STFC IMPACT ACCELERATION ACCOUNT (IAA) 2022 – 2025

APPLICATION FORM

Please upload to **Worktribe** under the documents tab on your project.

Section A: Applicants Details

Principal Investigator:	Poshak Gandhi					
Email address:	**poshak.gandhi@soton.ac.uk**					
Tel no:	**+44-(0)23-8059-2089**					
Co-applicants or Secondee:	**-**					
Faculty, School & Dept:	**FEPS, P&A**					
Project Title:	**Clear Skies - From Astrophysics to Air Pollution**					
Start Date & Duration	**Start Date**	**01/08/23**	**End Date**	**31/3/24**	**Duration** [1]	**8 mths**
Funding requested:	**£ 42,277.31**					

Section B: Collaborators

(If applicable; for projects with multiple partners, please repeat this table as required)

Organisation Name:	STFC Air Quality Network
Nature of Organisation: (Company, government, charity, etc.)	Research Network
Primary Contact Name, Position & Contact Details	Fleur Hughes
Address:	Wolfson Atmospheric Chemistry Laboratory University of York Heslington York YO10 5DD
Organisation Website URL:	https://www.saqn.org/
Main Areas of interest / Activities:	Bringing together research, industry and policy to enable STFC capabilities to contribute to addressing air quality challenges
Company/ Organisation Size: (Micro, <10 employees / SME / Large)	Micro
Role of partner organisation:	Multidisciplinary networking between national researchers, policy makers and other stakeholders. Funding an in-person meeting for the project partners.

[1] We would not expect projects to exceed 12 months in duration.

(Please ensure a Letter of Support reflects the collaborating partners role)	

Organisation Name:	Wolfson Atmospheric Chemistry Laboratories, University of York
Nature of Organisation: (Company, government, charity, etc.)	University
Primary Contact Name, Position & Contact Details	Dr Sarah Moller, Senior Research Fellow, sarah.moller@york.ac.uk Prof. David Carslaw, Professor of Urban Air Pollution, david.carslaw@york.ac.uk
Address:	Wolfson Atmospheric Chemistry Laboratory University of York Heslington York YO10 5DD
Organisation Website URL:	https://www.york.ac.uk/chemistry/research/wacl/
Main Areas of interest / Activities:	Air pollution research, atmospheric chemistry, urban air quality, air pollution emissions and sources.
Company/ Organisation Size: (Micro, <10 employees / SME / Large)	Large
Role of partner organisation: (Please ensure a Letter of Support reflects the collaborating partners role)	To contribute air pollution expertise, information about access to data, experience analysing this data before and understanding of research challenges. To facilitate links to policy makers in the Department for Environment, Food and Rural Affairs.

Funding Activity

Impact Secondment ☐	**Concept Development** ✔	**Relationship Development** ☐

Section C: Proposed Initiative

Aim(s) of project (Please ensure a clear link to the funders aims and objectives)
Executive Summary: This is a knowledge exchange project, leveraging rapid time-series techniques that have been developed and refined over decades in astrophysics for application in air pollution studies. The impact is expected to focus on policy development and intervention with regard to pollutant monitoring and resultant changes in practice. This is a collaboration between UoS and the University of York (primarily) facilitated by the STFC Air Quality Network (SAQN), and we request 8 months' researcher FTE for concept development covering three work packages. **CONTEXT: There is a wealth of air pollution monitoring data available at fairly low geographical and temporal resolution, namely from the Department for the Environment Food and Rural Affairs (Defra; https://uk-air.defra.gov.uk/networks/network-info?view=aurn) automated monitoring network. With advances in measurement technology, there are opportunities to collect, transfer and use monitoring**

data at higher temporal and spatial resolution. However, the added benefit from doing so has yet to really be demonstrated.

Of particular interest are questions around contributions to pollution from different sources. This is of direct relevance to policy makers as this is where most policy is designed to make a change. Currently identifying the impact of activities that produce pollution on *concentrations* and the effect of *policy* measures on that is not simple and rarely done well. This is an emerging field but one where so far a limited number of techniques have been applied to good effect (e.g. Grange et al., 2019, Ropkins et al., 2022) and none making use of the extra information available in higher time and spatial resolution data. Often policy efficacy is modelled using changes in activity and assumptions about the relationships to measured concentrations with little ability to check whether the modelled impact is being seen in real world concentrations.

AIMS OF PROPOSED KNOWLEDGE EXCHANGE: An important challenge in high temporal (or spatial) resolution work is the robust isolation of key parameters of interest from amongst confounding background sources. A number of such techniques have been developed and successfully applied in the field of astrophysics (e.g. cross-correlation analysis [cf. Fig. 1], Fourier red noise modelling). These could prove to be highly valuable in the field of air pollution. Using techniques taken from astrophysics, this project is a case study on air pollution data at high time and spatial resolution.

Specifically, we will utilise air pollution with either (i) a high temporal resolution (up to 1 Hz); or, (ii) covering a geographically dense monitoring network; and (iii) including data on multiple pollutants. The *Air Pollution Supersite* (cas.manchester.ac.uk/restools/firs/) provides access to such data, where many pollutant species and related variables are measured in the same place, enabling us to look at how this 'enhanced' monitoring data could be used to explore policy-relevant questions particularly around pollution sources.

The data include NO_x, NO_2, CO_2 and individual volatile organic compound (VOC) measurements at a variety of temporal resolutions exceeding the hourly measurements that are currently standard in this field. There is also access to (particulate matter) PM1,PM2.5-PM10 at 1 minute intervals from a network across Greater Manchester (enabled through University of York hardware), and 1-second time resolution multivariate data from the Chemical Ionisation Mass spectrometer [CIMS], which tends to be underutilised save for Positive Matrix Factorisation analysis.

Our proposed aims are divided into two main analysis work packages [WPs], together with policy assessment as a third WP. The WPs and deliverables are detailed on pages 5 and 6.

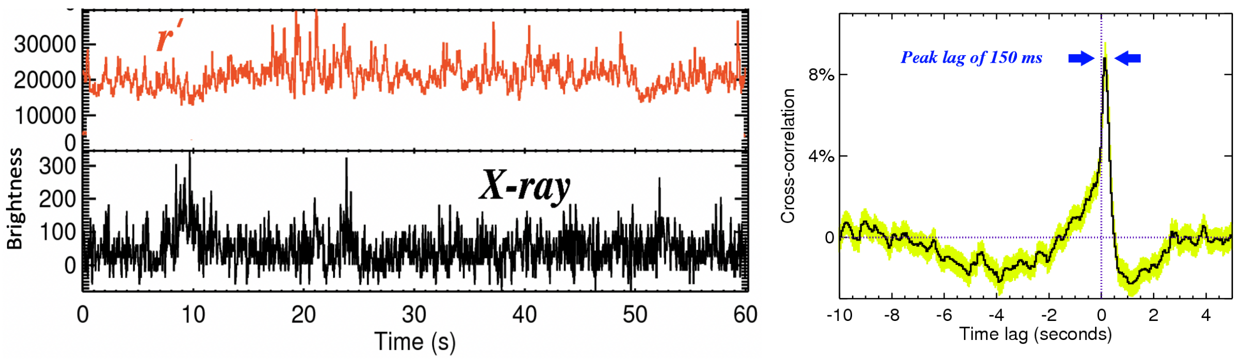


Fig 1: Example of the capability of statistical analysis techniques to isolate weak patterns. Consider two time-series data sets on the left. There is no obvious common pattern apparent to the eye. Cross-correlation techniques (right) can identify an underlying weak (~8%) correlation and measure time lags between the two. We propose to apply such techniques from black hole research (cf. Gandhi et al. 2010) to new air pollution datasets at high temporal resolution.

We expect that adapting these methods to datasets and applications outside the field of Astrophysics could bring return benefits and insights into future Astrophysics projects, e.g. in terms of novel data handling or benchmarking techniques, and in terms of better understanding of real-world (e.g. atmospheric) sources of noise.

REQUEST: For the above work, we request IAA funding for 8 months researcher FTE (justified below), in addition to minor costs related to training and one collaboration meeting.

RISKS: The data already exist, and are readily available through our collaborators at the University of York and the SAQN. There is no risk to deliverables. Null results from our analysis are possible, but these would still be a useful constraint on the efficacy of high temporal resolution data for air pollution studies, informing best monitoring policies.

LINK TO STFC IAA OBJECTIVES: Clear Skies aligns with IAA objectives as follows:

1) **'Clear Skies' strengthens knowledge exchange by leveraging astrophysics skills developed as part of STFC research in a novel domain. Here, we are road testing 'outside-the-box' thinking, in collaboration with researchers from other disciplines and by translating our expertise to new challenges.**
2) **We are developing partnerships with multiple external stakeholders (STFC AQN, University of York, and the wider air pollution community) that will lead onto building sustainable impact in the field of air pollution, and create downstream opportunities for applications to follow-on funding (see below);**
3) **In particular, our team includes expertise in policy intervention delivery (see Letters of Support). We are excited to see how astronomy research can be translated into real-world policy impact.**

PROPOSED TEAM:

- **<u>Researcher</u>: One researcher will lead the core analysis and its applications to the air pollution data.**
- **<u>P. Gandhi</u> is Professor of Astrophysics in P&A. He has developed expertise in the field of time-series analyses over the past decade (e.g. numerous publications in Nature journals, and an STFC Ernest Rutherford Fellowship focused on time-series analysis). He will supervise the researcher.**
- **<u>S. Moller</u> is a senior research fellow in air pollution science and policy. She has worked for 10 years embedded in the Defra air quality team and has extensive experience facilitating effective knowledge exchange and policy relevant research. She is the SAQN academic lead and National Centre for Atmospheric Science Theme Leader.**
- **<u>D. Carslaw</u>: Professor of Urban Air Pollution at the University of York, will provide pollutant data analysis expertise, and know-how on measurement hardware owned by the University of York and accessible through the SAQN network and the Supersite.**
- **<u>Fleur Hughes</u> is the manager of the SAQN and will help to facilitate our in-person meeting.**

FOLLOW-ON: We expect to build upon this proposal with future applications including 'STFC Horizons programme net zero call' and other cross-council calls. Once demonstrated in a national setting, the hope is to expand such analyses to other global sites.

IP: This is a knowledge exchange project, transferring methods and know-how from astrophysics to the air quality community. There is no IP related to Astrophysics research results being transferred. The methods are published, but the air quality community require transfer of know-how to be able to utilise these methods.

References:

- Gandhi P. et al. (2010), MNRAS 407 2166: Rapid optical and X-ray timing observations of GX 339-4: multicomponent optical variability in the low/hard state
- Gandhi P. et al. (2017), Nature A 1 859: An elevation of 0.1 light-seconds for the optical jet base in an accreting Galactic black hole system
- Grange S. et al., (2019), Science of the Total Environment, 653 578:Using meteorological normalisation to detect interventions in air quality time series
- Ropkins K. et al., (2022), Environmental Science: Atmospheres, 2, 500: Measuring the impact of air quality related interventions
- Vaughan S. (2010), MNRAS 402 307: A Bayesian test for periodic signals in red noise
- White R.J. & Peterson B.M. (1995), PASP 106 879: Comments on Cross-Correlation Methodology in Variability Studies of Active Galactic Nuclei

For secondments – please give an overview of secondee's background and suitability to project:

N/A

Description of activity and where appropriate please include the <u>starting and ending Translational Readiness Level (TRL)</u>[2] the activities would likely achieve (rationale, objectives/intended impact, plans, overall timescales) (approx. 500 words):

RATIONALE: Air pollution has been classified as the 'world's worst environmental health risk,' causing more than 7 million deaths annually (https://www.unep.org/explore-topics/air/about-air). This represents a health emergency, especially in dense urban areas. Most air pollution studies utilise data on temporal scales of order ~20 min–1 hour or longer. Such temporal resolution will be insensitive to, and/or undersample, any rapid localised environmental influences and incidents.

OBJECTIVES: We aim to explore gains possible through the analysis of time-series datasets with air pollution sampling rates much higher than before, and use these to inform policy on air pollution monitoring. Analysis of high resolution data remains under-exploited in air pollution, and will come with challenges, described below. In order to address these challenges, we will utilise techniques from astrophysics to (1) search for weak patterns amongst noisy data using cross-correlation analysis (WP1 below), and (2) develop long-term Fourier models of the underlying prevalence and variations of pollutants at specific sites.

WORK PLAN: The core analysis methodology is divided into two work packages (WPs) detailed here, and policy intervention is dedicated to WP3 described below.

1) **<u>Identifying patterns amongst background variability</u> is feasible if (i) competing effects sample different characteristic timescales, or (ii) if there are multiple observables for cross-comparison. Astrophysical time-series analyses achieve this by cross-correlation analysis techniques (Fig. 1; Gandhi et al. 2010). For example, if we expect NOx and PM2.5 to concurrently rise in response to a wood burning episode, a cross-correlation between these time series is expected to be positively valued, with little delay. On the other hand, meteorological variability over the same time period would show a different correlation (e.g. no correlation at all, or changes over differing characteristic times). Cross correlation techniques in astrophysics have been developed and refined for several decades, and allow for non-uniform data sampling, missing data points, and secondary continuum effects (e.g. in the case of accreting compact objects: White & Peterson 1995). These techniques will be leveraged for the Supersite data, with the goal of uncovering underlying common trends and measuring**

[2] Please refer to appendix 1.

characteristic timescales. Time lags between various geographical sites will be utilised to trace the source of pollutant episodes.

2) **<u>A robust time-series model</u> of the underlying air pollutant time-series prevalence will be constructed through power-spectral analysis. Such Fourier decomposition lies at the heart of most time-series analysis. Recurrent effects related to diurnal or seasonal changes should be identifiable as clear peaks in the power spectra. Care will be needed to account for common Fourier domain artefacts such as aliasing (an effect of sampling degeneracies), and red noise leaks (an effect of windowing). Once these are removed, any significant features that stand out will be signatures of previously unidentified activity of interest. In order to ensure that only significant new features are isolated, we will utilise Bayesian red noise sampling techniques developed in astrophysical studies of supermassive black holes (Vaughan 2010). This goal is to extract a model of the baseline pollutant prevalence(s).**

IMPACT AND DELIVERABLES: The key deliverables of this project will be:

- **WP1+2: Tests of the utility of high time and spatial resolution air pollution data from the work packages described above, and any improvements that these deliver relative to the current standard in the field. WP1 will deliver robust correlated pollutant trends, while WP2 will deliver a Fourier model for each site as a template, upon which future monitoring decisions can be based.**
- **WP3: The primary impact is expected to focus on policy. We will leverage expertise within the 'Public Policy' team at UoS to provide dedicated policy development and engagement training to the researcher. We will produce case studies of how these techniques could be used to derive evidence for policy development or appraisal and will communicate our results and these case studies to the Defra air quality team via the SAQN. We will develop recommendations, if any, for how air pollution policy could leverage this new technology and our knowledge transfer. We expect to increase the evidence of the impact of specific sources and activities on air pollution concentrations and thereby inform policy development around emissions mitigation and limiting human exposures.**

We will publish our methodology and analysis in international air pollution journals. The Recommendations will be disseminated to the wider air pollution research community and stakeholders, including government departments, and business partners.

Does the proposal accelerate any previous research? If so, please provide further details (approx. 200 words)

This project draws on core STFC domain expertise, developed within astrophysics. Specifically, the PI has a demonstrated record of multivariate and multiwavelength time-series studies, working with data sampling extremely fast temporal resolution (~milli-seconds), and developing Fourier models to isolate characteristic periodic features of interest (e.g. Gandhi et al. 2010, 2017). This project is an opportunity to apply these same techniques in a novel multidisciplinary domain. It also builds on studies from partners around impacts of air pollution policy interventions (e.g. Grange et al., 2019).

Inter-disciplinary links: (if relevant)

This is a knowledge exchange concept development project, leveraging techniques developed in astrophysics for application to problems and datasets available in the field of air pollution studies.

Have you received any IAA or internal funding previously? If so, how much, when and what was the outcome?
N/A

Expected outputs, outcomes, and impacts (you should consider changes you would expect to see because of this project and how it will create impact directly or lead to a more in-depth project which will create impact). Please indicate in the table[3] below how you plan to evidence and measure this (please refer to Appendix 2)

Activity	Output	Outcome	Impact
Knowledge Transfer	• New collaboration with external collaborators, facilitated by the SAQN. • Amount of cash or in-kind contributions leveraged from external partners: • WP1: Analysis of high and spatial time resolution datasets with multiple pollutants • WP2: Fourier models governing air pollution for individual sites.	• 1 new researcher employment opportunity during this concept development phase. • Future interdisciplinary applications expected (e.g. STFC Horizons programme net zero call, other cross-council sustainability calls) • Publications reporting results in WP1, WP2.	• Supporting external partner fill skills gaps in time-series data analysis in the field of air pollution studies. • Policy recommendations following from the analysis of WP1+2. • Developing techniques to get more value from the air pollution monitoring data already collected, particularly in terms of its use in supporting policy development and appraisal.
Dissemination	• Reports disseminated across the SAQN.	• Researcher career progression, in particular career acceleration through working in an inter-disciplinary area, and through the training provided (research and policy). • Informing policy.	• Expanding collaboration across SAQN and internationally. • Recommendations for practice change and/or need for further monitoring.

[3] Add more lines if required

Milestones – Please provide specific deliverables and timelines for the listed activities, outputs, outcomes and impacts as stated above. Include a Gantt Chart where possible.
(All times are cumulative, relative to the start date) **WP1** Milestone 1: Development of the cross-correlation code, adapting current codes from astrophysics to air pollution data. Code validation on astrophysical data: +1 month. Milestone 2: Identification of cross-spectral coherence and lags between pairs of pollutants. Experimenting with a variety of characteristic multivariate timescales: +1.5 months. Milestone 3: Documentation of results, with the aim to publish in air pollution journal: +1.5 months. **WP2** Milestone 1: Development of Fourier power-spectral analysis and red noise simulation codes, adapting current codes from astrophysics to air pollution data. Code validation on astrophysical data: +1.5 month (for two codes). Milestone 2: Characterisation of pollutant prevalence at individual sites (power-spectra) and search for features of interest (red noise tests): +1 month. Milestone 3: Documentation of results, with the aim to publish in air pollution journal: +1.5 months. **POLICY** Key milestone: Recommendations for policy and practice change to be identified from the WP analysis and discussed across the SAQN, as the results of each WP become clear, i.e. concurrently with Milestones 3 above. *(Gantt Chart included within attachments)*
How do the activities listed in this application, fit with the University strategies?
Environmental Sustainability is one of the core values of the University's strategy, with UoS recently ranked within the Top 100 universities in terms of sustainability (2022 QS Sustainability ranking). Access to Clean Air also underpins several of the United Nations Sustainable Development Goals including SDG 3 (good health and well-being for all), 11 (sustainable cities and communities), and 13 (climate action).

UKRI Science and Technology Facilities Council

Section D: Costs and Funding

Please specify the amount requested and any additional contributions

Source	**Amount (£)**
Amount requested from STFC IAA	Total: £ **42,277.31**
Contribution from external partners (cash & in-kind)	Cash: £0 In-kind: £ 1,500 (SAQN); £ 6,000 (York staff time); £ 100k (Estimate for provision of data access and operating measurement hardware; this is the costs relevant for the entire data set, of which we will use a part).
Contributions from other sources including personal reserves (*please specify source*)	-
In kind contributions[4] (*list activities and estimate the value*) This must include the Pi's time on the project, all estates, and indirect costs at least (details of which should be included on Worktribe)	PI time: £8,910.70 (10% FTE for 8 months to supervise the researcher). Estate costs: £14,236.47 Indirect costs: £65,877.52
Worktribe Reference:	8320854
Detailed breakdown and justification of above costs, including equipment, consumables, and travel costs.[5] We request 8 months FTE for a L4 researcher to lead the research proposed herein. We have two main WPs focusing on the core analysis (see Methodology). Each will require familiarisation with the data (from the air pollution field) and corresponding analysis techniques (from astrophysics). This will require a researcher with a willingness to explore out-of-the-box thinking. The relatively short timeline of the project will require a person with some research and coding experience. The above skills and expectations are beyond a starting researcher, and we thus propose to hire at spine point 29. One visit to the SAQN is proposed for networking with field experts, dissemination of results of the WPs. The SAQN is contributing cash funding towards an in-person collaboration meeting, which will include travel costs. Here, we request top-up costs of £550 for a 3-day trip (for the PI and researcher) to cover accommodation and evening subsistence not covered by SAQN.	

[4] List activities and the value e.g., PI time/£ salary, estates and indirect costs, other costs not funded by the IAA, should be included on Worktribe.

[5] Full details of what are allowable costs can be found in the STFC IAA guidelines.

Finally, we request £100 for researcher training in relevant software skills (specifically Python, Github). This request is based on typical 1-day workshop offerings by the Southampton Research Software Group (between £25-50 each).
Are any of the IAA funds going to external sources, if so, please articulate how much and the reasons why? No.

Section E: Other Key information

Please provide information on anything that could delay the start of the project. e.g. data access permissions, ethics approvals required. Please include all previous approval numbers, contract agreements, etc

- Any further information.

- Ethics Approval (Please list all ERGO references)

Not required. No personal data used.

- Contract Agreements

Section F: Approvals

Please ensure that you have completed and signed the checklist ahead of submission. Appendix 3

Name (Principal Investigator): …………Poshak Gandhi……………………………………

Signature (Principal Investigator): ……Gandhi……………………………………

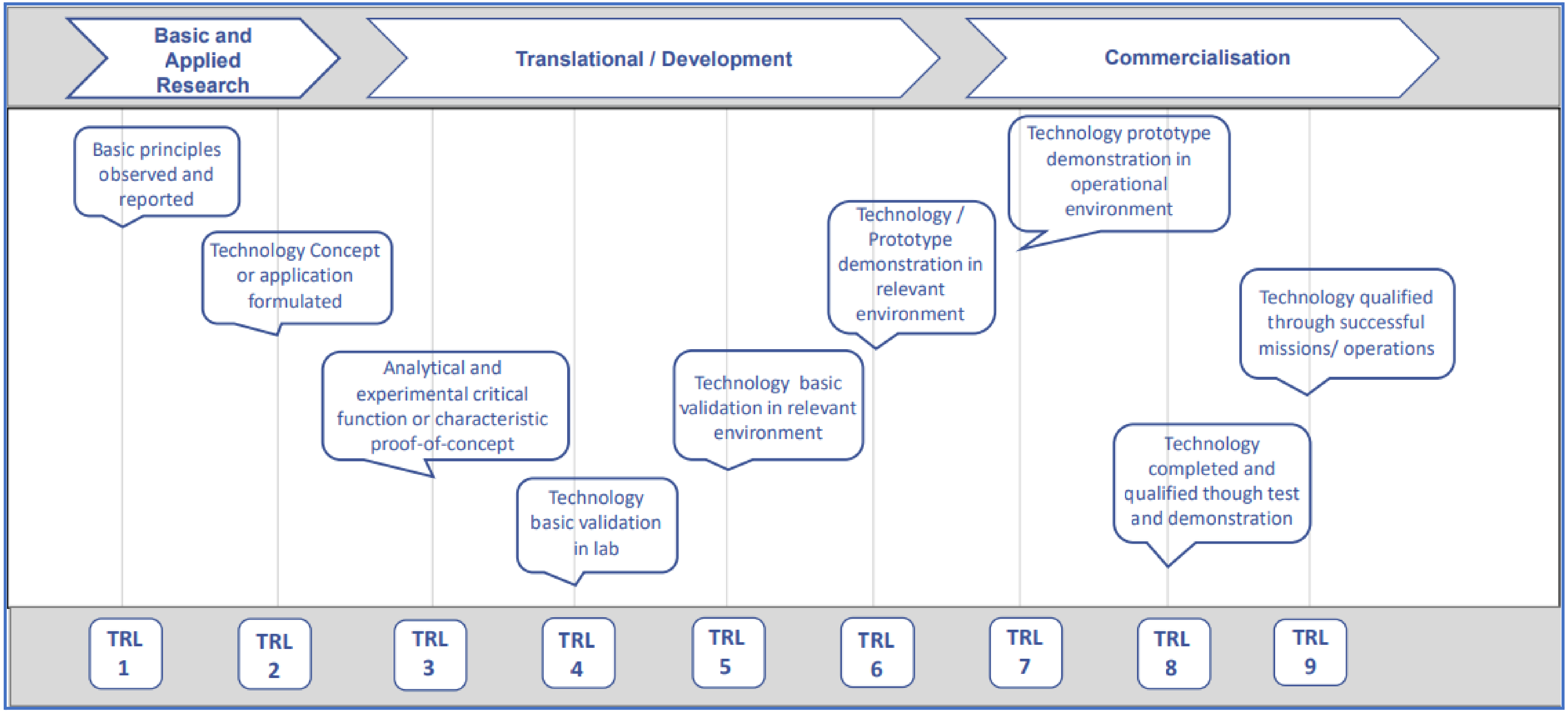
Date: …17 May 2023………………………………...

Science and Technology Facilities Council

V5 – April 2023

Appendix 1

Technology Readiness Levels (TRL)



Appendix 2

University of Southampton EPSRC IAA Key Programmes of Activity

Activity	**Outputs** (including)	**Outcomes** (including)	**Impacts** (including)
1. Knowledge Transfer through people Use of inward and outward secondments to share knowledge and build relationships with external organisations.	• No. of funded secondments and/or placements • Amount of cash or in-kind contributions leveraged from external partners • No. of secondments or KTP proposals developed with businesses	• No. external partners continuing further collaborations with Southampton • Secondee or researcher employment opportunities • No. of externally funded secondments or KTPs	• Increased profit/turnover/jobs at external partners • Policy and/or practice change • Increased R&D investment into Southampton from partners • Supporting external partner fill skills gaps
2. Accelerating Impact Projects to facilitate the transfer of knowledge and innovation from our research portfolio into industry, policy, and society.	• No. of impact projects for proof of concept, collaboration, and pump prime funding to be assessed against innovation, calculated risk-taking and sustainability • No. interdisciplinary projects supported with other UKRI IAA funding • - Amount of cash or in-kind contributions leveraged from external partners	• No. proof of concept (PoC) projects supported by external partners • Amount of continuation funding or other revenues • Number of applications to Innovate UK and other industrial strategy funding streams • Amount of investment/income to future collaborations, development, and consultancy (including from partners) and licensing • No. of PoC projects that progress to spin-outs & license deals	- Increased profit/turnover/jobs at external partners - Policy and/or practice change. - Increased R&D investment into Southampton from partners - No new commercialisation models - Cost savings to the external partner - Other societal impacts e.g. better self-management of health through the adoption of interventions and 'apps'

3. Engaging with external partners Facilitating engagement of researchers with business, industry, and policymakers.	• No. events providing opportunities for networking, knowledge exchange and facilitating future collaborations • No. policymaker and public engagement workshops, meetings, and events • No. events focused on Industrial Strategy Grand Challenges	• Enhancing relationships with existing partners and development of links with new partners • No. of bids with businesses to Innovate UK and other industrial strategy funding streams • Amount of investment to physical sciences researchers from future collaborations, development, and consultancy • No. collaborations with new external partners • No. of new interdisciplinary projects / programmes • Involvement of public in R&D e.g., through SOTSEF	• Strengthened and widened network of strategic partners, aligned with thematic priorities of the IAA • Increased profit/turnover/jobs at external partners • Policy and/or practice change • Increased R&D investment into Southampton from partners
4. Embedding culture change Training, mentoring, and coaching activities aimed at researchers to support them in developing and documenting impactful outcomes, with particular emphasis on supporting risk- taking and innovation in impact, moving beyond tried-and-tested modes of knowledge exchange.	• No. training seminars • No. case studies pa from IAA-supported activities • Creating a forum for researchers to explore ideas around business engagement and commercial enterprise (‘innovation clinics’) and support/mentoring for developing impact plans and identifying end-users (‘impact clinics’) • No. ‘culture change’ innovation projects	• No. researchers engaging with the IAA • No. researchers working with businesses • No. of innovative new processes or practices for impact and enterprise that depart significantly from established practice	• Researchers with better business skills, understanding of innovation and prepared to take risks • Increase in collaborative research • Increase in secondments and/or future employment of researchers • Engagement with Government Departments’ “areas of research interest” • Change in organizational culture, leading to innovative forms of impact and enterprise • Increase in commercialization activity and a pipeline of projects developed

Appendix 3

Checklist

	Reference Number (if applicable)	Yes	No	N/A
Activity Table read (Appendix 2)		✓		
Milestones included with a clear delivery plan		✓		
All travel expenses meet University Guidelines		✓		
Letter/s of Support (Financial)				✓
Letter/s of support (Other in Kind)			✓	
Work plan for all placements / secondees				✓
CV for inward or outward Secondee				✓
Ethics approval				✓
Pre-existing contract agreements				✓