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Earth Observation Skills Framework Research for the Caroline Herschel Framework Partnership Agreement for Copernicus User Uptake Project

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Contents

1 Context

JNCC's (Joint Nature Conservation Committee) 'Caroline Herschel Framework Partnership Agreement for Copernicus User Uptake' project aims to increase UK downstream environmental Copernicus applications through upskilling and cross border collaboration. This project includes a work package investigating existing frameworks of relevance to the skills and knowledge required for working with Earth Observation (EO), the findings of which are presented in the current report.

2 Aims

This report aims to enable staff and organisations to gain the knowledge, confidence and skills to become intelligent customers and practitioners of EO. For most organisations this will require additions to current expertise. This document aims to help with the identification of what is needed for this, how to maximise existing skillsets and how to bring the right skills together across a team or organisation. Many of the skills needed for EO will already exist in any given organisation for other purposes. Whilst some required skills are particularly EO specific, these can often be picked up by people with other spatial skills and the effort required for gain is relatively small. It is hoped that this will promote rapid uptake of EO to make a difference in the delivery of public functions. Information on relevant existing frameworks is presented, illustrating alignment and gaps between the skills needed for working with EO overall and current support and resources available.

3 What is needed to work with EO?

In addition to the more general 'soft skills' required in many jobs (such as networking, adaptability, ability to learn on the job), working in EO requires a number of technical skills and knowledge. These can be achieved to differing levels of proficiency, from basic to expert. Becoming a basic user will often require only a small knowledge and skill gain but will open up a wide range of applications. Whilst it is important for a team working with EO data to develop the full range of skills and knowledge listed below, this is most often achieved through bringing together people with different and complementary skillsets and knowledge bases, rather than expecting any one individual to be proficient in everything. EO is most powerful when used as a tool to provide information in many downstream applications which means that domain specific info is often needed in addition to EO. The required skills and knowledge listed in the following sections were identified through discussion among EO experts within JNCC.

3.1 Skills

The general skills required to work with EO are similar to those needed to work with many other types of data, and include: [1]

- **Requirements and business analysis** – understanding user needs and how data can be integrated into processes.
- **Data governance** – being able to collect, handle, publish and delete data effectively and understanding the responsibilities associated with data ownership

[1] Heeley, L. & Wilkinson, S. (2018) Data Skills Framework: A generic approach to assessing and developing data related competencies and skills, JNCC Report No. 590, JNCC, Peterborough, ISSN 0963-8091. Available at: https://hub.jncc.gov.uk/assets/6ef949ed-1c22-438f-b2f7-fd4818ec4566

- **Data management** – understanding data concepts, such as quality control and storage, both locally and in the cloud. Being able to combine data sources, for example across different sensors, domains and scales, as well as combining data from EO with ground-sourced data.
- **Access and security** – understanding of risk assessments, licensing, open data and access regulations.
- **Data manipulation** – being able to process, cleanse, combine and automate data, including in large quantities, both locally and in the cloud.
- **Analysis and modelling** – including statistics, processing chains, machine learning and predictive analytics, both locally and in the cloud.
- **Communication and visualisation** – interpreting, summarising and communicating data and modelling outputs. Adapting communication methods based on audience.

3.2 Knowledge

EO practitioners and customers will also need to have knowledge in topics that include:

- **Understanding resolutions** – understanding the scales and frequencies of observations and being able to select the appropriate option for a specific problem. A user does not need to be advanced to gain this knowledge.
- **Visual interpretation** – an ability to understand the data and options from simply looking at the data, without any further analysis. This includes an understanding of the effects of weather, angles and sensor noise on EO data. A basic user does not need to understand everything themselves but does need to understand which questions need to be asked to be able to interpret the data.
- **Intelligent customer function** – an ability to collaborate with and contract work to others effectively, as well as to plan projects with other teams and organisations. This includes a knowledge of the appropriate terminology and of what is and is not possible to physically detect and measure using EO.
- **Domain knowledge** – an understanding of a relevant system (land, air, sea, freshwater) and how both EO and *in situ* measurements can best be applied to measure relevant aspects of it.
- **Sensor knowledge** – an understanding of the scale sensors and which sensor type (e.g. radar / lidar / optical) is best used under which circumstances, and under which situations it is best to use an EO sensor rather than (or in addition to) an *in situ* sensor. It is possible to become a specialist in any one given sensor type, gaining an in-depth knowledge of its specifics, but it is possible to become a basic user with a much lower level of understanding.
- **Accuracy assessment** – understanding and being able to assess the level of accuracy of any measurements or analyses from EO data and understanding and communicating uncertainty.
- **Ground truth data** – understanding the importance of and being able to work with ground truth data.

4 Existing Frameworks

A number of existing frameworks cover some of the skills identified above. The content of a selection of these is summarised in Table 1. These frameworks were largely made known to the authors through consulting contacts in the EO field (and in particular within the UK public sector), within a time limited period. As such, the table is not designed to be a comprehensive assessment of all frameworks that currently exist, but it is hoped that it covers a selection that is most relevant and well-known in the EO field. Further detail on these frameworks and relevant links can be found in Appendices 1 and 2.

No frameworks identified within this review cover every aspect needed to work with EO, but many cover some, and could therefore be used in combination for organisations to identify recruitment or development opportunities to enable them to work with EO data more effectively. Of the frameworks identified, more exist that focus on skills than on knowledge. Knowledge that was not covered under any framework included understanding resolutions and visual interpretation.

Table 1. Content of existing frameworks of relevance to the skills required for working with EO.

	Skills							**Knowledge**						
	Requirements / business analysis	*Data governance*	*Data management*	*Access and security*	*Data manipulation*	*Analysis and modelling*	*Communication and visualisation*	*Understanding resolutions*	*Visual interpretation*	*Intelligent customer function*	*Domain knowledge*	*Sensor knowledge*	*Accuracy assessment*	*Ground truth data*
Within UK Government														
Analysis Function	x	x	x	x	x	x	x						x	
Science and Engineering Profession	x		x				x			x			x	
Geography Profession	x	x	x		x	x	x			x		x		
Data Digital and Technology Profession	x	x	x	x	x	x	x							
Outside of UK Government														
JNCC Data Skills Framework	x	x	x	x	x	x	x							
SENSE EO CDT Training Programme					x	x					x	x		
EARSC survey					x	x								
Skills Framework for the Information Age	x	x	x	x	x	x	x							
EO4GEO	x		x		x	x	x		x	x	x	x		

5 Existing Training and Useful Resources

Organisations that have identified the skills gaps they need to fill to advance their EO work may choose to either recruit the relevant skills into their team or focus on training to develop the skills of those currently within their team. Whilst specific research into this was outside of the scope of this project, relevant resources that were made known to the authors during the course of investigating relevant frameworks are recorded here.

Many of the frameworks in Table 1 signpost relevant training materials. In particular, the EO4GEO project has collated a report outlining a comprehensive list of the current supply of space / geospatial education and training, which may be of interest.

For an introduction aimed at those new to EO who need to develop their understanding of resolutions, what EO can and can't do and the basics behind the different types of sensor, JNCC's EO training may be of use (Session 1, Session 2 and Session 3). This will allow quick development of intelligent customer function and a basic ability to analyse imagery visually.

Many other online courses and training materials are also available, including the ESA's Massive Open Online Courses, SERVIR training materials and the official Copernicus Youtube channel.

For those organisations within UK public services, gaining membership of the Earth Observation Implementation Group may also be a useful development opportunity. At these groups, members can present methods and tools they have used for others to learn about or bring along problems they are facing in any EO related work that other group members can help to solve. To become a member, email your interest to earthobs@jncc.gov.uk.

6 Capacity Development Case Study

JNCC is one example of an organisation that has developed its EO capacity from zero to become a leading practitioner within the UK public sector. How this happened is explained here as an example that may be of use to other organisations wishing to improve their EO capacity.

Before the launch of the Copernicus programme, JNCC identified that the rich source of information the Sentinel satellites would provide, for free, was a key future opportunity. Defra agreed to fund JNCC to assist them in understanding how best to make use of this once the satellites were built. Initial work focused on mapping the extent of habitats and was largely carried out by contractors. A strong intelligent customer function was therefore the most important skill for much of the early work.

Following this, imagery analysis was identified as a skills gap to being able to carry out more in-house implementation. Through targeted recruitment, this gap was bridged. This resulted in an increase in capacity, ideas and ability to demonstrate the value of the work. This led to further recruitment, as the income generation potential of the work became better understood by senior management. The increase in EO specific expertise also further improved the intelligent customer function, meaning that more complex work could be contracted alongside the increase in in-house capacity. In addition, it meant that in-house EO training could be given to develop the required skillsets within staff already in the organisation, in particular those already familiar with spatial analysis and using GIS, for whom the addition of EO specific knowledge was a feasible step.

Separately, but in parallel to this, JNCC was also developing its analytical capacity. Eventually, the team with the analytical skillset and the team with the EO knowledge were merged into one larger team. This greatly increased the potential of EO applications within the organisation and demonstrates the ability for a rich set of skills to come from multiple individuals across a team, instead of every individual duplicating all required skills. Without this combination of complementary skillsets, JNCC would not be where we are today, carrying out complex projects that combine EO data with other information to achieve projects that involve complex modelling. For example, one project relied on the EO expertise of certain team members to create a habitat map of a viticultural region in Chile, and the

analytical skills of other team members to model the effects of various management practices on vineyards based on biotic and abiotic factors associated with the habitats mapped.

JNCC now has a strong EO capacity and is involved in many projects, ranging from assisting with the automation and production of analysis ready data for users across public sector environmental functions and development of standards, to the use of satellites to assist with the mapping of ecosystem services. Yet, it continues to assess its own skillset and identify gaps and opportunities to develop knowledge and capacity further.

7 Conclusions

A wide range of skills and knowledge are required to work with EO. To successfully develop EO into a work plan, an organisation will need to gain skills across this range – although this can be spread across the team rather than requiring individuals to have them all individually. Many frameworks exist that could help an organisation identify areas for improvement, but no one framework covers everything required. They should therefore be used in combination rather than isolation. In addition to frameworks, there are also many relevant training opportunities and resources that can help to bridge the skills gap once identified within existing staff.

Appendix 1 – Existing Skills Frameworks within UK Government

Government's overarching framework for assessing the skills needed to do any Civil Service job is known as Success Profiles, which have recently succeeded the Competency Framework. The Success Profiles assess performance across five elements:

- Ability – "the aptitude or potential to perform to the required standard"
- Experience – "the knowledge or mastery of an activity or subject gained through involvement in or exposure to it"
- Strengths – "the things we do regularly, do well and that motivate us"
- Behaviours – "the actions and activities that people do which result in effective performance"
- Technical – "the demonstration of specific professional skills, knowledge or qualifications"

As a specific professional skill, EO would largely fall under the technical element, although the other categories are of relevance if considering EO skills in a broader sense. Within the technical element, roles are generally attributed to one of 25 'Professions' or 10 'Functions'. The Head of each profession will define the specific skills, knowledge or qualifications required. Professions and Functions that could be of relevance to EO include:

- The Analysis Function "aims to improve the analytical capability of the Civil Service and act as the go-to-community for research and analysis services within government." With much EO work falling under the heading of analysis, any skills frameworks used here could be of potential relevance, although broader in scope than an EO specific framework. These include:
    - The Analysis Learning and Development Brochure – This is a collation of links to learning resources from within and outside of Government, covering any level. It aims to support in the development of several skillsets that would be relevant to EO, including data analysis, data visualization, data quality and more.
    - The Analysis Function Career Framework – This defines the skills and experience needed for typical roles across government and signposts relevant opportunities for learning and development. Of the typical roles described, the Geographic Analyst and Geospatial Information Specialist roles specifically mention working with remotely sensed images within the 'Typical Role Responsibilities' section and Earth Observation within the 'Key Skills' section. These roles also outline other skills that would be useful to work with EO data, such as geographic knowledge, geospatial data analysis, spatial statistics, geospatial tools and software and geospatial data management. Different levels of each skill are defined for different job levels, based on four broad bands of experience (whether you have an awareness of the skill, experience of the skill, are able to teach others, or are a recognised expert). Whilst EO is identified as a skill itself, this is not broken down into more precise detail on the skills required within EO. The document also provides information and resources on wider core skills that are useful to analysts whatever their more specific role, such as data visualisation, communication and quality assurance.
- The Government Science and Engineering (GSE) Profession aims to "make sure that government has access to the best expertise and advice to support decision making" and is part of the wider Government Analysis Function (above). Their responsibilities include developing high-performing, adaptable and skilled people and ensuring their access to skills and training. The GSE Career Framework, which has recently superseded the GSE Skills Framework, aims to outline the skills, knowledge and

experience required to be an effective scientist or engineer in government, in order to support personal development (signposting available resources and career progressions), management (identifying skills gaps across teams) and recruitment (best practice when considering applicants). Skills within this framework are relevant to all scientific and engineering related jobs, including those of EO specialists, but are very broad and general.

- The Government Geography Profession falls within the Government Science and Engineering Profession described above but is a smaller Profession of particular relevance to EO due to its spatial nature. This Profession is relatively new, having only been established in 2018. It has recently published guidance on the interpretation of the Analysis Function's Career Framework (see above) specific to geographers, but as yet has not published a Framework itself.
- The Digital Data and Technology Professions (see also the Civil Service website) is another Government Profession, covering roles that involve IT and data science. They have a capability framework which carries out the same function as the career frameworks described previously. It outlines a number of job 'families' within the profession, with further detail on the skills needed for each role within the family. The family relevant to EO would be the 'Data job family,' in particular the roles of 'Data analyst,' 'Data engineer' and 'Data scientist.' Whilst the skills they describe are again not specific to EO, or even to geospatial data rather than data more generally, they do provide a framework of broader skills that would be useful for those working within EO, such as data manipulation, visualisation, quality assurance and modelling.

Appendix 2 – Existing Skills Frameworks Outside of UK Government

- JNCC has a Data Skills Framework. Again, whilst this is not aimed specifically at users of EO, it would have use in developing broader skills of use within EO, including data governance, management, access and security, manipulation, analysis and modelling, and communication and visualisation. EO, remote sensing and geospatial data are mentioned several times throughout the document, although they are presented as component skills of the wider skill, rather than being broken down into the skills that are of use within EO. This framework gives more in depth detail within each of the skills it describes than the frameworks described previously, outlining specific criteria that must be met for each skill across three levels, as well as specific tools and software that individuals should be familiar with.
- The SENSE EO CDT is a centre for doctoral training with a focus on developing high capacity EO scientists. Training is provided to all students, the first cohort of which will begin in October 2020. Their framework is much more EO specific and much more content based than the frameworks described previously. The topics that will be covered are:
    - Software Carpentry and Good Code
    - Optical Earth Observation
    - LIDAR and SAR
    - Time Series Analysis
    - Oceanography
    - EO of Atmosphere
    - Machine Learning and AI
    - Cryo InSAR
    - Big Data and Climate
    - Field Spectroscopy
    - CEMS training with big satellite datasets

  These topics will be covered a week at a time and be led by experts in the different fields from the Universities of Leeds and Edinburgh and The National Oceanographic Centre. In addition to this the students will also be given generic training by their universities on research skills and topics like giving presentations and creating posters and there will also be opportunities for them to present their work at departmental events and also Sense specific events like our annual Industry Symposium. Further on, their training we will be focussing on things like Science Communication and Entrepreneurship. Each student will also complete a training needs analysis in conjunction with their supervisor. It may be that they need to tap into specific courses offered by their base university, or they may have to learn about a specific type of software, technique or equipment. This will usually happen within the first six months when the student is developing their research plans.
- The European Association of Remote Sensing Companies (EARSC) perform an annual survey of remote sensing companies. In 2020, for the first time, they looked into recruitment and the skills needed to work in remote sensing, the results of which can be viewed in their Industry Survey 2020. The survey showed that 80% of respondents are finding it difficult to find and hire candidates, supporting the need for a skills framework. As part of their EO4GEO project, a multi-disciplinary group from industry is aiming to create a ‘skills sector alliance’ that communicates training needs to academia for inclusion within academic courses. Although not yet operational, this could be useful in informing a skills framework in future. The survey revealed that the most sought-after skill according to respondents was programming and development capacity, followed by analytical methods.
- The Skills Framework for the Information Age (SFIA) describes the skills required by those working in the information and communication technology sector. Whilst not

specific to EO, many of the applications of EO would fall within this sector, and so many of the skills mentioned here will also be of relevance to EO practitioners. It describes in detail 102 skills required for working in this area across seven levels of responsibility, from following and assisting, to leading and setting strategy. Skills are grouped into seven main themes:
    - software engineering
    - cyber security
    - digital transformation
    - agile & DevOps
    - big data and informatics
    - knowledge
- The European Space Agency makes available a set of 'Massive Open Online Courses' (MOOCs) for those wishing to improve their EO skills. There are currently courses on radar data, optical data and using EO for climate monitoring. Although not setting out to be a framework, the skills covered within the courses can act as a framework of skills the course developers view to be important in developing EO capacity.
- SERVIR is a joint development initiative of National Aeronautics and Space Administration (NASA) and United States Agency for International Development (USAID). They work to improve the capacity of developing countries to make use of EO data in local solutions. A part of this involves providing training, some of which leaves online material that others can make use of. This training tends to be aimed at fairly specific applications (for example recent training has included 'Estimating Forest Stand Height (FSH) With Synthetic Aperture Radar (SAR),' 'SAR Handbook: Comprehensive Methodologies For Forest Monitoring And Biomass Estimation' and 'Forecasting And Communicating Water-Related Disasters In Africa.' However, many of the skills that need to be developed for these more specific applications are transferable to other applications. Although not setting out to be a framework, the skills covered within the courses can act as a framework of skills the course developers view to be important in developing EO capacity.