Institution: University of Leicester

Unit of assessment: 9 Physics

a. Overview

The Department of Physics and Astronomy, which is coterminous with this Unit, is a research intensive Department, consisting of 50 academic staff, attracting significant research income to support a further 57 research staff. The Department is one of seven in the College of Science and Engineering (CSE), which, in turn, is one of 4 academic Colleges in the University. The Department is divided into 6 research groups, Condensed Matter Physics (CMP), Earth Observation Sciences (EOS), Radio and Space Plasma Physics (RSPP), Space Science Instrumentation (SSI), Theoretical Astrophysics (TA), and X-ray and Observational Astronomy (XROA). Each group is semi-autonomous within the Department, each with a Head of Group responsible directly to the Head of Department (HoD). Each Head of Group is a member of the Department's Research and Strategy Committee (RSC), which is chaired by the Head of Department. Other members of the RSC include the two Departmental representatives on the CSE's Research Committee, both of whom are senior members of the Department, plus the Department's Director of Learning and Teaching and the Departmental Manager.

SSI and EOS form the Space Research Centre (SRC), housed in the Michael Atiyah Complex, while the other 4 groups are based in the Physics and Astronomy building, with part of the TA group in the Bennett building. Despite this separation, there is considerable cross research group collaboration, in particular between the SSI group and EOS, XROA and RSPP groups, XROA and TA groups, and EOS and RSPP. In addition links have been developed between SSI and CMP as well as SSI and TA groups through mutual research interests. Such internal collaborations are positively supported by the Department, and this has been enhanced by a recent cross research group initiative to develop its research activity in Exoplanets involving the RSPP, SSI, TA and XROA groups. The Department's research programme fits well within the broader context of the CSE's five research themes. Two of the these themes are led by staff from Physics and Astronomy, Astronomical, Earth and Planetary Science (**Fraser**) and Environment, Energy and Climate Change (**Remedios**), while members of staff play significant roles in two others, Life Sciences Interface (**Fraser, Lees, Sims**) and Materials and Nano-materials (**Binns, von Haeften**).

b. Research Strategy

Overview

The Department's main research focus is to continue world class research programmes in all its research groups. Our strategy to achieve this is to build on the research strengths that exist, while also enabling evolution of research activity. As the funding landscape evolves, we seek to continue to appoint high quality researchers and take advantage of new funding initiatives. Such a strategy enables the Department to develop its research programme from core strengths, ensures a diversity of research funding sources, and also ensures a continued strong linkage between its research programme and its undergraduate teaching programme. Recent strategic successes have included Leicester's role as a member of the DiRAC consortium, thereby enhancing its numerical simulation capability (see section d); Leicester's role in the European Space Agency Large Class, "L", mission, JUICE, which will be launched in 2022, thereby ensuring a long term research programme in the science of the outer planets of the solar system; Leicester's major contribution to a new beamline at Diamond, and establishing lead roles on space missions to Mars. Leicester now contributes leading roles in the National Centre for Earth Observation (NCEO) and the Centre for Earth Observation Instrumentation (CEOI). There is a strong collaborative ethos within our research programmes, partly as a result of the major programmes, such as space missions and large ground-based facilities, in which we have become involved. The Departmental structure of 6 research groups ensures each research area has a critical mass to maintain its research strength while the ethos fostered within the Department also enables collaborations across research groups, within the College and external to the University.

Comparison with previous position.

At the time of the last RAE in 2008 the Department had completed a period during which it had replaced several key staff in all research groups. This included the appointment of 3 RCUK Fellows all of whom have subsequently been taken on to the full academic staff as members of the

EOS (**Boesch**), RSPP (**Stallard**) and SSI (**Bridges**) groups. Additional appointments have also been made since the last RAE in the CMP (**Baker**), EOS (**Battaglia**), RSPP (**Imber**, from March 2014, **Nichols**), TA (**Alexander**) and XROA (**Blain, Hinton, Starling**) groups. In the case of the RSPP, TA and XROA groups these have been helped by the appointments of staff who have been awarded prestigious Fellowships (**Imber, Nichols, Alexander** and **Starling**). A full list of Fellowships awarded is given in section e below. Furthermore, as a result of the appointment of the former Head of Department to the post of Head of College, two new appointments (**Blain, Hinton**) have been made at Chair level.

At the time of the last RAE the University was in the process of reforming its own internal structure with the consequence that from 2009 onwards the Department of Physics and Astronomy became part of the CSE. This change has led to the College having a greater level of fiscal control over Departmental budgets, together with the overall support for research across the College. This collegiate approach has been beneficial for research in the Department through:

- Appointments of two College New Blood Lecturers (**Barkley, Leigh**) in Adapting to Changing Environments (ACE): an environmental and climate change research centre to create a multidisciplinary understanding of the causes and consequences as well as future responses to environmental change. These appointments have increased the academic staff complement in the EOS group from 3 to 5.
- Increased funds for College and Department supported Ph.D. students. We now have an average of 20 Ph.D. students per annum joining the Department compared with roughly half that number before the CSE was established.
- Two new appointments at Chair level in the XROA Group (**Blain, Hinton**) bringing two new research areas in astronomy to the Department, infra red astronomy and ground-based high energy gamma ray astrophysics.
- Development of five College interdisciplinary research themes (see above for Departmental leadership in these).

The University has also continued to invest in the Department through major construction, such as £1.9 million for the construction of Phase 3 of the Michael Atiyah Complex, opened in 2011 by David Willetts, which houses new clean room and laboratories, mostly used by the EOS group, as well as offices, seminar and meeting rooms to support EOS and SSI groups. In addition, the Department has been awarded internal research funds through the University's Research Infrastructure Fund (£475k since December 2011). Internal Departmental and Group investment has also supported international facilities and projects e.g. AstroSAT, CTA LOFAR, NGTS, SuperDARN and WASP.

Future Strategy

In ensuring the long term health of our research programme the two critical priorities are, first, to maintain a diverse and research active staff profile, with members of staff who are, or will develop into, world leaders in their field, and, secondly, to maintain access to and contribute to major new research infrastructure. The Department starts from a strong base in terms of its long term plans. We have been fortunate in recent years to attract high quality young staff who have won prestigious research Fellowships in open competition thereby demonstrating their quality. We have a staff profile which enables younger staff to be mentored by more experienced colleagues. This successful approach will be continued by aiming to attract young staff through Fellowships, and where possible through replacement of more senior staff as they retire. In recent years the University has played a key role in enabling this approach. Although we have been successful in recruitment in the last 6 years, it is clear that some research groups now need to see further investment. A key example is EOS which is smaller than other research groups, although they do have close research links to Departments elsewhere in the University, e.g. Chemistry and Geography. A central element of our strategy, therefore, is to ensure that all research groups maintain a critical mass to continue their world class research programmes.

In terms of provision of infrastructure, our strategy is to be actively involved in future major space missions, e.g. we currently have a major involvement in JUICE (**Bannister, Bunce, Cowley**), but

we also plan to have an instrumental contribution on at least one future ESA M class or L class space mission, as well as lead new ground based initiatives, e.g. CTA (**Hinton, O'Brien**). Such involvement is essential to maintaining a high quality research profile. In addition, we make use of national and international facilities such as Diamond and the ESRF. We have also developed a role in HPC, which has currently led to the TA group's leading role in the DiRAC consortium (**Wilkinson**), and we will look to continue this role as upgrades to this facility are agreed. Another IT related area in which we plan to make a significant contribution is in that of "Big Data".

c. People

(i) Staffing strategy and staff development

Strategy

Our staffing strategy is always to maintain the highest possible level of research quality. Since 2008 several staff have left through retirement or movement to posts elsewhere. In each case we have successfully argued for replacement appointments and we have always identified those individuals who will bring the best quality research to the Department. Thus, the Department continues to flourish, to maintain its world leading position, whilst also enabling its research programme to evolve through these new appointments. We have also taken advantage of internal University initiatives such as the College New Blood lecturers, where two of the three appointments have been placed in Physics. We also actively and successfully support our own junior staff in applying for prestigious Fellowships. We actively encourage senior research staff in promotion cases to high level academic positions, i.e. personal chairs and readerships, to demonstrate a commitment to career progression through the "research only" route. The University has supported this development with 3 staff receiving promotions in this way during the last 6 years (**Lees, Lapington, Osborne**), all of whom form part of the Department's submission.

Staff Development

The University has a centrally run staff development unit which provides support for all staff. A crucial element of staff development is the proactive promotion policy employed by the Department. The HoD is centrally involved in discussions with staff to promote career development, study leave and sabbatical opportunities. This includes regular meetings with junior staff to discuss personal career development, through gaining experience on national and international peer review committees, involvement in major projects, contributions to new research initiatives. The HoD also regularly confers with research group heads in order to identify such opportunities for their research group members. Statistics indicate that the overall policy is successful. Since 2008 there have been 8 successful promotions to personal chairs, 10 promotions to Reader and 1 promotion to Senior Lecturer.

We have an active Equality and Diversity Working Group (EDWG), whose role is to provide support to the HoD in ensuring these issues are actively fostered throughout the Department's teaching and research. The EDWG is a mix of senior academic staff, including the HoD, and junior research staff and meets on a monthly basis reporting back to staff meetings. The Department was awarded JUNO Practitioner status by the Institute of Physics in 2013 and an Athena Swan Departmental Bronze Medal also in 2013. Key elements of these awards are the action plans which the Department now follows to further improve Equality and Diversity within the Department. Through the EDWG, the Department has established a Research Staff Forum (RSF) which has organised workshops to provide guidance on Fellowship applications, and advice on promotion cases, including merit and achievement bonus awards. The University is a signatory to the Concordat to Support the Career Development of Researchers, and has recently been awarded the 'HR Excellence in Research Award' which acknowledges the University's alignment with the principles of the European Charter for Researchers. Our action plan underlines our commitment and examines where Leicester is in line with, or goes beyond, the requirements of the Concordat. Areas for further work have been identified, against key milestones and timelines, and these are being monitored by the Concordat Steering Group, which is chaired by the PVC for Research and Enterprise, and has representation from research and academic staff members from the University's four constituent colleges, Human Resources, and the Academic Practice Unit. The workshops held by the RSF are examples of how we contribute to these developments.

(ii) Research students

Recruitment

The Department operates a central recruitment process for postgraduate researchers (PGR), with a dedicated admissions tutor and a dedicated admissions secretary. Each group has a postgraduate admissions representative responsible for interacting with the admissions tutor on interviewing etc. Each year the Department invites applications from students through a central University system. This allows the Department to identify potential areas of scientific interest in the Department. All applicants are invited to one of two "Open Days" at which the students are interviewed by two members of each research group where there may be direct interest. Potential research projects are advertised on the Department's web pages. PGR numbers have increased since the last RAE as a result of a proactive stance by the Department and College on utilising Group, Departmental and College funds. Further University-wide initiatives to increase the number of international students to the University to study for a Ph.D. have also helped. The overall result is that while in 2008/09 13 students registered for a Ph.D, in the following 5 years we have averaged 20 registrations per year. We anticipate an increase in PGR due to the Department's involvement in two new recently announced Doctoral Training Centres by EPSRC (PI Hong Dong, Engineering, 87 PGR in 3 Universities, Physics Co-Is **Baker, Binns**) and by NERC (Leicester Co-I, **EOS** and **RSPP** involvement, between 100 and 150 PGR in 5 Universities).

Training program

All new students undertake a joint induction with students from the other Departments within the College as well as the College of Medicine, Biological Sciences and Psychology. The Graduate School requires our students to undertake a series of induction courses as well as graduate level taught courses. The principal mode of training, however, is by research under the direct supervision of a member of academic staff. To encourage effective research and enhance student employability we provide all PGRs with a broad range of advanced level academic courses (PGR level) as well as technical/skills sessions. Academic courses are run by members of academic staff within the Department of Physics and Astronomy, while skills training sessions are run through the centre. Students are initially appointed as Advanced Postgraduate Students (APGs), and must complete a minimum of 3 (8 hour) advanced level courses per year of study as a pre-requisite for progression to the full PhD program. The Senior Postgraduate Tutor is directly responsible for the content and implementation of the PGR training program. The Senior Postgraduate Tutor liaises with PGRs and staff in order that relevant training content be provided. Typically, PGRs are canvassed once a year to ascertain whether new content is required.

As members of the Department, PGRs are exposed to research both locally via lunchtime talks, and by international researchers via our local seminar programs. Each group runs its own seminar program with attendance compulsory for PGRs. Students are also given every opportunity to discuss their own research or topics of interest, via lunchtime talks, where they can present for up to 30 minutes, or group journal clubs. We expect our students to attend at least one international conference to showcase their research. A minimum requirement for conference attendance is a poster presentation, though we encourage our finishing students to present, if possible. To raise awareness of possible career paths/opportunities, all PGRs are required to attend careers skills/training sessions within the first year of study. We also provide a careers event in Physics, where PGRs attend presentations by ex-Leicester PGRs who have gone on to very successful careers in industry after completing their PhDs. These presentations are followed by question and answer sessions with the speakers.

In the spring of 2011, the Department joined the Midland Physics Alliance Graduate School (MPAGS). As members of MPAGS our PGRs can access the full program of advanced training modules offered by the other Midlands Physics Departments, i.e. Birmingham, Keele, Loughborough, Nottingham, Nottingham Trent, and Warwick, using our access grid node. This exposes our students to a far broader range of research activities/interests as well as to possible collaborative projects and future career opportunities. Modules within MPAGS are 10 hours duration and are assessed as pass/fail.

The Department also undertakes training at national and European level. The EOS group

(**Remedios**) co-ordinates the national training for the Centre for Earth Observation Instrumentation incorporating 10 NERC-sponsored PhD students and training days for students and early stage graduates in industry. The Department has hosted an EU Marie Curie training scheme, SPARTAN (**Barstow**) and is now hosting an ERASMUS IP Earth Observation school (FORMAT-EO; **Barstow, Remedios**) at Masters level, involving partners from four countries. In 2013, a new taught Masters programme in Space Exploration and Design (SEDS) was started by the Department to attract students whose main interest is a career in the industrial space sector, although this may also lead to CPD opportunities, as well as strengthening links with industry.

Monitoring

PGR supervision and monitoring adhere to the guidelines set out in the University regulations, and follow similar guidelines for postgraduate study and supervision provided by the research councils. Each PGR is assigned a thesis committee comprising 1st and 2nd supervisor and personal tutor. It is the 1st supervisor's responsibility to take care of the day-to-day management of the proposed research. PGRs are required to meet with their supervisors for at least 1 hour per week during the first year of study where any issues arising can be discussed. Thesis committees (+student) meet 3 times in the first year: at the start of the program, at 6 months for an interim review, and following the formal submission of a 1st year report and presentation by the PGR in June/July. In years 2 and 3, the thesis committee meets every 6 months. Assessment of the 1st year report is by members of the thesis committee. Presentations are formally assessed by members of academic staff. Progression to the full PhD program is at the discretion of the thesis committee and is based on the quality of the 1st year report, feedback from academic staff regarding the presentation, and overall progress during the 1st year of study. The 2nd year requirements include submission of 1 research chapter of their thesis and a thesis outline (an introductory chapter is not deemed sufficient). At the end of their final year of study, students are expected to be in a position to submit their thesis. The role of the thesis committee is to ensure that research progresses in a timely manner and to address any issues that may arise. In cases where a supervisor is absent for long periods of time, the 2nd supervisor becomes the PGR's first point of contact. The role of the personal tutor is mainly pastoral, but they are expected to step-in in those rare instances where issues arise between PGRs and their supervisors. In cases where PGRs wish to be re-assigned to a different research topic it is the responsibility of the Senior Postgraduate tutor to find alternative arrangements for supervision.

d. Income, infrastructure and facilities

Research income in the period from 2008 onwards is based on figures supplied to HESA. Starting in 2008-09, the total annual research income reported was £9.01m, £9.69m, £8.92m, £8.78m and £8.39m, totalling £44.78m, an average of £8.96m pa over the 5 complete financial years in the REF period. This compares with an average for research grant income, excluding research facilities, of £6.56m in the final 5 years of the preceding RAE. "In-kind" research income through successful application for and use of research council facilities, particularly STFC and NERC facilities, again starting in 2008-09, are £21.18m, £23.26m, £20.42m, £19.19m and £12.33m (note the last, 2012-13, is only a part year). Thus in the four complete years the average is £21.02m pa and an overall total over the 5 years of £96.40m. In addition to these facilities we have also been successful in gaining time on non-research council facilities. For example, **Stallard**, in conjunction with his PDRA Melin, has used a total of 552 observing hours as PI on the NASA InfraRed Telescope (IRTF) which total of order US$542,800, **Stallard** has also used in association with his collaborator (Baines) 48 hours on the Keck telescope which totals US$214,800. In addition **von Haeften** received 10 shifts (80 hours) on the FLASH free electron laser at DESY, Hamburg, which was used in 2010, and 18 shifts (equivalent to 144 hours) on the DORIS synchrotron light source also at DESY, used in May and June of 2012. No equivalent costs are available for this time. During the REF period our research income has supported staff at a range of technical and scientific levels. We currently have 57 research grade staff actively supported on research grants.

Infrastructure and Facilities

The Department has been enhanced recently with the construction of Michael Atiyah Phase 3 (£1.9M cost, opened in 2011), such that there are now 3 clean rooms in the Michael Atiyah complex, a planetary laboratory (15m^2), a large clean room (70 m^2) and an EOS clean room (20

m^2). In addition we have a clean assembly room in the main Physics building (25 m^2) associated with the a beam line facility (energy range 0.1 keV to 60 keV) In addition to this the Department has a mechanical workshop providing support for 3 research groups (CMP, RSPP, SSI) in the construction of laboratory, radar and space mission hardware, as well as extensive research laboratory space for CMP and RSPP (250 m^2 and 110 m^2, respectively). The Department is well served by HPC facilities with the University investing in the ALICE supercomputing cluster (£1.5m University plus £300K from BIS to the TA group), which is used by the TA, EOS and RSPP groups. This support has now been superseded for the TA group by the DiRAC facility (see below for a full description). The University has invested £400K in provision of a state-of-the-art data centre to house DiRAC. This data centre will achieve a Power Utilisation Effectiveness (PUE) of less than 1.2 making it among the most energy efficient machine rooms in the country.

Several research groups (CMP, SSI) in the Department benefit from the College-wide Advanced Microscopy Centre (AMC) funded through HEFCE's SRIF2. The centre includes four instruments, a scanning tunnelling microscope (STM), a scanning probe microscope (SPM), a field emission gun scanning electron microscope (FEGSM) and transmission electron microscope (TEM). SRIF-2 also supported the joint SSI/LRI Diagnostics Development Unit (DDU) at £0.5M to purchase equipment and convert space for the DDU as well as office and space at LRI. CMP also have a UHV XPS facility funded through HEIF and three large gas-phase nanoparticle synthesis facilities, two of which can move between the lab and central facilities such as the ESRF and Diamond. In addition **Binns** is the PI on a new hard X-ray nanoprobe beamline for Phase III of Diamond. This £10m instrument was successful in competition amongst several proposals and will be used by 60 research groups worldwide as well as by industry. The CMP group operates a portable ultra-low temperature spectroscopy instrument (**von Haeften**) which is currently deployed to the G2Elab/Institut Neel, Grenoble, France and used by an international collaboration (UK, France).

The Department includes staff funded as part of the NERC National Centre for Earth Observation (NCEO). **Remedios** provides a leadership role in NCEO through the NCEO Directorate and Board. The NCEO work gives the department overview roles (**Remedios**) in the National Climate and Environment Monitoring (CEMS) facility and access to cloud computing and data storage facilities for academic Earth Observation. It also affirms its key roles in generating and exploiting key climate quality research data sets for Essential Climate Variables (**Remedios, Boesch**). Leicester's role in the CEOI gives it important responsibilities in identifying, developing and guiding UK developments in this area for implementation in international missions.

RSPP operates the CUTLASS radars, which also forms part of the wider SuperDARN radar network, as specialist infrastructure for the group and the UK. We receive regular requests from national and international groups for support using these radars for activities such as rocket campaigns, heating campaigns, and balloon flights. As necessary underpinning to the SuperDARN activity, RSPP also run an electronics laboratory with two senior staff and three full-time technicians who undertake the design, construction, and deployment of RF and digital electronic equipment. In addition to supporting the in-house programme, these capabilities attract significant contract income from third parties including the provision of complete radar systems to overseas research organisations.

As mentioned previously, the University of Leicester now hosts a £2m, 100 Tflop/s High Performance Computing cluster as part of the BIS/STFC funded DiRAC facility which provides world-class HPC for research in theoretical astrophysics, particle physics and nuclear physics. The Leicester node has an all-to-all non-blocking inter-node communication architecture which is particularly suited to the study of problems which do not scale well on 2:1 blocking clusters due to their physical complexity. An example of such a problem is the simulation of feedback by a supermassive black hole at the centre of a galaxy, which is one of the research areas of interest to the TA group in the Department of Physics and Astronomy. The DiRAC cluster is supported by one FTE staff member funded by STFC, and is managed by the Research Computing Service of the University. In addition to the computer cluster itself, there will be 800TB of storage. We note that the future for DiRAC looks very positive. DiRAC has been explicitly named within the government e-infrastructure ecosystem and is therefore expected to receive further funding over

the coming decade. There are no firm commitments on the level of funding at the moment, but DiRAC as a whole has submitted a spending plan of £85m over the decade in response to the RCUK capital investment consultation process in 2013. If obtained, this funding would be spread across the four host HEIs (Leicester, Cambridge, Durham, Edinburgh).

The Department hosts the UK Swift Science Data Centre which provides processed Swift data to researchers around the world, and has ~1 million page views per month. This has been running since before Swift launch in 2004, and is funded by the UKSA as part of Leicester's Swift activities, having a current project cost of £400k/yr.

Members of the Department have successfully bid for time on national NERC facilities including the Molecular Spectroscopy Facility and the Field Spectroscopy Facility. The Department, through successful bidding for time, has access to a range of ground based Astronomy Telescopes, including ESO VLT, UKIRT, NASA IRTF, Keck, LOFAR, WASP, and HESS. Furthermore space based facilities which are used include the Hubble Space Telescope, Chandra, XMM-Newton, Swift, Envisat, GoSAT, Cloudsat/Calipso, Metop, MSG, Aura, Cassini, Stardust, Cluster, Mars Express, Venus Express, Rosetta, WISE, STEREO, AMPERE, Mars Science Laboratory, and Hayabusa. Some of these space based facilities award time through competitive bidding while for others the data are available through collaborative work or via public data centres.

e. Collaboration and contribution to the discipline or research base

Research Collaborations

Members of the Department are active partners in wide ranging international research collaborations, often leading or contributing to the leadership of these teams. This is best exemplified through the roles that the Department plays in formal international collaborations through staff members' involvement in many space missions both through hardware provision and scientific exploitation. Examples include the PI role on the EPIC instrument on the ESA cornerstone mission XMM (**Turner, Sembay**), PI of the XMM-Newton Science Survey Consortium (**Watson**), the PI role on the MIXS instrument on Bepi-Colombo (**Fraser**), PI of the UK Swift Science Data Centre (**Osborne**), which role confers the status of Co-I on Swift, membership of the Swift Executive Committee and of the Swift Science Team (**Osborne**), membership of the XRT instrument team on the NASA Swift mission (**O'Brien, Osborne**), which also involved hardware provision. In addition we have staff who have significant Co-Investigator roles in a number of space missions which also by their nature are multi-national collaborations. Examples here include a Co-I role at the science level in space missions such as ESA's cornerstone mission, Cluster (**Cowley, Milan**) as well as the ESA led Rosetta cometary mission (**Cowley**), the joint NASA/ESA Cassini (**Cowley, Bunce**), NASA's Swift Science Team (**Starling, Tanvir**), NASA's JUNO mission (**Cowley**), provision of the soft X-ray camera for the Indian AstroSAT mission (**Stewart, Fraser**), hardware roles on 3 instruments on ExoMars Rover (**Ambrosi, Hutchinson, Sims**), 2 of which have been removed due to descoping as a result of mission mass issues, major leading contributions to the Athena (**Fraser, Vaughan, Watson, Willingale**) and JUICE (**Bannister, Bunce, Cowley**) mission proposals for the ESA L1 mission, and to Athena+ for the L2/L3 mission science theme (**Fraser, Vaughan, Watson, Willingale**), contributions to the LOFT mission proposal for the M3 mission (**Fraser, Vaughan**), Co-I on the HiRISE instrument on Mars Reconnaissance Orbiter (**Bridges**), and on the ChemCam team of MSL (**Bridges**) science definition and instrument teams, many roles on the ATSRs, including PI (**Llewellyn-Jones**), Science Manager (**Remedios**), Validation Scientist (**Corlett**), such that the team leads the ATSR Science Advisory Group (SAG) and also participate in the Quality Working Group (QWG), and have a membership of the ESA MIPAS Quality Working Group (**Remedios**), the GERB International Science Team (**Remedios**), the NASA ACOS(OCO-2) Science Team (**Boesch**), the GPM NASA Precipitation Measuring Mission Science Team (**Battaglia**), the ESA EarthCARE Algorithm Developing Group (**Battaglia**), the Carbonsat ESA Mission Advisory Group (**Boesch**). Recent work at Leicester based on mission analysis has led to a new collaboration with the US Navy's Office of Naval Research on Space Based Maritime Domain Awareness (**Bannister**).

Ground-based systems, such as telescopes and radars, also have similar multi-national science and hardware collaborations. Current specific examples include Project Scientist on CTA (**Hinton**), project leadership, hardware and science definition contributions to the CTA project

(**Hinton, Lapington, O'Brien**), a science role in the HESS project (**Hinton, O'Brien**), science and project roles in SuperWASP (**Burleigh, Goad, West**), NGTS (**Goad, Burleigh**), membership of the LOFAR-UK Board (**O'Brien**), as well as the LOFAR Planets Working Group (**Nichols**), instrument, science and project roles in SuperDARN (**Lester, Milan, Yeoman**), including the Chair of the SuperDARN Executive Council which is responsible for the overall leadership of that programme (**Lester**). There is also a long standing collaboration with Moscow State University related to magnetospheric field modelling (**Cowley**), funded by the Royal Society.

The Department also plays a leading role in supporting data centres and systems for data analysis, e.g. the XMM SSC (**Watson**), UK Swift Science Data Centre (**Osborne**), the Gaia Data Processing and Analysis Consortium (**Barstow**), AstroGRID (**Watson**). These developments have also lead to new interactions in other disciplines, e.g. medicine and geophysics (**Tedds**). The High Performance Computing requirements of the TA group are such that these lead to large collaborations. Here the most recent is DiRAC, in which Leicester (**Wilkinson**) plays a lead role. The scientific exploitation of such space missions and large facilities is often supported through initiatives such as International teams supported by ISSI. Here members of the Department have either chaired teams (**Fear, Grocott, Hinton, King, Lester (2), Milan, Nichols**), or been members of such teams (**Badman, Lester, Hinton, Grocott, Milan, Fear**).

The Department also has two formal agreements with international Universities for collaborative research exchange programmes. These two agreements underpin collaborations between the University of Nagoya, Nagoya, and the Institute for Solar Terrestrial Physics, Siberian Branch of the Russian Academy of Sciences in Irkutsk. Several members of the Department have visiting positions at other prestigious institutions in Europe which lead to significant international collaborations. For example, **Battaglia** is a visiting professor at the University of Bonn, **King** has a long-term visitor position at the Astronomical Institute in the University of Amsterdam, **Milan** is an external member of the Birkeland Institute for Space Science at the University of Bergen, **and von Haeften** is a visiting professor at the Fourier University, Grenoble.

Support for and exemplars of interdisciplinary research
Interdisciplinary research is fostered as part of the ethos of the Department. The interdisciplinary nature of much of our activity, for example, nanoscience, has produced strong links with the Departments of Chemistry, Biological Sciences, Engineering and Medicine. In addition, the development of interdisciplinary College research themes in which the Department plays leading roles in 2 (see section a) and significant roles in a further 2 demonstrates the importance of interdisciplinary research to the Department. Support for such research has come in many forms including the direct leadership roles that the Department plays in the College research themes, as well as the appointment of two of the College new blood posts in ACE who are related to Physics (**Barkley**, **Leigh**). The EOS group works across Departments in the College with close collaborations with Chemistry (atmospheric chemistry and technology; **Remedios, Leigh, Lapington**), Geography (land surface properties and ecosystems; **Remedios, Leigh**) and with Biology (phytoplankton/flamingos; **Remedios**).

Other examples of interdisciplinary research include a joint grant funded by AHRC which supports X-ray imaging work of historical artefacts (**Fraser**), developing new bio-imaging systems based on those developed for astronomy space missions (**Fraser, Lees**), developing spectroscopic diagnostic techniques in ophthalmology, stemming from earlier work on the development of spectroscopic instrumentation for ground based telescopes (**Bannister**), and collaborations with Cell Physiology and Pharmacology as well as Chemistry on the development of high speed imaging cameras for confocal and super-resolution microscopy, and time resolved spectroscopies in life science applications (**Lapington**). The SSI group (**Sims**) is involved a collaboration with the Leicester Royal Infirmary (the DDU) to develop technologies for a physiological profile of a patient to aid diagnosis and subsequent treatment. Much of the CMP group's research is cross disciplinary, e.g. nanoparticles as both sensors as well as treatment for cancer cells (**Binns**), a new project on hip fracture is being led by **Maksym** in collaboration with Engineering and the LRI.

How research collaborations with research users, including industry have informed research activity and strategy

A new research programme which has successfully developed over the last period has been on radioisotope thermoelectric generators and radioisotope containment systems for space applications. This programme was initiated through a research collaboration with the US. Subsequently, the Leicester group (**Ambrosi, Bannister, Williams**) has led work involving other UK academic institutions (Queen Mary University of London), as well as UK Industry (National Nuclear Laboratory, Astrium, SEA, Lockheed Martin UK) and SMEs (European Thermodynamics Ltd). This international programme involves collaboration with European industrial partners and has generated interest in the US and links to several new initiatives, including a new Masters course in Space Science and Exploration, as well new mission proposals. This new research programme may lead to major new developments over the course of the next cycle and will have a major impact in the involvement of UK academia and industry in new space related activities. The University of Leicester is an integral member of a collaboration between academia and industry that has enabled the world class nuclear and space industries in the UK to work together to develop new technologies with technology transfer potential and spinoff applications.

Involvement in current missions also leads to future opportunities. An excellent example is our potential involvement in the joint China/France mission, SVOM, which has grown from both our role on the Swift mission through the data analysis side as well as the MCP optics developments for MIXS on the ESA mission to Mercury, BepiColombo. The Department has Co-I status on this proposed mission (**Fraser, O'Brien and Osborne**), with a key role as the MXT instrument scientist (**Osborne**).

The CMP Group have a major collaboration with a Norwegian company, Ensol, which has steered part of their research programme into the area of fourth generation solar cell technology. Further development of this collaboration will provide access to investment into other parts of the programme. This is already happening with the "buy out" of the PI (**Binns**) and an Experimental Officer provides additional support within the Department for the remaining programme. The collaboration also provides a route to scale up any of the technology towards commercialisation.

Leadership

Members of the Department of Physics and Astronomy demonstrate leadership of the discipline through their membership of various committees. Examples of contributions to the position of Physics as a subject include membership of the Wakeham Committee on Health of Physics (**Barstow**), the HEFCE REF 2014 Physics Panel (**Barstow**), HEFCE Impact Pilot Physics Panel (**Barstow**) and the RCUK Public Engagement with Research Advisory Committee (**Barstow**).

The large space programme and involvement in space projects at Leicester results in significant involvement in the advisory structure on the science programme of the European Space Agency (ESA). This has been a particularly important time as in the last 4 years, the science working groups, i.e. Astronomy Working Group (AWG) and Solar System and Exploration Working Group (SSEWG), together with the Space Science Advisory Committee (SSAC), have played a leading role in the determination of the long term science programme, Cosmic Vision. In that time these committees have been involved in the selection of the first two medium class missions, Solar Orbiter, (M1) and Euclid (M2), the first small class mission CHEOPS (S1), the first Large Class mission JUICE (L1) and the two science themes for the second and third L class missions (L2 and L3). Membership of these panels includes the SSAC (**Lester**), AWG (**Barstow**), SSEWG (**Lester**), Earth Observation Science Advisory Committee (**Remedio**s), Future Technology Advisory Panel (**Remedios**) as well as the Chair Cluster Active and Final Archive Review panels (**Milan**). Departmental staff have also played key roles in the development of the cases for major mission proposals to ESA such as two of the three L Class missions considered for selection in 2012, Athena (**Fraser**, **Watson, Willingale**), and JUICE (**Bunce**). Further involvement in mission selection has been as Chair of the review panel for the potential Mission of Opportunity with the Chinese, KuaFu (**Milan**). Contributions to the operations of current missions include membership of the XMM-Newton TAC (**Vaughan**).

Staff members have also contributed to several NASA review panels (**Alexander, Barstow, King, Lester, Nichols, Starling, Tanvir, Warwick, Watson**). Members of the Department also contribute to most, if not all, the major ground-based telescopes. These include the international ALMA Steering Committee and the ALMA North America Science Advisory Committee (both **Blain**), ESO Observing programme committee (**Burleigh**, **Tanvir**, **Wilkinson**). **Wilkinson** is a member of the National e-Infrastructure Project Directors Group, which coordinates activities between projects that are part of the National e-Infrastructure (e.g. DiRAC, JANET, etc).

There has also been membership of several different international advisory boards including Advisory panel member, Australian National Institute of Theoretical Astrophysics (**King**), South African NRG Astro Geosciences Facilities Review (**Lester**), Canadian National Science Engineering Research Council (**Lester**), Chair of Finland Academy of Sciences Review panel in Space Research and Astronomy (**King**), international assessor for the Italian VQR (**Stewart**).

The STFC is responsible for funding a significant component of the research in the Department. Consequently we play a major role in the advisory structure and review structure of the research council. These include membership of the two highest level bodies Council (**Barstow**) and Science Board (**Warwick**) as well as the Astronomy Grants Panel (**Watson**) and the Ernest Rutherford Fellowship Panel (**Bunce**). In addition we have provided membership of the various science advisory panels including Near Universe Advisory Panel (**Bunce**), Far Universe Advisory Panel (**O'Brien**), as well as the Chairs of two of the recently formed panels Astronomy Advisory Panel (**O'Brien**), and Particle Astrophysics Advisory Panel (**Hinton**). We have also contributed to the support on various facility and mission related panels, including Chair of the UK JCMT TAG and JCMT ITAC (**Blain**), membership of UK PATT (**Blain**, E-ELT Steering Committee (**Burleigh**) the PATT Time Allocation Committee for Isaac Newton Group of Telescopes (**Burleigh**), Liverpool Telescope user Group (**Tanvir**), the Cassini Post Launch Review Panel (**Cowley**) the Projects Peer Review Panel (**Pye**), Computing Advisory Panel (**Watson**), Astronomy and Particle Physics High Performance Computing Oversight Committee (**Watson**). Finally our involvement also demonstrates other interests within the Department such as fostering and developing the Impact agenda through membership of the STFC Innovations Partnership Scheme (**Lapington**) and as Chair of the Education Communications and Outreach Advisory Group (**Barstow**).

Since the formation of the UK Space Agency (UKSA), members of the Department have played central roles in its advisory and mission oversight structure, including the UKSA Aurora Advisory Committee (**Bridges, Sims**), Space Programme Advisory Committee (**Barstow, Lester**), Earth Observation Advisory Committee Chair (**Remedios**), Space Technology Advisory Committee (**Sims**), National Space Technology Steering Group (**Sims**), National Space Technology Committees (**Sims**), Solar Orbiter Oversight Panel (**Ambrosi**), BepiColombo Project Management Board (**Barstow**). The Department also receives considerable funding from NERC and we also have membership of the NERC Peer Review College (**Battaglia, Boesch, Leigh, Lester, Remedios, Wright**), with **Remedios** a member of the Pool of Chairs panel for the Peer Review College and **Lester** a core member of the NERC Peer Review College.

Members of staff also contribute to the Learned Societies, e.g. membership of Royal Society International Grants panel (**King, Wilkinson**), Advisory panel to the Leverhulme Trust (**Pounds**), Philip Leverhulme Prize panel for Astronomy and Astrophysics (**King**), Royal Society Sectional Committee 2 (**Cowley**), Secretary of the IoP's Astroparticle Physics Group Committee (**Hinton**) and membership of the RAS Council (**Barstow**, as Secretary, and now President-elect, **Bunce**), member of the Royal Society Equality and Diversity Advisory Network (**Starling**).

The Department also demonstrates leadership in industry and government through its membership of the International Space Innovation Centre, a joint academic-industry STFC venture at Harwell, for example **Barstow** has served on the ISIC Management Board. ISIC is now being subsumed into the Space Catapult. The BIS and UKSA have set up special Innovation and Growth Strategy for the Space Industry. **Remedios** is on the IGS Steering Board working alongside CEOs from major space companies. **Remedios** is also chair of the Defra GMES Atmosphere Networking Group. GMES (now called Copernicus) is the major EC EO programme to provide

government and industrial services from EO data. Defra has the UK lead for Copernicus/GMES.

Conference programme chairs
Members of the department have been involved in the organisation of many conferences both nationally and internationally. Below is a small selection as space precludes a more detailed list. Two Royal Society Discussion Meetings on "New windows on transients across the Universe" and "Interpreting signals from astrophysical transient experiments (**O'Brien**); Co-Chair of 4 for the ECI conference on Advances in Magnetic Nanostructures (**Binns**); Co-organiser of 3 week Aspen Center for Physics workshop on the Milky Way (**Wilkinson**, 2013); 50 years of Space Science event which could be adapted for the REF submission. The meeting title was "Exploring the Extreme Universe". (**Watson**, 2010); the University of Leicester 50 Years Symposium (19-21st September 2011) which focussed on observing the earth and planets. (**Remedios**, **Sims**, 2011)

Invited keynote lectures
Members of the department have been invited to give keynote talks at many conferences both nationally and internationally. From well over 100 examples, the following list is again a small selection. Key note speakers at national and international conferences include: a meeting sponsored by UKSA to celebrate *50 Years of the UK in Space*, held in the I-Max theatre at the Science Museum, London in 2012 (**Cowley, Fraser, Pounds; Tanvir**); keynote lecture at the European Space Agency Integral Symposium, Grande Biblioteque, Paris (**King**, 2012); invited talk at the UK-Russian Space Science Cafe series (Irkutsk, March 2013) sponsored by the UK Foreign and Commonwealth Office (**Lester**); invited talks to celebrate 50 years of X-Ray Astronomy at the Smithsonian Centre for Astrophysics as well as in Milan and Mykonos (**Pounds**); invited talks at the International Astronomical Union (**Blain**, 2009, **Starling**, 2012, **Alexander**, 2013, **Wilkinson**, 2013), Committee on Space Research, COSPAR (**Lester**, **Pounds**, 2008, **Tanvir**, 2010), collaborative workshop held at the Dark Cosmology Centre, Denmark (**Goad**, 2012); PI for a major review at the 2013 Protostars and Planets VI conference (**Alexander**); international workshop on Advanced Materials, UAE (**Binns**, 2012); Cluster-Surface-Interactions conference, Lyon (**von Haeften**, 2012); the Kavli Institute for Astronomy and Astrophysics, Beijing (**O'Brien**, 2011, 2013); reporter reviews for Other Magnetospheres beyond Earth, IUGG (**Bunce**, 2011).

Election to membership or fellowship of learned societies
Prof **Cowley** has been elected as Fellow of the Royal Society in 2011. Profs **Cowley** and **Fraser** have been elected as Fellows of The Institute of Physics.

Journal editorships
The following journal editorships have been undertaken by members of the Department: Editor of Cambridge University Press astrophysics Series (**King**), Deputy Chief Editor of Monthly Notices of Royal Astronomical Society (**King**), Senior Editor of Astrobiology (**Dartnell**), Associate Editor Journal of Geophysical Research (**Milan**), members of Editorial Board of Proceedings Royal Society A (**Cowley**), Astronomical and Astrophysical Transactions (**King**), Experimental Astronomy (**Fraser**), Journal of Instrumentation (**Fraser**), International Journal of Geophysics (**Milan**), invited editor of Nanomagnetism, Fundamentals and Applications (**Binns**).

Fellowships, awards and prizes
The following fellowships, awards and prizes have been awarded to staff who have held the Fellowships at Leicester during the REF period: STFC Advanced Fellowships (**Alexander, Hinton, Nichols**), an STFC Ernest Rutherford Fellowship (**Fear**), a Royal Society URF (**Wilkinson**), Royal Society Dorothy Hodgkin Fellowship (**Starling**), Leverhulme Early Career Fellowship (**Imber**), a NERC Fellowship (**Barkley**), RAS Fellowship (**Badman**), STFC Post Doctoral Fellowship (**Koch, White**), UKSA Aurora Fellowship (**Dartnell**), NERC Knowledge Exchange Fellowship (**Leigh**), a STFC Knowledge Exchange Fellow (**Maskell**), for which the grant holder is **Lees**, STFC Science in Society Fellowship (**Dartnell**), Feodor Lynen Research Fellowship of the Alexander von Humboldt foundation (Ohm), JSPS Visiting Fellowship (**Okimura**), Leverhulme prizes (**Alexander**, **Bunce, Hinton**), Wolfson Merit Award (**Blain, Hinton**), COSPAR Space Science Award 2008 (**Pounds**), Visiting Fellow at Isaac Newton Institute for Mathematical Sciences (**Alexander**), RAS Chapman Medal (**Milan**).