NERC Scientific Support and Facility Annual Report

Name of Facility: Field Spectroscopy Facility

Form completed by: R Ramsay (Equipment Manager), A Merrington (Operations Manager), C Atkins (Operations Technician), S Hancock (Facility Director)

Reporting period: 2023-06-01 – 2024-06-30

Please provide a brief narrative under the following headings:

1. A brief annual summary

<u>Executive Overview</u>
The facility continues to focus on its fundamental aim of providing a pool of modern, calibrated field instruments to support high quality NERC science. As part of this aim, we also provide training to the UK research community, with a focus on providing guidelines in the best practice of field spectroscopy. In addition, this contributes to the growth of the natural capital sector within the UK, which thereby contributes to the economic competitiveness, effective public policy, and overall quality of life globally and within the UK. The following section will provide a high-level overview of the discharge in the provision of our core capability and science impact, followed by a chronology of our activities from June 2023 to June 2024.

<u>Core Capability Provision</u>
The facility aims to maximise the use of our available pool of instruments to NERC and direct funded access UK researchers, judged by the number of loan applications, the percentage of those applications provided for, and the total "uptime" of our instrument pool.
Over the period from 2023-06-1 to 2024-06-30, we received:
- NERC Grant Funded project applications (excl. student projects) – 17
- NERC Grant Funded student project applications – 12
- Other UKRI Grant Funded project applications (excl. student projects) – 6
- Other UKRI Grant Funded student project applications – 2
- Other Academic Funding Streams – 4

Totalling 41 applications. All applications were accepted after review by the FSF Operations and Equipment Managers after technical assessment and logistically feasibility, followed by review by the FSF Steering Committee. Further details on breakdown of funding streams are provided below in section 4.

<u>Science Impact</u>
As part of our core capability, our instrument support should aim to produce high quality, peer reviewed NERC science. We judge achievement on this criterion based on the number of citations in scientific publications. For 2023-2024, total number of scientific publications citing support from the facility was 13 (included as an appendix to this document).

<u>Chronology of events since 2023-06-01</u>
The facility took stock of the panel responses to the recommissioning of the facility, and have drafted a series of goals based on those responses that the facility should seek to implement over the course of the commissioning period (2024-2031). These are provided in the document "FSFSC 2024 Update on Commissioning Goals for 2024-2034". Briefly, the facility will continue to assess current equipment stock levels

and seek funding to either replace ageing stock, or to seek investment in new opportunities for field spectroscopy; will engage on an open source model with regards to equipment capabilities, data processing and remote sensing products generated by the facility and its loan users; and will work closer with our loan user base to both develop networks between users and also provide them with training which adheres to the principles of FAIR (findable, accessible, interoperable, reusable). We will continue to update the steering committee and NERC on the progress of achieving these goals.

Throughout June 2023 to July 2023, the facility – in addition to ensuring the provision of equipment to loan users through a particularly busy application period – was engaged in providing in person support for multiple NERC funded projects. This included providing field spectroscopy and UAV data for the NERC SPLICE campaign held at Wytham Woods in July 2023, and maintaining the London GHG network into its final year of operation.

In August 2023, the facility engaged in the first of two major commercial engagements with the natural capital company Messium Ltd. Work was conducted at an experimental farm plot at Aberystwyth, Wales, providing field spectroscopy data for the determination of spectral indices that may be used for determining disease presence in potato cultivars.

Throughout October 2023 to January 2023, the facility was engaged in developing, in conjunction with Plymouth Marine Laboratory and NEODAAS, a calibration methodology for the TriOS line of underwater radiometers. This methodology was put in place for the calibration of 12 underwater radiometers held by PML, and the success of that calibration has led to further calibration of PML underwater radiometers, and a commercial calibration of underwater radiometers held by a natural capital commercial group based in Oxford.

During November 2023, the Operations Manager and Operations Technician travelled to French Guyana to conduct UAV operations using the facility's Headwall Co-Aligned VNIR-SWIR sensor. This was in support of a NERC funded grant application ("A next-generation approach for quantifying tropical plant diversity across scales", Dr. F Draper)

The facility ran a four hour workshop at the British Ecological Society 2024 Annual Meeting in December 2023. This was attended by 54 in person participants, both international and domestic. The workshop covered the acquisition and processing of field spectroscopy data, and how this can then be used to develop remote sensing products aiding satellite and airborne imagery classification.

Throughout 2024, the facility gradually moved to a new physical location within the Kings Building Campus at the University of Edinburgh. This new location is shared with the Edinburgh Airborne Research and Innovation group. The building greatly expands the working area available to the facility, and includes a dedicated "drone hangar" for the maintenance of UAV platforms, a greatly expanded optical calibration laboratory, and a training space for providing one-to-one and small workshop training to FSF loan users.

Over March 2024 to May 2024, the second commercial work package for Messium Ltd was conducted. This involved field spectroscopy data acquired over a number of days spaced throughout Spring, with the goal to determine the temporal changes in spectral reflectance signature in wheat crops subjected to different nitrogen application regimes.

In April, the facility attended both the Flow Country Research Conference and the RSPSoc Wavelength 2024 conference. Commercial opportunities were developed at the former, while a workshop and discussion with NPL regarding optical calibration laboratory working groups was developed at the latter.

Collaborating with NEODAAS, the facility provided a week long workshop in May 2024. This provided training to 19 in person and 6 remote attendees, the majority who were NERC funded PhD students, in the fundamentals of remote sensing. FSF's component consisted of lectures on the basics of radiometry, an in person training session in the use of ground spectrometers, and computer processing tutorials on the processing and integration of field spectroscopy data into airborne and satellite remote sensing products.

In June 2024, FSF attended the 43rd EARSeL symposium in Manchester, where progress on the implementation of the facility's 2022 capital award, the "NERC FSF Calibration Centre for UAV Sensors", was presented. International linkages with underwater and UAV spectroscopy groups were established, which the facility is keen to develop further.

Finally, at the end of June 2024, FSF submitted an application for NERC's "Annual Baseline Capital Call for NERC SF LRI for Summer 2024". Based on feedback from the Steering Committee and liaising with past and present loan users, the facility put forward three packages for submission:

- Next Generation Field Spectroscopy -- funding for three additional field spectrometers, two of which are bundled as a dual field of view system for simultaneous measurements of downwelling irradiance and upwelling radiance.
- Broadening Access to High Resolution UAV Hyperspectral Imagery -- funding for a relatively low cost UAV mounted VNIR hyperspectral imager with enhanced spectral resolution, which can be flown independently by loan users and does not require FSF staff involvement
- Providing Medium Load UAV and LiDAR Capability -- funding for a medium load UAV, and a low cost LiDAR system.

2. Describe the key successes or highlights during the reporting period. This could include, examples of science excellence and impact, new capability or instrumentation, leverage funds, influence/contribution to national and/or international groups etc

1. New Capabilities and Capital Acquisition – The final part of the "NERC FSF Calibration Centre for UAV Sensors" award – the lab goniometer – was delivered in 2024. This is now being integrated into the facility's workflows, and will be used to characterize the BDRF properties of the facility's extensive reference panel stock, aiding in the analysis of reflectance values acquired in the field. Due to the funding acquired through commercial opportunities, a transmittance/reflectance sphere attachment has been acquired for the facility's stock of SVC HR-1024i field spectrometers. This will allow users to take contemporaneous measurements of both reflectance and transmission of objects, particularly of leaves. This investment reflects increased engagement with steering committee and loan users, who have identified the need for the facility to increase the availability of equipment that can provide transmission spectra.

2. National and International Collaboration – The joint workshop on hyperspectral imager calibration between FSF and the NCEO Airborne Earth Observatory continues to be held annually, and occasionally if time permits, bi-annually. The radiometric and spectral calibration methodologies have now been fully developed with the aid of NEODAAS, and we are working on incorporating other calibration techniques (such as the use of monochromators and imaging photometers) to gain better understanding of imager characteristics, such as linearity and errors of coregistration. Journal publications are being discussed based on the three years of work that have now been conducted. Additionally, these workshops have seen increased "guest" attendance, particularly from NPL, Rothamsted Research, and King's College London. This, in turn, has led to the development of the UK's first "Headwall Hyperspectral Imager Working Group", which gathers together all users of Headwall hyperspectral imagers in the UK for discussion. FSF is leading the best practices for calibration sub-group, and is organizing an inter-comparison exercise between imagers to be held in October 2024. The facility continues to work closely with NEODAAS, particularly with regards to training and workshops, and has developed a good working relationship with PML, particularly on underwater radiometer calibration. Links with domestic natural capital groups, such as Messium Ltd., have been established, leading to increased commercial revenue. Internationally, and via the work conducted during P4001, the facility has developed links with calibration laboratories in Estonia (Tartu Observatory), Belgium (VITO), and has continued to boost links with Australia's CSIRO.

3. Science Highlights – Key NERC funded projects supported this year included NERC SPLICE, which involved direct involvement by the FSF team for the acquisition of UAV and ground based spectroscopy; and the NERC funded project "A next-generation approach for quantifying tropical plant diversity across scales", which also involved UAV and ground based data acquired by facility staff at site. Based on the strength of the London GHG campaign, FSF will also be involved in the NERC GEMINI-UK greenhouse gas monitoring network. The facility, utilizing the increased capabilities of its new optical calibration laboratory, has developed an increasingly refined calibration methodology for ground based, UAV, and underwater spectrometers, which has culminated in commercial calibration opportunities, as well as support for UK research groups (e.g. TriOS calibration for PML, and the "Agorah" leaf reflectance sphere for the University of Leeds).

4. Influence -- The facility provided several workshops this year, strengthening our capability in outreach and learning. These included a half day workshop at BES 2024, a full week workshop with NEODAAS in Many 2024, and 1-2 hour introduction sessions to spectroscopy at Wavelength 2024. The facility has also presented at international conferences, such as EARSeL 2024 and Flow Country 2024. The facility has also developed a more visible branding approach, developing leaflets, brochures and other material to raise the facility's profile, all of which have occurred in tandem with increased social media presence and the publication of a new website https://nerc-fsf.github.io/

3. Describe any significant changes during the reporting period in staffing, governance and management, or capability, or any other significant challenges or risks experienced, and how these have been managed.

There has been a significant change to the way that insurance is provided by the University of Edinburgh for equipment, which directly impacts drone operations. Prior to October 2023, the University of Edinburgh covered the insurance costs for UAV operations using the Headwall Co-Aligned VNIR-SWIR sensor when flights were conducted by facility staff. Since October 2023, however, the University of Edinburgh will not cover insurance costs in the event of damage or destruction of an item above £100k, including transit. Public liability insurance is still covered for flying UAVs. This means that our Headwall sensor is currently uninsured for flights, and is also uninsured if it has to be shipped internationally. This has effectively halted our provision of UAV flights using the Headwall for international campaigns, placing risk for reputational damage, particularly as the facility has established itself as the prime provider for free UAV hyperspectral surveying within the UK science community. The facility operations team and director are working hard to resolve the issue, whether by ensuring an exemption or looking at alternative cover, but currently, we have made the decision to limit all use of the Headwall to domestic, UK operations, and only when a rigorous safety and operations check has been conducted to ensure that the risk of damage is extremely small.

At 41 loans this year, the facility has seen a record amount of applications, building on last year's 37 total applications. Due to the use of better calibration methodologies and logistics planning, the facility has been able to support all applications, but as noted last year, this does place a strain on the facility's stock of field spectrometers. We have identified in our recent capital bid that funding for new spectrometer units is a priority.

4. Summarise the use and demand during the reporting period for your facility, and how you have supported users (please continue to provide quantitative data where possible i.e. number and type of projects or users supported, number of applications). Where appropriate, please also mention any training delivered, engagement with existing and any new user communities, and any user feedback.

As detailed in section 2, over the period from 2023-06-1 to 2024-06-30, we received:
- NERC Grant Funded project applications (excl. student projects) – 17
- NERC Grant Funded student project applications – 12
- Other UKRI Grant Funded project applications (excl. student projects) – 6
- Other UKRI Grant Funded student project applications – 2
- Other Academic Funding Streams – 4

Totalling 41 applications. Compared to last year's applications, NERC grant funded applications have increased significantly, NERC student applications have remained the same, UKRI funded projects have also remained the same, and other funding streams have decreased. Other UKRI funding streams have included the UKRI funded Open University Astrobiology Research Group (continuing the engagement with the astrobiology community that we established last year), the BBSRC funded BARIToNE Collaborative Training Partnership (CTP), and the DEFRA Darwin Plus Grant.

In particular, we have been pleased to see increased applications for our underwater and atmospheric measurement instruments.

For this year's reporting period, we have maintained a better track of instrument "uptime" for our field spectrometer and underwater bio-optics suites. Note that our field spectroradiometers – excluding the SVC HR-1024i 2098, which required a manufacturer repair – average at 9.8 months of uptime. The average number of

loans per field spectrometer is three, and therefore, three calibrations must be conducted each year on average for each spectrometer, leaving two months to conduct. As mentioned, changes to logistics and calibration methodology has allowed this to occur.

Instrument	Uptime (months) 2023-06 - 2024-06
ASD FieldSpec Pro 6239	9
ASD FieldSpec 3 16178	11
ASD FieldSpec 3 18454	11
SVC HR-1024i 2001	8
SVC HR-1024i 2003	8
SVC HR-1024i 2066	11
SVC HR-1024i 2098	6
PSR+ 3500	11
SeaBird Hyperspectral OCRs	5
SeaBird Multispectral OCRs	4
Walz Diving PAM	12
WetLabs AC-S	7
Midac OP-FTIR	6
Piccolo Ground SIF Sensor	6

5. Any progress during the reporting period towards sustainability; working towards Net Zero and social responsibility.

Last year, we identified carbon emissions from shipping instruments to be a key contributor to our carbon budget, and we highlighted that this could be reduced by encouraging more in person collection of instruments, which would also facilitate one-to-one training. Over the 2023-2024 period, we've encouraged loan users to visit us to collect in person, and from our records, we have increased in person training and in person collection significantly. Remote training and shipping of instruments has only been required in five applications, all of which were emergency.

We would like to continue engaging with NCEO's Environment and Sustainability Co-ordinator to develop our carbon accounting even further, to identify further areas where we could improve.

6. Anything else that you would like to raise with NERC or would like a follow up conversation about?

As always, we greatly appreciate the engagement with the NERC S&F team, who have remained attentive and helpful even during staff changes. Likewise, we would like to thank our Steering Committee members, who have been asked to review multiple applications during the busiest loan period the facility has ever had. We would like to extend an invitation to the NERC S&F team, and to the Steering Committee, to visit us at our new Edinburgh location, where we would be happy to provide a tour of our new optical calibration laboratory, drone hangar, and training hub.

Appendix A – Scientific Papers Published during 2023-2024 supported by NERC FSF

- Bisset, R.R. et al. Using thermal UAV imagery to model distributed debris thicknesses and sub-debris melt rates on debris-covered glaciers. (2023). Journal of Glaciology. https://doi:10.1017/jog.2022.116
- Brown, L. et al. Hyperspectral Leaf Area Index and Chlorophyll Retrieval over Forest and Row-Structured Vineyard Canopies. (2024). Remote Sens. https://doi.org/10.3390/rs16122066
- Burton, M., Aiuppa, A., Allard, P. et al. Exceptional eruptive CO_2 emissions from intra-plate alkaline magmatism in the Canary volcanic archipelago. Commun Earth Environ 4, 467 (2023). https://doi.org/10.1038/s43247-023-01103-x
- Chandler C.J. et al. Spectral Characteristics of Beached Sargassum in Response to Drying and Decay over Time. (2023). Remote Sens. https://doi.org/10.3390/rs15174336
- Humpage, N. et al. GEMINI-UK: a new UK network of ground-based greenhouse gas observing spectrometers to help track progress towards net-zero targets. (2024). EGU Conference Proceedings 2024. https://doi.org/10.5194/egusphere-egu24-15956
- de Kekelaera, L. et al. Airborne Drones for Water Quality Mapping in Inland, Transitional and Coastal Waters—MapEO Water Data Processing and Validation. Remote Sens. (2023). https://doi.org/10.3390/rs15051345
- Lane, J. et al. High pathogenicity avian influenza (H5N1) in Northern Gannets: Global spread, clinical signs, and demographic consequences. Ibis (2023). https://doi.org/10.1111/ibi.13275
- Li, X. and Plater, A.J. Projecting Saltmarsh Sub-Environments for a Managed Realignment Scheme Using Machine Learning. (2024). SSRN. http://dx.doi.org/10.2139/ssrn.4671593
- Ryan, R. et al. Measurement report: MAX-DOAS measurements characterise Central London ozone pollution episodes during 2022 heatwave. (2023). ACP. https://doi.org/10.5194/acp-23-7121-2023
- Simpson, G. et al. Species-Level Classification of Peatland Vegetation Using Ultra-High-Resolution UAV Imagery. (2024). Drones. https://doi.org/10.3390/drones8030097
- Smekens et al. Rapid Primary Sulfate Aerosol Generation Observed With OP-FTIR in the Eruptive Plume of the Fagradalsfjall Basaltic Eruption, Iceland, 2021. (2024). JGR Atmos. https://doi.org/10.1029/2023JD040574
- Stringer, C.D. et al. Quantifying sediment sources, pathways, and controls on fluvial transport dynamics on James Ross Island, Antarctica. (2024). Journal of Hydrology. https://doi.org/10.1016/j.jhydrol.2024.131157
- Tebbs et al.. Satellite Earth Observation for the Sustainable Management of the African Great Lakes. (2023). KCL Policy Brief. https://doi.org/10.18742/pub01-121