



**Science Programme Prioritisation 2010-2015  
Report from the Particle Physics, Astronomy and Nuclear Physics Science  
Committee (PPAN)  
January 2010**

**Background**

1. STFC undertook a prioritisation exercise which resulted in a prioritised science programme being recommended to Council in December 2009. To develop this programme, STFC sought advice from the Advisory Panels, PPAN and the Physical and Life Sciences Committee (PALS) and asked Science Board to consider their recommendations.
2. At its meeting on 28/29 September 2009, PPAN developed a preliminary prioritised list of projects not considered in the 2007/08 Programmatic Review. PPAN considered as additional input written submissions from the projects under consideration and input from the Near Universe Advisory Panel (NUAP), Far Universe Advisory Panel (FUAP), Particle Physics Advisory Panel (PPAP), Nuclear Physics Advisory Panel (NPAP) and Particle Astrophysics Advisory Panel (PAAP) as well as the Ground Based Facilities Review of Astronomy (GBFR). The reports from the Advisory Panels and GBFR can be found [here](#).
3. This preliminary ranking was presented to Science Board on 19/20 October. Science Board subsequently provided strategic advice and a budgetary envelope for PPAN and asked PPAN to develop a programme constrained by that envelope. It also asked for the effects of a £10M per annum increase or decrease in the envelope from 2012/13 to be explored. As an integral part of this process, PPAN was asked to finalise its prioritised list of projects, merge this with the ranked list of projects considered during the 2007/08 Programmatic Review and develop a prioritised science programme. PPAN undertook this exercise at its meeting on 30 November/1 December 2009 and an extraordinary meeting held by teleconference on 4 December 2009.

**Final Prioritised List**

4. PPAN developed its prioritised list using the following criteria developed following the STFC strategy consultation. Further information relating to these can be found on the STFC website at <http://www.stfc.ac.uk/About/Stats/Rev/Criteria.aspx>.
  - Excellence
  - Economic Impact
  - Societal Impact
  - Leadership
  - Synergies.
5. The final list of projects sorted by alpha ranking is shown in Table 1. Within each alpha ranking, projects are shown in alphabetical order.

**Table 1 Alpha Ranked List of PPAN Projects in alphabetical order within rankings<sup>1</sup>**

<b>Alpha 5</b>
Advanced LIGO
ATLAS
ATLAS UPGRADES
CMS
CMS UPGRADES
GAIA post-launch support
GridPP
Ground Based Gravitational Waves
Herschel post-launch support
JCMT
JWST – MIRI post-launch support
KMOS
nEDM
Planck post-launch support
Rosetta post-launch support
VISTA exploitation
<b>Alpha 4</b>
Aurora ESA subscription
Cockcroft
Cosmic Vision R&D
Dark Energy Survey
E-ELT R&D
E-ELT subscription
ExoMars national programme
Hinode post-launch support
IPPP
LHCB
LISA R&D
LISA Pathfinder post-launch support
nEDM upgrade
NUSTAR
SKA R&D
SNO+
Solar Orbiter R&D
STEREO post-launch support
SUPERNEMO
SuperWasp operations
SWIFT post-launch support
T2K
Zeplin III
<b>Alpha 3</b>
AGATA
ALICE
ANITA
AUGER
Cassini post-launch support
CDF
CLIC

<sup>1</sup> Acronyms are provided in the glossary in Annex One of this document

Clover
Cluster post-launch support
CTA
D0
eEDM
Einstein Telescope
e-MERLIN
Eureca
ING
Inverse Square Law (ISL)
ISOL (SPIRAL2)
JPARC Neutrino
LHCb Upgrades
Linear Collider Detector R&D
LOFAR
Low-mass Support Structures for Silicon Detectors.
Lux-Zeplin
MICE
NUSTAR additional
PANDA
Particle Flow Calorimetry
ROSA exploitation
SOHO post-launch support
SPIDER
UKNF
Venus Express post-launch support
XMM post-launch support
<b>Alpha 2</b>
ALMA Regional Centre
CCAT
COMET
ELENA
Gemini
JIVE
Liverpool Telescope
LSST
MINOS
MROI
NA62
UKIRT
UKIRT Planet Finder
<b>Alpha 1</b>
Bepi Colombo post-launch support
Boulby underground facility
JAI
LHeC
NG1df
SUPER B
<b>Below Alpha</b>
MoonLITE

## Development of the Prioritised Programme

6. After establishing the initial alpha rankings, PPAN discussed the programme in more detail. Within the budget envelope given by Science Board, it was only possible to fund the  $\alpha 5$  ranked projects. PPAN felt it was unable to construct a viable programme within this funding as it was clear that the subsequent programme would lack breadth in all scientific areas, as well as eliminating all projects in the Nuclear Physics programme. In an attempt to preserve some breadth in the overall programme and some future potential across all programme areas, PPAN made a number of recommendations:
  - i. to re-profile and reduce funding for the highest priority projects. PPAN recommended a detailed re-profiling for the following groups of projects:
    - Particle Physics: CMS, ATLAS and LHCb upgrades and GRIDPP;
    - Space Science: Cosmic Vision, Solar Orbiter, LISA and Aurora/ExoMars;
    - Astronomy: E-ELT and SKA.
  - ii. to reduce the studentships/fellowships line by 25% overall. PPAN noted and agreed with the high priority placed on support for studentships and fellowships by the Advisory Panels. However, in an attempt to preserve some breadth across all programmes and given the financial envelope, PPAN felt that there was little option but to explore a reduction in studentship/fellowship funding. PPAN noted that the suggested reduction was in line with the previous decrease in grant funding;
  - iii. to assume that it would be possible to achieve a flat profile for all the international subscriptions from 2012/13 with the exception of ESO, which would have a modest increase if E-ELT is endorsed by STFC and approved by ESO Council. PPAN recommended that STFC take strong action to ensure subscriptions were held to current levels wherever possible;
  - iv. to reduce all funded exploitation grants by an additional 10%. PPAN also reduced the facility costs of all projects not re-profiled above. These reductions were of the order of 15% for all  $\alpha 5$  projects, 20% to all  $\alpha 4$  projects and 25% cuts to all  $\alpha 3$  projects. The reductions were not applied to ring-fenced construction projects since such cuts were deemed not to be achievable.
7. In developing the programme a number of specific issues were discussed:
  - a. it was agreed to merge the LCABD3 funding line with that for CLIC and set this at a reduced level. PPAN agreed that the strategy for future Linear Collider accelerator R&D should be aligned with the CERN vision;
  - b. PPAN confirmed that JCMT should operate until 2012. The GBFR had recommended that it should run for longer but PPAN felt in the current financial circumstances that this was not possible;
  - c. on discussing the balance of the programme, PPAN felt that the current status of the Venus Express mission meant that it should be considered with other missions of a similar status and so changed the ranking of Venus Express to  $\alpha 3$ . Furthermore PPAN assumed that Venus Express would not operate beyond 2012;
  - d. in line with the reductions in grant funding, PPAN recommended reducing funding to the Cockcroft Institute by 10%.
  - e. PPAN discussed the potential projects searching for neutrinoless double beta decay, SuperNEMO and SNO+. PPAN believed that the merits of SuperNEMO outweighed those of SNO+. Whilst recognising that both were important

- experiments, PPAN felt that the additional tracking capabilities of SuperNEMO, the innovative technology used and the strong UK leadership meant that SuperNEMO offered better opportunities for the future. Therefore PPAN did not recommend funding for SNO+;
- f. PPAN did not make any provision for Hinode post launch support beyond 2014;
  - g. PPAN discussed the potential Clover follow-on projects. Concerns were raised about the timescale and competitiveness of the projects for which PPAN had received Statements of Interest and PPAN agreed to assign the projects a ranking of  $\alpha 3$ . Following discussions about these reservations, PPAN could not recommend inviting a full proposal for the proposed Clover follow-on projects.
  - h. PPAN recognised the importance of NUSTAR to the Nuclear Physics programme and for strategic reasons amended the NUSTAR alpha ranking from  $\alpha 3$  to  $\alpha 4$ ;
  - i. when looking at the programme as a whole, PPAN felt that, while the scientific case for the LHCb upgrade may prove to be strong, it was not yet convincing enough to displace other elements of the programme and the project was ranked at  $\alpha 3$ ;
  - j. following input from the NUAP and the GBFR and taking into account future science potential versus past strength in knowledge exchange, the Liverpool Telescope was amended to  $\alpha 2$ ;
  - k. PPAN maintained the current planning to support ING to 2012. This is consistent with the strategy to focus support on ESO following the UK accession. PPAN had hoped to be able to consider the ING as a means to retain access to observing nights in the Northern Hemisphere, post 2012; however it was not possible to recommend this in the current financial circumstances.
  - l. it was agreed to split the 'FAIR Additional' line into its constituent elements of NUSTAR and PANDA. In discussing the PANDA project, PPAN considered that the physics area which was considered most compelling by PPAN could be better achieved at JLAB through exploitation grants, and it was agreed to remove the additional PANDA element;
  - m. it was agreed that, in the current financial circumstances, funding would be available for at most one Dark Matter project. PPAN would await the outcome of the review of Eureka and Lux-Zeplin by PPRP before making a decision on which project that should be;
  - n. following the re-profiling and reduction of the SKA R&D line, PPAN assumed that it would not be sustainable to fund LOFAR from the same budget envelope. The costs for the operation of one LOFAR station were added to the  $\alpha 3$  LOFAR line;
  - o. PPAN considered e-MERLIN after discussing the output from the GBFR and the FUAP. The project was assigned an  $\alpha 3$  ranking in recognition of the on-going relevance to the SKA development programme and the fact that science is just being delivered from the investment in upgrades;
  - p. PPAN discussed CTA and whilst noting that there had been an increased support for this area following HESS and VERITAS, could not recommend funding at this current time;
  - q. PPAN noted the comments of the FUAP and recognised that whilst a UK-based ALMA Regional Centre was appropriate to the exploitation of the ALMA telescope, it was arguably not essential and that exploitation could occur without it. Given this, PPAN amended the ranking of the ALMA Regional Centre to  $\alpha 2$ .
8. Within the funding envelope given by Science Board, and including the reductions described above, only those projects ranked  $\alpha 4$  or  $\alpha 5$  were guaranteed funding (at a reduced level). PPAN recognised that this would lead to the destruction of the breadth and most of the future prospects of the programme.

9. PPAN discussed the potential for removing a large  $\alpha 4$  or  $\alpha 5$  project from the programme to enable them to support the breadth of the programme but could not conclusively identify such a project.
10. PPAN was unable to propose any workable scenario for a minus £10M funding profile.
11. PPAN recognised that the plus £10M scenario would enable STFC to fund a considerable proportion of the  $\alpha 3$  ranked projects. PPAN strongly recommended that Science Board allocate an additional £10M of funding to PPAN areas and provided a number of options that would allow them to support some of the  $\alpha 3$  ranked projects at the 75% level and thus maintain key areas of the programme. PPAN felt that, should Science Board recommend additional funding, further consultation with the Advisory Panels should be undertaken in order to determine which of the  $\alpha 3$  projects were the highest priorities. This would ensure community involvement with this difficult outcome. With that in mind, PPAN highlighted the following opportunities for consideration by Science Board:

#### *Astronomy*

- a. PPAN identified two opportunities for consideration within Ground-based Astronomy, namely LOFAR and ensuring observing access to the Northern Hemisphere in optical/IR wavelengths. PPAN stressed that if no additional funding could be found to fund these projects, and the community were insistent that these were the highest priorities, funding should be sought from within either the grants line or, in the case of LOFAR, funding for SKA R&D. PPAN also discussed an extension to JCMT operations but was not convinced that the extension should be given a higher priority at the moment.

#### *Space Science*

- b. PPAN identified a package of continued Post Launch Support (PLS) that could be supported if further funding were available. This PLS package should be set at an appropriate level to support current missions Cassini, Cluster, SOHO, Venus Express, XMM and the ground-based ROSA solar instrument.

#### *Particle Astrophysics*

- c. PPAN expressed concern that the entire breadth of the Particle Astrophysics Programme was at risk in the baseline scenario. Additional funding would enable PPAN to restore the Particle Astrophysics programme by funding projects such as ANITA, Auger and Inverse Square Law together with a suitable Dark Matter project.

#### *Particle Physics*

- d. PPAN recommended four packages for Particle Physics:
  - for neutrino oscillation experiments comprising MICE, JPARC-Neutrino and the UK Neutrino Factory;
  - future development for a lepton collider and includes both accelerator and detector R&D effort;
  - flavour physics comprising the LHCb upgrades, recognising the need to maintain expertise while further re-profiling project funding;
  - continued exploitation of current  $\alpha 3$  ranked experiments, namely CDF, D0 and eEDM.

#### *Nuclear Physics*

- e. PPAN were concerned that the breadth of the Nuclear Physics programme was at risk in the baseline scenario and proposed a package that included the

AGATA project together with exploitation for ALICE and the next generation of ISOL experiments (SPIRAL2 at GANIL and HIE ISOLDE at CERN). PPAN recognised that the latter maintained grant levels for the Nuclear Physics community whilst exploiting the CERN subscription something that the Nuclear Physics community was strongly encouraged to do.

12. It should be noted that PPAN did not prioritise within these options or between packages within the options.
13. Within the available funding, PPAN noted that it would not be possible to support the  $\alpha_2$  and  $\alpha_1$  projects. PPAN noted that, in some cases, withdrawal from an  $\alpha_2$  and  $\alpha_1$  project may not be possible. Where continued funding for a project may be unavoidable (for example, Bepi-Colombo), PPAN recommended that reductions to the funding, comparable to scaled percentage cuts of the rest of the programme, should be made.

## Prioritised Programme by Science Discipline

### *Ground-Based Astronomy*

14. In the 2007/08 Programmatic Review PPAN ranked both **JCMT/SCUBA 2** and **KMOS** as  $\alpha 5$ . This ranking recognised that these projects have the potential for truly revolutionary, breakthrough science. During the 2009 prioritisation exercise, PPAN re-affirmed these rankings in the light of the high priority of these projects but, as with all other  $\alpha 5$  projects, the recommended project funding was reduced by 15% in order to attempt to preserve breadth in the overall programme.
15. PPAN ranked **VISTA exploitation** at  $\alpha 5$  during the 2009 prioritisation exercise. PPAN thought that the surveys are a very high priority offering the potential for significant science impact. This was commensurate with the recommendations of both the FUAP and the NUAP. PPAN also noted the strong UK leadership in VISTA which gave the UK influential and competitive access in this field. VISTA is well aligned to STFC's science priorities and to the UK's membership of ESO. In line with all other  $\alpha 5$  projects, the recommended project funding was reduced by 15% in order to attempt to preserve breadth in the overall programme.
16. PPAN re-affirmed the  $\alpha 4$  ranking assigned in the 2007/08 Programmatic Review to the **Dark Energy Survey** in recognition that the project was a high strategic priority for the future. As the project was in the build phase, no change was recommended to the planned funding for the remaining year of construction.
17. PPAN confirmed the 2007/08  $\alpha 4$  ranking of R&D activities for both **E-ELT** and **SKA** and also the desire to participate in both projects, recognising that these projects were of the highest strategic priority for the future. This is fully in line with the high priority assigned to both projects by the Advisory Panels and the GBFR. In order to enable the support of both projects within the constrained funding envelope, PPAN substantially reduced and re-profiled the proposed project funding for these two activities. It was noted that, in order to contribute to the construction phase of a SKA, new funding would be needed, for example from the Large Facilities Capital Fund.
18. **SuperWASP** was considered to be a timely project that addressed high quality, core science questions and its  $\alpha 4$  ranking reflected this and the strong support from the GBFR. SuperWASP is UK-led and currently among the world-leading Exoplanet research facilities. PPAN noted that the project had a potential exit point around 2012. In line with other  $\alpha 4$  ranked projects, the recommended project funding was reduced by 20% in order to attempt to preserve breadth in the overall programme.
19. Following the recommendations of the GBFR, PPAN revised the previous  $\alpha 2$  ranked **e-MERLIN operations** to  $\alpha 3$ . This reflected the scientific potential that is just being delivered from the large investment in upgrades, and the on-going relevance to the SKA development programme. In line with all other  $\alpha 3$  projects, the recommended project funding was reduced by 25% in order to attempt to preserve breadth in the overall programme.
20. PPAN re-affirmed the  $\alpha 3$  ranking of **ING**; the WHT in particular was recognised as a productive and valuable asset to the UK's ground-based programme in the medium term. PPAN noted that retention of this facility had been a high priority of the GBFR. PPAN had hoped to be able to consider the ING as a means to retain access to observing nights in the Northern Hemisphere, post 2012; however it was not possible to achieve this in the current financial circumstances. In line with all other  $\alpha 3$  projects,

the recommended project funding was reduced by 25% in order to attempt to preserve breadth in the overall programme.

21. When the **LOFAR** proposal was reviewed in 2009, PPAN had recommended that LOFAR should be an integral element of R&D funding for the SKA. Following the re-profiling and reduction of the SKA R&D line, PPAN assumed that it would not be sustainable to fund LOFAR from the same budget envelope. The costs for the operation of one LOFAR station were therefore added to the  $\alpha 3$  LOFAR line. This was in recognition that, for a modest investment, a large number of UK astronomers would benefit from working at low frequencies in advance of SKA to address a number of important science questions.
22. As discussed in the NUAP report, the **ROSA** instrument may provide access to the planned and unique US-led Advanced Technology Solar Telescope. Its  $\alpha 3$  ranking reflected the potential for some results of fundamental importance, strong UK leadership, excellent value for money and the engagement with local industry.
23. PPAN revised the ranking assigned in the 2007/08 Programmatic Review to the **ALMA Regional Centre** to  $\alpha 2$ . Whilst a UK-based ALMA Regional Centre was appropriate to the exploitation of the ALMA telescope it was not considered essential. This should not detract from the high priority assigned to the UK exploitation of ALMA. Given the financial constraints imposed, PPAN reluctantly accepted that it would not be possible to make any provision for  $\alpha 2$  projects despite the high quality science opportunities these projects offered.
24. PPAN noted the recommendations of the NUAP and the GBFR when considering the **Liverpool Telescope** and revised the alpha ranking of this project from  $\alpha 3$  to  $\alpha 2$  taking into account future science potential versus past strengths in knowledge exchange. Given the financial constraints imposed, PPAN reluctantly accepted that it would not be possible to make any provision for  $\alpha 2$  projects despite the high quality science opportunities these projects offered.
25. PPAN assigned an  $\alpha 2$  ranking to the possible UK involvement in the **Large Synoptic Survey Telescope (LSST)**. It was acknowledged that this offered high quality science opportunities but the UK was not yet involved and the cost would be significant. PPAN considered that this would be difficult to justify given the existing facility portfolio. It also seemed unlikely that ESO involvement would be made in LSST given the priority of E-ELT in ESO planning. PPAN noted that the GBFR had assigned LSST the lowest ranking in its high priority medium size category. Given the financial constraints imposed, PPAN reluctantly accepted that it would not be possible to make any provision for  $\alpha 2$  projects despite the high quality science opportunities these projects offered.
26. PPAN re-affirmed the ranking of  $\alpha 2$  for UK participation in **Gemini** and **JIVE**, and for **UKIRT**. This was broadly consistent with the advice from the GBFR and the FUAP. Given the financial constraints imposed, PPAN reluctantly accepted that it would not be possible to make any provision for  $\alpha 2$  projects despite the high quality science opportunities these projects offered.
27. In addition, PPAN ranked as  $\alpha 2$  the following proposed projects for which it had received Statements of Interest:
  - a. PPAN noted that the GBFR had ranked the **Caltech Cornell Atacama Telescope (CCAT)** in the high priority list, although it was the lowest ranked of these. PPAN noted that the UK could potentially influence the programme but

would not lead it and no UK contribution to telescope construction was foreseen. The UK has a very strong sub-mm instrumentation and science background but other strong instrument groups are already in the partnership (Caltech, Cologne). Given that CCAT is not included within the ESO commitment and would require significant UK commitment to ensure UK leadership in construction and exploitation, PPAN felt that the assignment of an  $\alpha 2$  ranking was appropriate.

- b. the UK component of the US-led and built **Magdalena Ridge Optical Interferometer (MROI)** is a small project in a niche area. Whilst it was noted that the group has a long established reputation of innovation in this area and that the project may provide an important contribution, the wider return to a broad-based UK community was limited. This ranking was consistent with the GBFR which had ranked the project one of the lowest in its category;
- c. the proposed **UKIRT Planet Finder** instrument had a strong scientific case with a strong UK lead. PPAN noted that the GBFR ranked the proposed instrument highly and had acknowledged the difficulty of timely provision of funds. Given the ranking of UKIRT and the implication for its continued funding, it was felt unlikely that STFC could find the considerable resources required for the instrument to be developed in the crucial 2010-12 timeframe. PPAN therefore felt it was appropriate to rank the project as  $\alpha 2$ ;

Given the financial constraints imposed, PPAN reluctantly accepted that it would not be possible to make any provision for  $\alpha 2$  projects despite the high quality science opportunities these projects offered.

- 28. Although the Statement of Interest submitted for **NG1DF** promised good science, PPAN did not find the science case compelling as it met the needs of a small community and did not form part of a coherent programme for spectroscopic instrumentation at the current time. PPAN found it difficult to justify increased investment given the existing UK investment in the current facility portfolio. It was noted that, whilst the project had some link to ESO priorities, ESO was not considering investment. The project was ranked  $\alpha 1$ . Given the financial constraints imposed, PPAN reluctantly accepted that it would not be possible to make any funding provision for  $\alpha 1$  projects despite the good science opportunities the projects offered.

#### *Space Science and Exploration*

- 29. **GAIA** was assigned an  $\alpha 5$  ranking in the 2009 exercise in recognition that this ESA mission will have an unparalleled astrometry capability leading to significant scientific impact across a wide range of astronomy and astrophysics. The FUAP and the NUAP highlighted the appeal of this mission to a wide community. The UK had a strong history of leadership in this area of science and there was significant synergy with other aspects of large dataset management in other areas of STFC programmes. In line with all other  $\alpha 5$  projects, the recommended project funding was reduced by 15% in order to attempt to preserve breadth in the overall programme.
- 30. PPAN confirmed the  $\alpha 5$  rankings assigned to **Herschel post-launch support, JWST MIRI** and **Planck post-launch support** in the 2007/08 Programmatic Review. PPAN accepted that such high profile missions in which the UK had an important role should be at the highest priority. The alpha ranking recognised the future potential of the science from these missions. FUAP identified these as facilities that will give UK scientists a competitive advantage. In line with all other  $\alpha 5$  projects, the recommended project funding was reduced by 15% in order to attempt to preserve breadth in the overall programme.

31. In the 2009 exercise, **Rosetta post-launch support** was assigned an  $\alpha 5$  ranking. PPAN recognised that this was an ESA cornerstone mission in which the UK had access to a unique project, and had significant leadership. The comet rendezvous in the 2013-2015 period had the potential to generate high profile output. In line with all other  $\alpha 5$  projects, the recommended project funding was reduced by 15% in order to attempt to preserve breadth in the overall programme.
32. PPAN recognised the strategic importance and strong science potential of investment in the **Aurora** and **ExoMars** programmes and confirmed the ranking of both at  $\alpha 4$  as in the 2007/08 Programmatic Review. PPAN noted that the UK is a major participant in ESA's Aurora programme and the second largest contributor to the ExoMars components. PPAN also noted that the programme was timely and internationally relevant with considerable activity at present to redefine the ExoMars programme with available funds and to align the ESA and NASA programmes. However, there remained a number of technical and financial risks. NUAP cited the project as a high priority for the planetary exploration scientists who represent a third of the NUAP community. It was recognised that, given the high profile UK commitment to Aurora, to propose withdrawal would have a very high political cost both for STFC within the UK, and for the UK space programme internationally. Nevertheless, to attempt to preserve breadth in the programme, the proposed project funding for ExoMars was substantially reduced and reprofiled. PPAN did not consider it feasible to achieve a reduction in the planned Aurora subscription.
33. In the 2007/08 Programmatic Review PPAN assigned rankings of  $\alpha 4$  to **Cosmic Vision R&D**, **LISA R&D** and **Solar Orbiter**. These rankings were reconfirmed by PPAN. Missions within the Cosmic Vision programme will form the ESA mandatory space science programme for 2015-2025. As a result, they were of the highest strategic priority for STFC. NUAP had also identified Cosmic Vision as of the highest priority. PPAN felt that LISA and Solar Orbiter were now integral elements of the Cosmic Vision programme. As a result, the lines of funding for each were combined as part of an overall Cosmic Vision funding envelope. In line with other  $\alpha 4$  ranked projects, the recommended project funding was reduced by 20% in order to attempt to preserve breadth in the overall programme.
34. PPAN confirmed the 2007/08 Programmatic Review ranking of **LISA Pathfinder** as  $\alpha 4$ . As this was in the build phase, no change was made to the planned funding for the remaining period of construction.
35. The Japanese **Hinode** mission is currently scheduled until 2012. PPAN agreed that funding for post-launch support should be retained until 2013/14. In recognition of the scientific impact of this mission, it was ranked as  $\alpha 4$  in the 2007/08 Programmatic Review and this ranking was re-confirmed. In line with other  $\alpha 4$  ranked projects, the recommended project funding was reduced by 20% in order to attempt to preserve breadth in the overall programme.
36. **STEREO post-launch support** was assigned a ranking of  $\alpha 4$  in the 2007/08 Programmatic Review and this was confirmed. This is a NASA mission currently expected to end by 2012 and this mission remains a high science priority. In line with other  $\alpha 4$  ranked projects, the recommended project funding was reduced by 20% in order to attempt to preserve breadth in the overall programme.
37. PPAN assigned a ranking of  $\alpha 4$  for **Swift post-launch support** in the 2007/08 programmatic review and PPAN confirmed this ranking. The project has NASA approval until the end of 2012. PPAN recommended that STFC continue to fund exploitation until 2014/15 in line with the expected NASA extension. In line with other

$\alpha$ 4 ranked projects, the recommended project funding was reduced by 20% in order to attempt to preserve breadth in the overall programme.

38. In the 2007/08 Programmatic Review, PPAN assigned a ranking of  $\alpha$ 3 to **Cassini, Cluster, SOHO and XMM, post-launch support** in recognition that these were high impact missions and that there were still important science returns expected from these missions. These rankings were re-confirmed. For XMM, PPAN recommended that provision for funding be made for post-launch support beyond current planning assumptions and planning for the project was extended to 2015/16, pending further review. In line with all other  $\alpha$ 3 projects, the recommended project funding was reduced by 25% in order to attempt to preserve breadth in the overall programme.
39. In the 2007/08 Programmatic Review, PPAN assigned a ranking of  $\alpha$ 4 to **Venus Express post-launch support**. While recognising the excellent science return to date from this project, PPAN felt that the future science return would now have less impact and revised this ranking to  $\alpha$ 3. In line with all other  $\alpha$ 3 projects, the recommended project funding was reduced by 25% in order to attempt to preserve breadth in the overall programme.
40. **Bepi Colombo** was assigned a ranking of  $\alpha$ 1 in the 2007/08 Programmatic Review. This ranking was reconfirmed by PPAN.
41. PPAN reconfirmed the beta ranking of the **MoonLITE** project, originally assessed during the 2007/08 Programmatic Review.

#### *Particle Astrophysics*

42. In the 2007/08 Programmatic Review, PPAN assigned  $\alpha$ 5 ranking to **Advanced LIGO and Ground-Based Gravitational Wave Detectors** in recognition that these projects had the potential for truly groundbreaking science. These rankings were reconfirmed by PPAN, noting that the PAAP had recommended that involvement in these facilities was essential. In line with all other  $\alpha$ 5 projects, the recommended project funding was reduced by 15% in order to attempt to preserve breadth in the overall programme.
43. In the 2007/08 Programmatic Review, PPAN assigned an  $\alpha$ 4 ranking to **Zeplin III** in recognition that the project was currently delivering the highest quality results. PPAN re-affirmed this ranking noting that the PAAP regarded involvement in dark matter detection as essential. In line with other  $\alpha$ 4 ranked projects, the recommended project funding was reduced by 20% in order to attempt to preserve breadth in the overall programme.
44. PPAN noted that **ANITA** was a very small-scale project that may detect high energy neutrinos of cosmological origin. The project was good value for money and of high quality. PPAN broadly agreed with the view of the PAAP and the PPAP. PPAN felt that a ranking of  $\alpha$ 3 was appropriate. PPAN took account of the reductions in project funding recommended for all other  $\alpha$ 3 projects in order to attempt to preserve breadth in the overall programme, and recommended an appropriate level of funding for planning purposes.
45. PPAN agreed with the recommendation of the PAAP that the focus of the **Auger** project should be the continuing exploitation of data from Auger south. The  $\alpha$ 3 ranking from the 2007/08 Programmatic Review was re-confirmed. In line with all other  $\alpha$ 3 projects, the recommended project funding was reduced by 25% in order to attempt to preserve breadth in the overall programme.

46. PPAN discussed the potential **Clover follow-on** projects. PPAN agreed with the recommendation of the PAAP that the science case for CMB polarisation studies remained strong. Concerns were raised about the timescale and competitiveness of the follow-on projects for which PPAN had received Statements of Interest and PPAN ranked the Clover follow-on projects as  $\alpha 3$ . Following discussions about these reservations, PPAN could not recommend inviting a full proposal for the proposed Clover follow-on projects.
47. **CTA** was assigned an  $\alpha 3$  ranking in the 2009 exercise. PPAN noted that there is increased support for this science area and for the CTA project through a growing UK interest. CTA was therefore assigned a higher priority than that for the HESS and VERITAS projects in the 2007/08 Programmatic Review. PPAN noted that this was a priority area for the PAAP. The UK is a relatively minor player but there is now potential for more UK leadership via the growing contribution from new groups. Given the financial constraints imposed, PPAN was unable to make financial provision for CTA, at an appropriate level, at the current time.
48. The **Einstein Telescope** was assigned a ranking of  $\alpha 3$  in the 2009 prioritisation exercise. PPAN noted that the project addresses important science areas as a next generation gravitational wave facility with considerable potential for discoveries of great significance. The decision to proceed was very likely to be dependent on the detection of gravitational waves by facilities currently in development.
49. In the 2009 exercise, PPAN assigned an  $\alpha 3$  ranking to the dark matter projects, **Eureca** and **Lux-Zeplin**. This was in accord with the PAAP recommendation that involvement in dark matter experimentation was essential. In the current financial circumstances, PPAN recommended that provision for funding be made for a UK role in a single dark matter project. PPAN would await the outcome of the PPRP review of Lux-Zeplin and Eureca before making a decision on which project that should be. In line with all other  $\alpha 3$  projects, the recommended project funding was reduced by 25% in order to attempt to preserve breadth in the overall programme.
50. The **Inverse Square Law** project was ranked  $\alpha 3$  in the 2007/08 Programmatic Review. PAAP recognised that this small project had delivered promising preliminary measurements and the  $\alpha 3$  ranking was re-reconfirmed by PPAN. In line with all other  $\alpha 3$  projects, the recommended project funding was reduced by 25% in order to attempt to preserve breadth in the overall programme.
51. PPAN agreed that the ranking of the **Boulby** underground facility should be associated with the science that would be enabled by the facility. Boulby was cited as the location for dark matter experiments; however, it was now clear that this work would be undertaken elsewhere and the Boulby facility only used for background studies. The facility was considered to be good value for money at the current level of investment. However, it was noted that the facility would require a significant upgrade in order to develop and continue as a state of the art facility. On the basis of the projected STFC usage of the facility, it was ranked as  $\alpha 1$ . Given the financial constraints imposed, PPAN reluctantly accepted that it would not be possible to make any funding provision for  $\alpha 1$  projects despite the good science opportunities the projects offered.

#### *Nuclear Physics*

52. PPAN recognised the importance of **NUSTAR** to the Nuclear Physics programme and for strategic reasons amended the NUSTAR alpha ranking from  $\alpha 3$  to  $\alpha 4$ . This was in recognition that FAIR will be the premier international fragmentation facility and the

NUSTAR initiative would support the research programme of a large fraction of the NP community. As this was a construction project where a significant reduction in funding would not be viable, project funding was reduced by 10% rather than in line with other  $\alpha 4$  ranked projects which were reduced by 20%.

53. **AGATA** and **ALICE** were previously assigned rankings of  $\alpha 3$ . These rankings were re-confirmed. In line with all other  $\alpha 3$  projects, the recommended project funding was reduced by 25% in order to attempt to preserve breadth in the overall programme.
54. The ranking of  $\alpha 3$  assigned to **ISOL (SPIRAL2)** in the 2007/08 Programmatic Review was re-confirmed. It was recognised that the project should be regarded as an indicator for community involvement in the science programmes being developed for a new generation of ISOL beams (SPIRAL2 and HIE ISOLDE) and the likely form of this would be experimental instrumentation that could be used at both facilities. The SPIRAL/GANIL facility was seen as one of the stepping stones to the EURISOL concept and it should prove possible to exploit the ISOL facility at CERN. This view was consistent with that recommended by the NPAP. PPAN took account of the reductions in project funding recommended for all other  $\alpha 3$  projects in order to attempt to preserve breadth in the overall programme, and recommended an appropriate level of funding for planning purposes.
55. PPAN agreed that FAIR was the top-rated facility for the nuclear physics community. PPAN noted that the NPAP had considered NUSTAR and PANDA separately; PPAN considered this to be a sensible future approach and that updates for both projects would be reviewed separately on their merits. Following the ranking of PANDA, PPAN agreed that PANDA additional costs should be removed from consideration of FAIR additional costs and this funding opportunity should be re-labelled more correctly as **NUSTAR additional costs**. The ranking of  $\alpha 3$  was assigned in recognition of the importance of this facility to the NP community. In addition to the removal of costs relating to PANDA, PPAN took account of the reductions in project funding recommended for all other  $\alpha 3$  projects in order to attempt to preserve breadth in the overall programme, and recommended an appropriate level of funding for planning purposes.
56. The ranking of  $\alpha 3$  previously assigned to **PANDA** was re-confirmed. It was noted that further information provided by the NPAP suggested that the elements of the science programme that PPAN considered most compelling could be done better at different facilities for a smaller investment. In the light of this, PPAN could not recommend further funding of this project.
57. **ELENA** was assigned a ranking of  $\alpha 2$  in the 2009 prioritisation exercise. This was consistent with the priority assigned to the facility by the NPAP and reflected the fact that, at this time, the project was at a very early stage with a low level of community involvement. PPAN noted that, to enable this project to proceed, the upgrade costs for the Boulby underground facility would be significant. Given the financial constraints imposed, PPAN reluctantly accepted that it would not be possible to make any provision for  $\alpha 2$  projects despite the high quality science opportunities these projects offered.

#### *Particle Physics*

58. In the 2007/08 programmatic review, PPAN assigned an  $\alpha 5$  ranking to **ATLAS**, **CMS** and **nEDM** noting that these projects had the potential for truly revolutionary, breakthrough science. During the 2009 prioritisation exercise, PPAN re-affirmed these rankings noting that all were cited as world leading and of the highest priority by

the PPAP. It was noted that nEDM was a relatively small, UK-dominated experiment. In line with all other  $\alpha 5$  projects, the recommended project funding was reduced by 15% in order to attempt to preserve breadth in the overall programme.

59. In the 2009 prioritisation exercise, PPAN assigned an  $\alpha 5$  ranking to the **ATLAS upgrade**, noting that this was cited as world leading and of the highest priority by the PPAP. PPAN noted that the upgrade was likely to produce scientific results of critical importance. PPAN considered this project to be an essential element of the STFC particle physics programme as it includes maintenance of the experiment as well as an upgrade. Project funding was reprofiled to take account of likely savings as a result of delays in data taking at the LHC.
60. PPAN assigned an  $\alpha 5$  ranking to the **CMS upgrade** in the 2009 prioritisation exercise and noted that this was cited as world leading and of the highest priority by the PPAP. PPAN also noted the fact that the project was likely to produce results of critical importance. PPAN considered this project to be an essential element of the STFC particle physics programme. Project funding was reprofiled to take account of likely savings as a result of delays in data taking at the LHC.
61. **GridPP** was re-confirmed as  $\alpha 5$ , reflecting its critical role in the exploitation of the LHC. In an attempt to preserve breadth in the programme, a 20% reduction was applied to project funding across all years. In taking this decision, PPAN took account of the delays in data-taking at the LHC and considered that it would not be unreasonable for universities to contribute to these infrastructure costs, particularly for the Tier-2 centres.
62. The **Cockcroft Institute** had previously been assigned an  $\alpha 4$  ranking and this was reconfirmed. This was in line with the PPAP recommendation that strategic investment should be maintained in this world leading facility.
63. **IPPP** had previously been assigned an  $\alpha 4$  ranking. PPAN accepted the assessment of the PPAP that the institute had been a particularly successful contributor in this field and reconfirmed this ranking. In order to attempt to preserve breadth in the overall programme, the recommended project funding was reduced by 10%.
64. **LHCb** was ranked  $\alpha 4$  in the 2007/08 Programmatic Review, reflecting its strong UK leadership and importance to the Particle Physics programme. This ranking was reconfirmed following the recommendation by the PPAP that this project was world leading and a high priority. In line with other  $\alpha 4$  ranked projects, the recommended project funding was reduced by 20% in order to attempt to preserve breadth in the overall programme.
65. The **nEDM Upgrade** was assigned an  $\alpha 4$  ranking during the 2009 prioritisation in recognition that this upgrade was essential to ensure continuation of the current highly rated facility. This accorded with the PPAP assessment that this project was world leading and of high priority. It was noted that, whilst international competition exists, the UK-led team has a significant lead. The upgrade would maintain the UK's lead. PPAN took account of the reductions in project funding recommended for all other  $\alpha 4$  projects in order to attempt to preserve breadth in the overall programme, and recommended an appropriate level of funding for planning purposes.
66. **SNO+** was assigned an  $\alpha 4$  ranking in recognition that this project addressed an important area of science, capitalised on existing infrastructure and could be ready earlier than other competitors. The project was a high priority in the PPAP report. PPAN agreed that, because of the current financial circumstances, there is likely only

to be sufficient funding for a credible UK role in a single neutrinoless double beta decay experiment on this timescale. PPAN felt that the additional tracking capabilities of SuperNEMO, the innovative technology used and the strong UK leadership meant that SuperNEMO offered the best opportunities for the future. PPAN therefore did not recommend funding for SNO+.

67. PPAN confirmed the previous  $\alpha 4$  ranking of **SuperNEMO** in recognition that this project addressed an important area of science, the results from which may have high impact. PPAN accepted that funding for the first three years of SuperNEMO had already been adjusted as a result of additional, comprehensive peer review. As a result, the project would not be viable should the funding be reduced further before 2013; however, PPAN recommended that provision for funding in subsequent years be reduced.
68. The priority assigned to **T2K** in the 2007/08 Programmatic Review was reconfirmed and the project was ranked as  $\alpha 4$ . In line with other  $\alpha 4$  ranked projects, the recommended project funding was reduced by 20% in order to attempt to preserve breadth in the overall programme.
69. The status of **CDF** and **D0** was reconfirmed and they were ranked as  $\alpha 3$  to reflect the fact that, while the facilities were nearing the end of their lifetime, there remained an opportunity for revolutionary, ground-breaking results. This also accorded with the recommendation by the PPAP. In line with all other  $\alpha 3$  projects, the recommended project funding was reduced by 25% in order to attempt to preserve breadth in the overall programme.
70. PPAN acknowledged the importance of following developments at CERN towards a linear collider and the requirement to maintain key researchers in the programme and assigned **CLIC** a ranking of  $\alpha 3$ . This was in accord with the recommendation by the PPAP. It was noted that the UK leads in some areas of accelerator technology development; however, it was clear that the science return was very long term. PPAN took account of the reductions in project funding recommended for all other  $\alpha 3$  projects in order to attempt to preserve breadth in the overall programme, and recommended an appropriate level of funding for planning purposes.
71. The ranking of  $\alpha 3$  assigned to **eEDM** in the 2007/08 Programmatic Review was reconfirmed. In line with all other  $\alpha 3$  projects, the recommended project funding was reduced by 25% in order to attempt to preserve breadth in the overall programme.
72. **JPARC Neutrino** was assigned a ranking of  $\alpha 3$  in the 2009 exercise. This ranking took account of the fact that this project built on the capability of an excellent facility but noting that maintaining current investment in T2K was of a slightly higher priority as T2K is likely to remain the premier facility in this area. It was noted that future investment would be dependent on the performance of the existing facility. PPAN took account of the reductions in project funding recommended for all other  $\alpha 3$  projects in order to attempt to preserve breadth in the overall programme, and recommended an appropriate level of funding for planning purposes.
73. The **LHCb upgrade** was assigned a ranking of  $\alpha 3$  in the 2009 exercise. PPAN acknowledged the high alpha ranking of LHCb and concurred with the PPAP recommendation to wait until first physics results from the LHC before confirming any major funding decisions on future updates. PPAN took account of the reductions in project funding recommended for all other  $\alpha 3$  projects in order to attempt to preserve breadth in the overall programme, and recommended an appropriate level of funding

for planning purposes. This included reprofiling to take account of likely savings as a result of delays in data taking at the LHC.

74. Following the 2007/08 exercise, funding was established for **Linear Collider Detector R&D** projects since this area represents important R&D that is likely to have a key role in many future particle physics advances in science. Currently funded projects are a **Silicon Pixel Detector Research programme (SPIDER)**, **Particle Flow Calorimetry** and **Low-mass Support Structures for Silicon Detectors**. These projects, and future funding for other linear collider R&D, were assigned a ranking of  $\alpha 3$  which was in line with the PPAP recommendation that such involvement would offer a world-leading science opportunity. In line with all other  $\alpha 3$  projects, the recommended project funding was reduced by 25% in order to attempt to preserve breadth in the overall programme.
75. The ranking assigned to **MICE** in the 2007/08 Programmatic Review was reconfirmed and the project was ranked  $\alpha 3$ . PPAN noted that this technology demonstrator project located in the UK was aimed at ensuring the UK was at the forefront for hosting a future neutrino factory and would have scientific leadership in a key strategic area. PPAN recommended that STFC develop a clear, strategic view of the future level of investment in this area. In line with all other  $\alpha 3$  projects, the recommended project funding for operations and analysis was reduced by 25% in order to attempt to preserve breadth in the overall programme.
76. The **UKNF** was assigned a  $\alpha 3$  ranking in the 2009 exercise in recognition that, although currently a design study, it had the potential for significant science impact. PPAN agreed that it was important to continue design studies for future accelerator R&D and the UK should maintain a minimal level of funding to maintain UK involvement in the area. This was in accord with the PPAP assessment that such involvement would offer a world-leading science opportunity. In line with all other  $\alpha 3$  projects, the recommended project funding was reduced by 25% in order to attempt to preserve breadth in the overall programme.
77. In the 2009 exercise, **COMET** was assigned a ranking of  $\alpha 2$ . The ranking was in line with the PPAP recommendation that, while the project was a new concept that potentially offered good science opportunities, UK involvement in this Japanese-led experiment was not essential. PPAN thus felt it was difficult to justify involvement in this new project at the current time.
78. Taking into account the recommendations of the PPAP and the PAAP, PPAN confirmed the 2007/08 Programmatic Review  $\alpha 2$  ranking of **MINOS**. Given the financial constraints imposed, PPAN reluctantly accepted that it would not be possible to make any provision for  $\alpha 2$  projects despite the high quality science opportunities these projects offered.
79. PPAN confirmed the 2007/08 Programmatic Review  $\alpha 2$  ranking of **NA62** in acceptance that this project offered good science opportunities. PPAP had noted that this was a low cost, small activity and had recommended limited investment but had not recommended that UK involvement was essential. PPAN concurred with this view. PPAN had received a Statement of Interest relating to this project but could not recommend inviting a full proposal.
80. PPAN reconfirmed the previous ranking of the **John Adams Institute** as  $\alpha 1$ . Given the financial constraints imposed, PPAN accepted that it would not be possible to make any future funding provision for JAI beyond the current commitment.

81. **LHeC** was assigned a ranking of  $\alpha 1$  in the 2009 exercise. PPAN noted that this was an early stage concept project. The alpha ranking was in line with the fact that, whilst PPAN acknowledged that the physics explored might be interesting, LHeC had not been assigned a high priority by the PPAP. Given the financial constraints imposed, PPAN reluctantly accepted that it would not be possible to make any funding provision for  $\alpha 1$  projects despite the good science opportunities the projects offered.
82. The **SuperB** project was assigned a ranking of  $\alpha 1$  in the 2009 exercise. It was recognised by PPAN that whilst the project, should it go ahead, offered potentially interesting science, it was difficult to justify investment in this new project at the current time.

## Annex One: Glossary

AGATA	Advanced Gamma Tracking Array
ALICE	A Large Ion Collider Experiment
ALMA	Atacama Large Millimetre/submillimetre Array
AUGER	Pierre Auger Cosmic Ray Observatory
CCAT	Caltech Cornell Atacama Telescope
CDF	Collider Detector at Fermilab
CERN	European Organisation for Nuclear Research [Conseil Européen pour la Recherche Nucléaire]
CLIC	Compact e+e- Linear Collider
Clover	C/ObserVER
CMS	Compact Muon Solenoid
eEDM	electron Electric Dipole Moment.
E-ELT	European Extremely Large Telescope
e-MERLIN	Multi-Element Radio Linked Interferometer Network,
ESA	European Space Agency
ESO	European Southern Observatory
Eureca	European Underground Rare Event Calorimeter Array
FAIR	Facility for Antiproton and Ion Research (Darmstadt)
FUAP	Far Universe Advisory Panel
GAIA	Global Astrometric Interferometer for Astrophysics
GBFR	Ground Based Facilities Review
Herschel	Herschel Space Observatory
HESS	High Energy Stereoscopic System
IPPP	Institute for Particle Physics Phenomenology
ISL	Inverse Square Law
JCMT	James Clerk Maxwell Telescope
JIVE	Joint Institute for VLBI in Europe
JLab	Thomas Jefferson National Accelerator Facility (Virginia, USA)
JPARC	Japan Proton Accelerator Research Complex
JWST – MIRI	James Webb Space Telescope - Mid InfraRed Instrument
KMOS	K-band Multi-object Spectrometer [at the ESO VLT]
LHCb	Large Hadron Collider beauty experiment
LHeC	High-energy Lepton-Hadron Collider
LISA	Laser Interferometer Space Antenna
LOFAR	LOW Frequency ARray
LSST	Large Synoptic Survey Telescope
MICE	Muon Ionization Cooling Experiment
MINOS	Main Injector Neutrino Oscillation Search
MoonLITE	Moon Lightweight Interior and Telecom Experiment
MROI	Magdalena Ridge Optical Interferometer
nEDM	Neutron Electric Dipole Moment
NG1dF	Next Generation 1-degree Field
NPAP	Nuclear Physics Advisory Panel
NUAP	Near Universe Advisory Panel
NUSTAR	Nuclear Structure Astrophysics and Reactions
PAAP	Particle Astrophysics Advisory Panel
PALS	Physical and Life Sciences Committee
PANDA	anti-Proton ANnihilation at DArmsstadt
PPAN	Particle Physics, Astronomy and Nuclear Physics Science Committee
PPAP	Particle Physics Advisory Panel
R&D	Research and Development
ROSA	Rapid Oscillations in the Solar Atmosphere
SKA	Square Kilometre Array
SOHO	Solar and Heliospheric Observatory
SNO+	Sudbury Neutrino Observatory
SPIDER	Silicon Pixel Detector Research programme
STFC	Science and Technology Facilities Council
SuperNEMO	Super Neutrino Ettore Majorana Observatory
SuperWASP	Wide Angle Search for Planets
T2K	From Takai to Kamioka (Next Generation Long Baseline Neutrino Oscillation Experiment)
UKIRT	United Kingdom Infrared Telescope
UKNF	UK Neutrino Factory
VERITAS	Very Energetic Radiation Imaging Telescope Array System
VISTA	Visible and Infrared Survey Telescope for Astronomy
XMM	X-ray Multi-Mirror satellite