Capacity building in hyperspectral remote sensing between space agencies: the approach of the Horizon Europe EXPERT project

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***Abstract*—The Romanian Space Agency (ROSA; Coordinator), Italian Space Agency (ASI) and German Aerospace Center (DLR) have partnered in the framework of the Horizon Europe "Reaching Excellence in Hyperspectral Remote Sensing" (EXPERT) project, Grant Agreement No. 101160059, to build ROSA's technical capacity, analytical and computational resources and scientific skills in hyperspectral remote sensing through knowledge and best practices transfer. EXPERT is promoting a co-designed capacity building approach, by which specialist training is delivered in response to clear needs and in the perspective of enabling the trainee organization to develop a portfolio of research and application services based on spaceborne and airborne hyperspectral remote sensing. To cover the full chain – i.e. from data collection and management up to generation of value-added products –, dedicated training is also delivered with regard to how to collect reliable in situ reference spectroscopic data, for purposes of calibration/validation and for targeted observations supporting research. The project proves the benefit of inter-space agencies cooperation for capacity building in Earth Observation.**

Keywords—Hyperspectral Remote Sensing, field spectroscopy, PRISMA, EnMAP, capacity building

I. Introduction

After some years of lack of hyperspectral (HS) Earth Observation (EO) spaceborne sensors, recent launches of missions such as German Aerospace Center (DLR)'s Earth Sensing Imaging Spectrometer (DESIS) [1], the Italian Space Agency (ASI)'s PRecursore IperSpettrale della Missione Applicativa / Hyperspectral Precursor of the Application Mission (PRISMA) [2-3] and the DLR's Environmental Mapping and Analysis Program (EnMAP) [4], are boosting HS data exploitation and development of much improved algorithms. However, without a dedicated action of specialist training addressed to a wider community than the already expert research groups, it would be very challenging to ensure that a distributed network of scientific (researchers and academia groups) and commercial (developers, SMEs and geospatial services companies) users will be capable of analyzing these data and deliver application products and services. This situation is more likely to occur in those countries that, at the moment, do not have hyperspectral missions being operated by the respective space agency and/or commercial players.

To address this potential issue in Romania, Agenția Spațială Română (i.e. Romanian Space Agency – ROSA) is coordinating the Horizon Europe project "Reaching Excellence in Hyperspectral Remote Sensing" (EXPERT; https://expert-project.rosa.ro/), Grant Agreement n. 101160059, in partnership with Agenzia Spaziale Italiana (Italian Space Agency – ASI) and Deutsches Zentrum für Luft- und Raumfahrt e.V. (German Aerospace Center – DLR). By training its scientific and technical staff in HS remote sensing and field spectroscopy, ROSA is preparing for acting as an innovator hub to promote these technologies across the country and, potentially, more widely across Eastern Europe. Funded by the European Commission under the HORIZON-WIDERA-2023-ACCESS-02 (Twinning) Call, Topic HORIZON-WIDERA-2023-ACCESS-02-01, Type of Action HORIZON-CSA (HORIZON Coordination and Support Actions), EXPERT is the first capacity building project in HS remote sensing between space agencies, and takes advantage of the direct involvement of ASI and DLR who own and operate HS missions that are contributing to prepare the way for the Copernicus Expansion Mission CHIME [5].

II. EXPERT Project

EXPERT started on 1 June 2024, has successfully passed the mid-term review in December 2025, and will last until May 2027.

The concept behind EXPERT is underpinned by three fundamental pillars (Fig. 1):

- A research component represented by HS remote sensing;
- Coordination and support measures for stimulating scientific excellence and innovation capacity;
- The enhancement of research management and administration skills.

In practice, EXPERT involves:

- Capacity building through training delivered by ASI and DLR to ROSA scientific and technical staff members, in order to build specialist competence and hands-on technical skills in collection, processing, post-processing and analysis of HS data collected from ground-based, airborne and spaceborne sensors;
- Joint development of research use-cases focusing on the main applications that ROSA has identified as priorities to support the growth of the national satellite-based downstream and applications sector, i.e. mining, agriculture and cultural heritage;
- Outreach, networking and capacity building towards the user community, with the main focus on the Romanian academic, scientific and commercial sectors and, secondarily, neighboring countries in Eastern Europe. Specific actions include: outreach webinars for awareness about HS remote sensing and basic and entry-level training; summer school devoted to EO researchers and professionals for an intensive specialist training; networking events to expand the community benefitting from the EXPERT impact and create opportunities for future partnerships and development in HS remote sensing at national level.

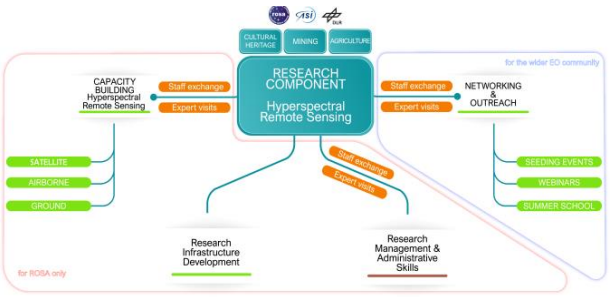


Fig. 1. The EXPERT concept, with capacity building being both an enabling process and a continuous action to develop the research component.

III. Training Actions

The training actions were co-designed between the three space agencies, as opposed to a top-down approach led by the more experienced partners. In particular, in the first months of the project a competence mapping and gap analysis exercise was undertaken. This was aimed at delineating ROSA's technical profile in HS imaging, i.e. background knowledge, previous experience, existing capabilities, skills and HD/SW resources available at ROSA in collection, processing, post-processing and analysis of HS data, as well as current gaps. An initial session for introduction and brainstorming with ROSA staff members was held at the project kick-off milestone. Then, an online questionnaire with a set of questions was compiled by all ROSA staff members. Online meetings were subsequently held to discuss together the outcomes of the questionnaire and deepen the understanding of ROSA's current organization, expertise, expectations, and training needs. The final iteration with ROSA team led to extract patterns and key conclusions from this exercise, and input into the plan of training activities for Year 1. This plan is currently being expanded to encompass more advanced training modules in Year 2.

A. Satellite and airborne HS remote sensing

As ROSA highlighted the need to start with fundamental concepts and then move to more specialized content, training in HS remote sensing was intentionally structured according to two main levels, i.e. initial (basic) and advanced, delivered in Year 1 (June 2024 – May 2025) and Year 2 (June 2025 – ongoing), respectively. Both satellite and airborne HS remote sensing techniques and data are addressed.

Figs. 2 and 3 show some examples of basic training activities. ROSA staff learnt about the technical specifics making PRISMA a state-of-the-art HS asset, the different processing levels and data formats, nominal performance of the mission, data policy and T&Cs to access the data, characteristics and opportunities offered by the existing mission archive, and the current tools provided by ASI to facilitate data tasking, collection and utilization by the users (e.g. the PRISMA pre-feasibility tool, the PRISMA Toolbox – Fig. 2, the high geolocation accuracy for L2D product generation). Furthermore, ROSA staff was trained in processing HS airborne and satellite imagery using ENVI software (Fig. 3).

Tutorials and homework assignments let ROSA practice on how to: generate a suite of standard products from HS imagery, such as maps of state-of-the-art spectral indices (e.g. Normalized Difference Vegetation Index – NDVI; Green NDVI – GNDVI; Red Edge; Soil Adjusted Vegetation Index – SAVI; Carotenoid Reflectance Index 1 – CRI1); interpret the results in a real-world use-case (e.g. archaeological applications); and assess the effectiveness of the various indices for the specific analytical task to undertake (e.g. detection of cropmarks). In particular, Figs. 4 and 5 show an example of comparative qualitative assessment between two different spectral indices.

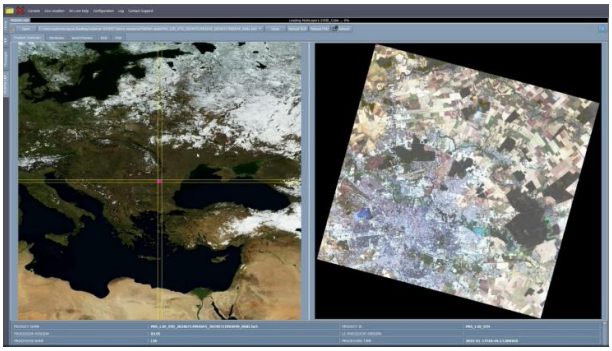


Fig. 2. A moment taken during the live demonstration on the use of the PRISMA Toolbox on a sample PRISMA image collected over Bucharest, Romania.

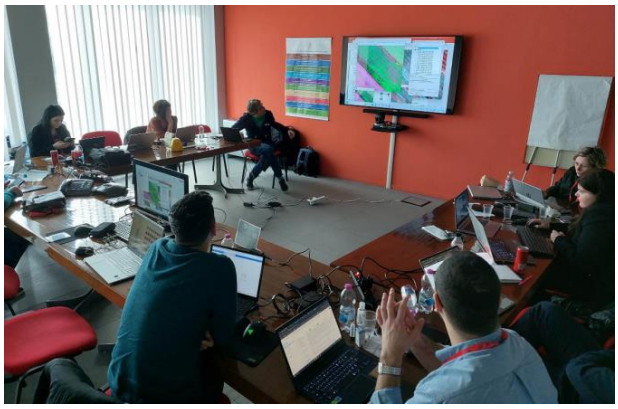


Fig. 3. Example of tutorial on HS data processing and analysis, specifically on how to combine HS image bands to highlight cropmarks in archaeological sites.

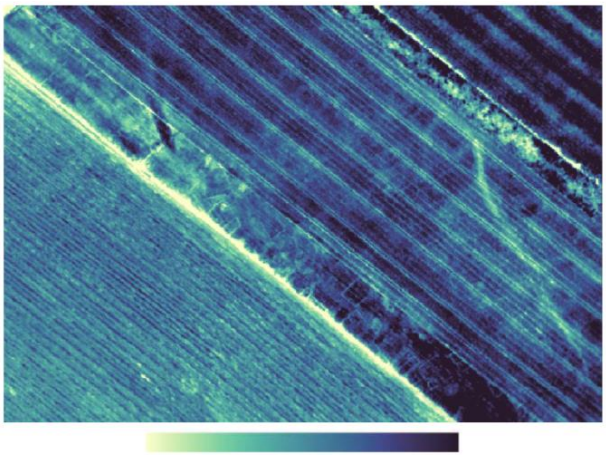


Fig. 4. Example of SAVI index map, with pseudocolor scale (computed based on Band 30 and Band 50 of Aisa EAGLE). The main ancient road is readily distinguishable, and a number of subsurface structures are apparent. Overall, the performance of this index for cropmark detection was rated by ROSA staff as moderate to high.

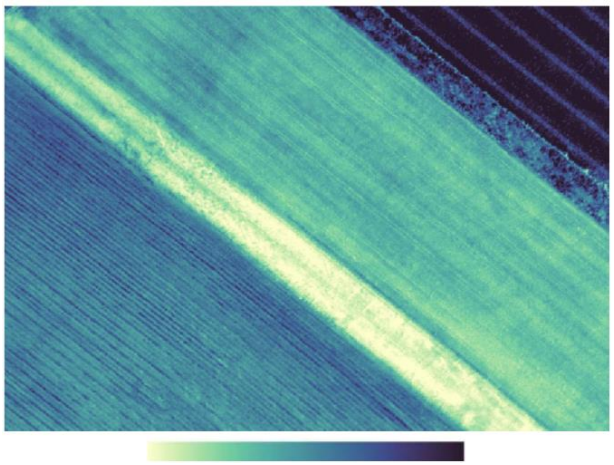


Fig. 5. Example of CRI1 index map, with pseudocolor scale (computed based on Band 13 and Band 18 of Aisa EAGLE). Not even the main road is visible; none of the buried elements can be observed. Overall, the performance of this index for cropmark detection was rated by ROSA staff as low.

These indices were generated by processing an airborne dataset that was acquired over the archaeological site of Carnuntum in Austria by means of the sensor Aisa (Airborne Imaging Spectrometer for Applications) EAGLE (Specim Spectral Imaging Oy Ltd., Oulu, Finland), and made available for download as a supporting dataset for the ARCTIS MATLAB® toolbox, which is released under the creative commons license [ARCTIS] (under Testdata © LBI ArchPro, available on: https://luftbildarchiv.univie.ac.at/resources/software/arctis-archaeological-toolbox-for-imaging-spectroscopy/). The exercise stimulated ROSA staff's critical thinking in the use of simple consolidated spectral indices.

B. Field spectroscopy

According to the same approach, initial and advanced capacity building modules are also undertaken with regard to ground-based field spectroscopy. The rationale for including such training component lies on the fact that field spectrometers remain indispensable tools for calibration/validation campaigns and for targeted observations supporting research. As field teams have a limited operational coverage compared to satellites, a network of operators is needed to collect reliable reference data across Europe. This would also help to introduce hyperspectral applications to new communities. This requires widespread knowledge transfer regarding the effective use of field spectrometers including instrument handling, campaign planning, acquisition strategies, data processing and quality control, and inter-comparison methods with satellite observations.

Capacity building activities addressed the full chain, from theoretical fundamentals to field validation. Initial training focused on the physical principles of reflectance spectroscopy, instrument characteristics, sources of uncertainty, and laboratory and field acquisition of spectral measurements for vegetation, soils, and synthetic materials. For example, ROSA staff was engaged in practical tutorials including demonstration of the Kautsky effect [6] on a living plant and collection of sample spectra on synthetic materials, liquids, rocks and human skin in the lab. Furthermore, a supervised exercise of field measurements was undertaken over an open area (Fig. 6) to let ROSA staff learn how to use Spectra Vista Corporation (SVC) hand-held field spectrometer, the same model purchased by ROSA under EXPERT project funds.



Fig. 6. Guided field spectroscopy training, illustrating SVC instrument setup and reference panel usage.

Subsequently, the ongoing advanced capacity building is combining presential training sessions, remote tutorials, and joint working activities. These actions directly flow in the development of research use-cases in agriculture, cultural heritage, and mining, applying the newly acquired skills in real scientific workflows. Indeed, in Year 2, this training action is also matched with the so-called "Pilot demonstrations", i.e. a series of field campaigns undertaken autonomously by ROSA staff collecting spectroscopy measurements as well as soil/vegetation samples, in the project test sites in Romania, according to best practices and methodological approach learnt from DLR and ASI who, in turn, support ROSA via remote monitoring. Measurements were designed to be temporally aligned with PRISMA and EnMAP satellite overpasses whenever feasible. Additionally, soil and vegetation samples at different phenological stages were collected at various sites to support validation and application development. UAV-based RGB and LIDAR measurements were additionally used where required to prepare the development of measurement strategies and to facilitate the interpretation of the measurements. An earlier account of these activities for the agricultural research use-case in Moara Domnească Didactic Farm, north-east of Bucharest, Romania, is reported in [7]. The collected datasets were finally evaluated and prepared for scientific exploitation during joint online sessions organized by DLR and ASI.

IV. Conclusions

As a project undertaken by partnership between three space agencies, EXPERT is an example of the benefit achievable via inter-space agencies cooperation for capacity building in Earth Observation. The approach proposed by EXPERT is rooted in the co-design of the training activities to address specific needs and building skills by on-the-job training and exploitation of newly acquired abilities in real-world scenarios. In this respect, the EXPERT experience demonstrates that capacity building is a living process, which gets stronger through repetitions of practical activities and constant learning.

During the first year and half of the project, the achievements made with regard to capacity building and training are as follows:

1. Training at least 50% of ROSA's Earth Observation experts in hyperspectral remote sensing, leveraging existing expertise in multispectral and Synthetic Aperture Radar domains;

2. Organizing five (so far) intensive capacity-building sessions led by ASI and DLR, including short-term staff exchanges, expert visits, and virtual training workshops to ensure knowledge transfer;

3. Organizing two intensive research management training modules led by ASI;

4. Developing and deploying dedicated research infrastructure at ROSA, including essential software and hardware tailored for hyperspectral remote sensing activities for which ROSA received dedicated training.

ROSA staff has developed a background in satellite and airborne HS data processing and analysis that is currently being consolidated during the conduction of specific research use-cases. Same approach applies to skills gained in field spectroscopy. At this point of the project, ROSA team has undertaken several field campaigns autonomously with minimal remote assistance. From the training activities and field campaigns, some best practices for capacity building in field spectroscopy emerged: alignment of measurements with satellite sensor characteristics; inclusion of soil and vegetation sampling to support validation; flexibility of field protocols to account for constraints; and a rapid post-campaign data review to improve subsequent acquisitions. The partnership efforts in the second half of the project will be focused on the completion of the research use-cases and roadmapping for developing a future portfolio of R&D activities based on HS remote sensing at ROSA.

Acknowledgment

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