scottish science advisory council

Research Infrastructure: SSAC Recommendations

SCIENCE AND ENGINEERING DELIVERING THE FUTURE

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The Scottish Science Advisory Council (SSAC) is Scotland's highest level science advisory body, providing independent advice and recommendations on science strategy, policy and priorities to the Scottish Government.

The terms of reference for the SSAC are to advise the Scottish Government's Chief Scientific Adviser on a broad range of scientific issues and science-related policies that will grow our economy and raise our quality of life and will further enhance Scotland as a science nation. To address the breadth of the remit of the SSAC the membership of the Council has been drawn from right across the science, business and academic communities and has a broad range of expertise and experience in science-related matters.

Full details about the SSAC, including a full list of members, can be found on its website: www.scottishscience.org.uk

This report was drafted by a working group drawn from the SSAC, and listed below.

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Executive Summary

This Scottish Science Advisory Council (SSAC) report on current and future requirements for research infrastructure was produced in response to a request from the Minister for Learning, Science and Scottish Languages, and relates to the BIS (Department of Business, Innovation and Skills) consultation on the same subject. Information was gathered from universities, research pools, Innovation Centres and industry associations by questionnaires, analysed by a working group, and discussed by the Council at its June 2014 meeting.

The SSAC are strongly supportive of the BIS initiative. In recent years, although there have been some substantial and specific investments in infrastructure, general support has been reduced: it is some time since initiatives such as SRIF (Science, Research Investment Fund) were in place, and Research Council policy on expenditure on capital equipment has become more restrictive. The infrastructure base has aged and eroded. Hence we would very much welcome initiatives and policies to promote development of a sustainable research infrastructure.

Many researchers are entirely dependent on access to facilities, but at different scales often characteristic of their subject: international (e.g. for telescopes and particle accelerators); national, in Scotland and the rest of the UK (e.g. synchrotrons, neutron sources, some types of high-performance computing etc.); or at the level of individual institutions (e.g. analytical equipment such as mass spectrometers, X-ray diffraction etc.). Thus, the tension between large, medium and small facilities is in some respects equivalent to a tension between different subjects. A key issue arising from the consultation was the unresolved question of how medium-scale institutional facilities and their running-costs should be paid for. Medium-scale facilities also include those in which individual items of equipment might cost only ~£0.1 million, but where the facility to be useful requires a suite of such items at a total cost of several £ million.

There is general satisfaction with existing access arrangements, tempered by growing anxieties of diminishing capacity (with some facilities already over-subscribed), ageing equipment, and difficulties in meeting running costs (including for staff). Hence there is a clear driver for infrastructure investment, but with recognition of the tension between capital investment and revenue expenditure; and a need to achieve better alignment of priorities for capital and revenue expenditure to ensure that running costs can be met. The optimum process of allocating resource between specific subject areas was seen to be peer review (which was often considered to be diminished in 'strategic' funding decisions for infrastructure) and hence, for universities, most appropriately handled by the Research Councils.

There were some good examples of equipment sharing, e.g. in some of the research pools, and between research institutes where there are close working relationships. However, it is evident that many researchers do not know what facilities might be accessible in other institutions, or how access might be obtained. Thus it would be worthwhile to establish an easily accessible information system of facilities, and perhaps some standard access arrangements.

The importance was recognised of allocating at least some infrastructure investment in support of research relevant to growth of the economy. At present, access by industrial users to facilities at least partly funded by public money is relatively limited, and a suitable access scheme would be especially helpful to smaller companies.

1. Introduction

The purpose of this paper is to provide a report from the working group, established by the SSAC at its March meeting, to conduct the work programme on scientific infrastructure in Scotland, based on the proposal in Appendix A1, which included a request from Dr Alasdair Allan (Minister for Learning, Science and Scotland's Languages) containing the following questions:

(a) What are the benefits and disadvantages of the current access arrangements to infrastructure across the UK?

(b) Does collaboration through initiatives, such as research pooling and innovation centres, prove effective in enabling access to funding for medium-sized infrastructure?

(c) What future infrastructure needs are anticipated if Scotland is to maintain its reputation for research excellence?

(d) What proportion of UK scientific infrastructure is located in Scotland, where and what is it?

This paper provides an outline summary of the findings of the group which were discussed at the June 2014 meeting of the SSAC. The outputs from the discussion have been used to formulate recommendations of the final report. A purpose of the report is as an input to the BIS consultation on capital investments and research infrastructure[1] (Appendix A2) issued on 25 April 2014.

1 Creating the Future: A 2020 Vision for Science & Research – A Consultation on Proposals for Long-Term Capital Investment in Science & Research https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/307989/bis-14-757-consultation-on-proposals-for-long-term-capital-investment-in-science-and-research.pdf

The working group collected its evidence by issuing a questionnaire to relevant stakeholders in Scotland: universities; Research Pools and Innovation Centres; research institutes; and industry associations. Requests were sent to 59 institutions, and 46 responses were received. A list of organisations contacted is included as Appendix A3, and the invitation and questionnaire as Appendix A4. The questions asked were:

1. What facilities are of strategic importance to your principal scientists and the longer-term aims of your organisation? (It would be helpful here to distinguish between medium-scale facilities, national facilities and international ones. ‘Medium-scale’ is defined as equipment and facilities typically in cost range of ~£250k–£10 million, often used to support the work of relatively small single-PI teams.)

2. Do current access arrangements fully meet your needs?

3. Will usage grow, maintain or reduce over the next 10 years?

4. What medium-scale (or larger) facilities do you have in your own institution? (It might be helpful here to enumerate equipment and other infrastructure that your institution defined as ‘facilities’ for TRAC (Transparent Approach to Costing) purposes.)

5. What would be your priorities for new facilities, of whatever scale?

6. Are you aware of any Scottish priorities for large-scale capital investment (including international collaboration)?

7. It is probable that future investments in mid-range facilities will seek to maximise efficiency through equipment sharing, and ‘leverage’ through contributions from the private sector. Can you offer current examples of effective sharing or leverage, and in particular any that arise from Innovation Centres? Can you identify future opportunities for sharing and offer advice on successful sharing arrangements?

The report is based on data gained from the questionnaires. Section 2 summarises our responses to questions (a) and (b) above. Recommendations are offered in Section 3, in response to question (c). Question (d) has not been addressed quantitatively, but the summaries of questionnaire responses provide a picture of the UK’s research infrastructure in Scotland.

2. Summary of Responses

2.1 Facilities of Strategic Importance

The types and scales of facilities required are strongly dependent on the specific subject discipline and field. However, it is not an exaggeration to say that many of Scotland's researchers are absolutely dependent on facilities ranging through the international, national, regional, institutional and even down to the level of individual research groupings.

Scotland's research institutes demonstrate particular strengths in animal health, agriculture, land use and marine science; its university research pools span chemistry, physics, geoscience, the life sciences, marine science, computer science, engineering and energy. An important role of some elements of Scotland's scientific infrastructure is to sustain, or improve, Scotland's level of security and emergency readiness (in the context of e.g. food, animal disease, plant disease, chemical or biological attack, cyber attack etc).

There are some areas where Scotland has pre-eminence in the UK for the quality and capabilities of existing facilities and infrastructure. One example is in land-based science through, for example, the long-term investment in experimental platforms that are designed, developed and maintained by the Scottish Government Main Research Providers (MRPs) where the total value of the investment in the MRPs from the Scottish Government is circa £50 million per annum. Another example, is the capability in animal science and welfare. There are opportunities to ensure these platforms are connected with broader UK initiatives such as the Natural Environment Research Council NERC-led 'instrumenting the countryside' capital investment planning, and to open out the facilities and the data generated to wider scrutiny and co-working with the Scottish HEI community and beyond. This ties in with moves at a strategic level to integrate capacity and capability around animal and plant health at a UK level.

The requirements for facilities are discipline-specific. For chemists, there is a fundamental requirement for the usual analytical facilities (Nuclear Magnetic Resonance (NMR), mass spectroscopy, X-ray diffraction etc.) some of which are available at institutional level, but others regionally. For physical scientists and engineers, many research groups are dependent on national and international facilities: accelerators, neutron sources, high performance computing (regional and national), fabrication facilities (e.g. for semiconductors) and telescopes. Relevant facilities include ISIS (Neutron Facility), Institut Laue-Langevin (ILL), European Synchrotron Radiation Facility (ESRF), Deutsches Elektronen-Synchrotron (DESY), European Organisation for Nuclear Research (CERN), DIAMOND (Diamond Light Source), High-End Computing Terascale Resource (HECToR) etc. Research groups in 'big' physics (particle physics, astrophysics etc.) are fully dependent on large-scale international facilities such as LIGO (Laser Interferometer Gravitational Wave Observatory) and CERN.

Other research groups often depend on smaller-scale facilities at their own or neighbouring institutions, such as carbon sequestration labs, high performance computing (for which medium-scale facilities are most usefully provided regionally), geochemistry labs, Centre for Science at Extreme Conditions (CSEC), Collaborative Optical Spectroscopy, Micromanipulation and Imaging Centre (COSMIC), the UK Centre for Astrobiology, low temperature measurement labs, the Academic Research Computing High End Resource (ARCHER) national UK supercomputer, Scottish Microelectronics Centre, Glasgow Polyomics Facility, the James Watt Nanofabrication Centre, the Glasgow part of the National Wind Tunnel Facility Network, the Scottish Universities Environmental Research Centre (SUERC) NERC Isotope Facility, a range of imaging and spectroscopy facilities, FloWave and other wave tanks.

In the life, earth and environmental sciences, there are similar needs to chemistry for analytical equipment, a widespread demand for advanced imaging equipment (for materials and medical applications), facilities for research with animals, plants and fish, farm platforms, experimental field installations, pest and pathogen control facilities and large-scale equipment for field research, including ships, access to satellites etc.

The research pools identified some similar priorities. All have medium-scale facilities, some of which are shared: e.g. for analytical facilities for chemistry, such as the shared Raman facility between St Andrews and Dundee; and for physics, the Scottish Centre for Accelerator Physics and its Applications. Some use large-scale facilities, notably in physics and astronomy (CERN, European Southern Observatory (ESO) telescopes, European Synchrotron Radiation Facility (ESRF) etc.) and in the marine and environmental sciences specialist facilities for high risk (e.g. pathogen) testing. A number of themes emerged including: the need to preserve access to international facilities, the possibility of a major multidisciplinary facility in Scotland (e.g. in the life sciences, in support of agri-tech strategy; the possibility of a Scottish synchrotron was also mentioned), the growing need for imaging equipment and a desire to see a an easily accessible information system of facilities for more efficient uses of the existing infrastructure.

Research institutes responded similarly to universities. Whilst some institutes share facilities (especially in agriculture), mostly they have extensive specific requirements of considerable diversity: analytical instrumentation; imaging facilities; genetic and molecular sequencing and proteomics; neutron sources; synchrotron facilities; isotopes and isotope analysis; laboratory test-beds; livestock facilities; ships; and satellites. It is often also necessary for such facilities to be accredited, which adds to their cost. A current project led by Sir Mark Walport through Government Office for Science (GO-Science) and the Department for Environment, Food and Rural Affairs (Defra) is determining the UK's future needs for capability in the provision of research, evidence and laboratory services to underpin the assurance of best practice management of animal and plant health.

Industry associations expressed priorities specific to their subject areas (Life Sciences Scotland; Chemical Sciences Scotland; and the National Microelectronics Institute, NMI). For the Life Sciences, the Continuous Manufacturing and Crystallisation Centre is important, as is the European Lead Factory (Biocity) and the Clinical Research Imaging Facility. Access to clinical trial facilities and scale-up facilities (for bio/pharma) is a priority (where facilities do already exist for brewing and anaerobic digestion). Chemical Sciences, meanwhile, have little requirement for large-scale facilities, and instead prefer to work by means of bilateral tactical relationships with specific universities (and, often, specific academics). The NMI's particular priorities related to the James Watt Nanofabrication Centre, the Scottish Microelectronics Centre, the Kelvin Nanotechnology Centre, and access to facilities for power electronics. Surprisingly, there was no mention of UK facilities, such as DIAMOND.

Different research areas inevitably require facilities of different scale, and thus the tension of distributing resources between large, medium and small facilities is in many respects equivalent to a tension between different subject areas. There is also the tension between the different modes of organisation of research: large facilities which are generally housed in 'institutes' outside individual universities, and hence require their own autonomous ecosystems; medium facilities housed in universities, but requiring institutional co-ordination; and small facilities that can be maintained and managed by the individual academic. Thus it is probably incomplete to examine infrastructure and facilities in isolation.

2.2 Access Arrangements

Most respondents who use established national and international facilities are content with current access arrangements, whilst expressing anxiety that current arrangements needed to be at least maintained, and with a general wish to see a smaller administrative overhead, lower cost access and general improvements in the facilities that would be offered in anticipation of a growth in demand.

Research institutes were generally satisfied with access arrangements, although for large facilities (and especially ships), lead-times can be long. However, there was a concern that the available equipment was becoming old, and that it was becoming more difficult to meet running costs, especially for technical staff, and for maintenance, calibration and accreditation. Some respondents noted that access to and maintenance of large-scale experimental facilities in the longer term ought to take account of the changing governance arrangements for many research institutes.

However, industry users were dissatisfied with access to facilities, perceiving access arrangements as opaque, bureaucratic and expensive, often lacking suitable staff to provide a good service. There is clearly a gap between university and industry perceptions, with industry expecting that when facilities have been provided by the public purse, they should be publicly accessible.

Some facilities were considered to be over-subscribed (e.g. the BRE Fire Safety Laboratory, the Engineering and Physical Sciences Research Council (EPSRC) Electron Paramagnetic Resonance (EPR) facility at Manchester, and northern-hemisphere astronomical telescopes). Those who use large, international facilities expressed concern about the extent to which the Science and Technology Facilities Council (STFC) would be willing and able to pay subscriptions on an adequate scale in the future (with strong hints about particular concerns over Scotland's position).

There is an extensive requirement for imaging facilities, and a perceived tension between research and clinical needs.

Respondents are less satisfied with access to facilities in other universities or institutions where there are either no established formal access arrangements or where such arrangements are not publicised. In those cases, access seemed to work well only when there were established collaborations between researchers at the host institution and those who wished to have access to the facilities.

There was an expressed need for ongoing investment in established national and international facilities, embracing running costs (including staff) as well as capital; and an unease that access to such facilities might be affected by constitutional change.

2.3 Growth of Usage

There were general expectations of growth, with each respondent expressing broad themes of interest. Most respondents were more concerned with issues of capacity and with keeping facilities up-to-date rather than with entirely new facilities or directions of research. For example: analytical equipment in chemistry; accelerators, electron microscopes, nuclear magnetic resonance, clean rooms and material characterisation in physics; and nanofabrication, manufacturing and material testing facilities in engineering. However, there were some specifics outlined in the summary documents. Imaging (medical and biological) facilities were mentioned by a few as an area for growth, as was infrastructure to support food (including aquaculture) and drink research; others mentioned photonics and manufacturing.

Most expected demands on computing infrastructure to increase (both in the high performance area, High Performance Computing (HPC), and the high throughput area, HTC) with emphasis on 'big data', environmental monitoring and the health and life sciences. A further example was in the potential need for a full-scale aquaculture test facility to support the Innovation Centre.

There was a reminder that there are capital requirements in the arts and humanities, too (e.g. digital humanities requires significant computer resources; art history creates demand for scientific analytical equipment; media research requires data storage and state of the art visualisation facilities). An essential component of the infrastructure in these disciplines is their requirement for large data sets and archives, with the need for continued investment.

The perceived tension between revenue and capital priorities for the Research Councils was evident. Universities and pools saw the current policy of providing only 50% of full economic costs for capital equipment as unhelpful.

2.4 Facilities within Respondents' Own Institutions

Some general themes emerged in the responses:

- **Chemistry:** see 2.1. The requirement for analytical facilities was common to all responses, and was also emphasised in the relevant pool submissions. Examples include high quality imaging equipment including scanning electron microscopy (EDAX), transmission electron microscopy, confocal microscopy and atomic force microscopy, local or regional computing clusters and data storage, linear accelerators, molecular imaging, mass spectrometers, X-ray diffraction, CT and NMR imaging, various other microscopies, Gas chromatography mass spectrometry (GCMS), and Liquid chromatography-mass spectrometry (LC-MS), atomic spectroscopy.
- **Physical sciences:** an emphasis on subject areas in which individual items of equipment are not in themselves expensive, but which when assembled to form a facility require expenditure in the scale of £ million. Perhaps the most pervasive examples were in photonics and condensed matter.
- **Engineering:** various facilities for manufacturing and fabrication, especially at the micro and nano scale and for semiconductor materials; civil engineering facilities (e.g. wave tanks, high speed rail test-bed).
- **Life, environmental and earth sciences:** analytical equipment; assemblies of equipment for terrestrial and marine environment trials; imaging equipment (see above); genome sequencer, medical cyclotron.

Placing infrastructure in universities has at least the potential benefit of improving access by other disciplines.

The Scottish research institutes have a considerable array of specialist facilities.

2.5 Own Priorities

In general terms, university responses were more about maintaining an adequate scale of existing facilities to meet demand, and keeping them up-to-date (see Q3). However, more specific requirements for particular facilities were enumerated in responses from the Pools and Innovation Centres, including advanced imaging (several respondents), ion beam sputtering (Scottish Universities Physics Alliance (SUPA)) and facilities for water and waste studies for engineering and environmental science. There was cross disciplinary interest in a UK free electron laser facility also.

There is clearly a focus on growing needs for both regional and national high performance and high throughput computing (and its associated data storage and communication links), microscopy and scanning/imaging, and genome-related equipment. A frequent issue related to the difficulty in fields requiring suites of equipment, a typical quote was "some of these facilities may be at modest cost, but the integrated cost to provide a full suite of technology is of the order of £10 million". Chemistry and material science are probably the subjects in which there is the clearest consensus on the importance of maintaining standard sets of analytical and diagnostic equipment, but with the greatest uncertainty over how that was to be achieved under current arrangements. Most respondents expressed concern that the facilities in their institutions were aging, with an expectation that little equipment could be expected to have a lifetime of more than 10 years before becoming obsolete, but with no obvious route to funding of replacements.

A number of respondents noted that meeting the capital costs alone was insufficient, and resources were also required for running facilities, especially for staff. Some went even further and said that the provision of capital resource should be accompanied by grants for those who would use the facilities – i.e. that that there is little point in providing funding for capital without confidence that the facilities thus provided would be used intensively, which would in turn require additional resources. The general point, whether from universities or research institutes, was the need to see that there were adequate running costs in place when planning capital investments, and that there were suitable arrangements to see that the consequent facilities were used to full capacity, often implying multiple users from different institutions, with resulting needs for suitable access arrangements and administrative and technical support.

Changed research council rules on purchase of capital equipment have had a significantly inhibiting effect. Nevertheless, some respondents expressed the view that more control of capital spending should be returned to the Research Councils and the Funding Councils (Scottish Funding Council (SFC) in our case).

2.6 Scottish Priorities

The most commonly expressed academic priorities were facilities for advanced imaging and for digital data generation (not just academic: there were also wishes noted in this aspect by SRUC (Scotland's Rural College) and other research institutes, recognising the existing databases) and data management (i.e. HPC with the associated infrastructure to store, transport, and analyse the data generated).

Recently, the Higgs Centre for Theoretical Physics was funded by the SFC and the Higgs Centre for Innovation by BIS and the STFC. These developments might serve as models for support in other subject areas.

There were suggestions that there could be a case for a major Scottish interdisciplinary facility such as a light source to serve the physical and engineering sciences as well as the life sciences and medicine. Further enhanced investment in Aquaculture facilities would fit well with our Scottish priorities as would enhancement of the mass spectrometer and other analytical facilities at the SUERC (and elsewhere, e.g. at the National Museum); access to a reactor is essential for further radioisotope work.

Industry users would like to see more availability of pilot-scale plant for food and drink, stating that none was currently available except in brewing; access to a human and animal development facility (for the development of vaccines); and in electronics, capital investment in some relevant university facilities (III-V semiconductors, Complementary metal–oxide–semiconductor (CMOS) and power electronics). Innovation Centres responded similarly, with a desire to see the creation of independent, non-competitive space.

Some respondents made the practical suggestion that before defining priorities for new facilities, a database of existing facilities and access arrangements should first be compiled (see Section 2.7).

2.7 Sharing

Sharing of equipment is obviously desirable in improving the efficiency of usage of facilities.

There were some good examples of equipment sharing, but in general there were concerns over the practicalities, with most respondents expressing a preference to have the equipment in their own institutions. Difficulties were cited over the complexity and diversity of administrative arrangements and a concern over the cost of access. Sharing worked best within 'families' of researchers who habitually collaborate, often without money changing hands or formal arrangements. A number of respondents would welcome the development of an easily accessible information system of facilities for which access was available, including a summary of the procedures for gaining access, and a general simplification of access arrangements.

The EPSRC 'Uniquip' project (see http://equipment.data.ac.uk/) provides an opportunity for universities to enumerate EPSRC-funded equipment that they possess, that is in principle available to other users. The data can be freely downloaded. Although over 7,000 items of equipment are listed, the information is far from comprehensive and gives only the briefest description of the nature of the equipment. Contact names are given, but no details of access or charging arrangements (e.g. for commercial users). However, it might form a starting point for future development.

Most respondents in universities and research pools emphasised the need to maintain their own medium-scale facilities. There are good examples of facilities in universities being shared between disciplines.

The potential for leverage and sharing with industry/business was mentioned in only a few responses, sometimes negatively, and only once positively. Interestingly, whilst industrial respondents expressed a wish and expectation that university facilities should be made more available to them, they did not expect themselves to be making their own facilities available for sharing. Enabling industry to make use of university facilities has obvious potential benefits in improving engagement, and in future impact.

The pools (especially the Scottish Universities Physics Alliance (SUPA) and EaStCHEM – the Edinburgh and St Andrews Research School of Chemistry) offer examples of equipment sharing. Institutions seem keen to continue and deepen these pooling arrangements. Sharing with the private sector seems to be modest at present, and so there might be scope to expand this (if industry can be persuaded). Investment in future facilities also requires investment in people alongside it.

3. Recommendations and Conclusions

The SSAC are strongly supportive of the BIS initiative. In recent years, although there have been some substantial and specific investments of public funds in research infrastructure, general support has been reduced: it is some time since initiatives such as SRIF were in place, and Research Council policy on expenditure on capital equipment associated with project grants has become more restrictive. In consequence, the general infrastructure base has aged and eroded. Hence, we would very much welcome initiatives and policies that will promote development of a sustainable research infrastructure. We offer the following recommendations:

3.1 Capital–Project Balance

(a) It is important that capital equipment facilities are not established unless there is confidence that they can be operated effectively and used efficiently, thus requiring resources for staffing to operate the equipment, its maintenance and calibration, and running costs, with sufficient demand to achieve full usage. It does not necessarily follow that the equipment funding must be directly accompanied by additional resource to meet the other costs; however, it should be a requirement of equipment funding that there is robust explanation of how the additional costs will be met, which might include the possibility that some or all of the running costs would be met by the equipment grant itself.

(b) It was noted that current initiatives for infrastructure development are usually 'strategic' in nature, with subject areas often defined highly specifically—and thus, in that sense, the 'strategic' approach is inconsistent with the Haldane principle, and therefore contrasts with the mechanisms by which the project funding required to actually make use of the infrastructure is derived. We therefore recommend that as far as possible, funding mechanisms for 'infrastructure' and 'projects' should be made as mutually consistent as possible, with the same criteria for support, and with planning horizons of similar duration; that would be more easily achieved if both were the responsibility of the same agency, e.g. the Research Councils.

3.2 Medium-scale Institutional Facilities

Medium-scale facilities are those that provide a service, within a single institution and primarily for internal use, where the total equipment costs within the facility would be typically up to £10 million. A common example would be analytical equipment often found in chemistry departments, including NMR, X-ray diffraction, mass spectrometry etc. There has never been a clear consensus on how such facilities were to be sustained, e.g. between funding via Research Council project grants, the Full Economic Costing 'fEC' element of Funding Council grants, or initiatives such as SRIF. Policy changes have reduced the opportunity for supporting such facilities by Research Council grants; there have been no initiatives such as SRIF for some years; and many universities have tended to use fEC support to increase capacity rather than maintain sustainability. We recommend that:

(a) a consensus be developed on how medium-scale university facilities are to be sustained (both in terms of equipment and running costs, including staff);

(b) … including models for access arrangements (and see Recommendation 3.4 for comments on opportunities for sharing);

(c) in the short-term, an equipment initiative (perhaps similar to SRIF) should be introduced;

(d) 'facilities' should be defined to include suites of equipment, where although individual items may be relatively inexpensive (e.g. ~£100k), the total assembly of equipment required to deliver the necessary service would cost ~several £ million;

(e) 'facilities' should also include software, computing hardware and associated costs;

(f) further debate is required on the tensioning between revenue (project) and capital (infrastructure/facilities) demands.

3.3 Large-scale National and International Facilities

Some areas of research (e.g. particle physics, astronomy, earth observation, deep ocean observation and remote sensing etc.) are completely dependent on facilities too large to be the responsibility of single institutions. The requirement is not geographically specific. It is simply the case that groups in those fields cannot undertake research of competitive quality without access to world-class facilities. The allocation of resources between facilities of different scale and nature is essentially equivalent to an allocation between different general topics of research, but because prioritisation processes for 'facilities' and 'projects' are different, there is a real risk of inconsistencies and unintended consequences, e.g. that facilities will be available, but without the resources to make use of them. We, therefore, recommend:

(a) debate be instigated to develop processes to define relative priorities between fields requiring infrastructure of different character;

(b) and hence to align resources for provision of facilities with those for access and running costs; and

(c) demonstrating consistency between priority and total resource provision, recognising the very different timescales involved in different fields.

3.4 Wider Engagement with the Economy and Societal Needs

We agree that it is appropriate to allocate resources with the objective of stimulating the economy and meeting other societal needs (defined here as gaining 'capability', and embracing issues expressed in a number of research council strategies), in balance with resources directed with the primary objective of gaining scientific understanding. We recommend that:

(a) the processes used to tension resources between 'understanding' and 'capability' should not differ between 'infrastructure' and 'projects', recognising that currently, infrastructure support is often driven 'strategically' whereas project support is more frequently responsive and involves a greater element of peer review;

(b) in our view, policy initiatives that create mechanisms and structures for 'capability' support tend to be more effective than those that select highly specific topics (by analogy with the Haldane principle). Specific activities supported should be based on peer review involving all relevant stakeholder groups (including researchers and the potential or actual users of the research);

(c) some elements of 'capability' support are not geographically-specific, but others (and especially those for SMEs) are definitely regional in character and appropriately so in support of industry clustering. A study and identification of relevant and actual or nascent Scottish industry clusters would form the basis for proposing specific infrastructure in support of needs of the economy and society generally; and

(d) access to facilities is particularly important for SMEs, who would like to know what is available in universities and research institutes, and what the access arrangements would be (see Recommendation 3.5(d).

3.5 Sharing and Access

There are many situations in which it is essential for researchers to have access to facilities in their own institution. There are also some good examples of equipment-sharing across Scotland, e.g. in the Research Pools. However, there are also examples of unused capacity in facilities where sharing would improve efficiency. A significant inhibition is ignorance of what facilities are available, uncertainty and inconsistency of access arrangements, lack of skilled staff to support access by external users, and uncertainty over cost and other resource arrangements. We, therefore, recommend that:

(a) a Scotland-wide easily accessible information system of facilities and access arrangements should be set-up and maintained;

(b) consideration should be given to developing standard access arrangements, covering contractual and pricing details, in support of future infrastructure funding initiatives;

(c) adherence to standard access arrangements and levels of service should be a condition of funding by such initiatives; and

(d) policies should be developed to promote use of facilities by users from industry and business (and especially SMEs).

3.6 Specific Priorities

Our consultation was not comprehensive, and topics mentioned here should be taken only as examples to stimulate discussion. However, the following issues and topics were identified:

(a) the need to support the core research of the Research Institutes, universities and their research pools with a coherent strategy for medium-scale facilities at individual institutions, including general purpose analytical equipment;

(b) provision of advanced imaging equipment for medical and materials applications;

(c) support for information systems infrastructure (and note related issues in Section 2 regarding access to remote sensing and imaging data, e.g. from satellites);

(d) pilot-scale production facilities (especially for support for industry);

(e) it is possible that for the medium-scale priorities (e.g. (a) and (b), and possibly (c) above), a pan-Scotland service could be provided from a single facility, if an appropriate arrangement for access and service level could be developed, and we recommend that wider debate be initiated regarding the feasibility of establishing as a generally-available service, pan-Scotland centres for medium-scale facilities, e.g. for analysis or imaging;

(f) further enhancement of the integrated Scottish land-based research facilities to provide a UK-wide facility with high strategic relevance to address challenges in food, water and energy security and enable integrated experimental land-based science on scales ranging from molecules, microcosms, pot, plot, field, farm and land systems, catchments and landscapes; and

(g) the opportunity to develop virtual facilities to pool resources and research capabilities around societally relevant challenges (e.g. as in Centres of Expertise developed by the Scottish Government).

Appendix A1

Letter from Dr Allan, Minister for Learning, Science and Scotland's Languages to SSAC Co-Chairs – Scientific Infrastructure

Ministear airson Ionnsachadh, Saidheans agus Cànain na h-Alba
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17 February 2014

Prof Calder and Dr Masters,

SCIENTIFIC INFRASTRUCTURE

I recently received a copy of the UK Government's response to the House of Lords Select Committee on Science and Technology report on Scientific Infrastructure published in November 2013. This report highlights that for many areas, scientific infrastructure underpins our reputation for research excellence. It is also clear from this report that Scottish researchers benefit from access to world leading shared infrastructure some of which is located in Scotland as well as access to international facilities.

In light of this I would like the SSAC to consider current Scientific Infrastructure and Scotland's needs and requirements in the future. I believe this work would provide useful evidence for the Scottish Government. I would be particularly interested in the following areas:

- What proportion of UK scientific infrastructure is located in Scotland, where and what is it?
- What are the benefits and disadvantages of the current access arrangements to infrastructure across the UK?
- What future infrastructure needs are anticipated if Scotland is to maintain its reputation for research excellence?
- Does collaboration through initiatives such as research pooling and innovation centres prove effective in enabling access to funding for medium sized infrastructure?

I look forward to hearing how this work progresses over the coming months.

ALASDAIR ALLAN

Appendix A2

Creating the Future: A 2020 Vision for Science and Research – A Consultation on Proposals for Long-term Capital Investment in Science and Research.

CONSULTATION QUESTIONS:

1. **KEY QUESTION: What balance should we strike between meeting capital requirements at the individual research project and institution level, relative to the need for large-scale investments at national and international levels? (1000 words maximum)**

   Our world-class research environment is underpinned by funding for capital requirements of individual research projects and institutions. To complement this, strategic decision making at the national and international level is often required to coordinate investments in the national interest. This consultation seeks views on how to balance these complementary needs.

2. How can we maximise collaboration, equipment sharing, and access to industry to ensure we make the most of this investment? (1000 words maximum)

   Collaboration across institutions can be particularly helpful in terms of enabling the purchase of state of the art equipment which would be neither affordable nor perhaps fully utilised by one institution alone. For example, the N8 universities all benefit from a shared £3.25 million high performance computing facility, giving both researchers and industrial users access to larger and higher specification machines than would otherwise be possible.

3. What factors should we consider when determining the research capital requirement of the higher education estate? (1000 words maximum)

4. Should – subject to state aid and other considerations – science and research capital be extended to Research and Technology Organisations and Independent Research Organisations when there are wider benefits for doing so? (1000 words maximum)

5. **KEY QUESTION: What should be the UK's priorities for large-scale capital investments in the national interest, including where appropriate collaborating in international projects? (1000 words maximum)**

The impressive strength and breadth of the UK research base means that we are presented with a huge range of potential investment opportunities. Demand inevitably outstrips funding. Therefore, there is a constant need to prioritise, and this consultation seeks your views to inform our approach. These strategic judgements require us to look first at what international competitors are investing in, and identifying where it is in the UK national interest to collaborate in international infrastructure projects. This may involve significant contributions to projects around the world or hosting them in the UK. We are seeking views on which of the important projects laid out in this consultation (pages 54-58) should be the highest priority. We are also welcoming suggestions of new potential high priority projects not identified here.

Alongside the provision of a world-class research environment there are large-scale strategic investment which, because of their scale, requires separate consideration and decision. Some of these are national decisions, some international; some are of sufficient size to require the pooling of resources, e.g. The Large Hadron Collider, CERN.

6. What should the criteria for prioritising projects look like? (1000 words maximum)
7. Are there new potential high priority projects which are not identified in this document? (1000 words maximum)
8. Should we maintain a proportion of unallocated capital funding to respond to emerging priorities in the second half of this decade? (1000 words maximum)
9. Are the major international projects identified in the consultation the right priorities for this scale of investment at the international level? Are there other opportunities for UK involvement in major global collaborations? (1000 words maximum)

Appendix A3

List of Organisations Contacted

RESEARCH INSTITUTES/CENTRES
Moredun
James Hutton
University of Aberdeen Rowett Institute for Nutrition and Health
Royal Botanic Garden Edinburgh
Scotland's Rural College (SRUC)
Marine Science Scotland
National Museum of Scotland
Roslin (University of Edinburgh)
Scottish Association for Marine Science (SAMS)
Scottish Universities Environmental Research Centre (SUERC)
Sea Mammal Research Unit, University of St Andrews
Centre for Ecology and Hydrology (CEH)
SEPA
Scottish Natural Heritage (SNH)
British Geological Survey (BGS)
BioSS
UK Astronomy Technology Centre (UK ATC)

RESEARCH POOLS
Scottish Universities Physics Alliance (SUPA)
Scottish Universities Life Science Alliance (SULSA)
Scottish Informatics and Computer Science Alliance – SICSA and Data IC
ScotChem (EastChem/WestChem)
Scottish Alliance for Geoscience Environment and Society (SAGES)
Scottish Imaging Network a Platform for Scientific Excellence (SINAPSE)
Edinburgh Research Partnership in Engineering and Maths (ERPem)
Glasgow Research Partnership in Engineering (GRPE)
Marine Alliance for Science and Technology for Scotland (MASTS)
Energy Technology Partnership (ETP)
NRPE
INNOVATION CENTRES
CENSIS – Sensors Imaging Systems Innovation Centre
Stratified Medicine Innovation Centre – Health Sciences Scotland
Industrial Biotechnology Innovation Centre (IBioIC)
Digital Health Institute
RESEARCH DIRECTORS – UNIVERSITIES
University of Edinburgh
University of Dundee
Heriot Watt University
University of Stirling
Strathclyde University
Glasgow University/GRPE

Aberdeen University
St Andrews University
Edinburgh Napier University
Glasgow Caledonian University
University of Abertay
University of Highlands and Islands
Queen Margaret University
University of the West of Scotland
TRADE ASSOCIATIONS
Scottish Optoelectronics Association
SEMTA Scotland
Scotland IS
Chemical Sciences Scotland
Scottish Lifesciences Association
Scotland Food and Drink
Scottish Renewables
Life Sciences Scotland
NMI (National Microelectronics Institute)
Carbon Capture and Storage Association
OTHER
Edinburgh Bioquarter
Beatson Cancer Research Institute

Appendix A4

Letter from SSAC Working Group to Organisations

By email

April 2014

Dear xx

Scottish Science Advisory Council: Review of Scientific and Research Infrastructure

I am writing to you on behalf of the Scottish Science Advisory Council (SSAC) to ask for your help in responding to a request for evidence in support of a review of scientific and research infrastructure. The request to the SSAC has come from Dr Alasdair Allan, Minister of the Scottish Government for Learning, Science and the Scottish Languages.

The request has been stimulated by last November's report from the House of Lords Select Committee on Science and Technology, chaired by Lord Krebs. The key recommendation of the report was that a long-term strategy and investment plan should be developed for scientific and research infrastructure. The Department for Business, Innovation and Skills responded by expressing a long-term commitment to substantially increased capital investment. BIS have announced that they will shortly be issuing a consultation on the subject. Inevitably, it will be important to establish the correct balance between investing in medium-scale infrastructure, e.g at the level of individual research projects and in large-scale infrastructure, including international collaborations.

The SSAC is anxious to ensure that the needs of Scottish researchers are fully taken into account in the development of an investment strategy for infrastructure, and it is with that intention that I am now writing to request information and views representing researchers at your own institution/organisation. In particular:

1. What facilities are of strategic importance to your principal scientists and the longer-term aims of your organisation It would be helpful here to distinguish between medium-scale facilities, national facilities and international ones. 'Medium-scale' is defined as equipment and facilities typically in cost range of ~£250k–£10 million, often used to support the work of relatively small single-PI teams.
2. Do current access arrangements fully meet your needs?

3. Will usage grow, maintain or reduce over the next 10 years?
4. What medium-scale (or larger) facilities do you have in your own institution? (It might be helpful here to enumerate equipment and other infrastructure that your institution defined as ‘facilities’ for TRAC purposes).
5. What would be your priorities for new facilities, of whatever scale?
6. Are you aware of any Scottish priorities for large-scale capital investment (including international collaboration)?
7. It is probable that future investments in mid-range facilities will seek to maximise efficiency through equipment sharing, and ‘leverage’ through contributions from the private sector. Can you offer current examples of effective sharing or leverage, and in particular any that arise from Innovation Centres? Can you identify future opportunities for sharing and offer advice on successful sharing arrangements?

We would be very grateful for your response in whatever form is most convenient for you. However, a proforma is attached that you might wish to use in providing a written response, which we would need to receive **before April 30**. However, I would also welcome the opportunity for a short telephone discussion with you, probably lasting around 15 minutes. Would that be acceptable to you? I shall be in touch to arrange a mutually convenient time.

It is probable that once the UK science and research infrastructure strategy has been developed, that it will set the direction for the coming decade. The SSAC therefore wish to give the best possible advice to government during the consultation period. We believe that the most authentic input must come from the science and research community itself, and we therefore hope that you will be able to find time to help us in our endeavour.

Yours sincerely

xx

SSAC Member

Appendix A5

Abbreviations Used

ARCHER	Academic Research Computing High End Resource
BIS	Department of Business Innovation and Skills
CERN	European Organisation for Nuclear Research
CMOS	Complimentary metal oxide semiconductor
COSMIC	Collaborative Optical Spectroscopy Micromanipulation and Imaging Centre
CSEC	Centre for Science at Extreme Conditions
Defra	Department for Environment Food and Rural Affairs
DESY	Deutsches Elektronen – Synchrotron
Diamond	Diamond Light Source
EaStCHEM	Edinburgh and St Andrews Research School of Chemistry
EPR	Electronic Paramagnetic Resonance
EPSRC	Engineering and Physical Sciences Research Council
ESO	European Southern Observatory
ESRF	European Synchrotron Radiation Facility
FEC	Full Economic Costing
GCMS	Gas chromatography – mass spectrometry
GO-Science	Government Office for Science
HECToR	High-end Computing Terascale Resource
HPC	High Performance Computing
ILL	Institut Laue-Langevin
ISIS	Neutron Facility
LIGO	Laser Interferometer Gravitational Wave Observatory
LCMS	Liquid Chromatography – mass spectrometry

MRPs	Main Research Providers
NERC	Natural Environment Research Council
NMI	National Microelectronics Institute
NMR	Nuclear Magnetic Resonance
SFC	Scottish Funding Council
SRIF	Science Research Investment Fund
SRUC	Scotland's Rural College
SSAC	Scottish Science Advisory Council
STFC	Science and Technology Facilities Council
SUERC	Scottish Universities Environmental Research Centre
SUPA	Scottish Universities Physics Alliance
TRAC	Transparent Approach to Costing