

Research Centres *Triennial Report*

Cover Sheet

Name of Centre	Centre for Astrophysics & Planetary Science (CAPS)		
Director	Professor Michael D. Smith		
Date established	2001	Period of Approval	2001-2015
Departmental and/or Faculty affiliation	SPS, Sciences		
Summary of the original aims of the Centre <i>(max 100 words)</i>	CAPS was established to act as a forum to draw together all those with research interests in astronomy and space science. As a Unit with an international reputation, it would attract visitors and provide a consolidated basis for funding. The Centre has proven to be an invaluable focus not only for research activity, but also providing a strong public profile for astronomical and space science activity within Kent.		
Case for Continuation	<p>The purpose of continuing the Centre is:</p> <ol style="list-style-type: none"> 1. To raise the profile of Kent in the international community, acting as a host for short and long term visitors, supporting collaborations and the use of external facilities. 2. To focus research that crosses disciplinary borders, and to construct a larger coherent grouping. 3. To host seminars, workshops and conferences. 4. To raise the profile and awareness of astronomy and planetary science in Kent by involving schools, amateur astronomers and the general public. 5. To provide a common infrastructure, sharing archival data, knowledge and computing resources. 6. To provide a forum for cross fertilisation of doctoral and postdoctoral training and support, and to support their interests. 7. To provide a local host for Astronomy in the South-East of England through the SEPNet-Astro Community. 8. To provide networking opportunities to exchange ideas and information between departments and other interested parties. <p>CAPS research revolves around large-scale international collaborations. Studies often require expertise not only in many wavebands but also across disciplines. Indeed, astronomy and space science are a combination of disciplines bringing together a mixture of natural sciences, computing, engineering</p>		

and observation, with astrobiology, astrophysics and astrochemistry of significance to the CAPS research portfolio. For a full range of CAPS activities see: <http://astro.kent.ac.uk>

In the coming years, the Centre will boost our **ability to contribute** to upcoming surveys with international space telescopes, space missions and ground telescopes. This includes our heavy involvement with Rosetta, Herschel, Gaia, the Large Synoptic Survey Telescope, and new NASA missions to solar system objects.

Wide Participation. CAPS has obtained Beacon funding for the new Beacon Observatory erected in 2015 and now in operation. This remarkable fully-automised telescope provides a superb basis for University-wide engagement in the fascination of the Universe. CAPS is now developing projects for undergraduates and local schools where inquiry through research is considered to be an essential element of modern learning.

Astronomy is quite unique in providing a range of **citizen science** opportunities. CAPS has been successful in gaining funding for upcoming participation of amateur astronomers and lay persons in research called HOYS-CAPS. CAPS has provided training sessions and the programme has now begun. This initiative will permit enthusiasts from Kent astronomy societies to actively participate in obtaining research-level data.

The Centre continues to benefit from further investment from SEPnet. The prospects for CAPS are enhanced through this established brand name, known internationally. In the coming years, CAPS PhD students will benefit from growing **GRADnet**, and SEPnet Employer and Public Engagement opportunities. In January 2016, a student-led cosmology workshop will be held at Kent, mentored by CAPS staff.

CAPS will provide **an interface** which encourages the participation of all those interested in progress in astronomy and planetary science within Kent. The Kent Space School has become an annual August fixture with an ever improving activity programme for children.

External Support. Planetary science is to forge ahead with **new ESA and NASA support**. It is thus crucial to organise these diverse activities into a synergistic entity, as encapsulated by the latest CAPS Strategic Plan as contained in the 2014 CAPS Annual: (<http://astro.kent.ac.uk/annualreports.html>).

Networking. CAPS organised two large-scale workshops in 2015. Holding a full seminar schedule, bringing in visitors, and maintaining an identity as a small astronomy enterprise among giant UK institutes, is enabled by the Centre's identity. Networking will continue through the Royal astronomical Society and the National Astronomy Forum.

Funding through research councils is promoted by the Centre. The STFC, our major funder, operates Consolidated Grants rather than soliciting individual applications. Two one-off applications are allowed, once each three years. These require a strong synergy and coordination from CAPS to be successful. The Kent Consolidate proposals submitted in 2015 for funding of £2.9M to cover the period 2016-2019 has just been submitted. In this new climate, the Centre carries extra weight

	<p>through the coordination it allows.</p> <p>Archive Service. CAPS will continue to maintain and update several web-based astronomy resources used regularly by the international community. (astro.kent.ac.uk/resources/index.html)</p> <p>Recruitment. Recent new lecturers to CAPS have noted that their enthusiasm for Kent was enhanced by the fact they would join CAPS with associated management, annual reports, website and strong public relations which they can help shape.</p> <p>2020 REF. The outstanding 2014 REF submission in UoA9 (Physics) consisted of the CAPS staff for Outputs with valuable Impact Cases from Forensics and Applied Optics. The result was the highest income per FTE (over £30k) in the entire University for UoA9, and first nationally in UoA9 for all small-to-medium size submissions (under 20 staff). We propose to promote and build on this success.</p> <p>High Impact Publications. CAPS staff have published in prestigious Science and Nature journals four times in the last three years and we intend to continue this trend.</p> <p><i>CAPS unites astronomical activity inside the University and around Kent, and plays a leading role in the alliance in the south-east of England, SEPNET, which funded recent CAPS-led workshops. The Centre bestows an identity in a competitive world and emphasizes our status as highly productive researchers. The established world-wide reputation promotes collaborations with many larger institutes. We therefore request that the Review recommend that the Centre is continued.</i></p>
--	---

Current Staff & Resources

Current staff associated with Centre

Current Faculty: Prof Mark Burchell, Dr Dirk Froebrich, Dr Stephen Lowry, Dr Jingqi Miao, Dr Mark Price, Prof Michael Smith, Dr Penny Wozniakiewicz, Dr James Urquhart (from Nov.),
Research staff: Michael Cole (Exp. Officer, 0.5 FTE), Dr Kathryn McDermott, Dr Jon Hillier
Honorary/Senior Visitors Prof Ofer Lahav (UCL), Dr. Duncan MacKay (Simon Langton for Boys, Canterbury), Prof Richard Holdaway (RAL)
Associate Research Staff: Dr. Alex Rosen (Atlanta), Dr Anthony Moraghan (S. Korea), Dr David Wilson (Barclays, London), Dr Sam Duddy
Observatory Team: Dr John Kemp
Space School ScienceTeam: Dr. Jo Mann (Rocket Scientist), Dr Robert Gore (Rocket scientist), Dr David Wilson, Dr Vicki Fitzgerald, Anika Walls-Bruck, Elizabeth Mannering (Univ. Bristol), Gregory Williams + SPS student volunteers
Students: 17 PhD, 3 MSc

Other resources

Hardware Resources: SGI Computer (Forge), The Beacon Dome, Telescope. Outreach activity takes place at the Observatory.
Experimental Resources: Two Stage Light Gas Gun, In addition, CAPS has potential to share a range of other analytical equipment within the School, SPS.
External Resources/Facilities: present staff as Principle Investigators of many international facilities. See CAPS reports, with high income-in-kind.

Achievements of the Centre in past 3 years

Summary (*max 200 words*)

With the recent expansion in Space Science, CAPS can claim to be a key player in the UK for this field. A relatively large number of publications, seminars, visitors and invited talks provide quantitative evidence of CAPS success. The ability of CAPS to organise and promote research activities is demonstrated in annual reports to the Faculty. All reports are available online at: <http://astro.kent.ac.uk/mds/Publicity/CAPS>
The scope of the research is underpinned by Galactic and Solar System studies for which Kent has long-held reputations in the UK community. The group leads international optical and infrared surveys and campaigns. The reach of the research has also broadened with participation in many international consortia, surveys and missions.

Publications

CAPS published more papers than ever before, 88 journal papers between 2012 and 2014. They are updated online: <http://astro.kent.ac.uk/publications.html>
Publications are almost all in high-impact journals including many in each of Science, Nature and the Astrophysical Journal. Complete publications lists are in the Annual Reports. See Appendix D.

Visits/Exchanges

CAPS hosts a large number of visitors. These are reported in the Annual Reports.

Seminars

See <http://astro.kent.ac.uk/seminars.html>
Weekly seminars are held within CAPS in addition to some Colloquia. Staff give a large number of Invited Talks at conferences, institutes and universities.

Conferences

As a highly active small group, we take part in many external conferences, using our time to network and disseminate. Staff are heavily involved in conference and workshop organisation, as Chairs and members of Scientific Organising Committees.

Grants

External Financial Resources 2012-2015: Grants & Enterprise, held & awarded (Small awards, travel awards, etc omitted)

The Centre has received support through the award of time on facilities to the estimated value of £6 Million over the last five years. This is the allocated in-kind value to CAPS as Principle Investigators (data submitted to REF)..

1. Marie Curie FP7-PEOPLE-IRSES-2008/230843 International Research Staff Exchange Scheme, e43,000 (total) Awarded, 2009-2012, PI = Dr. N. Kumar (Porto)

2. ST/H002553/1: Observational Detections of the Asteroidal YORP Effect. £315,260. 18/07/10 - 17/7/13. PI = Dr. S. C. Lowry.
3. ST/I001662/1, £439,679.18 1/6/2011 - 31/5/2014, PI = Prof. Mark J. Burchell (subsumed into Consolidated)
4. STFC - ST/K000888/1 \ Consolidated grant for Astrophysics and Space Science PI M D Smith Col: Mark Burchell, Mark Price, 01/04/2013 to 31/03/2016 £406,113
5. STFC Aurora programme grant, PI M. price, 2012-2014, £100,000
STFC - ST/J501062/1 Quota Studentship 2011
PI: HoS P Strange 01/10/2011 - 30/09/2015 £68,702
6. STFC - ST/K502455/1 Quota Studentship 2012 PI: HoS M Green
01/10/2012 - 30/09/2017 £69,642
7. STFC - ST/M503551/1 Training Grant Kent, PI: HoS M Green
01/10/2014 - 30/09/2018 £70,867
8. NASA: Burchell is PI on a \$25,000 (approx. £16k) sub-contract to provide services to NASA for impact testing of new sensor designs (May 2014).
9. KC Research Fund award to HOYS-CAPS team:
Dirk Frpebrich, Mark Price, Vicky Mason, Chrysa Avdellidou, £2,000
10. Col Jingqi Miao: 2013, XinJiang Observatory in China £29,000
11. SEPnet Froebrich: £4,500, PI, for a SEPNET workshop funding, for RAS workshop on Galactic Plane Science with widefield surveys
12. STFC - ST/TBA Training Grant for CAPS, Kent, PI: HoS M Green
01/10/2015 - 30/09/2019 £71,000

Enterprise activity (if applicable)

Substantial activity. See Appendix A: A Pathways to Impact statement for CAPS.

Impact activity (including public engagement)

See Appendix B on Outreach
See Appendix C on Academic Beneficiaries

Other

Plans for the future continuation and development of the Centre

Summary (max 200 words)

The Revised 2015 Research Portfolio for CAPS. The Kent researchers aim to remain at the forefront of world science through an integrated programme of infrared and optical observations, three dimensional numerical simulations. advanced theoretical modeling and unique high-speed experiments, all aimed at exploring the physics governing the evolution of clouds into stellar systems, and the consequent evolution of our solar system.

Activities

New Research Strategy 2015: The Themes Explained Our themes are aimed at constructing new foundations for our local structure: A: Star and Cluster Formation: Infrared observations and the interface with models. B: Computer Simulations of Feedback: involving clouds and feedback through radiation, shock waves, jets and hypersonic flow. C: Galactic Astronomy: the physics of the interstellar medium and interacting nebulae. In particular, we will investigate the most common molecule in the Galaxy, molecular hydrogen. Within our Solar System: D: Solar System Impacts: laboratory experiments and computer simulation to understand how the objects and surfaces in the solar system evolve. E: Asteroids and Comets: observations and interpretations of small bodies leading to a new view of how our Solar System work. **History: 2005 – 2007: reorganisation of portfolio into a focussed: Our Home Ten Kiloparsecs.**

2015 – 2019: Strategy 1: Environment. The nature of the CAPS research environment will be modified to promote new ideas and novel concepts. Meetings will be mainly discussion of new concepts and recent developments, SEPNet lectures will be increasingly used for graduate training. **Strategy 2: Leadership.** CAPS members will be seeking leading roles in both facility collaborations and pioneering research. **Strategy 3: Pathways to Impact & Beneficiaries:** CAPS is actively involved in considering who our external partners are and how to collaborate. Statements are appended. **Complete statements are appended in the online version of this document.** **Strategy 4: Research Impact:** Crucial to CAPS strategy is the dissemination of research findings. As a small Centre, members must regularly attend meetings or visit collaborating institutes (not requiring expensive equipment or considerable laboratory space). Therefore, external out-of-the-box thinking for research collaborations and research funding will be sought. **Strategy 5: Open Lectures:** CAPS intends to organise events to surround and complement other campus activities for the 2015 University anniversary and also to promote public involvement in astronomy and space science by developing the CAPSule, a new outreach initiative. **Strategy 6: Expansion:** We seek to boost our capability by increasing grant income for facilities and staff by exploiting a broader base of opportunities with the intention of increasing our staff to 8 FTE.

Grant applications and other funding

STFC Consolidated support to cover the period 2016-2019 submitted. See below. We will continue to seek funding, through Europe, Sepnet etc.

Burchell is PI (with co-Is Lowry, Price and Wozniakiewicz) on a new application to **STFC** for support for Planetary Sciences Research at Kent (2016 – 2019), we have asked for £1.77m.

Smith, Froebrich, Miao applied for an **STFC Astrophysics award** requesting £1.22m. In addition, **European funding** proposals are in preparation (Wozniakiewicz).

New NASA award won: a further contract for 2015-2016 and is worth \$29,000.

Staff

See Strategy 6 above

Resources available and/or required

No exceptional items anticipated.

Any additional points/information

The Extended Report with details in appendices can be found here:
<http://astro.kent.ac.uk/mds/Publicity/CAPS/caps-triennial-report15.pdf>
Triannual and Annual reports here:
<http://astro.kent.ac.uk/mds/Publicity/CAPS/>

Head of School Statement

The Head(s) of School(s) should provide a statement indicating agreement with and support for the continuation of the centre, that the centre's activities are consistent with the Department's Research Plan, and that they accept any resource implications resulting from the centre.

Statement

The School of Physical Sciences supports the continuation of CAPS which brings considerable direct and indirect benefit to the Physics research and outreach programmes, and helps coordinate related teaching activity. It is presently anticipated that CAPS may continue to form the physics REF submissions and it is vital to demonstrate a consolidated research environment to both the UK STFC research council and the international research community. The latter is the main purpose of CAPS as a Centre.

I agree with and support the continuation of the Centre. The activities are consistent with the School's Research Plan, and I accept any resource implications resulting from the Centre.

Head of School Signature

e-signed by Professor Mark Green August 24, 2015

APPENDIX A: ENTERPRISE ACTIVITY STATEMENT

Pathways to Impact: Knowledge Exchange Plan

Context. The Kent output submission to the Physics UoA of REF2014 consisted solely of staff from the Centre for Astrophysics and Planetary Science. The impact case studies were related to past research publications in imaging and optics. One of the two case studies was based on research in planetary sciences. The impact profile in the Kent Physics REF result was rated 4*: 60% and 3*: 40%. In a REF Impact league table published in December 2014 by the THE, if rankings were solely by Impact, Physics at Kent was ranked 7th equal in the Physics UoA.

CAPS plans to continue to expand an established impact programme. The impact of research undertaken by staff is focused on three main user groups:

- (1). National and International businesses that include space technology and applied optics companies, for example Astrium, Qinetiq and Optos,
- (2). National and International public bodies that includes NASA and ESA and
- (3). Education at schools and through public engagement, via an extensive, proactive outreach programme.

Innovation. CAPS has developed explicit impact objectives and mechanisms, which are supported by central services within the University, including the Innovation and Enterprise unit (KIE). They result in a clear path to identifying impact opportunities and building relationships with external stakeholders. As a result of this accumulative and purposeful strategic investment in research impact, from 2009 to 2013 SPS grew from 4% to 15% of the total Innovation and Enterprise income at the University of Kent. The Star Formation Group has taken advantage of this resource, with Miao gaining a KTP related to the hydrocode employed in research. We plan to continue to interact and to network with companies and employers in order to seek further opportunities where our expertise may be needed.

The Centre for Astrophysics and Planetary Science has a strong record in both Knowledge Exchange & Public Engagement. The Planetary/Space Science Group gains requests and contracts for a variety of uses of expertise, services and facilities, as we now outline.

We conduct enterprise related contracts for a variety of uses, placing our expertise at the service of others. These contracts are typically at the level of one per year and help provide specialist services to clients with specific needs. In the past 3 years, people involved in this submission have held contracts from the Netherlands Forensic Service (£11k, material response to impact), a sub-contract for sales of impact services to a US group who are contracted to NASA (\$25k), and are currently (2015) working on an impact related contract for AWE (£10k + VAT). We envisage continuing this throughout the grant period, and, for example, have negotiated a new contract for ~£20k for 2015-2016.

We also assist groups who are acquiring skills in the impact field. In 2013/14 we hosted a researcher from Mississippi State University which had acquired a light gas gun. He spent time here learning how we operate our gun in a flexible and safe manner. We similarly offer advice to commercial people designing experiments for impact testing at other facilities (typically one such exchange a year).

To help network these services, members of CAPS are assisted by the University of Kent Innovation and Enterprise team who arrange on-site briefings to interested parties (e.g. in 2013 with DSTL, although that did not lead to a contact for our group), provide contract advice, and so on.

APPENDIX B: OUTREACH ACTIVITY STATEMENT

Pathways to Impact: Public Engagement Plan

CAPS is highly active in Outreach. We plan to directly connect our specific research into the following outreach projects.

The Beacon Project. We have obtained funding for a new telescope facility on campus as part of the 50th anniversary of the University of Kent. The £106k funding will provide us with an attractive means for engaging the public.

Hunting Outbursting Young Stars with the Centre of Astrophysics and Planetary Sciences (HOYS-CAPS) is a citizen science project initiated by Froebrich to involve amateur astronomers and astronomical societies in our star formation research programme. The programme aims that amateurs obtain images of young star clusters at convenient times. The images are calibrated and collected in CAPS to search for newly erupting young stars (potentially FU-Orionis type objects).

Training has been provided to interested amateurs in workshops funded by a small grant from the University of Kent. Several people have now taken up the project and more than 20 images have been obtained. Some first results include the detection of a number of interesting variable stars are available on the project website. The project got a UK wide exposure on April 25th 2015, when Froebrich gave a presentation about it at the annual meeting of the British Astronomical Association (BAA). We are already working closely with the Director of the Variable Star Section of the BAA and hope to roll out the project UK-wide in 2015. The new telescope will be directly used to further the research of this proposal. Amateur astronomers and school students will be invited to participate in determining light variations from stars, and will contribute to our knowledge relevant to stellar evolution.

The Kent Space School. Initially supported by STFC (until 2011), Space School is now an established event supported by SEPnet and SPS. Space School is a weekend summer residential camp for space enthusiasts aged 11-

18. It is staffed by CAPS academics, former members and the outreach team. Smith is the Director and Froebrich is active staff at the events. As a result of its success we recently introduced a Forensic Science weekend. We plan now to update the programme of the Space School to incorporate the Origin of Stars as a theme under a general origins theme. This theme will provide the opportunity to inspire the young enthusiasts =directly with the research we do.

Public Lectures. Star formation Group members hold between 30 and 40 public lectures to adults each year. These are given at a variety of levels and locations throughout the world. We intend to further this programme in the future. All of these lectures will introduce Kent research at some point since it adds vitality and significance to the lectures. To be able to state: " At Kent, we observed these and actually found that" makes a static lecture much more personal.

School projects. Two new collaborations with local schools are planned. The idea is to bring research into the classroom. The two Canterbury schools, King's and CATS, will work closely with the CAPS staff in establishing projects through which little experience is necessary in order to follow through research projects with significant results. Public engagement is also coordinated through a web interface, the CAPsule:

<http://astro.kent.ac.uk/mds/Capsule/> .

The website directly connects to our research pages.

Wider Support for Impact. SEPnet is a HEFCE funded alliance of nine physics departments in the south east of England. It enables Kent to share graduate teaching resources and research facilities across the region, and provides a strong platform for outreach and employer engagement. Directors in graduate studies, outreach, employability, and diversity and equality coordinate a team of associated officers at each of the sites. Sharing resources and experience, such as research equipment, and lectures broadcast via videoconference, enables SPS and CAPS to provide a richer and more fulfilling environment for its students and staff. The escalating numbers and diversity of the undergraduate and postgraduate population in physics at Kent is widely attributed to a substantial extent to the success of SEPnet and SEPnet-Astro.

SEPnet Outreach. SEPnet provides a strong platform for Outreach and In this plan, SEPnet will continue to bring us into contact with non-academics. A full-time Outreach Director coordinates many of the activities of a team of Outreach Officers, one based in each department. Sharing resources and experience enables SPS to develop and disseminate best practice which has contributed to the increased numbers and diversity in the UG and PG populations. CAPS members are constantly invited to schools and events requiring science demonstrations, theme-led discussions or lectures. SPS has also hosted SEPNet GCSE Physics Revision Events.

The Astrodome is a very popular portable, inflatable Astrodome acquired in 2008 by Smith. It 'sets the scene' for space science events. We will continue to use this to inspire. In particular, we will use the planetarium to point out where stars are forming in our Galaxy.

APPENDIX C: ACADEMIC BENEFICIARIES

Benefit to other researchers in the field. The planned fundamental CAPS research will provide a legacy of observational and computational data that will be used by others in combination with their own data and models in order to verify broader theories. In addition, the interpretation of the data, including those from computer simulations and the impact laboratory, will benefit other researchers by providing evidence that can be quoted in the context of the major issues within the theme. Both the data sets and the computer codes will be available, through archives and via requests.

Wider benefits outside the field. The work has a broader context in that by learning about other Galactic Stellar systems, we provide a more certain background knowledge to lead the discussion on more speculative fields such as primordial star formation, extrasolar planetary systems and galactic evolution. In particular, space scientists can compare to our particular Solar System which is thus put in a quantitative context.

Multi-disciplinary aspects also include other distant parts of the University. In a collaboration with Creative Writing groups in the Humanities and the School of English and American Literature, we help explore an exchange of concepts such as the use of metaphors and allegories. Duncan MacKay leads this initiative, taking the CAPS flag into arenas such as the British Society for Literature & Science and participates in other national forums. This work will continue.

The academic community of planetary scientists will benefit from CAPS research. We will communicate with them via talks at the leading conferences (LPSC, EPSC, MetSoc, ACM, AAS/DPS, etc.), papers in the leading journals, seminars etc. Key disciplines will include those interested in cosmic dust, asteroids, comets, icy satellites, impacts and astrobiology. Given the potential interest of this project to other fields, we would also present at large, multi-disciplinary conferences such as the American Geophysical Union Fall meeting (for example).

To achieve the above benefits, we will make our data accessible in user-friendly forms, as we do now, such as on searchable databases, Astrophysics Data System catalogues, web interfaces, code sharing, and collaborative sharing. The studies will also be disseminated through workshops, seminars and conferences which range in audience from narrow to broad, both in location and subject. We will continue to organize some of these ourselves such as:

To engage the general interest of academics it is expedient to submit our results to IAU Colloquia, Joint European National Astronomy Meetings, Royal astronomical society meetings. All publishable results will appear in journal papers and, on a regular basis, be also available on the astro-ph free-access archives world-wide.

Ensure continued distribution of benefits. We will continue to network strongly, through organizing more workshops, using SEPnet (South-East Physics Network, 9 university physics departments).

We will also use our Honorary Senior Fellow and Artist-in-Residence, Dr Duncan Mackay to continue our multidisciplinary connections.

Computer code development, evaluation and testing is also undertaken and the improvements shared with colleagues working in other adjacent areas. The research proposed here will further benefit research within the ZEUS user communities in particular.

As part of SEPnet, Smith set up a Capabilities programme in which our research facilities and capabilities are made available for sharing under the appropriate conditions. Thus, it is made open and clear what kit and expertise is available not only within the south-east of England but elsewhere. SEPnet can thus respond to enquires in the name of seven physics departments.

The research teams are generally international and several involve large communities, such as Gaia, UKIDSS, Hi-Gal, Spitzer Large Surveys. Many other less formal but strong collaborations benefit astronomers from many countries such as Armenia, China, Japan and South Korea. The roles the collaborators take are too varied to state simply: from healthy debate, to sharing knowledge, synergizing ideas, providing techniques and instruments, donating algorithms, codes and specialized materials.

Specific new collaborators and their roles. Froebrich will be beginning a new collaboration with Connelley in Hawaii, Miao will be visiting Sugitani's group in Japan who provides the observational data to interpret. And Smith is working closely with Yorke (JPL/Caltech) who is providing a new code to implement.

Our work also crosses over into engineering, when we consider high speed impacts on space vehicles and the consequences on materials of extreme shock pressures. We therefore make sure we publish work in engineering journals and attend occasional engineering meetings, to bring our work to the attention of such audiences. As well as published results, we have for decades had a data management policy which involves retaining the physical products we produce (targets from our gun) and making these available to external groups of researchers. We also do specific shots of our gun on request for University academics based elsewhere, to enable their research.

All data from telescope observations is archived for future users. Examples of these academic disciplines (and beneficiaries) are given below:

- 1) Biologists and astrobiologists interested in the aspects of this proposal which deal with the production and detection of bio-significant compounds formed by impacts in the Solar System, with particular emphasis on terrestrial bodies (Mars, Earth, Europa, Titan and Enceladas). Hypervelocity impact shocks into simple ice mixtures can generate complex organic molecules and such molecules are believed to be essential for the origin of life. Data from

this project will be invaluable to those seeking a source of such molecules.

2) Geochemists and geologists interested in the evolution and alteration of minerals in extreme environments, both high pressure and low temperature environments.

3) Material scientists involved in the investigation of physical properties of materials at extremes of pressure, temperature and strain rates which exist during a hypervelocity impact.

4) Planetary Scientists interested in the formation and evolution of planets, planetary surfaces and atmospheres through cratering and cratering induced hydrothermal activity.

5) Meteoriticists who are involved with the investigation of heavily shocked bodies and the shock metamorphosis of minerals.

6) Lunar scientists interested in investigating the transfer of organic components to the lunar regolith.

7) The asteroid science community will benefit greatly from the results obtained from the study of the YORP effect, as it will lead towards a more detailed understanding of how the YORP effect affects the physical evolution of small asteroids. The ground-based observational study will result in much-needed observational measurements of the YORP effect on a range of asteroid compositional classes. These measurements will drive theoretical developments in this area by providing critical calibration points for the theoretical calculations. Furthermore, the results from the observations have the potential to identify worthy targets for a future asteroid rendezvous mission.

In summary, the research will directly benefit the international standing of CAPS science.

APPENDIX D: PUBLICATION LISTS

Full publications lists are contained in the Annual Reports available here:

<http://astro.kent.ac.uk/annualreports.html>

Lists with citation indices are published here:

<http://astro.kent.ac.uk/publications.html>