UK-Australia Cal-Val Space Bridge

Final Report
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Assimila

Symbios

FRONTIER SI

Executive Summary

The preliminary phase of the UK-Australia Cal-Val Space Bridge Project has confirmed that there are exciting opportunities for collaboration between UK and Australia in the area of Earth observation calibration and validation. Both countries have niche and complementary capabilities in this area. Australia has announced its first National Satellite Mission for Earth Observation (NSMEO) - the Satellite Cross-calibration Radiometer (SCR) series of satellites - which is firmly in the category of a cal-val mission and which serves to underline the importance of partnerships in cal-val to Australia.

A series of workshops and follow-up investigations has identified a number of areas as priorities for UK-Australia collaboration, including:

- Strategic and structural: Strategic alliances of UK & Australia, through the Space Bridge framework, including to define collaborative cal-val activities and share facilities. For example in the event that the UK leaves the Copernicus Programme. This might be supported under a UKSA-ASA MOU on EO Cal-Val.

- Cooperation on the Australian and UK 'cal-val missions' - being SCR (Australia) and TRUTHS (UK/ESA), including through a technical cooperation agreement between GA (Australia) and NPL (UK).

- EO Data Quality and Integrity Monitoring Framework - proposing that Australia and the UK could be at the forefront of a rules-based framework that seeks to develop and support open source tools, standards and communities to establish and apply EO data integrity monitoring capabilities.

- Biomass cal-val cooperation: Reflecting the strong capabilities in Australia, the coming needs of the UK/ESA Biomass mission, the desire of the CEOS community to establish harmonised biomass products and the increasing importance and market for those products in carbon farming, climate inventory and other applications.

- Commercial sector cooperation: exploring the development of the commercial sector around the provision of cal-val products and services that can serve to optimise the societal benefit of the new generation of smallsat missions and optimise the contribution of existing public infrastructure to that end.

The funding and programmatics around Australia's NSMEO should provide a solid foundation and motivations for advancing a collaboration with the UK, including in relation to the development of an EO Data Quality and Integrity Monitoring Framework and of the AUSCALVAL concept. A follow-on Space Bridge project with a continued focus on cal-val would have plenty of scope to progress specific collaborations between the two countries, building on the findings of this phase.

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1 Introduction

1.1 Purpose

This is the final report on a project led by Symbios (Australia), with support from Frontier SI (Australia) and Assimila (UK), with the objective of exploring opportunities for collaboration between the UK and Australia focused on the calibration and validation aspects of EO satellite missions, and seeking to identify opportunities and specific projects for follow-up.

The project was funded under the UK-Australia Space Bridge Framework arrangement aimed at enhancing cooperation in the space industry in a number of focus areas: Earth Observation and Climate Resilience; Agriculture and Land Management from Space; Enabling Connectivity and Innovative Space Communications; and Quantum Technologies for Space. Funding was provided by SmartSat CRC (pursuant to the Australian Cooperative Research Centre Program), the Satellite Applications Catapult and the UK Science and Innovation Network. Support was also provided by Austrade and the Australian Space Agency.

1.2 Contents

This report is the final deliverable due under the Space Bridge project agreement, along with an accompanying presentation deck.

Section 2 presents a summary of the project activities, key events and materials.

Section 3 summarises the key conclusions regarding the activities and capabilities in each country and the outcomes of our investigations regarding mutual priorities and the opportunities that might be explored further beyond our initial investigations.

Recommendations for further steps are summarised in Section 4.

1.3 Glossary

AGB	Above Ground Biomass
AI	Artificial Intelligence
ASA	Australian Space Agency
AusCalVal	Australian Strategy for Calibration and Validation
Cal-Val	Calibration and Validation
CEOS	Committee on Earth Observation Satellites
CLARREO	Climate Absolute and Refractivity Observatory
COP 26	Conference of Parties (26) - 2021 in Glasgow

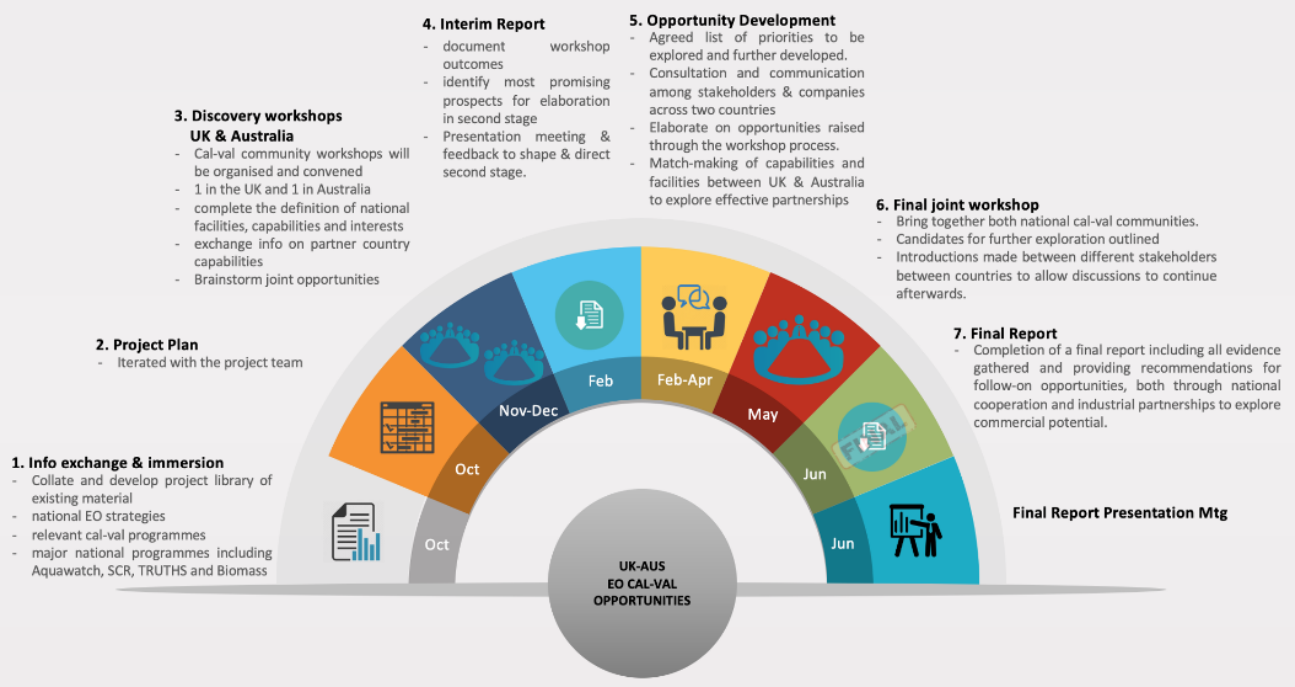
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSRB-LIBRA	Chinese Space-Based Radiometric Benchmark Mission LIBRA
EC	European Commission
EDAP	Earthnet (ESA) Data Assessment Pilot
EO	Earth Observation
EO-AIM	Earth Observation - Assurance and Integrity Monitoring
EOSURE	ESA study to examine how to better understand and improve the quality assurance of end-to-end Earth Observation (EO) supply chain.
ESA	European Space Agency
FLEX	Fluorescence Explorer (planned ESA mission)
FORUM	Far-infrared-Outgoing-Radiation Understanding and Monitoring mission (ESA)
FRM4GHG	Fiducial Reference Measurements for Ground-Based Infrared Greenhouse Gas Observations
GA	Geoscience Australia
GCOS	Global Climate Observing System
GEDI	Global Ecosystem Dynamics Investigation
GEO	Group on Earth Observations
GEO-TREES	GEO's Forest Biomass Reference System from Tree-by-Tree Inventory Data
GEOBON	Group on Earth Observations Biodiversity Observation Network
GLAMIS	Space Borne EO LIDAR concept
GOFC-GOLD	Global Observations of Forest Cover and Land-use Dynamics
GSD	Ground Sample Distance
JAXA	Japanese Space Agency
ML	Machine Learning
MOU	Memorandum of Understanding
MWIR	Medium Wave Infrared
NCRIS	National (Australian) Collaborative Research Infrastructure Strategy
NERC	Natural Environment Research Council (UK)

NIMCAM	Near Infrared Multispectral Camera for Atmospheric Methane
NIR	Near Infrared
NPL	National (UK) Physical Laboratory
NSMEO	National (Australian) Satellite Mission for Earth Observation
QA4EO	Quality Assurance framework for Earth Observation
QC	Quality Control
RadCalNet	Radiometric Calibration Network
RAL	Rutherford Appleton Laboratory (UK)
RCN	(Australian) Research Coordination Network
SAR	Synthetic Aperture Radar
SCR	Satellite Cross-calibration Radiometer
SECO	NERC Project for resolving the current and future carbon dynamics of the dry tropics
SI	International System (of units: French acronym)
SITSAT	SI Traceability Satellite
SLSTR	Sea and Land Surface Temperature Radiometer (instrument on Sentinel-3)
SSTL	Surrey Satellite Technology Limited
STFC	Science and Technology Facilities Council (UK)
SWIR	Shortwave Infrared
TERN	(Australian) Terrestrial Environmental Research Network
TPZ	Telespazio
TR	Transfer Radiometer (TRUTHS calibration instrument)
TRUTHS	Traceable Radiometry Underpinning Terrestrial- and Helio- Studies
UKSA	United Kingdom Space Agency
USGS	United States Geological Survey
WGCV	(CEOS) Working Group on Calibration and Validation

2 Project activities

2.1 Project Plan & Schedule

The overall project plan with the different phases and their timing is shown below, replicated from the project proposal. One development that differs from the original proposal is the replacement of a 'final joint workshop' (intended to bring together UK and Australian stakeholders after their individual national workshops). It was judged that - given the very disparate nature of the communities interested in or active in cal-val that we encountered in the course of the project - that it would be more effective to have more focused and directed partnership calls on specific topics; and this was undertaken from February to June 2022.



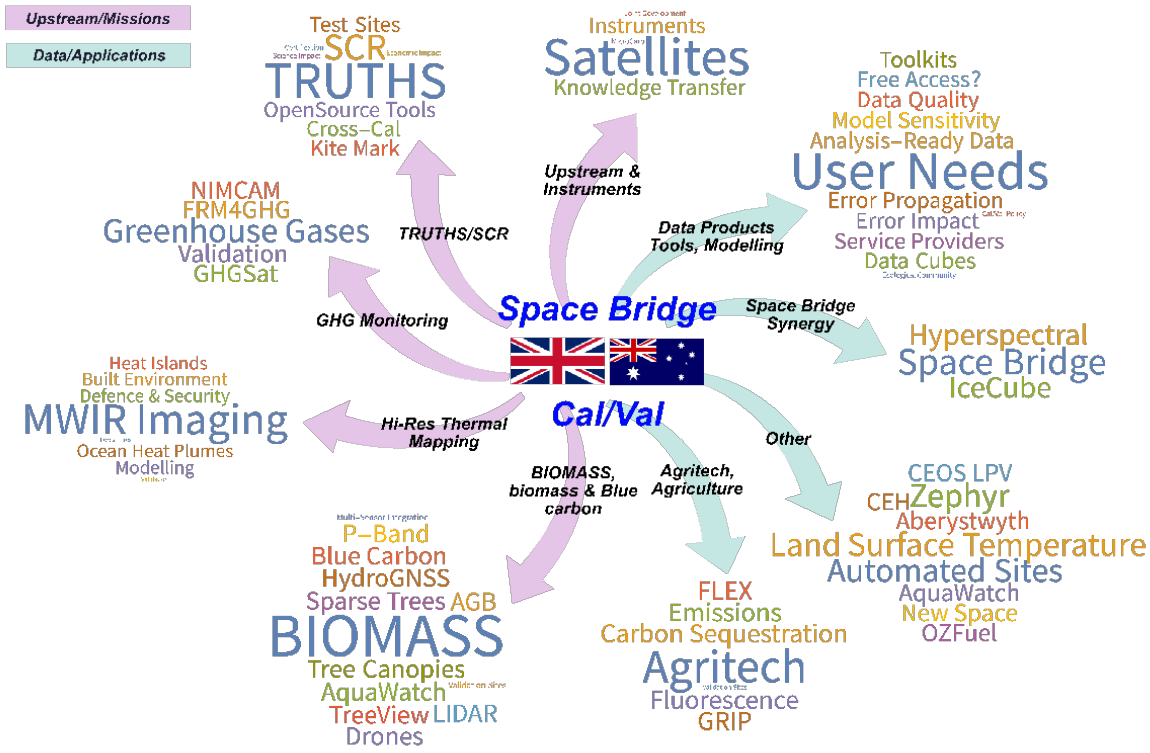
Australian Workshop

The Australian discovery workshop was held as a hybrid event - with both online and in person participants joining the project team at CSIRO, Black Mountain, Canberra on 1 December 2021. Around 50 attendees participated from 28 different organisations - spanning federal government agencies, state government agencies, universities, and the space industry - including several from specialist agricultural market companies. Attendee lists are shown in the Appendices to this report. This first workshop was intentionally exploratory and aspirational, laying out a vision for Auscalval as a national facility and seeking feedback on who needs to be involved and how. The workshop outlined three cal-val Space Bridge case studies:

- Biomass and carbon markets;
- Open source data quality and integrity tools;
- SITSAT cooperation (TRUTHS (UK) and SCR (Australia) missions)

UK Workshop

COVID complications delayed the UK workshop until 19th January 2022, and it was held as an online event only. 29 participants joined with a good mix of academic, government and industrial participants. The diverse audience raised a very broad range of possible topics of interest for collaboration with Australia - summarised in the word map below.



Opportunity Development

An unexpected opportunity arose with the visit of Assimila (UK) to Australia in support of a separate EO4Agroclimate programme, and Symbios and Assimila took the opportunity to meet with a number of stakeholder agencies in Sydney and Canberra in March 2022. This included the SmartSat CRC, CSIRO and Geoscience Australia.

Following the discovery workshops the UK and Australian teams settled on a shortlist of topics to concentrate further enquiries on, based on both the interest from the workshops and opportunities identified in the funding landscape - notably with Australia's announcement of the funding of the NSMEO and the SCR mission. The topics to be explored fell under the following headings:

1. **Strategic and structural:** Strategic alliances of UK & Australia, through the Space Bridge framework, including to define collaborative cal-val activities and share facilities. For example, in the event that the UK leaves the Copernicus Programme.

2. **SCR-TRUTHS Cooperation:** Mission intercomparison work is complex and needs a global effort. Missions such as SCR and TRUTHS seek to establish Australia and UK at the forefront of this capability and cooperation in this area is a natural focus and opportunity

3. **EO Data Quality and Integrity Monitoring Framework:** The proposition being that data integrity monitoring can be expected to be of increasing interest as EO data is used for more regulatory and monitoring purposes and subject to legal scrutiny. Australia and the UK could be at the forefront of a rules-based framework that seeks to develop and support open source tools, standards and communities to establish and apply EO data integrity monitoring capabilities.

4. **Biomass cal-val cooperation:** Reflecting the strong capabilities in Australia, the coming needs of the UK/ESA Biomass mission, the desire of the CEOS community to establish harmonised biomass products and the increasing importance and market for those products in carbon farming, climate inventory and other applications - considering a thematic case study for Aus-UK cooperation on biomass cal-val.

5. **Commercial sector cooperation:** There is a significant change in the demographic of the EO satellite sector with the explosion of New Space missions. The project will seek to explore the development of the commercial sector around the provision of cal-val products and services that can serve to optimise the societal benefit of these new missions and optimise the contribution of existing public infrastructure to that end.

These topics were the basis for the prioritisation of our further investigations and networking efforts with UK and Australian organisations.

2.2 Networking, partnerships & funding investigations

The January to June period involved more detailed investigation with individual stakeholders and exploring potential partnerships, by both email and teleconference. A brainstorming and prioritisation workshop was held with Frontier SI, GA, and CSIRO in Canberra in late May in order to develop a consensus as to which of the threads should make it to the recommendations and to ensure that they reflected the latest thinking, programmatics, and budget developments in the Australian sector.

Since the UK workshop the team has followed up with one-to-one discussions in key topic areas, including: biomass cal-val - both specific to the BIOMASS mission and exploring the wider issues; commercial; TRUTHS/SCR cooperation; commercial services in greenhouse gas monitoring; and cal-val systems, processes and tools.

During the execution of this project, team members have been engaged in a parallel project funded by STFC examining UK-Australia collaboration on the use of EO data in climate smart agriculture. This project has identified several areas where improved data fidelity and traceability enabled by better cal-val could accelerate new applications. The team has continued working with STFC/RAL in the UK to take advantage of a number of calls for funding proposals relevant to this area and focused on a UK-Australia partnership

in cal-val for EO. We await the outcome of those proposals as a possible vehicle to implement multiple of the recommendations from this preliminary Space Bridge phase work.

Symbios and Frontier SI have also begun work with Geoscience Australia in the development of a new round of budget applications to the Government, in relation to the establishment of new facilities for Australia to develop a niche around space governance and data integrity. This programme offers scope to provide matching funds to any budget available from the UK.

3 Conclusions

The main conclusions arising from our workshops and consultation efforts are presented in this section.

3.1 National priorities and capabilities

This initial phase of the Cal-Val Space Bridge was proposed by Symbios and partners precisely because both the UK and Australia have world-leading and niche capabilities in the area of EO satellite calibration and validation. We sought to explore where opportunities lie and could be further developed, reflecting the political and technical contexts and ambitions of each country. Since the inception of the project, Australia has announced its first National Satellite Mission for Earth Observation (NSMEO) - the SCR series of satellites which is firmly in the category of a cal-val mission and which serves to underline the importance of partnerships in cal-val to Australia.

The UK is clearly a more mature player in the calibration field, with long-established specialist facilities and teams at establishments such as RAL and NPL for the calibration of EO instruments. UK industry has benefited significantly from UK participation in and support to the EO satellite programmes of ESA and the EC, and in particular the substantial cal-val activity run from ESA ESRIN. This includes programmes such as QA4EO and the ESA Earthnet Data Assessment Pilot (EDAP) project - which performs assessments for various missions to ensure the delivered data is fit for purpose. Companies like Telespazio UK have developed a substantial market share of specialist support to ESA programmes such as these and developed pan-European consortia to handle almost any kind of sensor cal-val.

For its part, Australia is widely recognised as a world leader in the provision of cal-val sites, making best use of the size of the Australian continent and the diversity of geographies that it encompasses. The AUSCALVAL concept has sought to bring an identity and renewed purpose to these capabilities and there is significant activity underway to bring additional funding and ambition to AUSCALVAL, set in the broader context of the NSMEO, as well as the cal-val needs of individual national missions being proposed such as AquaWatch.

Australia also has extensive expertise in the calibration and validation of EO derived products, having world-class long-term monitoring ecological field sites funded under the Terrestrial Ecosystem Research Network (TERN) and National Collaborative Research Infrastructure Strategy (NCRIS). In addition, Australia has contributed significantly through targeted field collection of spectral libraries, to the validation of international space agency missions, such as the USGS Landsat program and the Copernicus Sentinels. Most recently, this was exemplified through the Landsat 9 underfly where targeted collection of spectra was undertaken to assist the USGS in calibration of Landsat 9 with other Landsats and Sentinel 2. Australia has long been a collaboration partner of choice for these types of exercises due to the southern hemisphere location, national level of access to scientific equipment and expertise, and wide variety of land cover types present and accessible as representative of world landcover, all found within the same continent. The geometric control point library currently used by the USGS and Copernicus for the Australian continent was developed by Australia and later incorporated into the workflow pipeline for these international missions.

3.2 Strategic and Structural Opportunities

The Cal-Val Space Bridge study has confirmed that real and exciting opportunities exist for UK And Australia to further develop a strategic alliance, possibly under the Space Bridge framework, in relation to collaborative EO satellite cal-val activities and shared facilities. Both countries appear to be highly motivated to pursue such an alliance:

- Australia seeks to develop the know-how to define and operate its planned EO satellite missions, and to fulfil a niche in the global space cooperation frameworks - in relation to space governance and assuring quality and integrity of data, as well as seeking to extract increased economic and societal benefits from New Space smallsats through access to free, open and transparent services to better characterise and calibrate these systems; Australia would benefit from like-minded partners seeking to establish the role of space in a rules-based world, and recognising its contribution to the digital economy, if suitably trusted and reliable.

- The UK is a pioneer in the intellectual formulation of EO data policy, and the science of ensuring that EO data is fit for rigorous purposes such as climate monitoring. The UK has built a substantial public and private space sector through its association with the broader European space programme, and with the Copernicus programme in particular in relation to EO and cal-val aspects. With UK future participation in Copernicus in some doubt, they will be looking for new geometries, new partners, new suppliers and new markets for their public and private stakeholders and companies. Our studies confirm that Australia might represent an ideal alliance partner for the UK in the field of EO cal-val.

Australia's big picture of 'giving back' to the EO sector through calibration transfer from SCR, and through using open source cal-val tools to improve the suitability of New Space smallsat data, represents a rather unique strategy that we think both countries could easily rally behind given the public and commercial benefits associated with it. Increasing trust in EO satellite data and providing proof that it meets quality needs of major industries like mining and agriculture can open up significant commercial opportunities beyond the niche segment around cal-val. All EO data providers will benefit from access to more customers, for more applications.

The fact that both countries are heavily invested in national SI Traceability Satellites (SITSATS - being SCR for Australia and TRUTHS for the UK (technically an ESA mission)), provides further weight and scope for a focused alliance and would benefit both missions substantially (more details in the sections that follow).

UK expertise might also help build technical capacity in Australia in order to help define and execute the cal-val aspects related to national missions such as AquaWatch. UK support and mentorship for the development of Australia's specialist industry to support future concepts around cal-val and the work for national missions, as well as that for AUSCALVAL, can help accelerate these programmes whilst offering commercial opportunities to UK companies.

A UKSA-ASA bilateral agreement to develop cal-val industries and capabilities would have substantial benefits. The respective programmes on both sides would benefit, including SCR, TRUTHS, AquaWatch

and AUSCALVAL. Together the UK and Australia might sponsor an acceleration of the technical cooperation underway in the Committee on Earth Observation Satellites (CEOS) and their Working Group on Calibration and Validation (WGCV) in relation to SITSATs and to Open Source Cal-Val Toolkits. This would bring further leverage to the activity and would have the benefit of a national gateway to the respective EO data providers in the main countries (like USGS to the US companies, ESA to the European companies, and JAXA to the Japanese companies). Using a global cooperation to develop facilities and processes to extract more value from future generations of smallsats can represent a niche role for both public and private space sectors in the UK and Australia.

3.3 SCR-TRUTHS Cooperation Opportunities

The mission intercomparison and calibration transfer work which is the goal of SITSATs is complex and needs a global effort typically involving systems and satellites of multiple countries. SITSATs are the focus for a very small club of nations, being: China (CSRB - LIBRA), USA (CLARREO), UK (TRUTHS, an ESA mission. ESA also has the FORUM mission in definition), SCR (Australia). SITSats can transfer their SI-traceable reference calibrations to hundreds of orbiting sensors across a large part of the reflected solar and thermal infrared spectrum.

TRUTHS is amongst the most ambitious of all of these projects and is not expected to be operation before the end of the decade - given the technically challenging nature of the mission. SCR has much more modest ambition and is assumed to be launched within 2-3 years from now.

The routine transfer of calibration characteristics from one satellite to multiple others, using a 3rd mission such as SCR (or indeed any mission) is not yet a working reality, and there will be many practical, technical and operational issues to understand, address and gain experience in. Regardless of the difference in the target accuracy for SCR and TRUTHS, we anticipate that there is substantial scope for a working-level technical cooperation agreement between the UK and Australia on these missions. TRUTHS is a decade away and subject to funding uncertainty. SCR is funded, happening soon, and will develop valuable operational experience that can certainly support the TRUTHS programme. In turn, NPL can help mentor and develop technical capacity within Australian agencies like GA. For broader context and benefits, both UK and Australia can sponsor the escalation of the ongoing SITSAT thread within CEOS WGCV such that experts from all relevant countries might be tapped through the neutral CEOS forum, to help solve problems as they arise in the mission programmes.

TRUTHS will not provide data much before the end of the decade, however there is much to be done to prepare for TRUTHS and to develop tools and systems to deliver the desired cross calibration function in support of SCR and other third-party missions. Preparatory work can be done with e.g., Sentinel 2 and in due course with CLARREO Pathfinder. NPL is developing tools now and has a vision to develop a virtual sensor model to build in redundancy and independence into the tools without the need to rely on RadCalNet and Libya-4 for example. Regarding TRUTHS/SCR collaboration, there needs to be a detailed discussion between NPL and Geoscience Australia, so that the requirements for SCR are clear to NPL, and there is scope also to assist GA in designing the best possible payload elements in anticipation of the deployment of SITSat cross calibration. A major design consideration for hyperspectral sensors is minimisation of, and taking account of, stray light in the instrument. The smaller and more compact the instrumentation, the worse the stray light tends to be.

SCR would not need the ultimate accuracy of TRUTHS, but it needs to have a defined and stable measurable SI traceable uncertainty. It is likely that this will be addressed in stages beginning with the uncertainty derived from the as-built characterised sensor and improved in stages using the tools under development by NPL and others, which will be further enhanced by the inclusion of CLARREO Pathfinder data, and ultimately using TRUTHS as a reference.

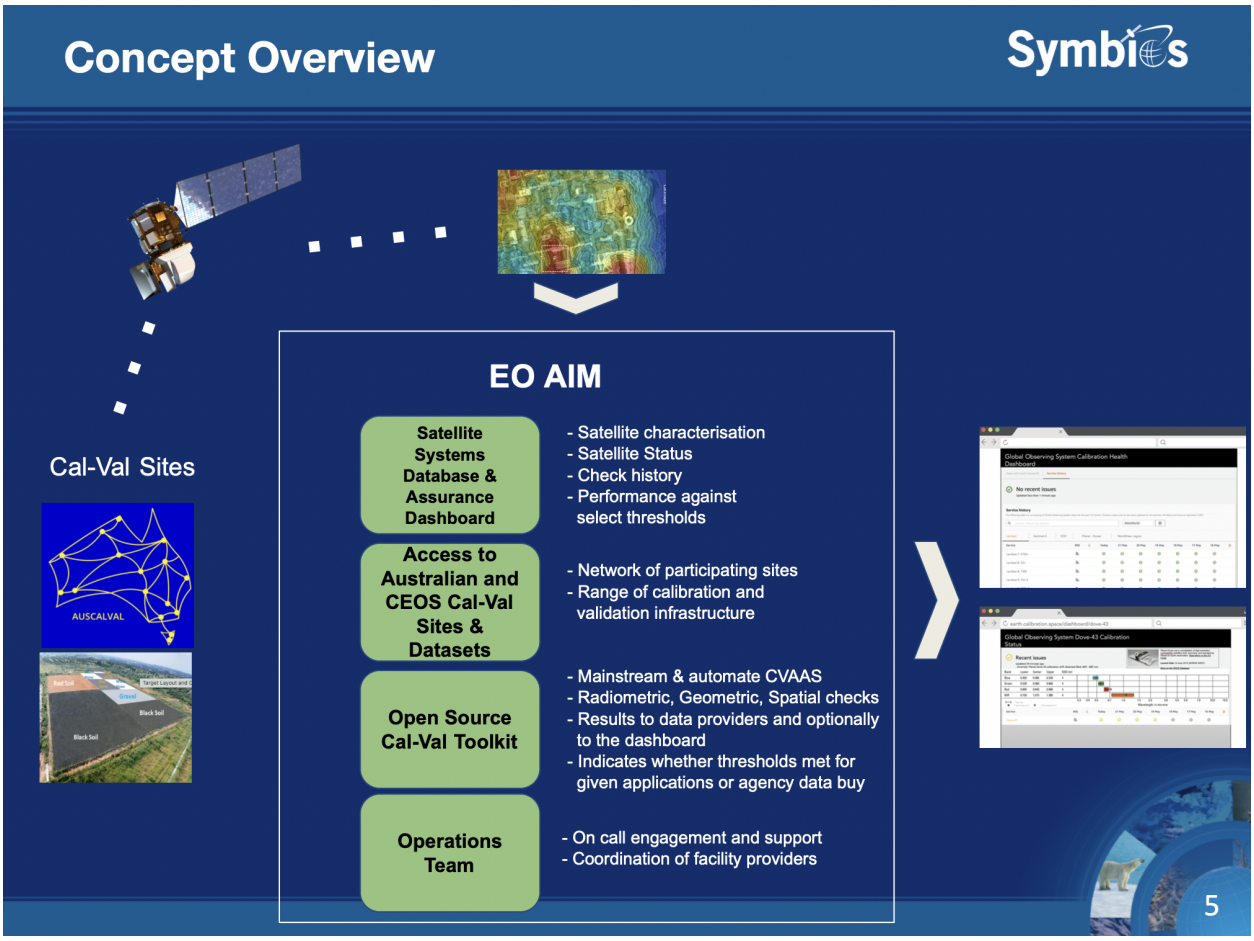
In parallel with development of the cross-calibration methodology and toolset, it will be necessary to engage with the user community, i.e., the ultimate consumers of the certified products to determine exactly what level of accuracy they need, and specifically what difference these new certified products will make to their applications. Examples include accuracy of crop yield forecasts, and risk forecasts. This is not a straightforward undertaking, as many of the ultimate users may not fully understand the meaning of the certified uncertainties, or how to trace the uncertainties through their models to provide trustable conclusions. The suggested approach is to undertake collaborative case studies within the user communities, which would be done in collaboration with EO data experts, instrument experts, and the downstream users who need to provide concrete and understandable results to their decision makers. This would be a good fit for Space Bridge funding, tackling the ‘so what’ issue prior to completing the detailed toolsets and methodologies for SI-traceable cross-calibration, and to avoid over engineering.

SCR and TRUTHS seek to establish Australia and UK at the forefront of this highly niche capability and cooperation in this area is a natural focus and opportunity for both countries. NPL (UK) and GA (Aus) would be the natural counterparts for any technical agreement or MOU. The UK has a special interest in EO data being fit for climate monitoring purposes and current space-based observations are typically factors of 5 to 10 less accurate than climate-change science requirements. Higher-accuracy observations can reduce the time to verify rigorous climate trends by decades compared to current sensors. International metrology laboratories and space agencies have developed and demonstrated new technologies to provide space-based SI-traceable reference instruments on SITSATs to achieve climate-change accuracy requirements. The economic value (through to 2100) of a higher-accuracy climate observing system referenced to SITSATs has been estimated at between $US 5 and 20 trillion.

3.4 EO Data Quality and Integrity Monitoring Framework

In addition to the core programme around the definition and building of the SCR mission, Australia agencies are planning to undertake substantial activities related to institutional and geopolitical issues related to the cal-val sector and its potential to bring societal and economic benefits. Australia is late to the space table of nations and, in looking for a seat at the table with its natural allies, has identified a role in space governance and improvement of data integrity as an unfilled niche - with a good fit to its initial satellite programme priorities, and one with substantial promise of improved revenues and jobs, both from the niche role and from the increased penetration of EO data sources to new customers and new applications.

EO AIM (EO - Assurance and Integrity Monitoring) is the working title of a GA-led concept to harness AUSCALVAL infrastructure and Australia's world-class cal-val sites with a new satellite systems database and dashboard and an open source tool-kit of automated cal-val functions that satellite data providers can use routinely to improve the characterisation and calibration of their data and products. Such a service aims to improve trust in the many smallsat missions that are typical of the New Space era. Compared to the 1-tonne, long life, very expensive and superbly characterised and calibrated flagship missions of the public space agencies (like the Landsat series or the Sentinel series), these smallsats are considerably less characterised and calibrated. The free provision of services to address this, aims to increase trust in this data and to support its application to more uses for more users. It also seeks to support the expectation that data integrity monitoring can be of increasing interest as EO data is used for more regulatory and monitoring purposes and subject to legal scrutiny. Australia (with the UK) could be at the forefront of a rules-based framework that seeks to develop and support open source tools, standards, and communities to establish and apply EO data integrity monitoring capabilities.



EO AIM Concept Overview

UK interest in collaborating in EO AIM will be multi-dimensional, but we expect it to include: new markets for UK specialist cal-val companies; strategic interest in the evolution of satellite EO data for climate monitoring purposes; new sources of cal-val services and facilities outside of Copernicus; competitive advantage for UK New Space companies.

CEOS WGCV has a long heritage in this area and can be a source of considerable expertise and support in the pursuit of such a facility. The current (JAXA) and incoming (ESA) Chairs have indicated that this is an area of direct interest to their WG. Together, UK and Australia could pioneer an international collaboration, under a CEOS banner, to define and develop this capability.

Funding for this initiative in Australia is subject to the ongoing feasibility study and to a successful budget application. In the UK, investigations under their EO4AgriClimate study with Australian partners have resulted in a proposal for a combined effort in this direction: *"A UK-Australia Global Centre of Excellence for EO Data Quality for Agriculture, Climate and Trade."* So, some momentum towards a strategic alliance already exists.

The industrial sector is also engaged in data quality issues. Telespazio UK have undertaken some initial development for an **EO QC Toolset Suite** for which they see there is a current need, and which also supports the intentions laid out in the Australian EO Roadmap. The EO QC Suite is envisaged to be an online platform with the facility to host multiple EO data tools, with a specific focus on data QC, all accessible through a single GUI. The platform would present an excellent opportunity for collaboration and development with Australian partners as it is intended to have the facility to host bespoke developed tools as well as those developed by other partners or third parties. TPZ UK are keen to employ their expertise in geometric calibration, radiometric calibration and image quality assessments, working alongside Australian partners to co-develop new QC or cal-val tools relevant to an array of satellites (e.g. SAR, optical, RF satellites), and host these tools on the platform. These tools would then be integrated with the common front end GUI, making them available online and integrating them with the supporting modules automating the operation of these tools where appropriate, and extracting and collating the outputs/results into a single, centralised database. Report generation modules would then extract the relevant information from the centralised database for the specific needs of the international users. The objective is that the co-developed EO QC Suite becomes a joined up, 'one-stop-shop' portal through which QC teams can monitor a variety of datasets using a range of tools, with the facility to integrate additional tools and modules as required. The longer term goal to be to enable online access to the QC Suite for external users (outside the specific QC teams), to allow other teams or satellite providers to use/benefit from the tools for their own purposes, through dedicated license agreements.

TPZ-UK would propose a joint project building on their work on the application of Artificial Intelligence and Machine Learning techniques to the **detection of anomalies** within EO datasets. The greatly increasing volume of EO data being generated in recent years creates an equally increasing workload on the EO data quality assessment teams, who can struggle to scale up their activities at a similar rate given the limited resources typically available. The use of AI and ML in this domain has the potential both to mitigate the increasing amount of data produced and enhance and improve upon the assessments currently undertaken. Different tools and techniques are required to support the generation of AI-based detection algorithms for different satellite datasets. TPZ UK has been applying AI techniques to detect anomalies in optical data products, allowing enhanced data quality assessments to be performed against large EO data sets, on an operational basis or on offline whole-archive reprocessing campaigns. A collaboration activity to develop new AI-based models for Australian EO datasets would support the evolution of these existing QC models by expanding their capability to new sensors and sensor types, while providing Australian operational teams a more powerful toolset to enable them to better adapt to the increasing amount of data being received - significantly improving the efficiency of their QC teams and allowing them to better focus their effort on critical events.

3.5 Biomass calibration and validation collaboration

Reflecting the strong capabilities in Australia, the coming needs of the ESA BIOMASS[1] mission, the desire of the CEOS community to establish harmonised biomass products and the increasing importance and market for those products in carbon farming, climate inventory and other applications, there is a strong case for the establishment of a UK-Australia Research Coordination Network (RCN). Both Australia and the UK have considerable expertise in above ground biomass (AGB) measurements, with opportunities building on existing collaborations, as well as new collaborations that flow into the emerging commercial sector for carbon monitoring and measurements. Commercial opportunities in this area will be fostered by government policy that advocates for more and accurate AGB measurements to meet national and global carbon emissions reporting.

AGB provides a measure of carbon storage and is typically used to quantify the level of carbon maintained within a system. Any reductions in AGB can be thought of in simplistic terms as carbon emissions. Such reductions typically occur through a variety of human and naturally induced phenomena including land clearing, fires and natural vegetation senescence. Given the recent emphasis on climate change mitigation, reduction in carbon emissions as well as carbon offsets, has become a central pillar in climate policy. As such the accurate monitoring of AGB has an important role to play in national climate change policy aimed at mitigation of emissions, and maintenance and increases in current carbon stocks. A number of targeted policy schemes within Australia and the UK look towards natural capital monitoring including the measurement of AGB. AGB also has a critical role to play in ecosystem condition monitoring, the maintenance of natural capital on farm assets, and is a key metric used for the assessment of fuel load-associated fire risk.

Traditionally AGB is measured by species dependent statistical (allometric) equations, that require the diameter and/or tree height to produce a biomass estimate. These methods are costly, inefficient and accuracy can vary widely amongst species where generic algorithms are used. One method to overcome the inaccuracies of these methods is to quantitatively measure the AGB using three dimensional (3D models) that are collected with terrestrial laser scanning (TLS) or ground lidar or volumetric photogrammetry. Both methods can however only be used to collect small field plot measurements, typically a few hectares in size. Other forms of remote sensing such as airborne or spaceborne lidar or radar are needed to scale AGB estimates over large areas from regional, national and global.

There are also a number of implications for public climate policy, with accurate carbon measurements being a hot topic politically. A gold standard reference dataset would go a long way towards providing confidence in assessment of AGB across climate and biodiversity policy initiatives. There is also significant potential to leverage the connection to financial markets, and the emerging requirements globally for reporting on company compliance across environment, social and governance aspects of various ESG guidelines.

[1] BIOMASS is an ESA Earth Explorer mission, but has a UK-based Principal Investigator.

Both the UK and Australia have significant expertise in measurement of AGB using TLS and photogrammetry to accurately model 3D carbon stocks across varied ecosystems. The field data collected across academia and government from UK-AU partnerships has been used to calibrate and validate national and global biomass maps including those produced from the JAXA ALOS PALSAR 2 and NASA GEDI missions.

Two new space missions were identified as part of the UK workshop series with a target focus on AGB measurement:

- The ESA BIOMASS mission will be a world first P-band radar aimed specifically at AGB measurement. The use of P-Band radar is a novel application of this wavelength in EO (previously restricted due to the conflicting use of P-Band). In EO terms it is the most suitable wavelength for measurement of high biomass such as rainforests (other wavelengths saturate at high biomass levels). BIOMASS is planned to launch in 2023/24, with plans already in place to use calibration sites in Australia. Calibration will require measurements across a range of low to high AGB sites, in particular collection of new sites within high biomass rainforest regions (to enable accurate calibration and sensitivity to be established at high biomass levels).

- Most of the biomass in Australia can be characterised as dry tropical forest, woodland and savannah, and as such represents a large store of biomass which needs to be taken into account. The dry tropics, like the wet tropics, act as sinks and sources of CO_2 and are also subject to degradation and deforestation, but these processes are currently poorly understood. Measurement of dry biomass, particularly important in Australia, is probably best done by multi-sensor approach, e.g., with shorter radar frequencies, using in-situ methods and/or air- and space-borne lidar. To this end, the UK Natural Environment Research Council's (NERC) SECO project is addressing the current and future carbon dynamics of the dry tropics. The University of Edinburgh noted that much of the existing biomass related activity such as GEO-Trees, and much of CEOS best practice, is focussed on the wet tropics. SECO is tackling these issues with over 600 field plots around the globe, many of which are in Australia. The in-situ work is complemented by radar remote sensing, notably X-, C-, L-, S-, and soon P-band SAR through BIOMASS. The shorter wavelength SARs are more sensitive to the dry biomass. Thus, all these sensors contribute different and valuable information. Many of these sensors will measure soil moisture, which will also affect the signal from BIOMASS. We may add into the mix in-situ measurements, airborne and spaceborne lidar, and soil moisture measurements from e.g., ESA's upcoming HydroGNSS.

- At present there is a strong need to integrate and cross-analyse the observations from all these sensors, including in-situ measurements, into a common framework and processing system for study of the dry tropics, with traceable cal-val pedigree and data product quality indicators. This does not exist at present, and no funding appears to be available to support it. The UK is very well placed to address this as it hosts many SAR and radar experts, as well as experts in tree and vegetation science. Thus, there as a clear science gap which the UK/Aus partnership could fill. This could provide a very fruitful collaboration via Space Bridge, and the results will also be applicable over many other areas of the globe including Africa and South America.

- Recent developments in lasers have made lidar from space a viable technique, and the GEDI (Global Ecosystem Dynamics Investigation) mission, deployed on the ISS, has demonstrated near-imaging sampling density with useful swath width for tropical forest carbon and other studies. The technologies continue to improve, and laser diode technology is now at a point where power and efficiency are sufficient for quasi-imaging lidar from low-Earth orbit. The University of Edinburgh and collaborators are developing the GLAMIS space lidar concept. They will use tapered laser diode technology to overcome some of the swath and sampling limitations of the GEDI system, while conceptualising a compact power-efficient payload that could be deployed on smaller satellites. While GEDI-2 is likely to focus on biomass issues, GLAMIS with its full waveform lidar and short pulse length will focus on vertical tree structure, notably tree crown structure/plant area profiles, which can be applied for example to estimation of fire risk. It could provide synergy with the OZFuel mission, providing tree structure information to complement the combustibility maps from OZFuel, thereby significantly improving the fidelity of fire risk assessment. An improved space lidar mission would also add into the integrated multiple sensor mission system envisaged by SECO.

The expertise and current infrastructure within Australia and the UK lends itself to the establishment of calibration and biomass field sites for these missions, as well as collaboration on the products to be derived from the satellites. For the BIOMASS mission there are plans to deploy transponders and to use calibration sites in Australia owing to difficulties in using sites in Europe and North America due to issues with frequency conflicts with space object tracking systems. One calibration site has already been selected at New Norcia, Western Australia (near Perth) where ESA owns a ground facility, currently operated by an Australian company. Tasks to be completed in Australia will include: estimation of the full 2-D antenna pattern using 21 passes over 1 (or more) transponders, estimation of channel imbalance and crosstalk, testing of geolocation correction, as well as characterization of selected targets of opportunity.

For GLAMIS, the cal-val databases of TERN and airborne lidar facilities of CSIRO etc. are of great interest to the University of Edinburgh and would be invaluable for cal-val if and when a GLAMIS mission is flown. Currently the GLAMIS project is in the middle of an instrument and mission trade-off study to assess the best and most achievable design to go forward.

To set up for the upcoming launches of satellite EO missions focused on AGB measurement it is proposed that a UK-AU Research Coordination Network (RCN) is set up to extend current field operations and infrastructure. Such a centre would enable the collection of representative field sites to characterise global AGB, as well as bring together researchers from across the two countries in order to advance the science behind accurate AGB measurements. Furthermore, the centre would include a policy focus that aims to engage the climate mitigation angles that biomass targets, and integrate science with policy. This ties in nicely with the data integrity side of things, and provides a downstream product cal-val angle that would likely be an added functional extra to Australia's EO-AIM concept. As a starting position, the centre is proposed to activate the existing Australian research network across TERN, CSIRO, state governments, academics from University of Queensland, University of South Australia and University of Tasmania, combined with the UK academia experts from University of Edinburgh, University of Salford, University of Aberystwyth, and University College London, while also linking in with the existing Group on Earth

Observations program GEO TREES. Further linkages could be made to other more global initiatives including CEOS, GOFC-GOLD and GEOBON.

The establishment of the RCN could also provide publicly available datasets for use in the validation of current commercial offerings targeting measurement of biomass. Within Australia, a number of companies exist in this space, and have indicated that the collection of field data is too costly and time consuming, and that they would welcome a publicly available source of AGB field data samples/and or EO derived regional/national datasets of EO. Current examples of EO AGB products are being used for carbon offsets reporting, as well as reporting on supply chain environmental criteria. Existing funding for NCRIS, TERN and CSIRO research programs could be used to leverage additional data collection for field sites. The setup of global sharing mechanisms is already well underway and a renewed investment in such platform cloud storage options could speed up this delivery process. The above recommendations would support TERN's stated objective of becoming a global standard facility for biomass measurements.

3.6 Commercial Sector Cooperation Opportunities

There is a significant change in the demographic of the EO satellite sector with the explosion of New Space missions. Australia has signalled its intention to develop a niche capability to use cal-val to increase the economic potential and societal benefit of these missions which might otherwise be poorly characterised, calibrated and therefore not trusted for many applications. We consider this to be an extremely intelligent strategy with enormous potential and associated commercial opportunities (for both EO data providers in improving their data and their accessible markets, and for companies supporting the provision of such 'cal-val as a service' offerings). AUSCALVAL will provide a foundation of varied cal-val sites to be used by data providers, ideally to be supplemented with further CEOS agency sites, including in the UK.

As Australia begins to develop its first ever national EO missions, like AquaWatch, it is discovering that it lacks some of the detailed technical expertise required to define and implement the associated calibration activities required of such missions. The UK sector (public and private) has benefited from participation in the large satellite missions of the ESA and EC and of the cal-val programmes that support them. Companies such as Telespazio UK have developed a specialist niche and are likely the single biggest supplier to the Sensor Performance, Products and Algorithms section of ESA, including in running programmes such as EDAP for their Third Party Missions and most recently the EOSure programme which has much in common with the Australian EO-AIM concept. Australia will need to develop similar expertise in order to successfully design and implement the cal-val aspects of its national EO missions. As well as to realise the strategic objectives of the SCR mission which seeks to support the transfer of calibration to multiple EO satellites and thereby to improve their value. Further, efficient and competitive operation and evolution of AUSCALVAL needs a deep technical understanding of the global scene, cal-val needs and trends. There is a great opportunity for UK organisations and companies to mentor and support the development of Australian domestic capacity in this area, and we assume that commercial opportunities will exist for UK companies willing to support this objective of mentoring and capacity building.

Australia can learn from the UK commercial sector on building a specialist cal-val industry and we envision strategic partnerships emerging from these relationships. "AUSCALVAL+" (as an expansion of the

Australia-only concept) could include UK facilities, geographies and atmospheres and would bring further capabilities to the offering to the global industry. Participation of UK institutions and companies in an augmented AUSCALVAL could include support for Australia's key optical calibration sites to achieve RadCalNet standards.

Noting that CSIRO has a broad MOU in place with ESA around EO, this could be helpful around our suggested technical capacity building ambitions and allow UK companies to supply ESA-owned documentation and knowledge. We would propose to also use a CEOS dimension for this and to support other agency knowledge transfer to Australia through the WG Cal-Val and the bilateral discussions it facilitates.

3.7 Agritech

In parallel with the execution of this project, some of the team members have been engaged in a parallel project examining the opportunities for collaboration between the UK and Australia in the use of Earth observation data for climate smart agriculture. Beyond the general desire for high quality data for agriculture applications, there are some areas where improved data fidelity and traceability enabled by better cal-val could accelerate new applications. These are generally in the domain of demonstrating adherence to environmental regulations or standards, particularly concerning carbon accounting. The use of EO for operational quantitative carbon accounting to underpin carbon trades remains in its infancy. Current applications rely on indirect measurements and inference though interpreting land use changes and farm practices from satellite imagery. Quantitative estimation from EO of carbon fluxes and stores in an agricultural context using remote sensing is still in its infancy but would require strong traceability and calibration if EO data were to underpin financial transactions. While not operational now, several research organisations in the UK and Australia are working on the topic, but there is a lack of a widely agreed standard for what constitutes required precision and traceability. Advancing this topic could form the basis of further collaboration.

3.8 Emerging EO areas related to climate

Methane emission detection and monitoring: COP26 identified that if the source of methane emissions from industrial and other localised sites can be identified and subsequently eliminated, that would be a quick win for climate. This has become something of a bandwagon, as instrumentation, missions and services are under investigation across the globe. New missions with sensors at the spatial resolution needed to unambiguously detect sources are either in flight or in development. GHGSat have a constellation in operation. The emerging regulatory and legal issues demand that the measurement of methane and other GHGs is backed up with verifiable measurements and transparent and reliable cal-val systems that would allow measurements of release rates and volumes to stand up to possible legal scrutiny. Several organisations in the UK are engaged in developing instrumentation, missions and services for methane release detection and to measure distribution of the gas in the atmosphere. There is a degree of sensitivity, as the regulatory and legal issues suggest commercial potential for robust and

reliable services. The University of Edinburgh is developing the NIMCAM mission concept, which is aimed at continuous monitoring to pick up new and transient methane emissions across the globe. There is potential for UK/Australian collaboration in the cal-val of any measurements from space and/or airborne platforms. GHGSat and University of Edinburgh would like to engage with any grouping in Australia tackling these GHG cal-val issues. NPL would be interested in consulting and/or participating with ground validation of methane measurements. They have sophisticated ground instrumentation for methane measurement in the atmosphere (a DIAL sensor facility truck) and facilities for calibrated controlled gas release.

While Australian industry is not yet subject to carbon audit as large companies in the US and UK are, they may well be in the future, and may wish to be prepared. Even if Australia does not go down this route, the international trading environment may demand that Australian supply chains comply with these carbon audit requirements. On broader cal-val case there is a significant opportunity for the UK to assist Australia on the science and validation in those broad public policy initiatives, perhaps in collaboration with NPL and in the context of FRM4GHG. Workers in the UK (university and commercial) are of course interested in hearing from potential users/customers in Australia with the need for methane release detection and measurement services. The University of Edinburgh is also interested in calculation of carbon budget for Australia and has worked on this in the past. We note that GHGSat already do a lot of measurement in Australia.

Thermal Imaging: A collaboration between Leonardo (MWIR detectors), SSTL (DarkCarb spacecraft) and Satellite Vu (downstream commercial services) will result in new services for high-resolution (3.5m GSD) thermal imaging of the Earth's surface. This is likely to be a world first, but other organisations in the UK are also interested (University of Cambridge with an alternative imaging system). The primary goal is measurement of thermal efficiency of the built environment. Several customer streams are envisaged including government/regulatory, corporate customers, and even domestic customers interested in the heat efficiency of their homes. Other applications include fire detection, with wildfires being particularly important for Australia, defence and security, heat island effects, thermal plumes in the ocean and volcanic activity. The temperature maps will require cal-val processes to be applied, and there is a secondary task of thermal modelling of buildings to determine how the rooftop temperature maps relate to energy input and building efficiency. There may be scope for collaboration between UK and Australian groups in cal-val and data QA, and of course Australia will be seen as a customer for services.

4: Recommendations

The recommendations from the Cal-Val Space Bridge Preliminary Phase are presented below.

1. **Continuation of the cal-val Space Bridge:** The Cal-Val Space Bridge study has confirmed that real and exciting opportunities exist for UK And Australia to further develop a strategic alliance, possibly under the Space Bridge framework, in relation to collaborative EO satellite cal-val activities and shared facilities. Both countries appear to be highly motivated to pursue such an alliance. We recommend that EO Cal-Val be considered for further rounds of Space Bridge funding should this be available.

2. **Implement a UKSA-ASA bilateral agreement to develop cal-val industries and capabilities.** This broad agreement should benefit respective programmes on both sides and aim to support objectives of SCR, TRUTHS, Biomass, AquaWatch and AUSCALVAL, as well as commercial opportunities.

3. **UK and Australia should sponsor an acceleration of the technical cooperation underway in the Committee on Earth Observation Satellites (CEOS) and their Working Group on Calibration and Validation (WGCV) in relation to SITSATs and to Open Source Cal-Val Toolkits.** Using a global cooperation to develop facilities and processes to extract more value from future generations of smallsats can represent a niche role for both public and private space sectors in the UK and Australia.

4. **Implement a working-level technical cooperation agreement between NPL and Geoscience Australia in relation to the TRUTHS and SCR missions.** SCR will develop valuable operational experience that can support the TRUTHS programme. In turn, NPL can help mentor and develop technical capacity within Australian agencies like GA. UK and Australia can sponsor the escalation of the ongoing SITSAT thread within CEOS WGCV such that experts from all relevant countries might be tapped through the neutral CEOS forum, to help solve problems as they arise in the mission programmes.

5. **Pursue Case Studies with potential users of SITSat enhanced data products.** Study application areas and the effect of SI traceable enhanced accuracy on model outputs and determine the impact of the enhanced products. Studies should be done collaboratively between users, modellers, EO experts and measurement experts.

6. **Pursue the establishment of a UK-Australia Global Centre of Excellence for EO Data Quality for Agriculture, Climate and Trade.** This will involve analysis, prototyping and development of a framework for data quality assurance to enable applications that require high fidelity information products, with full traceability to original data – including in financial services, carbon market assurance and climate impacts. Cementing UK / Australia leadership in high fidelity EO:

    - design of a Data Integrity Monitoring Facility;
    - analysis of end-to-end impact of TRUTHS / SCR on information quality / integrity on user applications beyond climate monitoring;
    - carbon market data assurance case study;

- identification of Joint cal-val campaigns and infrastructure to make EO data fit for purpose in high fidelity applications;
- STFC/RAL has already submitted a funding proposal to UK Govt for this Centre. On the Australian side, matching funding might be provided by the studies into a Centre for Space Governance, and development of the EO AIM (EO - Assurance and Integrity Monitoring) facility.

7. **Establish a joint UK-Australia Biomass and Carbon Applications Research Coordination Network (RCN).** The RCN is suggested as a joint academic, government and industry co-ordination group, with funding to facilitate a working group between Australia and the UK including communication, travel to workshops, researcher exchanges, publication of research and data, and calibration and validation activities for upcoming satellite Earth observation missions where biomass is the focus. The RCN would build on existing research programs and current field data collection programs i.e. GEOTREES and TERN, by bringing researchers together with the aim of facilitating a step-change in the development of remote carbon/biomass assessment and accuracy. The RCN would focus on:

   - developing novel methods for biomass field data collection and analysis that enable improved efficiency of data collection and extraction of biomass measurements, and build on the existing CEOS Biomass data collection protocols;
   - biomass sample points to be collected across a more representative set of vegetation types
   - overall improvement in accuracy of local to global biomass estimates derived from remote sensing products, particularly those in Savannah type environments, where biomass measurements are sparse;
   - broaden biomass activities to embrace methods for dry tropical biomass Earth observation, and to accommodate current and future space-based LIDAR systems;
   - remote sensing derived biomass estimates for carbon accounting, fire risk assessment (fuel loads), natural capital assessment, and vegetation condition, that are trusted by decision makers (data integrity) and are regularly used in policy and management decisions;
   - integration of biomass field measurements into a global database for researchers and commercial application development (and calibration and validation of current, future and new products). Note: this biomass database could be spun-off into an application programming interface (API), where a per query fee is charged to cover service and maintenance requirements.

8. **Commercial sector mentoring and opportunities.** Should a future Space Bridge phase with a focus on cal-val be possible, we recommend exploring the opportunity for UK organisations and companies to mentor and support the development of Australian domestic capacity in this area. Funding could be assigned to an extended secondment of relevant UK company experts. We foresee commercial opportunities for UK companies willing to support this, including in the implementation of AUSCALVAL and EO-AIM.

9. **Explore the concept of an augmented AUSCALVAL.** An expansion of the Australian cal-val infrastructure and tools could include UK facilities, geographies and atmospheres that would bring further capabilities to the offering to the global industry. Further commercial collaborations and opportunities will emerge from this activity.

10. **Explore CSIRO-ESA cooperation on EO Cal-Val in support of AUSCALVAL and EO-AIM ambitions.** This will facilitate the development of Australian technical capacity and perhaps allow UK companies to supply ESA-owned documentation and knowledge. This might also be connected to the recommendation to jointly develop a CEOS activity relevant to all of the above ambitions.

11. **Explore cooperation on cal-val and data quality in emerging EO areas:** New missions offer detection and monitoring of 'fugitive' methane releases from industrial and other localised sites. This is seen as a quick win for climate, as methane is a powerful greenhouse gas, but does not persist in the atmosphere, and its removal would have much-needed short term impact. The assessment of the accuracy of the retrievals and the quality of the resulting data products will be increasingly important as legal frameworks are put in place, and the UK and Australia could collaborate in this area. It is expected that commercial services for thermal imaging will begin in 2023, addressing the heat signatures from the built environment at high resolution (~3.5m GSD) and other temperature signatures (fires, thermal plumes, heat island etc). The accuracy of the temperature measurements will be important for owners of industrial facilities, regulatory bodies, and decision makers. The relationship of rooftop thermal signatures to thermal efficiency of buildings requires modelling and uncertainty analysis, and as such is a potential area for collaboration.

Appendices

A: Workshop Attendees

Australian Workshop Attendees

Name	Organisation
Convenors	
Stephen Ward	Symbios
George Dyke	Symbios
Jasmine Muir	Frontier SI
Brendon McAtee	Frontier SI
In person attendees	
Arvind Ramana	Australian Space Agency
David Hudson	Geoscience Australia
Alex Held	CSIRO
Mark Broomhall	Geoscience Australia
James Prior	EOS
Online attendees	
Tim Neale	Data Farming
Stuart Phinn	EOA
David Antoine	Curtin Uni
Peter Scarth	Cibo Labs
Stefan Maier	Maitec
Ian Lau	CSIRO
George Coulloupas	Leonardo
Janet Anstee	CSIRO
Julian Kruger	Astron
Amy Parker	CSIRO
Liesda Marsdon	Deloitte
Mike Petkovic	Nova Systems

Name	Organisation
Cindy Ong	CSIRO
Nicolas Younes	ANU Ozfuel
Mike Petkovic	Nova Systems
Rafael Kargren	Maxar
Stephen Gensemer	CSIRO
Thomas Gooch,	OPO
Sebastian Chaoui	Arlula
Sam Shumack	Climate Friendly
Scott Owens	Arlula
Karli Jeffrey	Deloitte
Lindsay Mitchell	Tas Govt
Medhavy Thankappan	Geoscience Australia
Neil Sims	CSIRO
Oli Madgett	Cloud Agronomics
Peter Hausknecht	Earth i
Carl Seubert	Smartsat CRC
Craig Williams	Smartsat CRC
George Coulloupas	Leonardo
Henry Zhong	Spiral Blue
Alisa Starkey	Ozius
Arko Lucieer	UTas
Bart Huntley	WA Govt
Benoit Legresy	CSIRO
Andrin Tomaschett	Nova Systems
Arran Salerno	Arlula
Andrew O'Reilly	Climate Friendly

UK Workshop Invitees

With Attendees shown in shaded cells

Stakeholder	Type	Nominated POC
UKSA	Central govt	Beth Greenaway
DEFRA	Central govt	Ailsa Stroud
DEFRA	Central govt	Jon Hicks
JNCC	Govt agency	Lawrence Way
JNCC	Govt agency	Paul Robinson
NPL	Govt agency	Nigel Fox
RAL Space	R&D/Academia	Dave Smith
University of Sheffield	R&D/Academia	Shaun Quegan
University of Edinburgh	R&D/Academia	Iain Woodhouse
University of Edinburgh	R&D/Academia	Paul Palmer
University of Edinburgh	R&D/Academia	Mat Williams
University of Leicester/CEOI	R&D/Academia	Josh Vande Hey
University of Leicester/NCEO	R&D/Academia	John Remedios
Imperial	R&D/Academia	Helen Brindley
Imperial and RAL Space	R&D/Academia	Jacqui Russell
UCL	R&D/Academia	Jan-Peter Muller
UCL	R&D/Academia	Phil Lewis
UCL	R&D/Academia	Alan Smith
Kings College London	R&D/Academia	Martin Wooster
Aberystwyth	R&D/Academia	Richard Lucas
SENSE	R&D/Academia	Ed Mitchard
QinetiQ/CEOI	Commercial	Chris Brownsword
BAE Systems	Commercial	Peter Meadows
JCR Systems	Commercial	Janet Charlton
Sat Apps Catapult	Commercial	Dan Wicks
Earth-i	Commercial	Chetan Pradhan

Open Cosmos	Commercial	Tobias Hafner
Clyde Space	Commercial	Peter Anderson
Alba Orbital	Commercial	Tom Walkinshaw
Spire	Commercial	Tom Greig
Telespazio Vega	Commercial	Richard Lowe
Airbus	Commercial	Ralph Cordey
GHGsat	Commercial	Adina Gillespie
Craft Prospect	Commercial	Steve Greenland
SSTL	Commercial	Rachel Bird
Airbus/CEOI	Commercial	Nic Leveque
Global Surface Intelligence	Commercial	Matt Tyburski
Space Intelligence Ltd	Commercial	Murray Collins
SatelliteVu	Commercial	Simon Tucker
Ecometrica	Commercial	Dimitrios Michelakis
Assimila	Commercial	Andy Shaw
Assimila	Commercial	Jon Styles
ScottSpace/CEOI	Commercial	Rob Scott
Environment Systems	Commercial	Steve Keyworth
SSTL	Commercial	Andrew Haslehurst
Telespazio	Commercial	John Swinton
University of Southampton	Academia	Jadu Dash
University of Southampton	Academia	G Roberts
Telespazio	Commercial	Kevin Halsall
JNCC	Govt agency	Gwawr Jones
UCL	Academia	Mat Disney
Telespazio	Commercial	Alexandra Barker
Earth-i	Commercial	Peter Hausknecht
University of Edinburgh	Academia	David Milodowski
Symbios Communications	Commercial	Stephen Ward

EOSENSE	Commercial	Stephen Mackin
TAS	Commercial	John Vrublevskis
SatAppsCatapult	Commercial	Manuwar Kazi
RiskAware	Commercial	Robert Gordon
RiskAware	Commercial	Simon Agass
CEH	Government	Daniel Morton
Amey	Commercial	Abigail Sanders
Telespazio	Commercial	Kajal Haria
Imperial	Academia	Richard Bantges