and ASI VNIR camera
Sun-sync orbit (early PM)
5+ bands TIR, 2+ bands VNIR
935 km swath, 3 day revisit
60 meter GSD
0.2K NeDT

Pre-decisional draft; for discussion and planning purposes only.
### Pre-Phase A (Pre-Concept Study Phase) Schedule

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- **Collect Science and Applications Requirements**
- **SBG Community Quarterly Webinars**
- **Establish Foundation**
- **Develop Technical Baseline**
- **Prep Cost and Schedule**
- **Prep for MCR**
- **Prep for KDP-A**
- **Convene MCR (NLT FY22-Q3)**
- **Convene KDP-A (FY22-Q4)**

### Phase A (Concept Study Phase) Schedule - Notional

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- **Refine Science and Applications Requirements**
- **SBG Community Quarterly Webinars**
- **Refine Foundation**
- **Refine Technical Baseline**
- **Refine Cost and Schedule**
- **Prep for SRR/MDR**
- **Prep for KDP-B**
- **Convene SRR/MDR (FY23-Q4)**
- **Convene KDP-B (FY24-Q1)**
NASA's Project Life-Cycle
NASA Headquarters Perspective

Woody Turner  
NASA Program Scientist, Biological Diversity and Ecological Forecasting

Laura Lorenzoni  
NASA Program Scientist, Ocean Biology and Biogeochemistry

Ben Phillips  
NASA Program Scientist, Earth Surface and Interior
## Pre-Phase A (Pre-Concept Study Phase) Schedule

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### Phase A (Concept Study Phase) Schedule - Notional

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SBG – ASI Technical Interface Meeting

Rome, Italy (Hybrid meeting)

September 22-24, 2022
Earth System Observatory Data Latency and Ground Segment Study

| Study Goal | Minimize product latency and support cross-ESO science product generation by evaluating flight hardware and ground system architectures  
| **maximize commonalities and efficiencies across missions** |
| Objectives | Seek approaches to minimize or reduce latency with respect to  
| - Space to ground communications  
| - Terrestrial communications  
| - Level 0 processing (L1-4 processing will be considered separately) |
| Approach Summary | Space to Ground Architecture should  
| - Enable higher-level processing to be conducted in a low latency manner  
| - Consider any input data such as predicted orbit or ephemeris required to enable low latency processing  
| Driven by science and applications latency requirements  
| - Science goals or high value applications  
| - Consider cost impacts of reducing latency further  
| Include commercial and government options  
| Workshops with study team members |
| Schedule Drivers | MCR milestones for SBG, AOS, MC |
| Study Leads | ESDIS / Aerospace (Karen Michael and Andy Mitchell)  
| ESTO (Marge Cole and Ben Smith) |
Other factors of applications value needs chart, which was used in the Architecture Study design targets for latency

How this input was used

- 24 hour latency with event-driven capability enables 77% of SBG SATM applications
- 24-hour latency target used in architecture design sessions
- Event-driven needs documented
The Meanings of “Open” in Open Source Science

Open (Transparent) Science
Both the scientific process and results should be visible, accessible and understandable.

Open (Inclusive) Science
The process and participants should welcome participation by and collaboration with diverse people and organizations.

Open (Accessible) Science
Data, tools, software, documentation, publications should be accessible to all (FAIR).

Open (Reproducible) Science
The scientific process and results should be open such that they are reproducible by members of the community.
OSS for ESO Mission Processing Study Goal

Identify and assess potential architectures that can meet the ESO mission science processing objectives, enable data system efficiencies, seek opportunities that support earth system science, and promote open science principles. Per the Project Authorization Letter, will evaluate options to expand participation in mission science beyond the funded science teams.

Aligns with the challenge set by NASA to create a single observatory that combines data from the ESO missions to understand the earth as a system and accelerate our ability to apply this understanding.
# OSS for ESO Mission Processing Study Workshops

<table>
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<tr>
<th>Workshop #1</th>
<th>October 19-20, 2021</th>
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<td>Receive input from NASA Program Officers and ESO Missions regarding requirements, constraints, recommendations, and opportunities for science data processing</td>
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<th>Workshop #2</th>
<th>February 2022</th>
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<td>Understand the state-of-art in big data processing systems. Open invitation for agencies to share insights into their data processing approaches.</td>
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<th>Workshop #3</th>
<th>August 2022</th>
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<td>Receive results of the architecture study.</td>
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SBG Algorithms Working Group

- Team: Phil Townsend, Kerry Cawse-Nicholson, 250+ community members

- Goals: support mission concept development by assessing the status of existing algorithms, identifying gaps and opportunities, and assisting in traceability studies.

- Biweekly meetings:
  - Deep dive into proposed products to identify development needs
  - Average 43 members per deep dive (each focusing on a particular research specialty)

- Achievements:
  - More than 200 individual products identified
  - Narrowed down to 10 product suites
  - Manuscript published in RSE
SBG Modelling Working Group

- Team: Ben Poulter, Shawn Serbin, and many community members
- Cross-mission modeling exchange
  - Data modeling and simulations working group established with ESA’s CHIME mission
    - Sharing of E2E workflows, synthetic data & instrument models
- Fall 2021 webinar series
  - September: Drs. Kerry Cawse Nicholson & Ann Raiho
    - Intrinsic dimensionality & algorithm performance trades
  - October: Dr Derek Posselt
    - OSSE studies for AOS Designated Observable
  - November: Dr Fabian Schneider
    - Spatial resolution effects on VSWIR retrievals
SBG Cal/Val Working Group

• Team: Kevin Turpie, Ray Kokaly, 100+ community members (government, industry and research institutions)

• Goals: Support mission development by recommending radiometric, thermal, spectral and geometric calibration and validation strategies and identifying resources, methods and standards supporting data product validation.

• Weekly meetings:
  • ~4-6 per general meetings year.
  • Webinar Series (weekly): 52 speakers on 2020 & 2021 schedules

• Recent Achievements:
  • Completed the 2021 Webinar Series; slides and records are available.
  • Developing manuscript regarding SBG Cal/Val concept for JGR-B.
  • Presenting at paper at AGU annual meeting.
  • Looking at SBG, CHIME, LSTM and TRISHA orbits and intercalibration opportunities.
  • Considering Cal/Val synergies with PACE and GLIMR.
SBG Applications Group

- Team: Christine Lee, Jeff Luvall, Stephanie Uz, and 200+ community members

- Goals: Supports SBG mission development by recruit, coordinate and integrate input on applications needs, data product requirements and training/education and other needs

- Regular meetings:
  - ~8-12 per meetings and seminar talks per year
  - Slides and notes of past meetings are available

- Currently working with RTI International to develop SBG community assessments for urban heat and health, coral reef health, global food security, biodiversity, conservation, and deforestation/ reforestation.
Modeling End-to-End Traceability (MEET-SBG) Pathfinder

1) Hypertrace
   • Supporting VSWIR UQ traceability

3) Ames Global Hyperspectral Synthetic Dataset (AGHSD)
   • Pre-launch global timeseries

4) Temp. Emiss. Unc. Sim. (TeuSIM)
   • Supporting TIR UQ traceability

4) Observing System Simulation Exp.
   • Land-surface model data assimilation

[Diagram showing TIR Uncertainties with labels for atmospheric correction, detector noise, and emissivity uncertainties]
Primary Objectives & Timeline

- Prototype architectures and workflows to generate prototype high-dimensional, high-value SBG data
- Distribute prototype SBG data for community evaluation and training

**FY21 (Oct 2020 – Sept 2021)**

- Prototype workflows & system components

  **Deliverable:** Distribute land & water reflectance for community evaluation / feedback

**FY22-23 (Oct 2021 – Sept 2023)**

- Implement select prototype L2B+ algorithms

  **Deliverable:** Distribute prototype L2B+ products for community evaluation / feedback

**FY24-25 (Oct 2023 – Sept 2025)**

- Adapt workflows based on emerging SBG ATBDs

  **Deliverable:** Refine and redistribute prototype SBG products for community evaluation / feedback

Prototype Data Available To-Date

- **NASA Ames Research Center**
  - Global Hyperspectral Synthetic Data (AGHSD) is available at [https://data.nas.nasa.gov/aghsd/data.php](https://data.nas.nasa.gov/aghsd/data.php)
  - Hyperion L1 radiance and L2 reflectance in progress

- **NASA Jet Propulsion Laboratory**
  - Select* AVIRIS-Classic, AVIRIS-Next Generation, and PRISMA scenes for surface reflectances and uncertainties; topo, BRDF-corrected reflectances; terrestrial vegetation traits

  *More scenes, data streams, and workflows (e.g., aquatic, snow/ice, geology) will continuously be incorporated in FY22+
SISTER: Prototyping SBG Algorithms using PRISMA and DESIS

**ISOFIT** (Thompson et al. 2018)

- PRISMA

**Bathymetry** (Thompson et al. 2016)

- DESIS Lago Trasimeno, Italy June 04, 2021

**Vegetation Biochemistry**

- PRISMA Snæfellsjökull, Iceland July 02, 2020

**Snow grain size** (Nolin and Dozier 2000)

- PRISMA Surnadal, Norway April 21, 2020
SBG-CHIME-UZH 2022 Joint Campaign

May – July 2022

180 flight hours
50+ sorties
9 countries

Dozens of science field teams
Example spectra from the SBG/CHIME AVIRIS-NG 2021 Campaign

- Quicklooks and orthorectified radiances available at the JPL AVIRIS-NG data portal
- Reflectances processed with ISOFIT will be posted to the data portal soon
2021 HyTES Joint Campaign in the UK and Sweden

- July – August 2021
- 12+ sorties, hundreds of flight lines
- Products available at hytes.jpl.nasa.gov

New camera model for improved geolocation
Intrinsic Dimensionality as a Metric for Mission Design

Kerry Cawse-Nicholson¹, Ann Raiho², Ben Poulter², David Schime¹, David Thompson¹, Shannon Kian Zareh¹, Fabian Schneider¹, Philip Townsend¹, Kimberley Miner¹, Glynn Hulley¹, Charles Miller¹

¹ Jet Propulsion Laboratory, California Institute of Technology
² NASA Goddard Space Flight Center
Intrinsic Dimensionality

• Defined as the dimension of the signal subspace (the number of image covariance eigenvalues greater than some threshold defined by noise)

• Can be thought of as the number of unique pieces of information contained in spectroscopic data (principal components)

• Hypothesis that ID can be used as a metric for science content as the result of different architectural decisions.
Intrinsic Dimensionality

\[ X = S + \Delta \]

(Assuming centered and scaled data)

- Image
- Signal
- Noise

Principal component K

Principal component K+1

\[ XX^T \]

Eigenvalue

Eigenvalue index
Random Matrix Theory

\[ \lambda < \lambda_{RMT} \]
Visualizing dimensionality

Abundant minerals

Rare minerals

Noise

VSWIR

TIR
Airborne data used for this study

- NEON Sites: OSBS, UNDE, KONZ, DELA, SOAP, TEAK
- AVIRIS-NG and PRISM

Figure 1: RGB composites of subsets of AVIRIS-NG images over 8 different biomes.

Figure 2: RGB composites of subsets of PRISM images over three different regions.
Information content as a function of noise

Scenes with wide, distinct spectral features are less significantly impacted by noise.

Scaled by ID at SNR=450:1
Information content as a function of spatial resolution

Data loss varies widely by scene heterogeneity

~30% information loss moving from 30 m to 60 m

Scaled by ID at 5m resolution
Information content as a function of spectral resolution

Information loss ~40% moving from 10 nm to 20 nm

Scaled by ID at 5nm resolution
VIIRS data for temporal analysis

Figure 1: The biodiversity hotspots (red) and agricultural regions (green) selected for temporal dimensionality evaluation.
Information content as a function of revisit

**ID for VSWIR**

- Information loss of \(~40\%\) when moving from 8 day to 16 day revisit
- Scaled by ID at 8 day revisit

**ID for TIR**

- Information loss of \(>50\%\) when moving from 1 day to 3 day revisit
- Scaled by ID at 1 day revisit

Shading represents the 25\(^{th}\) and 75\(^{th}\) percentile, and the solid line represents the median.
Cloudiness impacts information content

(Left) Temporal dimensionality in the visible quickly approaches zero in Canada, whereas some information is still obtainable even at higher revisits in California (right).
Intrinsic dimensionality covaries with physical variables

- Nitrogen estimation accuracy
  - Nitrogen R^2 vs. Spectral resolution (nm)
  - Mean ID vs. Spectral resolution (nm)

- Trait variation at NEON sites
  - Mean trait variation (%) vs. Spatial Resolution (m)
  - Mean ID vs. Spatial Resolution (m)

- Central California Agriculture
  - Scaled difference in peak NDVI vs. Revisit (days)
  - Mean ID vs. Revisit (days)

- Kaolinite detection
  - Realized:Desired Error vs. Spectral resolution (nm)
  - Mean Intrinsic Dimensionality vs. Spectral resolution (nm)

- Nitrogen estimation accuracy
  - Nitrogen RMSE (mg/g) vs. SNR
  - Mean ID vs. SNR

- Snow Albedo
  - Realized:Desired Error vs. Revisit (days)
  - Mean Intrinsic Dimensionality vs. Revisit (days)

Ann Raiho, Fabian Schneider, Ting Zheng, Kyle Kovach
Summary

- Intrinsic dimensionality is an application-agnostic metric that can be used to integrate across the diverse geophysical parameters that may be retrieved from imaging spectrometers, rather than analyzing performance targets algorithm by algorithm.
- ID decreases with increasing pixel size, increasing spectral bandwidth, decreasing revisit frequency, and decreasing signal to noise ratio.
PRISMA Mission update

Ettore LOPINTO – ASI

Prepared by: E. Lopinto, P. Sacco
# Acquisitions on CHIME sites

- **European ESA CHIME sites acquisitions** with requests in the period 1-May to 31 Jul, performed at high priority and every 2 weeks

- Continued since today, but at a lower priority (the same used for the near #600 sites of interest routinely acquired worldwide) and with one request each month

- **99 Acquisitions on the CHIME sites from 01-May up to 11-Oct**

- **Acquisitions with these modalities will continue up to end of Oct 2021**

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<td>378_AVIRIS_2021_Jolanda</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>408_AVIRIS_2021_Evo</td>
<td>4</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>418_AVIRIS_2021_Kokkino</td>
<td>2</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>420_AVIRIS_2021_Veleuwe</td>
<td>2</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

Total acquisitions 42 18 10 2 21 6 99
The «quasi-Open» data policy will be further expanded, in order to also allow the commercial exploitation of the products but still maintaining the data completely free of charge (even for these applications)

Specific rules will apply, e.g. based on nationality of the users, but are yet to be frozen (target is end of 2021)

A PRISMA acquisition feasibility tool is now online http://prisma-prefeasibility.asi.it

- is freely accessible even without a PRISMA account
- performs the analysis on a single or multiple Areas of Interest (AoI) described by the lat,lon of their central point
- gives in output the UTC time at which the satellite has in view the AoI plus characteristic parameters of that view (roll angle, solar zenith angle)
998 Licenses to Use activated @ 11.10.2021

Showing the (statistically) most representative part of the user population:

- 15 nations covers 80% of the users
- the Italian users are only 1/3
- India, USA and Germany together account the 1/4 of the users
Mission Statistics – User category

- **63%** of the total users are scientists (50% of the users belongs to non-Italian Science and is the largest category)
- Institutional (9%) and commercial (12%) represents **21%** of total users
- Foreign commercial (8%) is two times the Italian commercial (4%)
- **6%** of user are still freelance!
Mission Statistics – Use of data

33 thematic areas cover **70%** of all applicative usages
PRISMA scientific program, co-funded by ASI

- **Budget ~3 M€ with max co-fund 200k€/proposal**
- **41 proposal received, 15 will be (co-) funded, 23 are eligible**
- **Largest participation came from universities with algorithmic studies**
- **5 themes accounts for 60% of study areas**
110k images (including those from the background mission) all over the world @31.08.2021; a new approach to background planning is going to be used to improve global land coverage.
Info, contacts, inquiries:
prisma_missionmanagement@asi.it

portal:
https://prisma.asi.it
DESIS Mission - Update

German Aerospace Center (DLR)
12.10.2021, Online
Teledyne Brown Engineering (USA) and DLR (Germany) have partnered to build and operate the DLR Earth Sensing Imaging Spectrometer (DESIS) attached to the Multi-User System for Earth Sensing (MUSES) Platform on the ISS.
DESIS Status Acquisitions

- 27 August 2018 installed on International Space Station
- Since that time, DESIS has been providing hyperspectral data

World (Status July 2021)
~60,000 scenes processed
<35% of the land surface of the Earth
~29 TB data in the archive

Note: DESIS is not a mapping mission
CHIME – ESA’s imaging spectroscopy Copernicus mission

Different sites across Europe serving for different application
Each CHIME site is supported by a CHIME MAG member
CHIME preparatory campaign in 2020 and 2021
Supported by field, airborne and spaceborne measurements
12 High Priority Prototype Products (HPPPs) to cover initial key products (e.g. Canopy nitrogen, Soil Organic Carbon, Kaolinite) for potential operational development

27 sites across Finland, France, Germany, Spain, UK, Italy, Netherlands and Switzerland
1st DESIS User Workshop

September 28th to October 1st, 2021
Virtual event

- 235 registrations
- 30 nations
- 53 presentations
- 10 sessions on 4 days

Topic | # of Proposals
--- | ---
Urban Thematic Exploitation & Material Composition | 2
Landcover & vegetation | 6
Water Resources | 7
Ocean Applications | 4
Coastal Applications | 7
Calibration | 1
Natural Resources | 9
Geology | 4
Biodiversity | 2
Others (e.g. methods development, data fusion) | 4

~39% are related to water applications; VNIR (400 – 1000nm) & 2.5 nm spectral sampling

DLR responsible for scientific exploitation
1st DESIS User Workshop - Outcome

- Wide range of applications even DESIS is only sensitive in the VNIR
- Tendency to use multitemporal data in order to map Earth system processes
  => data quality needs to be consistent over time
- ISS as EO platform with a complex observation geometry needs new ideas in data evaluation
  => e.g. value of acquisitions of different times during the day for photosynthesis analyses of vegetation
- Data access could be more automatized – up to date technology (APIs), data provisions on processing platforms such as HPC (High Performance Computing) …
- Less studies from ML/AI domain – why?

- Use of a new sensor that is available needs time – several studies emphasize that they are preliminary, DESIS as stimulator for more regular use of such data and method development? Good outlook for EnMAP, EMIT, CHIME, SBG …
1\textsuperscript{st} DESIS User Workshop - Outcome

Important – clear explanation necessary about:

- manufacturing defects
- rapid change of performance below 450 nm
- limitation in automatic geolocation
- zero or negative values in L2A spectra
- the AOT uncertainties and the uncertainties in the BOA
- L2A processing over water pixels (put more effort into correction/validation of water pixels/dark pixels)
Thank you for your attention!

uwe.knodt@dlr.de
rupert.mueller@dlr.de
utaheiden@dlr.de

... and the whole DESIS Team!

Negev Desert / Israel, May 2021
Current status of the EnMAP mission

Sabine Chabrillat (1), Karl Segl (1), Saskia Foerster (1), Luis Guanter (1, 2), Anke Schickling (3), Tobias Storch (4), Hans-Peter Honold (5), Sebastian Fischer (3)
And the whole EnMAP team

(1) Helmholtz Center Potsdam, GFZ German Research Center for Geosciences, Potsdam, Germany
(2) Universitat Politècnica de València, Valencia, Spain
(3) Space Administration, German Aerospace Center (DLR), Bonn, Germany
(4) Earth Observation Center (EOC), German Aerospace Center (DLR), Weßling, Germany
(5) OHB System AG, Weßling, Germany

SBG community Webinar 12 Oct 2021
EnMAP mission and sensor parameters

**Orbit characteristics**
- **Orbit / Inclination**: sun-synchronous / 97.96°
- **Target revisit time**: 27 days (VZA ≤ 5°) / 4 days (VZA ≤ 30°)
- **Equator crossing time**: 11:00 h ± 18 min (local time)

**Instrument characteristics**

<table>
<thead>
<tr>
<th>Spectral range</th>
<th>VNIR</th>
<th>SWIR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>420 - 1000 nm</td>
<td>900 - 2450 nm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of bands</th>
<th>88</th>
<th>154</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral sampling interval</td>
<td>6.5 nm</td>
<td>10 nm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spectral bandwidth (FWHM)</th>
<th>8.1 ± 1.0 nm</th>
<th>12.5 ± 1.5 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal-to-noise ratio (SNR)</td>
<td>&gt; 400:1 @495 nm</td>
<td>&gt; 170:1 @2200 nm</td>
</tr>
<tr>
<td>Spectral calibration accuracy</td>
<td>0.5 nm</td>
<td>1 nm</td>
</tr>
<tr>
<td>Ground sampling distance</td>
<td>30 m (at nadir; sea level)</td>
<td></td>
</tr>
<tr>
<td>Swath width</td>
<td>30 km (field-of-view = 2.63° across track)</td>
<td></td>
</tr>
<tr>
<td>Acquisition length</td>
<td>1000 km/orbit - 5000 km/day</td>
<td></td>
</tr>
</tbody>
</table>

**Flight Altitude**: 653 km
- **Coverage**: Global in near-nadir mode
- **# of orbits / repeat cycle**: 398 orbits
- **# of images / day**: Up to 166
- **Covered area / day**: 150,000 km²
EnMAP status

• HSI instrument
  - HSI calibration & characterisation closed end-2020
  - Successfull HSI acceptance review Jan 2021

• Satellite
  - Satellite integration and finalisation closed, transport IABG Jun 2021
  - Environmental test campaign (thermal, acoustic)
  - Functional characterization, 2d end-to-end test with GS
  - Flight acceptance review Oct 2020-Jan 2021

• Launch
  - Falcon 9 (Space X) rideshare
  - Launch 28.02-30.06.2022, reduced to 30d, Florida, USA
  - Data available to users after commissioning (6M) through EnMAP data portal
  - Mission life time: 5 years

EnMAP data products:
- L1B: radiometrically-corrected and spectrally-characterized radiance data
- L1C: geometrically-corrected L1B data
- L2A: atmospherically-corrected L1C data

EnMAP satellite at TVAC preparation at IABG with the golden foil
EnMAP calibration, validation, data quality control

- Pre-Flight Calibration & Characterization by space segment
- Commissioning
  - In-Flight Calibration by ground segment based on satellite equipment
  - Cal-val and data quality control activities by ground segment for all mission data
  - Validation activities by science segment: Product Validation Plan (L1B/L1C/L2A)
    - Independent validation effort
    - Estimation of quantitative error figures and potential error sources, report non-compliance & recommendation for improvement
    - Based on Level 1B/1C/2A products & in-situ and reference, airborne & spaceborne data
    - Support from the science community

In-situ / reference data
- Demmin/Camarena (agriculture, soils; S. Chabrillat)
- Lake Constance (water; A. Bracher)
- Munich North Isar (agriculture; T. Hank)
- Makhtesh Ramon (geology; E. Ben-Dor)
- Mammoth Mountain (snow; T. Painter)
- Ivanpah Playa (USA ; R. O. Green)
- Pinnacles (Australia; C. Ong)
- Amiaz Playa (Israel; E. Ben-Dor)
- RadCalNet (Railroad Valley, USA; Gobabeb, Namibia), Hypernets, AERONET, PICS...

Airborne
- Demmin (HySpex on Cessna207)
- Lake Constance/Munich North Isar (TBD)

Spaceborne
- all, S2 (L1C REF), DESIS, PRISMA, EMIT...

Core sites International sites Network/others

Brell et al., Whispers 2021
SBG-EnMAP potential areas of cooperation

- **a) Cal/Val activities:** Cross-calibration, sensor performance assessment, cal/val data collection
  - E.g. CP 2022
    - 3 sites in the US to provide field data to EnMAP
    - Airborne campaign?

- **b) Science and applications:** Campaigns and ground-truth data collection, algorithm and software development, publications

- **c) Outreach activities:** Education, training, community events and networking

- No exchange of funds and hardware

Thank you for your attention

enmap.org
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Thank you for your attention
enmap.org
SBG Items of Interest

- **AGU Call for Papers: The Earth in Living Color**
  - Open through **August 2022**

- **12th EARSeL Imaging Spectroscopy Workshop** (June 22-24, 2022)
  - Abstract deadline: TBA

- **NASA Open Source Science Workshop** (October 19-20)
  - Register now at earthdata.nasa.gov

- **AGU Fall Meeting 2021:**
  - **NASA SBG: The Earth In Living Color Town Hall**
    - Tuesday, December 14, 2021, 9:15 – 10:15
  - **Advancing Global Imaging Spectroscopy and Thermal Infrared Measurements**
    - Multiple Oral and Poster sessions, Monday, December 13, 2021
  - Other relevant AGU FM and OSM sessions will be posted on the SBG website.
SBG Opportunities for Involvement

- In-person SBG community workshop in 2022 (more details to come)

- Internship programs at JPL and other NASA centers:
  - Dave Schimel (dschimel@jpl.nasa.gov)
  - Ben Poulter (Benjamin.poulter@nasa.gov)

- SBG working groups: ongoing, regular meetings and seminars
  - Algorithms (kcawseni@jpl.nasa.gov)
  - Modeling (benjamin.poulter@nasa.gov)
  - Calibration/Validation (kturpie@umbc.edu)
  - Applications (christine.m.lee@jpl.nasa.gov)

- Email us (seriously we want to hear from you): sbg@jpl.nasa.gov

- Join the conversation at the SBG Slack Channel