AstroGrid : Virtual Observatory Service for the UK
Proposal to PPARC
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(1) Executive Summary.

By the end of 2007, the AstroGrid project will have completed development all of the core infrastructure software components needed for an operational VO system, and will have had experience setting up and running a prototype working system. Using both the AstroGrid software product, and the skills of key data centre staff, we propose to construct a fully operational and sustainable VO service for UK astronomers. This will be targeted at key databases and facilities in the PPARC roadmap, with the aim of giving UK astronomers a competitive advantage in extracting science, and so maximising the return from PPARC's investment. Our plan involves several areas of work.

(i) Setting up core VO services at each data centre site - Registry, Job Execution Service, MySpace, and Community Authentication.

(ii) Publishing an agreed list of specific prime data services and applications, to VO standards and with VO interfaces.

(iii) Working with the astronomy community to optimise science return from key missions, using the VO - including user guides, helpdesk, training workshops, and competitive "science tools" calls.

(iv) Working with system administrators and tools writers across all UK departments, providing training workshops, automated and reliable auto-install versions of any components they wish to deploy, and easy methods for tools in any language to interact with VO services.

(v) Maintaining and upgrading the core software product to engineering standards. New functionality will be added, and re-engineering will be necessary as the standards emerging from the IVOA and the rest of the e-Science world mature.

(vi) Keeping abreast of the changing technology landscape, assessing new technologies and constructing prototypes of possible new infrastructure components.

The service will be run for the benefit of all astronomers in the UK, but its delivery is centred on a handful of key centres. The consortium consists of institutions which were involved in constructing the AstroGrid product, and which are closely involved in the delivery in just about all of the key databases expected over the next decade - such as XMM, WFCAM, VISTA, SDO, Planck, GAIA, ALMA, e-MERLIN, and WFMOS. Ensuring that these databases are available through VO interfaces is the main aim of this project. Huge investment has been made in building each of these facilities or missions, and substantial investment has been or will soon be made in the basic data management for these missions - pipelining and archiving the data. Integrating all these datasets into the VO infrastructure, and setting up and operating core VO services such as data discovery, workflow, community storage, single sign on, and tool interoperability, will add substantially improved science for relatively little money. Most of the cost is in the staff required to install, maintain, and improve services, with a small hardware investment for running core services.

Our five-year workplan starts in October 2007, with a staff complement roughly the same as the current project (~20 funded FTEs), tapering down with time towards what we propose is a sustainable size of ~14 funded FTES.

(2) Scientific Case

2.1 Introduction

In the original AstroGrid proposal of April 2001 we said that it would take something like six years for a real Virtual Observatory (VO) to emerge. This prediction is proving correct. With eighteen months to go to the end of the AstroGrid project, we have already completed all except one of the core infrastructure components; developed most of the necessary standards and protocols with our international partners; built a user interface and a set of science tools, and an API that allows third parties to write VO compatible tools; built a prototype working system capable of doing real science, and which is already producing new publishable science; and begun working with the community, running training workshops and establishing a registered user base of several hundred astronomers. Between now and the end of 2007, we will finish these elements of work, completing the software to robust engineering standards. We will be ready to move into constructing an **operational VO service** for UK astronomers.

AstroGrid is creating a flexible framework for the creation of a 'real' Virtual Observatory. With European partners it is providing the infrastructure for the Euro-VO, upon which a wider community of partners can easily add specialised data and applications. In the UK, AstroGrid is providing a complete Virtual Observatory Service to its astronomical community, providing a place to create science through access to data, applications, and a secure environment in which to carry out data analysis and interpretation. The fundamental aim is enhanced exploitation of all the facilities on the PPARC roadmap, including all areas of astronomy from cosmology to the solar system.

2.2 The VO vision

The power of the World Wide Web is its *transparency* - it feels as if all the documents in the world are inside your PC. The idea of the *Virtual Observatory* (VO) is to achieve the same transparency for astronomical data. All the world's data on your desk - all archives speaking the same language, accessed through a uniform interface, and analysable by the same tools.

The VO offers not just access to the data, but operations on the data and returned results which are essential for their full exploitation - for example the ability to stack and mosaic images, to query catalogues and create subsets, to integrate data from different origins, or to calculate a correlation function. Until today such analysis has been done by end-users after downloading data. From here on we expect that the normal mode will be for such calculations (many of which are quite standard) to be *data services* offered by the expert data centres holding the data. These operations then also need to be standardised to be compatible across many archives. The result is a *service grid*. The VO is not a monolithic system, but, like the Web, a set of standards which make all the components of the system *interoperable* - data and metadata standards, agreed protocols and methods, standardised mix-and-match software components, application APIs, and standard interfaces to data services. The standards, software modules, software collections, and VO-aware tools constitute the *VO Framework*.

This vision aims at making day-to-day science with global astronomical datasets easier and quicker. But it also aims at making complex and data-intensive analyses possible, so that astronomers attempt ambitious projects that would otherwise be impossible. This will be partly be achieved by data centres offering high powered services - eg very fast searches, or clustering analyses - but also through a key UK addition to the basic framework - the idea of *workflow.* This means the ability to programme a sequence of services, piping results from one to another, looping, and re-running with adjustable parameters.

2.3 Why the VO is needed

The VO concept is clearly attractive, but is it necessary ? In fact it is more or less inevitable; the real need is to do it well, and keep UK astronomers ahead of the game. The VO is driven by three things.

(a) Astronomer demand. An increasing fraction of astronomical research is done using on-line science archives, using both large survey databases and classical "PI time" facilities. At the same time, nearly all astronomical problems require multiple sources of information for their solution - eg photometry at many wavelengths; spectra of such and such subset of a survey; magnetometer readings following a Coronal Mass Ejection. Older astronomers are possibly happy enough doing this by hand; but each successive intake of new graduate students and PDRAs is more impatient with how clumsy this is, compared with the transparent ease of finding documentary information on the Web. (Actually, most older astronomers will benefit from access to the intuitive VO interfaces and keep ahead of the game..) Finally, more and more astronomers wish to attempt ambitious data-intensive analyses - eg three point correlation functions on millions of galaxies, or searching for the elusive z=7 quasars or Y dwarfs. Such analyses should become standardised and available as services.

(b) External Technology. Current developments in information technology - XML, web services, and distributed computing techniques ("Grid") - make the transparency we aim at plausible. Our requirements are similar to, but more demanding than, the commercial sector and the life sciences. This means that we can be confident that we are using leading edge but sound technology. It also means that this is the way the world will work in the future; astronomy infrastructure must adapt to this world as rapidly as possible. At the same time, new algorithms - eg kd-trees, variable-pixel linear reconstruction, or streaming methods for roaming around very large images - make data-intensive analyses plausible.

(c) Data requirements and bottlenecks. UK astronomy is building towards an impressive list of facilities, missions, and associated databases, as discussed in Section 2.4. The main concern is not the number of bytes, but the number of archives, and their potential incommensurability. The key issue is therefore *archive interoperability* and the need for a *transparent data infrastructure*. However, bytes do matter as well. All current major archives are growing at TB/yr rates; next year VISTA and e-MERLIN will grow at 100TB/yr; from 2008 SDO will grow by 500TB /yr while ALMA will grow at PB rates. Each of these databases needs significant investment in processing, storing, and making these data available, typically through queryable relational databases; the VO infrastructure is what makes them interoperable. Of course we are used to the idea that computing power grows exponentially; but two things have not grown at Moore's Law rates. The first is CPU-disk I/O, and the second is last-mile end-user internet bandwidth. However, data centres can have "fat pipes" between each other, and specialised machines providing fast query services and data-mining applications.

These drivers lead us towards a data infrastructure based around services offered by a small number of data centres to a large community of end users. The key is to target these data services at agreed scientific priorities. This is what we examine in the next section.

2.4 UK astronomy strategy : key missions and datasets

The UK astronomy community is currently seeking to answer a number of fundamental questions aimed at furthering our understanding of the cosmos from the largest to smallest scales, from the formation of the Universe, to the quest for life on other planets,. The key astronomy questions are currently encapsulated in the PPARC Road Map:

- What is the universe made of and how does it evolve?
- What is the origin of mass?
- Are we alone in the Universe?
- How do galaxies, stars and planets form and evolve?
- Is there a unified theory of all particle interactions?
- What are the laws of physics in extreme conditions?
- How does the Sun affect the Earth?
- What are the origins and properties of the energetic particles reaching the Earth?

Each of these key questions are addressed via use of specific data streams from a range of high quality instruments, missions, and surveys.

For instance: the question: 'How do galaxies, stars and planets form and evolve?' will be investigated by analysis and interpretation of data from ALMA, e-MERLIN, Gaia, Herschel, JWST/MIRI, KMOS (VLT), Planck, SCUBA2, and VISTA. A number of these high value missions will have significant UK involvement in the design and construction of the instruments. Several of these missions will have significant UK leadership in the delivery of their science data products.

For the question "How does the Sun affect the Earth", three major new data sets will shortly come from the Solar-B and STEREO missions in 2006 and from SDO in 2008. By operating in an overlapping manner, these missions are well placed to revolutionise the Solar Physics and Sun-Earth disciplines. However for the active and highly skilled UK community to retain a world-leading position in these fields, it will be necessary for practicing individuals to have optimum access to these data sets if they are not to be placed at a disadvantage with respect to other major research groups e.g. in the USA.

<u>AstroGrid Consortium Members and data management</u>

Construction and operation of these facilities is typically through international entities, such as ESO, ESA, and the Gemini partnership. Data management involves these same entities, but also university groups across Europe. UK groups play a leading and often dominant role in the downstream data management - pipeline processing, archive construction, and user access arrangements. The AstroGrid consortium is responsible for *most* of such downstream data management for UK astronomy both today and over the next decade. Appendix C3 lists the key datasets and pipelining activities for which we have leading or significant responsibility.

These datasets represent the primary source material for UK astronomy, but also for much of European and world astronomy. UK astronomers therefore find themselves in a competitive arena. The aim of the current proposal is to maximise the science return from these datasets in general, but specifically for UK astronomers. An operational VO service based on the AstroGrid software is therefore of benefit to the entire UK community. We aim to provide the best possible services from UK-managed datasets, and to provide the best possible infrastructure and tools for UK astronomers. However, because we follow (and indeed often set) international standards, astronomers using the UK based VO services will also be able to access and analyse data from all over the world.

2.5 Example mission needs

The AstroGrid service will provide capabilities to support the science programmes of a number of major new missions from 2008 onwards.

The VISTA IR survey telescope is being built by a UK consortium to be delivered and operated by ESO. It will generate data flow of the order 100TB/yr, several times larger than UKIRT's WFCAM. The sophisticated data flow and archival systems are now being developed by VDFS, a UK consortium, with the pipelines being developed by CASU (IoA, Cambridge), and the science archive system being developed by WFAU (IfA, Edinburgh). The derived source catalogues are more important than the images, and they will contain billions of objects. The key needs are to make queries to such large catalogues part of VO workflows - crossmatching with other wavelengths, piping to photo-z applications, searching for very rare objects, sending to specialised services to calculate high-order correlation functions, and so on.

VISTA in the infrared and VST in the optical will become operational towards the latter half of 2007. Currently there is an assessment procedure taking place, by which ESO and the community are selecting a small number of ambitious public surveys which will be undertaken by these facilities. The VST surveys are now known, with two of the three having UK PI's: namely Shanks (Durham) for the ATLAS programme – a large (~5000sq deg) area optical survey of the southern hemisphere; and Drew (Imperial) for the VPHAS galactic plane H-alpha survey. It is anticipated that the science survey products will be generated in the UK, and be disseminated both via the ESO Science Archive Facility and through the VDFS system. It is probable that there will be matching IR surveys with VISTA, for instance the Vista Hemisphere Survey (VHS) aims to survey the southern sky (~20000 sq deg) in four colours.

Gaia is an approved ESA cornerstone project, currently scheduled for launch in late 2011. Gaia will provide photometric, positional, spectroscopic and radial velocity measurements with the accuracies needed to produce a stereoscopic and kinematic census of about one billion stars in our Galaxy and throughout the Local Group, addressing its core science goals to quantify the formation and assembly history of a large spiral galaxy, the Milky Way. Gaia will achieve this by obtaining a six-dimensional (spatial & kinematic) phase-space map of the Galaxy, complemented by an optimised high-spatial resolution multi-colour photometric survey, and the largest stellar spectroscopic and radial velocity surveys ever made.

The Gaia data set will be constructed from ~2×10^{12} observations (image CCD transits), whose analysis is a very complex task, involving both real-time and end-of-mission data products. The UK Gaia Data Flow System project, the UK contribution to the European wide Gaia Data Processing and Analysis Consortium, will construct the processes required to handle the photometric reduction of the data from Gaia's 100+ focal plane CCDs, the pipeline needed to support the 'science alerts' and epoch photometry handling, and the spectroscopic processing system. All data products will be generated to ensure compliance with emerging VO standards, fully in accordance to ESA specifications in this area.

From 2012 onwards, a key VO objective will be to enable on-demand synthesis of data from Gaia and supporting data sets such as that from the VISTA VHS survey. In particular, Gaia optical photometry and astrometry, when combined with this IR data will allow for the degeneracy in stellar spectral type to be broken, as the IR in combination with optical colours allows for reddening to be solved, thus stellar types, and eventually absolute magnitudes to be found. This allows then for a complete three-dimensional map of the Milky Way to be determined. The size of this task is large, and will require access to high volume computing resource (provided through for instance the NGS) to support the processing demands necessary in carrying out these multi-data, multi application computations.

Over the next few years the FIR-submm window will be opened up - first by SCUBA2, which will begin survey operations by early 2007, then in 2008 with Herschel and Planck. Planck is of course primarily aimed at mapping the cosmic background, but it will also produce an enormous wealth of information about the Milky Way, and a complete sky survey, detecting starburst galaxies and obscured quasars to very high redshifts. Together SCUBA2, ALMA, Herschel, and Planck will provide insights to a large range of astronomical problems ranging from planetary disks and star formation through to galaxy evolution and the formation of black holes in the early Universe. The key VO interest here is that much of the value of deep FIR-submm observations requires matching observations at other wavelengths, for example to provide reliable typing of sources in statistical studies. AstroGrid will make it transparently easy to construct key data sets spanning radio/FIR/IR/optical/UV/X-ray data.

2.6 An example science question

The AstroGrid service will provide capabilities that directly support key science questions.

For example - *how do galaxies, stars, and planets form?* λCDM models suggest that galaxies, including our own Milky Way, form via a series of hierarchical mergers. With the discovery of the Sagittarius dwarf (Ibata et al, 1994) there was direct evidence of galaxy merging with the Milky Way. The 2MASS infrared survey has been used to trace galactic structure (e.g. Majewski et al, 2003), and exciting new studies based on optical SDSS data are revealing tantalising new evidence for complex merger streams in our galaxy (Belokurov et al, 2006). The combination of VISTA VHS infrared data with the SDSS data, both covering large areas of sky, and benefiting from the much deeper VISTA data which will probe galactic structures at much greater distances than possible with the shallower 2MASS data, will enable astronomers to progress their understanding of the merger history of the galaxy. By mapping out, to large distances (VHS will probe a factor of 40 fainter than 2MASS, thus 6 times further in distance out to 50kpc for the stellar streams remnants of merger events associated with the formation and genesis of our Galaxy). and over the entire galaxy it will be possible to decide which of the currently proposed models describing how the Milky Way reached its current state are most appropriate (e.g. Abadi et al. 2003, 2006; Bullock and Johnston 2005; Font et al. 2006)

AstroGrid will provide a vital role in addressing this science question. It will allow for the automation of the comparison of optical and infrared data sets via the federation of the VHS and SDSS catalogues. The system design will allow for the high throughput analysis of the 10,000 sq degrees of VHS data with stellar samples up to 10^{10} objects. Relevant applications to allow for the identification of stellar over-densities – thus highlighting the positions of stellar streams – will be implemented in the AstroGrid workflow environment. Capabilities such as 'AstroScope' will be used to automate the cross reference of discovered features to identify, for instance, known or new features such as globular clusters, dwarf galaxies, etc (see for instance the discovery of new dwarf galaxies from the SDSS stellar density maps – Belokurov et al 2006).

Major galaxy evolution occurred at z>1. Deep IR surveys (as proposed with VISTA, reaching K ~21.5 which equates to the detection of a L_* galaxy at z~4) will probe the evolution of clusters of galaxies with a focus on the period of major evolution, namely $1 < z < 4$. AstroGrid will play a vital role in enabling the combination of these data sets with those from the X-ray to allow for the comparison of the cluster gas phase properties with the integrated stellar properties of the component cluster galaxies. Combination with SZ telescope data – such as that from APEX – will facilitate the detection of new galaxy clusters at the highest redshifts – thus a powerful evolutionary probe. Key elements of AstroGrid here will be in enabling the combinatorial analysis (images, catalogues) of the large diverse key datasets: X-ray, Optical, IR, Far-IR, Sub-mm.

2.7 Moving to full UK VO service operation

At the completion of the AstroGrid2 project at the end of 2007, AstroGrid will have completed the development of its baseline system components, and so will be ready to deploy them across the constituent consortium institutes, and so form a VO science service for the UK astronomy community. The benefits of this service are summarised in Section 3; the technical case for the system and how we implement it is given in section 4; the management plan is given in section 5; and the costs are analysed in section 6. In short, we need to :

- work with the data centres to ensure "VO readiness" of all the key datasets
- deploy all the key datasets through our "Data Set Access (DSA)" software
- set up new MySpace disk storage and processing power to run VO services
- deploy "core" VO services at the six main sites (see below)
- help University Departments across the UK to install "local" VO services
- set up thorough documentation
- set up and run a Help Desk system for astronomers
- run a training and support programme for astronomers
- run a series of competitive "Science Calls" to develop new tools
- maintain and upgrade the software
- assess and test new technologies, to keep refreshing the infrastructure

This will require significant initial setup effort, but will taper down to a steady state operation.

The "core VO services" are **Registry**, to enable data discovery; **Job Execution Service**, to allow complex workflows; **MySpace**, to enable extracted data storage, and a group collaboration space; **Astro Runtime**, to allow almost any data analysis application or tool to interoperate with the AstroGrid system; and a series of **standard applications** which will be launchable from the system, the most important of which is the **AstroGrid Workbench** which allows one to query the registry, browse the MySpace filestore, monitor job progress and so on; but also has tools such as **Astroscope** for interactive global data discovery, and third party tools such as **Aladin** for manipulating images, **VOSpec** for analysing spectra, and **TopCat** for manipulating tables and plotting.

The "local" services at all University Departments are **Community**, which handles the registration and authorisation of users and so makes single sign-on possible; **Publishing Registries** which make it possible for anybody to include their own data in the VO; and any **third party tools** which a Department cares to offer to its local users or others. These latter are the responsibility of the locals, not of AstroGrid, but the Astro Runtime makes it easy to write tools that work with the framework.

The AstroGrid service is targeted to support the professional UK astronomer user base – some ~ 2000 UK astronomers located in ~40 institutes across the UK. (The underlying architecture is in fact capable of supporting many more users.) This user base informs the specification of the baseline system elements required to underpin the AstroGrid VO service in the UK. The service described in the following sections assumes that possible extensions of the system to support the data processing, workflow and data access needs of wider audiences (e.g. amateur astronomers, etc) would be sought via supplementary funding proposals. The AstroGrid baseline service provision will be supported via a limited hardware provision in the first instance to provide for user storage space (MySpace), and some workflow computing provision. In terms of providing a scaleable and sustainable service in the longer term, all AstroGrid components are deployable on standard institutional computing equipment. With the expected increase in astronomer analysis of discovered data utilising the AstroGrid workflow capabilities, we expect that the computing power to support this will eventually be provided via departmental servers.

The "Science Tools Call" is an interesting new aspect of our plan. May 2006 saw the first science tools call. This programme was to solicit user programmes to be enabled by the development of AstroGrid science workflows. The three initial programmes, selected through an independently judged peer review process, which will be supported Jul-Dec 2006, cover a cosmology, galactic structure and solar physics case. Developing AstroGrid specific capabilities for these will enable topical science programmes to be carried out. One programme focuses on providing specfic workflows to automate the process of information retrieval for objects in the XMM Cluster Survey. Another will allow access to galactic plane survey data, whose science data products will only be accessible through AstroGrid VO protocols, allowing for the generation of galactic structure maps using certain stellar samples as probes of structure.

Continuation of this 'on-demand', peer-reviewed, rapid turnaround science call opportunity will be a component of the AstroGrid Virtual Observatory Service. This will allow AstroGrid to develop specific capability (at modest additional effort) to meet high priority needs of the community, especially relevant to benefit those programmes of newly emerging importance (e.g. future programmes equivalent to the GRB ToO programmes of today).

2.8 AstroGrid and the global VO

Our move to a service system is timely in the context of global developments.

Within Europe, the two major organisations to which the UK provides significant contributions, namely ESO and ESA, will be making available a wide range of science data products through their emerging Science Archive Facilities. The SAF at ESO (Garching) and the ESAVO Science Archive at ESAC (Vilspa) will be largely operational by 2008-2009. In this context, AstroGrid is working closely with ESO and ESA (through the VOTECH project) to ensure the practical takeup of the core AstroGrid VO components leading to the accessibility of their science data products. Additionally initial discussions (Aug 2006) are now underway with CADC to provide the AstroGrid system level access to UK data sets held there – including the Gemini science archive data. Through the UK

AstroGrid service, any UK user will gain full access to science data resources held at ESO/ESA – through the complete range of VO protocols offered by AstroGrid (e.g. image access, catalogue access, spectrum access and so forth). It is worth noting that ESO and ESA are concentrating their VO activities on the distribution of science ready data products generated by their facilities (VLT, VST, etc for ESO; XMM, GAIA etc for ESA). They will not offer a VO service *per se* to the UK, but rather offer key VO resources, which will be accessible via AstroGrid.

Through the Euro-VO initiative (see later sections) ESO and ESA will gradually move in the direction of fuller service provision, but in the medium term this will not provide the level of service to the UK that we propose; and our intention is to retain our technological leadership within Euro-VO, so that much of such a fuller service may eventually be effectively outsourced to the UK.

In the USA, the NVO is moving towards creating a service architecture, after concentrating for some time on tools and user relations (the inverse of our evolution !) Their plans, like ours, are focused on the integration of the major US resource providers - CfA, IPAC, STScI etc. Their remit will be to provide facilitating services to the US community. Very likely therefore UK or European users of the NVO system itself would be severely limited in terms of the functionality that they are able to access (in terms of access to workflow systems – slow queues, limited disk space for storage etc). However, UK astronomer use of the UK AstroGrid system will give full access to US data resources (Chandra, SDSS, VLA etc) coupled with the range of AstroGrid service - fast workflow, large MySpace staging storage, access to large computing provision, access to UK/ European data resources.

2.9 The next wave: building on the full VO service

In addition to providing a stable VO service, AstroGrid will continue to develop new capabilities to meet both the evolving needs of the UK science community and the changing IT environment in which the AstroGrid exists. Thus it may need to adapt to exploit for instance availability of new computational grids, network topologies and so forth. The focus of the core VO engineering team will be to ensure that the AstroGrid service remains at the forefront of VO systems, with the ability to provide the relevant capabilities to meet the evolving needs of the UK astronomy community.

The computational infrastructure within which AstroGrid operates is also ever changing – thus AstroGrid will continue to adapt to these changes (e.g. in operating systems, in development tools, in languages such as Java). AstroGrid will be the point of interface between the astronomy and information technology communities.

New technologies, new standards will be assessed, and where appropriate exploited to give new capabilities. Thus, ontologies will form the basis of powerful new resource discovery tools, for instance allowing the automation of the development of spectral energy distributions of objects (c.f. the work in the Radio with SPECfind, a tool to extract cross-identifications and radio continuum spectra from radio catalogues: Vollmer et al, A&A 2005, 431, 1177)

In developing and adding these new capabilities to the services provided through AstroGrid, the science support team will have a key role in the quality assurance of these new products to ensure the scientific validity of the tools.

(3) Benefits and Objectives

3.1 Objectives

Our aim is to create and run a sustainable Virtual Observatory service for UK astronomers, in close collaboration with data centres hosting the key datasets for the next decade. The top level objectives will be:

● to maximise the science return from investments in missions and facilities such as WFCAM, VISTA, XMM, e-MERLIN, SDO, GAIA, ALMA, and so on, completing the end-to-end science chain;

● to give UK astronomers a headstart in extracting the science from these international facilities;

● to make getting science from the data faster and better; and

● to make possible ambitious data intensive analyses which otherwise seem implausible.

● to provide a virtual space where astronomers can collaborate on science projects.

In achieving these objectives, we will deliver both scientific and technical benefits to the UK astronomy programme.

3.2 Key benefits : Science

AstroGrid will deliver capability targeted to enable key UK science programmes:

- Seeking earth mass planets – from IR/Optical surveys, transits
- Structure of the galaxy – from large scale optical and IR surveys with ESO's VISTA, VST
- Formation and Evolution of galaxies at the epoch of reionisation
- Reactive capability to match evolving science priorities through to 2012
- Formation and evolution of stars using ALMA, e-MERLIN

3.3 Key benefits : Science Process

AstroGrid will offer astronomer end users the following science benefits which will fundamentally improve the data – information – knowledge – insight cycle:

- On-line space for data discovery, analysis and intepretation (workbench integrated virtual storage, also logbook functionality)
- Seamless comparison between observational and theoretical simulations
- Single point of access to global data resources through simple workbench
- Common and fast (high speed) access mechanisms to global data resources
- Single point of access and common interface to wide range of server and client side applications

- Workflow builder and workflow engine enabling advanced science analysis
- Single point of access to both local and high end (HPC class) compute resources (appropriate for both large oand small scale tasks)
- Ability to publish reduced data products to the community via MySpace (c.f. papers on astro-ph)
- Ability to publish the science process to the community (e.g. workflows to MySpace)

3.4 Key benefits : Service

AstroGrid will offer UK Data providers the following benefits, improving their competitive advantage :

- Economies in data distribution – reduce overheads in terms of UIs, access control, authorisation, interface protocols
- Single point of contact for information on APIs
- Flexible VO infrastructural components within which science data specific alogorithms/ workflows/ processes can be published
- Ability to rapidly create value added data collections – science data plus associated datasets (c.f. database VIEWS)

3.5 Key benefits : Technical

AstroGrid will deliver key technical advantages:

- Complete VO system and infrastructure
- Component architecture for deployment by partner organisations and VO projects
- Best practice in s/w development – knowledge transfer to other PPARC s/w projects
- Interfaces to the VO – available for use by developing data flow systems (e.g. VISTA, GAIA)

(4) Technical Case

4.1 Activities for a UK VO service

In order to achieve the objectives listed in section 3.1 we will do three main things :

● install, operate, maintain and periodically upgrade all necessary software infrastructure components at each participating data centre

● provide user support and training outreach to the user community

● run a modest programme assessing and prototyping new emerging technologies, in order to stay ahead of the international game, engineering new software components as necessary.

In the following sections, we will first step back and analyse what is needed to achieve the VO vision; then will take a look at how far we have already got, internationally, and within AstroGrid; and then we will examine the above activities a little more carefully.

4.2 Building the data infrastructure

The arguments of section 2.3 point towards a service infrastructure centred around key data centres and resource centres. (i) The size of databases, the last-mile problem, and the requirement for I/O and CPU-intensive analysis all move us away from the "download and analyse at home" paradigm to the "analyse at source" paradigm. (ii) For good scientific reasons, a variety of different institutions and consortia will be responsible for each of the upcoming key databases, including not just processing and storing but providing science access services. The management of the data and the associated services,need to stay next to the scientific experts. Although the supporting staff can sometimes be geographically separate from the data, central warehousing is not in general a solution, except possibly for legacy databases.

The astronomical data infrastructure is therefore not a monolithic system; it is not a hierarchy, like the LHC computing grid; neither is it a democratic peer-to-peer system. Rather it is a small collection of professional resource centres, and a large diverse community of end users. What is needed to create the data infrastructure is :

1. Creation of the data by facilities, and processing to a useable state.
2. Design and construction of science user archives.
3. Development of standards and protocols, and their international agreement.
4. Design and construction of "glue" software components - registry, workflow, virtual storage, single sign-on, data publication tools, application interfaces.
5. Construction of client tools and server-side applications to do science with the data.
6. Publication of access to the science archives as data services, using VO interfaces.
7. Deployment of the "glue" services.
8. Deployment of tools and applications using VO APIs.
9. Establishing and maintaining resource registries and user support systems.
10. Running an operational system.

Items 1-2 are hopefully in hand, and represent most of the cost. Items 3-5 are what the AstroGrid project has been doing (with international partners) since 2002. Items 6-10 are what we have to do next. Experimental versions of 6-10 are already beginning, but from 2008 we propose to implement a fully engineered and reliable service. At the same time, the work of 3-5 will continue to evolve. Finally, we propose to ensure a firm link between the datasets and the VO infrastructure by *sharing staff* between data centre activities and VO operations.

4.3 Status of the global VO

We now have most but not all of the necessary standards in place, a working but not yet robust set of infrastructure software components, a considerable number of working services, and a clear international willingness to complete the vision.

The IVOA. Three major inititiatives began in 2001 - the US National Virtual Observatory (US-NVO) project, the UK AstroGrid project, and the European FP6 funded Astrophysical Virtual Observatory (AVO) project. (AstroGrid, along with ESO, ESA and CDS, was actually a partner in AVO. This enabled the addition of funded positions to AstroGrid, but also meant that a fraction of our effort was explicitly directed to European ends). In 2002 these three projects formed the International Virtual Observatory Alliance (IVOA). Over the next few years smaller national projects began all over the world and joined up; the IVOA currently has eighteen members. The IVOA has two roles - it is a standards body, with processes closely modelled on the W3C, and a forum for sharing of ideas, software, and experience. It has a set of technical working groups and twice yearly international "interoperability workshops". Standards are not agreed until example uses have been implemented by working projects. Once agreed by the IVOA, they are passed on to the IAU for formal endorsement. Progress in agreeing key standards has not always been as fast as we wished, but compared to the traditional methods through IAU working groups, it has been lightning fast. This clear progress and global community cohesion has been widely admired throughout the e-science world.

Progress on standards. Most of the key standards are now in place - resource and service metadata, resource identifiers, registry standards, universal content descriptors (UCDs), data query language syntax, table data exchange format, data access protcols for images, spectra, line data, time series, and catalogues, and a whole series of web and grid service interface standards. The final key first generation standards are expected to complete over the next year - authentication methods, and storage addressing protocols. By the end of 2007 therefore everything will be in place to make a joined up global VO. Throughout this development, AstroGrid has been ensuring that its software infrastructure is compliant with standards - often of course by pushing standards that fit the prototypes that we had already engineered.

Complementary approaches. The three main projects (NVO, AstroGrid, AVO) took interestingly complementary approaches. NVO concentrated on getting simple datasets, coarse-grained registries, and tools available for users as soon as possible, but had essentially no architecture or back-end infrastructure. AstroGrid, by contrast, concentrated on designing and building infrastructural components - MySpace, workflow, fine-grained registries, application interfaces, authentication. This was risky, as for some time there was very little to *see*, but has now paid off, as users have a much more powerful system to use. AVO concentrated on implementing end-to-end demonstrations of science useage, and building towards a politically viable solution for Europe.

4.4 AstroGrid software and services

AstroGrid has now built most of its core infrastructure, has running implementations, an initial set of data services, and approximately 300 registered users. A full update on AstroGrid progress is provided at Annex C.

The AstroGrid Software. The AstroGrid software is Java based and is structured around inter-communicationg web services. It has an asynchronous architecture - necessary for running workflows using distributed services. The key components are as follows. (i) **Registry** - a database listing metadata about available services, including worldwide data services, applications that can be run, and internal AstroGrid services. IVOA compliant registries around the world can harvest from each other. (ii) **Job Execution Service**. The engine room of Astrogrid workflows. The flow of processing is made possible by our Common Execution Architecture (CEA) which enforces standard process interfaces. (iii) **MySpace** - virtual storage in cyberspace. Sites offering bulk storage run MySpace Server; sites offering access run MySpace Manager. (iv) **Community**. This is software for administering users and transmitting identification information to allow single sign on. It is installed and run at local sites, not by a central AstroGrid "authority". Users can then, for example, define a "group" of collaborators who can see the same MySpace. (v) **Astro Runtime**, built on the (CEA). This allows applications writers easy access to AstroGrid services, and methods for applications to interoperate. (vi) **AstroGrid Workbench**. Any applications can use the AstroGrid services (read and write to MySpace, run workflows etc), but we offer a standard interface offering resource discovery, registry search, query builder, workflow builder, etc, as well as access to some applications that already "speak AstroGrid" - Aladin, for viewing images; VOSpec, for analysing spectra, and TopCat, for manipulating tables. Note that all of these applications were written outside AstroGrid. (vii) **Data Set Access (DSA)**. This is software intended to enable data providers methods to publish data through standardised VO interfaces. (viii) **Science Services**. A small number of ambitious workflows to produce end-to-end science have been pre-packaged as "parameterised workflows".

Data services in AstroGrid. IVOA protocols currently allow us to address (i) libraries of images, (ii) libraries of spectra, and (iii) catalogues of sources. Over the next year a protocol for time series should be complete. The catalogue access protocol so far allows simple searches by position (cone search) but we expect over the next year to reach agreement on protocols for accessing any astronomical relational database through a SQL-like interface. (This will also allow crossmatching between different databases). Publishing data services using these protocols is however a significant amount of work. A considerable number of image and cone-search services are now available, although most of these are in the US; a relatively small number of preliminary SQL services are available. This is where the most progress needs to be made in order to get a working VO of real value.

Working with users. AstroGrid has started a series of workshops in University departments, training astronomers in the use of the new technology. We decided to start this process early, even though the system is not quite complete, robust enough, or with enough data services. Feedback has been very positive, and the experience has been influential in producing our final design. We have also just run the first of a series of "Science Calls".

Readiness for operations. The key software components are almost all complete, but need significant re-engineering and "productisation" to reach the standards of reliability, robustness, and performance speed that we need. (Robustness also needs deployment redundancy). Some first data services are in place, but a lot more needs to be done. We have a preliminary user interface, and have begun a user community relationship, but genuine user support has yet to be established. In short, in a year's time we will be exactly poised to move into full deployment and an operational service.

4.5 Why is an organised UK VO service needed ?

The VO *per se* is not a monolithic system, but a way of life - standards and protocols; data services that all speak the same language; software modules that can interoperate; applications and tools that are "VO aware". Even our own AstroGrid software components are designed to be "mix and match" so that other projects and data centres and University departments can deploy which components they see fit. One might then argue that once we have defined standards and built the core software, the VO should happen spontaneously, in a kind of data centre free market. This is in principle possible, but in our judgement not the best value for the UK. Instead, as a consortium of data centres we choose to offer <u>combined services</u>, sharing continuing development and maintenance, and offering a uniform interface. We still offer separate and diverse constituent data services, but *share* what is necessary to provide a surface layer of VO services - virtual storage, job execution services for workflow, registries of resources, and VO appplications. As well as providing a *better* service for UK astronomers, it will provide VO services more *cost effectively* than would be the case if the data centres provided these services in competition with each other. (Data centres will still of course compete with each other to build the actual archives and data services that populate the VO).

An alternative suggestion could be that core VO operations should be provided by a central service organisation, such as ESO or ESA. Such organisations certainly have a key role to play, and AstroGrid will collaborate with them closely. However, this is certainly not sensible as a complete solution, as the VO services should stay closely connected to the data services, which are distributed. Furthermore, this will not produce a competitive enough solution for *UK astronomers* on a fast enough timescale. Even for continuing development and improvement, the data centres have the most incentive to do this rapidly and effectively. Another familiar argument is that one should simply wait for the US to finish; because they will ignore us and everybody will end up using their software. In fact, the US and UK projects have collaborated closely, and the IVOA process ensures that none of us are building systems that are dead ends. Furthermore, although the US NVO has some key strengths, in many respects we are in a substantially stronger position to move to an operational service, and so we would be foolish not to do so.

4.6 Running a VO service

In Annex A and in section 4.2 we provide full details of the work we need to carry out. Here we examine briefly the principles of what is needed.

<u>Deployment</u>. A large amount of work at the start of the project will involve deploying software and data services. First and foremost we need to work with the existing and planned data archives to publish data services using the Astrogrid DSA, so that they are visible to the global VO infrastructure. This work will of course be led by the "embedded staff" shared with the data centres. We will also provide assistance to organisations outside the consortium who wish to deploy datasets against the DSA. Second, we will deploy core VO services at each of the six main sites - MySpace, Registry, and Job Execution Service, along with server side applications and launch points for a

wide range of Java Web Start applications. (These are applications which run on the client, but update each time they are launched from a server-held version). Finally, we will seed and assist deployment of "local" VO components in Astronomy Departments across the UK. This includes the "Community" software that manages user authentication, so that users can achieve single sign on simply by logging on locally, and "publishing registries" (as opposed to the "Full Registries" at core sites) via which users can make their own resources (FITs files, mini-databases, local tools) available to the VO.

Most of the above concerns staff effort and software installation. DSA components will be deployed on the hardware hosting the actual data services; however a small amount of VO-specific hardware is necessary to make a robust and reliable VO service. For each of the core sites we will deploy one server running core VO services (Registry, JES, MySpace) and one running and launching VO applications. Attached to the MySpace server we plan 10TB of storage per site.

<u>Operation, Maintenance, and Upgrading</u>. Running the deployed system is significant work, because the world does not stay still. We will need to undertake routine system management, backup, bug fixing, and so on. We will continually be improving and enhancing the code. We will need to regularly upgrade code, both because of external changes - new IVOA or GGF standards, language and platform upgrades, incorporation of new technology - and because of evolving user demands, i.e. adding new functionality. This will include for example building reference implementations of new standards, or re-engineering to use external components from other e-science projects that we decide have become preferable to our in-house components. Some of this work is relatively routine, and is included in our work plan as "VO operations". Other parts involve significant re-build or even re-design, including extensive integration and testing, and is included in our work plan as "VO engineering". We will maintain a "Chinese Wall" between Engineering on one side and Deployment and Operations on the other, issuing carefully controlled releases of new component suites.

<u>Sustainability</u>. We expect to work with the rest of the e-Science world to achieve long term sustainability of our software. Some of our software solutions will be put forward for adoption by the Open Middleware Infrastructure Institute (OMII) ; in other cases we will adopt OMII recommended components in place of our own if and when they are stable and meet our needs. For example, we are already investigating whether to replace our Workflow builder with Taverna; and how to integrate DSA and OGSA-DAI. Such developments will give us long term stability and performance improvement, but at the short term cost of extra re-engineering work.

<u>User Support</u>. We intend to provide active support to two classes of user. The first class is that of technical users - data centre staff, applications, programmers, and departmental systems administrators. We will be making our components as "plug and play" as possible, with semi-automated installation, configuration scripts, and thorough documentation. However we will also provide active support, with a Help Desk and training workshops. The second class of user is of course astronomical end users. Again, our VO services and applications tools are designed to be as straightforward and self-explanatory as possible, and we will provide (and update) user guides, FAQs, and tutorials, but active support is essential - we plan to provide a Help Desk, and run science-user workshops.

In addition, we plan to run a series of regular "Science Calls". This is a method of encouraging uptake, of flushing out new user requirements, and most importantly of engaging the community in the VO enterprise. May 2006 saw our first competitive science tools call, peer reviewed by the

Science Advisory Group. We invited proposals for new tools or workflows aimed at specific science goals, and are providing staff effort to work with the successful proposers to implement their programmes. The first three programmes cover cosmology, galactic structure and solar physics cases. Continuation of this 'on-demand', peer-reviewed science call opportunity will be a component of the AstroGrid Virtual Observatory Service. It will have a rapid turn-around (6 months) so that we can meet newly emerging high priority programmes.

Staying ahead of the curve : R&D. AstroGrid is in a strong position today for three main reasons - because we concentrated on building a genuine infrastructure; because we have played an active role in developing new standards; and because we have experimented *critically* with new technology. Our acknowledged role as "prime contractor" for Euro-VO technology development recognises our ability to do this. If the UK data infrastructure is to still be world leading in five years time, we must invest in continuing R&D. The general plan is that within VO service operations we maintain a modest stream of R&D effort at a minimum level, and that we seek funds elsewhere (FP7, JISC, EPSRC) to build a more ambitious R&D programme with our European partners, equivalent to the current successful VOTECH project.

Currently a significant fraction of our effort goes towards planning, developing, and testing VO standards within the IVOA working groups, and we foresee this continuing indefinitely. Many of the IVOA standards we see as first generation standards that will need to be significantly overhauled or even completely re-conceived. Meanwhile we need to identify and utilise emerging leading edge technologies - for example, the semantic web, authentication technologies, distributed computing (grid) technologies, new data mining algorithms. We have no intention of doing any original research. The point is to identify, critically assess, test and prototype, and decide what is ready to deploy in engineered product - and what is *not* ready.

4.7 A sustainable VO service.

For some years now, offering any kind of professional public service has involved offering web pages, requiring both web page design and development, and running a web server using Apache server software. In addition, a modern data centre needs to have its archives available online and properly documented; and increasingly it is expected that data are accessible through a query-able interface running over some kind of relational database. All this imposes both a development and operations burden, and so makes it *harder* to be a data centre, but *easier* to be a working scientist. It would be a false economy to not provide the infrastructure, given the aim-point of more and better science. The VO-based data infrastructure is simply the next stage in this evolution. Having invested in *building* that infrastructure, another burst of effort is needed to *deploy* it, and thereafter a slightly lower steady state effort is needed to *operate and refresh* it. Our proposal includes a taper of effort aimed at making the transition from building to operating, to produce a *sustainable service*.

In principle one might imagine future VO-service costs devolved to individual missions. For some aspects, such as data service design, development, and publication, this is correct in the long term, and is where most of the money will be spent. For other aspects, it makes economic sense for the major data centres to pool their efforts in core service operation, maintenance, upgrade, user support, and R&D. These core sites can also for example optimise inter-site bandwidth, establishing UK Light nodes and so on. However, there is also a very diffuse aspect to the VO future, with Departments all over the UK running Community software, astronomers publishing their private data sets, and third party applications writers in a variety of locations contributing VO aware tools.

The other key issue in long term sustainability is the gradual integration of our software with the rest of the VO world and the rest of the e-Science world. Part of the solution is working with OMII, both to deposit our code, and to take advantage of OMII recommended components. But our main target is the rest of the astronomical world; we are encouraging the uptake of Astrogrid components in other VO projects so that they become standard. This has already happened in parts across Europe and in Japan, and the AstroGrid infrastructure has been adopted wholesale in Russia. We have started discussing the idea of forming an "AstroGrid Software Foundation" to which contributions can be made in an open source style.

Figure 1 below illustrates the resulting data infrastructure. Note that the Departments shown are not a complete list, but an illustrative set.

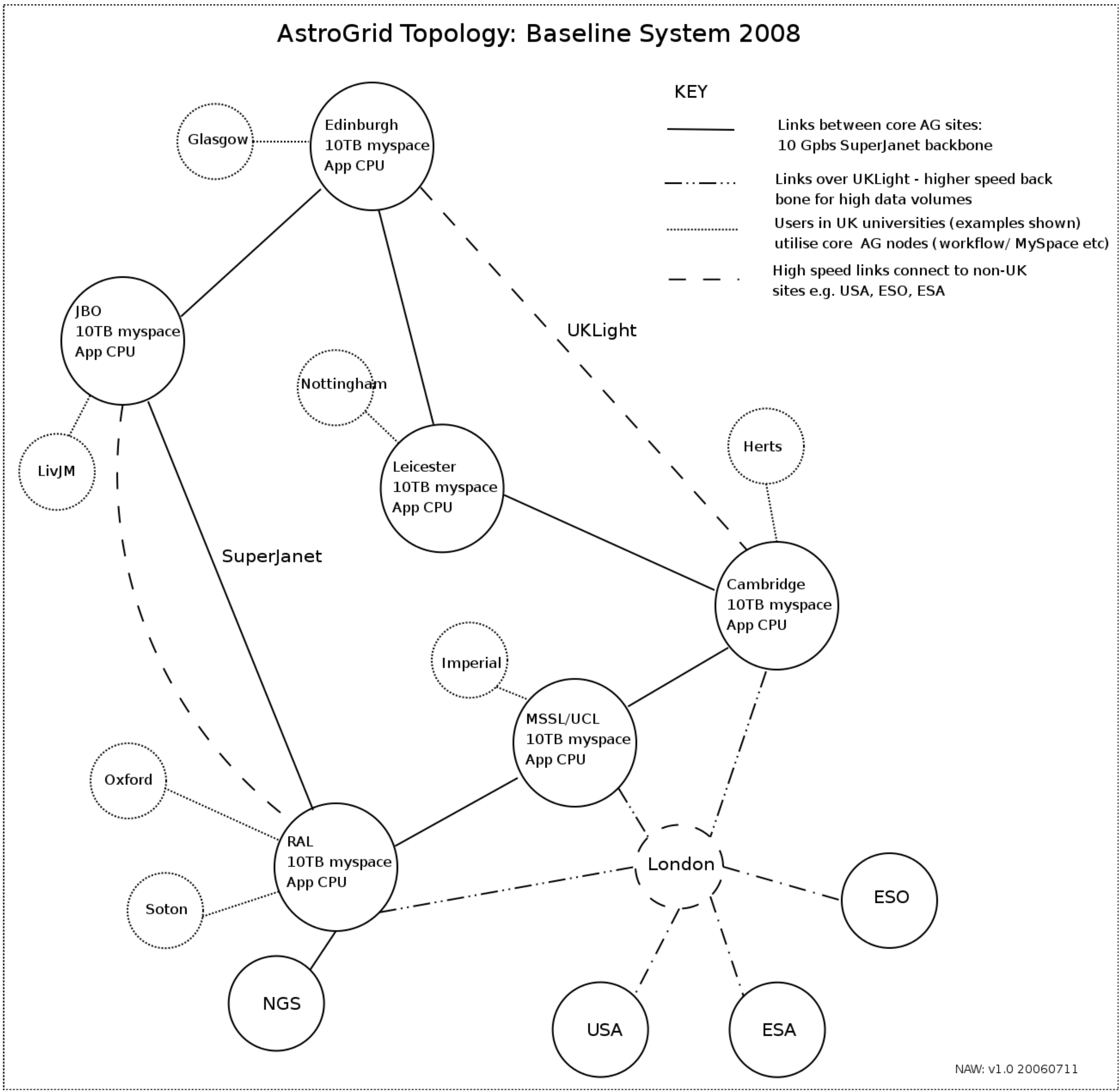

Figure 1 : Illustrative structure of AstroGrid UK VO service

(5) Management Plan

5.1 Work Breakdown Structure

The planned work consists of four workpackages, each with several sub-packages, and each of these composed of several tasks. The full work breakdown is described in Appendix A. Below we show the top level packages and subpackages. The individual tasks are briefly described in section 4.2. Note that WPs are not allocated to institutions. In accomplishing these tasks, the AstroGrid project works as a single distributed team.

Table 1: AstroGrid UK VO Service : Top Level Work Packages

A0 Leadership, coordination and management

A0.1	Policy and Leadership
A0.2	Management

A1 User Support

A1.1	Help Desk
A1.2	Science Engagement
A1.3	Science Call

A2 VO Service Operations

A2.1	Technical Support
A2.2	Deployment
A2.3	Technical Engagement
A2.4	VO-enabling Data Sets

A3 VO Engineering

A3.1	Maintenance
A3.2	Code Enhancement
A3.3	Release Packaging

A4 VO New Technology

A4.1	IVOA Standards
A4.2	New technology

5.2 Brief Description of Workpackage Tasks

Here we present a very brief description of the tasks within the workpackages. Staff effort planned against these tasks, along with a fuller description, is presented in Appendix A.

A0: Leadership, co-ordination, and management

A0.1	**Project Management**
	● Science Leadership

	● Policy and Planning
A0.2	**Technical Leadership**
	● Science Management ● Technical Management ● R&D Management ● Administration

A1: User Support

A1.1	**Help Desk**
	● Identify and deploy suitable Trouble Ticketing system ● Create Help Desk Service Level Agreement (SLA) ● Run Help Desk
A1.2	**Science Engagement**
	● Science user requirements ● Website ● Workshops ● User Education ● Tutorials ● User guides ● User tools help
A1.3	**Science Call**
	● Use case capture ● Science workflow development ● Science verification ● Documentation

A2: VO Service Operations

A2.1	**Technical Support**
	● Define SLA for SysAdmin support ● Define SLA for application programmer support ● Define processes for managing support requests including escalation paths etc ● Deliver SysAdmin and Programmer Support ● Provide support to Deployment teams (A2.2 and A2.4)
A2.2	**Deployment**
	● Deploy AG components to core AG sites running a Deployment and Trouble-shooting Workshop at the same time. ● Publish new Releases ● Identify and encourage non-core Data Centres to deploy AG components ● Maintain deployed systems
A2.3	**Technical Engagement**
	● Programmer documentation ● API documentation ● Tutorials ● HowTos ● FAQ ● Website

	● Workshops ● Scripting ● Application Development
A2.4	**VO-enabling Data Sets**
	● Work with Data Centres to deploy and Register DSA against their data holdings

A3: VO Engineering

A3.1	**Maintenance**
	● Define processes ● Bug fixing ● Standards compliance ● Manage platform and utility upgrades (new OS release, Java upgrades etc)
A3.2	**Code Enhancement**
	● Extend existing code to utilise new standards, interfaces etc ● Add new functionality ● Enhance and improve existing codebase ● Incorporate new technology ● Build reference implementations of new standards
A3.3	**Release Packaging**
	● Integration, testing, and Release Management

A4: VO New Technology

A4.1	**IVOA Standards**
	● Participate in definition of ● Test suitability of ● Identify need for new standards
A4.2	**New Technology**
	● Identify ● Assess ● Prototype

5.3 Project Schedule

As we are moving into an operations phase, most activities are continuous. However there are some key planning milestones, as shown in the table below. Note that our standard planning process produces very detailed plans for each six month cycle.

Leadership		
L1	First issue of Project Lifetime Plan	Y1 / Q1
L2	Lifetime Project Plan review	Y2 / Q3
L3	Lifetime Project Plan review	Y4 / Q1
Support		

S1	Help Desk software installed and running	Y1 / Q1
S2	SLA defined	Y1 / Q1
S3	Workshops	1 / Qtr
S4	Science call	1 / Year
S5	Help desk operation	On-going
S6	Web site maintained	On-going
S7	Documentation maintained	On-going
Operations		
O1	Sysadmin support SLA defined	Y1 / Q1
O2	App programmer support SLA defined	Y1 / Q1
O3	Phase 1 deployment delivered	Y1 / Q2
O4	Phase 2 deployment delivered	Y1 / Q4
O5	Phase 3 deployment delivered	Y2 / Q2
O6	Phase 4 deployment delivered	Y2 / Q4
O7	Workshops delivered	2 / Year
O8	Sysadmin/programmer support	On-going
O9	Deployment Team support	On-going
O10	Maintain deployed system	On-going
Engineering		
E1	Problem resolution processes defined	Y1 / Q1
E2	Cycle 1 plan produced	Y1 / Q1
E3	Cycle 2 plan produced	Y1 / Q3
E4	Cycle 3 plan produced	Y2 / Q1
E5	Cycle 4 plan produced	Y2 / Q3
E6	Cycle 5 plan produced	Y3 / Q1
E7	Cycle 6 plan produced	Y3 / Q3
E8	Cycle 7 plan produced	Y4 / Q1
E9	Cycle 8 plan produced	Y4 / Q3
E10	Cycle 9 plan produced	Y5 / Q1
E11	Cycle 10 plan produced	Y5 / Q3
E12	Code maintained	On-going
E13	New functionality added	On-going
E14	Releases packaged and published	On-going
Research		

R1	New Technologies Opportunities report	Y1 / Q4
R2	New Technologies Opportunities report	Y3 / Q4
R3	IVOA stds defined and tested	On-going
R4	New technology identified and prototyped	On-going

5.4 Management Structure

The management structure follows the model we are currently using successfully, with some minor adjustments and name changes.

AstroGrid Consortium Board (ACB). This consists of one of the Co-Is from each consortium institution. The ACB defines top level policy and takes decisions on resource allocation. It also provides oversight and guidance, and monitors progress of the project against agreed goals and against the expenditure plan.The ACB meets quarterly or more often as necessary, receiving formal reports from the Project Manager and Project Scientist, and other papers as required. Minutes and actions are recorded and tracked.

Table 2: AstroGrid Consortium Board

Institute	Board Member	Notes
Edinburgh	Prof Andy Lawrence	Chair
Cambridge	Dr Richard McMahon Dr Nic Walton	 Project Scientist
RAL – Space Data	Prof Peter Allan	
RAL – Solar System	Dr Ian McCrea	
Leicester	Prof Mike Watson Mr Keith Noddle Mr Tony Linde	 Project Manager R&D Manager
MSSL, UCL	Prof Len Culhane	
Jodrell Bank Observatory, Manchester	Dr Simon Garrington	
University of Portsmouth	Prof Bob Nichol	

AstroGrid Management Team (AGMT). From day to day, management of the actual work is undertaken by the senior staff - Project Manager, Project Scientist, and R&D Manager. These people are supplemented by the PI and one-two other members of the ACB to form the Management Team. (The ACB members of AGMT can rotate.) The AGMT holds planning telecons approximately once per fortnight, and is consulted by the senior staff on a regular basis in between. The AGMT is responsible for strategic direction and planning, for producing the six-monthly plan and seeing that it is implemented; for producing material for PPARC; and for liaising with external partners, such as Euro-VO and IVOA. They report quarterly or as required to the ACB. Clear changes are put to the ACB for approval.

Advisory Groups. Advice is taken approximately every six months from meetings of two bodies commissioned and run by the project. The first is the AstroGrid Science Advisory Group (AGSAG), with a mixture of active astronomers who advise on whether the project is meeting its scientific goals, provide input to new developments, and assess the competitive science calls. The second is the Resource Providers Group (RPG). This brings together representatives of data centres from outside the consortium, applications developers, and systems managers from the community, to provide advice on whether the project is delivering their technical requirements in participating in the new infrastructure.

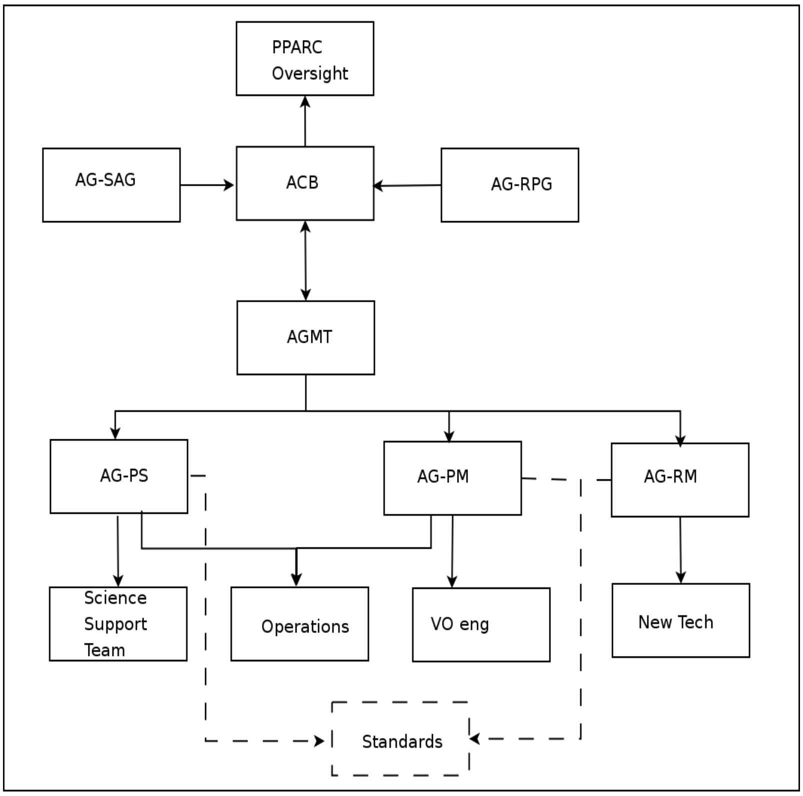

Figure 2 : Management, Oversight, and Advisory structure for AstroGrid UK VO service operations

Internal Staff Teams. Within the project, staff effort is structured into teams matching the top-level workpackages - Science Support Team, Operations Team, Engineering Team, and R&D Team. These teams are fixed within any one (six-month) planning cycle, but not necessarily from cycle to cycle; the Project Manager can deploy staff to teams as required by developing circumstances. The Project Manager has overall responsibility for planning and overseeing deployment of staff effort. Within this overall planning, the Project Scientist is primarily reponsible for the Support Team, the Project Manager for the Operations and Engineering Teams, and the R&D Manager for the R&D team. Note that, by agreement with local line managers, the Project Manager has direct control over individual staff members, rather than working through local workpackage managers.

5.5 Project Planning and Change Control

Internal Planning. Project planning will follow the pattern we have established for AstroGrid-2. At the beginning of the project we will agree a "Lifetime Project Plan" with a set of intended goals and milestones. (This will be considerably fuller than the very brief schedule shown in section 4.3). Within this framework we then follow a six month planning cycle. Following a set of planning meetings involving more or less all the staff in various combinations, the AGMT are responsible for producing the "Top Level Cycle Plan" which is set of typically about 10-20 dated deliverables to be achieved during that six month cycle. This plan is put to the ACB and amended as required; it then becomes formally agreed and does not change during the Cycle. The Project Manager is then responsible for expanding the Top Level Cycle Plan into a Detailed Project Plan, but this is for the benefit of himself and his staff, and can evolve rapidly. The AGMT monitor progress against the top-level plan and make planning changes as necessary. The ACB receive reports on progress against the Top Level Cycle Plan on a quarterly basis.

Software Release Control. AstroGrid-2 will by completion have delivered a set of infrastructure software components, complete with installation methods and documentation. These will be deployed both by internal organisations (the data centres in the consortium) and external entities such as other data centres, astronomy departments, and external VO projects. During the project, these software components will evolve, improve, and be replaced, as a result of the work in A3 and A4. New versions will be packaged and issued in distinct releases, after full integration testing.

Oversight and change of Goals. We assume that PPARC will maintain an Oversight Committee. We expect that the Oversight Committee will approve our Lifetime Project Plan, and will have sight of our six-monthly Cycle Plans in order to track our progress. If it seems necessary to alter the scope or goals of the project, the ACB will develop a Revised Lifetime Project Plan for approval by the Oversight Committee. AstroGrid will establish a set of operational performance targets appropriate for the delivery of a VO service to the community. Therse targets will cover areas such as service availability, response targets, helpdesk item turnaround and so forth. These targets will be established at the start of service operations (Jan 2008) and continually monitored throughout.

5.6 Resource Allocation and Monitoring

Financial Resource allocation is relatively simple, as our costs are dominated by staff effort, and this will primarily be decided up front at the beginning of the project by the ACB. However, if staff leave, or it is thought necessary to call on the Working Allowance, the Project Manager will make a proposal to the ACB on how to spend resource; the ACB will decide; and we will ask for our constituent grants to be re-announced as necessary. AstroGrid staff require extensive travel. Each institution holds a local travel budget, but travel is only by the approval of the PS, PM, or R&DM for the appropriate teams. If institutional spend rates differ for good reasons, we will arrange fund transfer as necessary.

The key element of resource allocation is the allocation of staff effort to tasks. This is under the control of the Project Manager, but is monitored by the AGMT. Note that WPs are not allocated to institutions; the project works as a single distributed team. For planning purposes, we have an initial expected allocation of tasks to individuals (see Appendix A); but from cycle to cycle the PM allocates staff effort flexibly as required.

Overall expenditure will be tracked using the part time administrative help planned, and reports provided to the ACB on a quarterly basis.

5.7 Consortium Members and Key Personnel

Consortium Members. Our consortium is made up of groups at six Universities plus the Space Science and Technology Department at RAL. Six "core sites" are seen as the key data centres; the seventh, Portsmouth, has the potential to develop into a key data centre, and represents specialised experience in advanced data mining algorithms. The seven members are the majority of the consortium which has developed the AstroGrid software and the current preliminary working system, so that a smooth transition to an operational service is assured. Just as important, the consortium partners host the majority of the key science archives for UK astronomy, both today and in the near to medium term future. This then is the consortium that stands to gain the most by pooling effort and offering a combined VO service; and is able to offer the best possible enhanced service to astronomers. Data holdings of the consortium partners are summarised in Annex C.

Project Team. Our plan is based entirely around existing staff, who are either very experienced in the development of VO systems over the last five years, or are experienced data centre staff involved in the development or running of key science archives. Over the last five years, we have gradually arrived at an absolutely top flight team of engineers and scientists. A number of our proposed staff are planned as 50% on this project, with the intention of sharing their time with closely related projects. Note below that some people are members of more than one team.

Andy Lawrence : Project Leader. Lawrence is one of the leading figures in the VO movement worldwide; he was chair of the IVOA in 2005, and is a member of the (four person) Euro-VO Executive Board. He is chair of the Scientific Organising Committee for the upcoming VO Special Session at the IAU General Assembly. The PL is responsible for developing overall strategy and policy, in partnership with the AGMT.

Other investigators. All other investigators have been part of AstroGrid either from the beginning or during AstroGrid-2, and represent key data holdings or science areas - for example optical/IR (McMahon, Lawrence, Nichol); radio astronomy (Garrington); solar physics (Culhane) ; STP (McCrea); X-ray astronomy (Watson, Osborne). There is also a strong tradition of interest in astronomical software and data mining algorithms (Allan, Nichol, Mann). Finally, we note that all of Noddle, Linde, and Walton are seen as "Researcher Co-Investigators" - although they are directly incurred funded staff, they are part of the intellectual and technical leadership of the project.

Keith Noddle : Project Manager. Noddle is a very talented software engineer and manager with extensive experience in the corporate IT sector, who has now been working in the academic sector for the last four years. He joined AstroGrid in 2002 as "Technical Lead" but became Project Manager in 2005. The AGMT works as a team, but the PM has overall responsibility for project delivery, and by agreement of all partners has the power to assign work to all staff, and plan and approve travel and equipment expenditure, regardless of location, in order to achieve project goals. As well as managing delivery and resource, the PM leads the development of the technical vision and architecture for AstroGrid. The PM is aided by Peredur Williams, who provides administrative and financial information.

Nic Walton : Project Scientist. Walton is an active scientist, an experienced telescope manager, and has been with the AstroGrid project since 2001. He has been secretary to the IVOA Executive Committee during most of this period, and is part of a three person team that organises all of the bi-annual interoperability workshops. The PS is responsible for seeing that the AstroGrid VO service meets the scientific needs of the UK community. He has prime responsibility for user support, especially the outreach elements such as training workshops and the bi-annual "science call". He leads the work of the Science Team, and helps the PM to plan their staff effort. We are requesting funding for 75% of Walton; he is expected to work 25% of the time on Gaia, one of the key databases within the future VO.

Tony Linde : R&D Manager. Linde, like Noddle, is a software engineer and manager with long experience in the commercial IT sector. From 2001 to 2004 he was AstroGrid Project Manager. In 2005 he became Project Manager for the FP6 funded VOTECH project, while also increasing his external responsibilities in IVOA working groups, and e-science liaison, especially at JISC, and was re-styled as overall AstroGrid Programme Manager. For the operations phase, we are re-focussing his effort explicitly on R&D, looking towards the future VO. He will lead the work of the R&D team, although formal allocation of staff effort rests with the PM. We are requesting funding for 50% of the time of Linde, with the aim of recovering the remainder through further R&D proposals to FP7, JISC, and ESPRC.

Embedded Staff. We need a close relationship with the science archive activities at the root of the VO concept. We therefore propose that AstroGrid should pay for half the time of a series of staff, the rest of whose time is recovered from data centre activities and/or scientific research. There are two such staff proposed at each of the six core sites. They deliberately have a mixture of skill sets - scientists, web developers, and system managers - in order to match the overall work plan. More effort from such staff is needed at the beginning than at the end of the proposed plan, so we have planned a tapered request. (Names of the embedded staff members for whom we have requested funding are available in the confidential version of the proposal).

Science Team. We propose to use half the time of a team of excellent young scientists, working in four main areas - working with local data centres to publish science archives, undertaking the user support programme, working on the R&D programme, and continuing the development of science requirements. In some cases the other part of their funding comes from the data archive activities, and in some cases from astronomy research grants. (Note that AstroGrid does not request any funded research time). As with the embedded staff, we expect an initial burst of science activity declining to a steady state, so we are planning a tapered request. Science team members are chosen to represent a spread of science interests. (Names of the science team members for whom we have requested funding are available in the confidential version of the proposal).

Engineering Team. Over the last few years AstroGrid has been lucky enough to build up a team of exceptionally talented software engineers, most but not all of whom have been recruited from the IT industry, but who have quickly adapted to the needs of science, while retaining the discipline of the commercial sector. Given a realistic scope for the project, and the increased importance of the embedded staff and the science team, we cannot guarantee keeping all of these talented individuals within the UK astronomy system, but have selected a team that is both very strong and has the right skills mix for the new operations phase. (Names of the core engineering team staff members for whom we have requested funding are available in the confidential version of the proposal).

R&D Team. R&D effort is small overall but is spread across a number of individuals. The key person is Tony Linde who will manage the effort (25% FTE) and also participate (25% FTE), especially in developing new IVOA standards. All of the scientists will spend a fraction of their time developing IVOA standards and scouting out new technologies. Potentially almost any of the engineers could be involved in assessing technologies and building prototypes, but our plan is to concentrate this work on individuals who have shown the most aptitude and creativity in this area, and who already have experience and knowledge in key areas. (Names of proposed R&D team members are available in the confidential version of the proposal). A planned taper is built into this already modest team, but as mentioned elsewhere, our intention is to use this effort as a springboard for applying for other funds to make this work considerably more ambitious.

5.8 Risk Analysis

A full Risk Plan is presented in Annex D. As well as planning mitigation actions, we have used a simple formula to estimate a Working Allowance. The major risks (in the sense of those likely to cause the largest expenditure from the Working Allowance) are, perhaps unsurprisingly, all connected to activities that are new in the operations phase, as opposed to the build phase we are now in. (i) A group of high cost risks centre around the provision of the Help Desk system - queries may be harder to answer than we have estimated; turn round may be too slow leading to user frustration; it may be harder to set up an automated system than we had thought; the system might need additional administration. (ii) The concept of "Science Calls" to engage the community may be more expensive in staff time support than we had estimated - because users proposed very demanding ideas, or because it is hard to organise, or because the proposers need more "hand-holding" than we had thought. (iii) Deployment of components may be more work than we had estimated - for DSA because data centres are not finding it as easy as we expected, or for our own components, because our engineers find it harder to switch to maintenance and upgrade work than we had expected. (iv) Our R&D in new technologies may produce items that are seen as very desirable or even essential to deploy - eg for consistency with new Web or e-Science infrastructure - leading to substantial new design and engineering work.

5.9 Outreach Plan

AstroGrid and the Virtual Observatory have significant potential to improve access to the wealth of science being produced by PPARC's astronomical community. AstroGrid will be able to provide a conduit to connect for instance the superb images acquired by UK researchers to the general public. Potentially it will form the basis for a powerful information infrastructure to enable the general public to analyse PPARC datasets or to enable schools to use suitably designed (for schools) datasets (from PPARC, ESO, ESA etc) within their curriculum project work. This would expose children to astronomy and thus enrich their science curriculum at an early stage. Key 'outreach themes' include:

- VO awareness – inform the astronomy and amateur astronomy communities
- VO use in developing countries – the AstroGrid system is ideally suited to providing world class access to high quality data – no matter where the end user. Therefore this can give astronomers in developing countries improved science access. AstroGrid will seek opportunities to gain additional funding with external partners in this area (c.f. the work with South Africa in AG2)
- Use in schools – AstroGrid will seek to work through the BNSC National Space Science Education Initiative (NSEI) – to develop a VO system suitable to deliver the goals as outlined in the recent Barstow Report.

Public Outreach Plan. Methods by which we will address these themes build on methods that we have successfully developed during the initial stages of AstroGrid (2001-2007) including :

- Interaction with external press: through contact with the PPARC press office
- Interaction with the wider educational establishment: activities based on the use of AstroGrid delivered data products, as exposed through Virtual Observatory protocols, in the context of secondary or even primary education would be pursued through contact with the PPARC schools officer.
- Key contacts at both the ACB and AGMT team level would be identified within the consortium, initially being Nichol and Walton - both with backgrounds in outreach activities.
- The AstroGrid online web presence will contain a section aimed at the general public and provide pointers to outreach material provided through partner VO projects (such as the NVO).

AstroGrid would build on the links that it has begun to form during the AstroGrid2 project to develop outreach programmes – with the expectation being that AstroGrid would partner these outside groups in those programmes likely to benefit from access to AstroGrid VO technology. AstroGrid believes that working with expert external partners represents the most effective method to proceed. An incomplete list of some of the key partners is given below. For many of these there are existing institutional or personal links with the AstroGrid team:

- Royal Observatory Greenwich/ National Maritime Museum
- The National Schools Observatory
- Planetariums − e.g. Armagh
- Science Centres − e.g. The National Space Centre (Leicester), Jodrell Bank Science Centre, Explore@Bristol,
- Museums − e.g. The Science Museum (London)
- Curriculum enrichment projects − e.g. the Millenium Maths Project
- Outreach activities of other VO groups (e.g. NVO)
- Earth and Space and Astronomy Continuing Professional Development (CPD) programme

Links with industry play a complementary role. Some of the partners with whom we already have contact include research units within IT companies (e.g. Microsoft (BARC and Cambridge)), but we also need to look to widen these partnerships.

5.10 Exploitation Plan

Maximising and optimising the exploitation of UK and international data resources by UK astronomers is precisely the point of the AstroGrid VO service.

However we will also make sure that the technical work that AstroGrid does is published and/or publicised appropriately - this means presentations and papers to IVOA and ADASS meetings, to e-science conferences such as the Grid Global Forum and UK All Hands meetings, and appropriate reference to use of AstroGrid in science analysis in as many papers and conferences as possible.

5.11 External Liaison : Euro-VO

AstroGrid has always been a leading part of Europe-wide initiatives in the VO. Together with CDS, ESO, and ESA we were part of the FP5 funded AVO programme (Astrophysical Virtual Observatory). This was seen as a pilot study leading towards the definition of a VO infrastructure for Europe. From that study, we defined three component structures. (i) The VO Facility Centre (VOFC), which concentrates on community support for Europe, and is led by ESO and ESA. (ii) The Data Centre Alliance (DCA), which aims at exchange of best practice and partial funding of deployment activities. The DCA is led by CDS Strasbourg. (iii) The VO Technology Centre (VOTC), which aims at R&D for new software developments, and Europe-wide sharing of new software. The VOTC is led by AstroGrid. As well as putting us in a position to win R&D funding, this recognised leadership of AstroGrid in VO technology means that we expect broad uptake of AstroGrid software components across Europe.

This structure is rapidly becoming a reality. An MOU for Euro-VO has been created which has been signed by six agencies (including PPARC). This does commit any specific funds, but "is an agreement between the partners to conduct a coordinated program of work entitled the EURO-VO that is directed towards the establishment of a persistent Virtual Observatory (VO) research infrastructure for European astronomy." The Euro-VO is overseen by a four-person Euro-VO Executive, which includes A.Lawrence.

Meanwhile, ESO and ESA have committed a small amount of staff effort to "VO systems"; and we have obtained FP6 funding for VOTC and DCA. This provides roughly 6 FTEs in the UK to the end of 2007. A prime target is to achieve FP7 funding at a similar level in order to boost the very minimal R&D strand included in this AstroGrid proposal. None of the Euro-VO plans are ambitious or coherent or reliable enough to provide the operational service that we propose for UK astronomers. But Euro-VO will grow in importance and our strategic aim is to be its core.

5.12 External Liaison : IVOA and other VO projects

The VO only works if it is global. Participating in IVOA workgroups is a crucial part of our workplan. However as well as developing standards, the IVOA is a forum for keeping in contact with all other VO projects. From these contacts we will maintain active collaborative work with key partners. Apart from our European partners, the key projects with which we will keep constant contact are the US NVO project, which also hopes shortly to move to an operational phase, and the Japanese VO project, which has lead responsibility for developments in VO Query Language.

5.13 External Liaison : other e-Science projects

Our closest relationship is with another UK project, eSTAR, which is developing agent based technology for telescope control and has applied for separate funding. This is particularly interesting for automated observatory response to rapid events. There is worldwide interest in developing standard VO protocols for event messages (VOEvent). The AstroGrid VO service will certainly want to be able to deal with such events.

Possibly the most important relationship will be with the National Grid Service (NGS). For some time, AstroGrid steered carefully clear of Globus based Grid technology, as opposed to industry standard web services, as it did not meet our needs and was not stable or mature. However, the Grid and Web service worlds have now largely converged, and there is a working NGS system with considerable computational power. Our aim is to integrate technologies so that the NGS can be straightforwardly used by astronomers within the AstroGrid infrastructure.

We will also actively pursue collaborations with other e-Science projects, such as MyGrid and OGSA-DAI, and especially the national initiatives, NeSC, OMII, and the Digital Curation Centre (DCC). As mentioned elsewhere, part of sustainability target is one the one hand to adopt external components where this seems best, and to have our components adopted as standard.

(6) Cost Analysis

6.1 Costing Methods

This section summarises the methodology for arriving at project costs. Final costings, analysed in various ways, are presented in Annexes B1,B2,B3. Note that, except for RAL, separate requests have been submitted through the JeS system for each individual AstroGrid consortium institute. These are linked as a joint proposal under the common reference number F331005 with Edinburgh as lead institution. The RAL request will go through the CCLRC SLA with PPARC and is costed according to that agreement.

Please note: cost figures, and staff effort numbers given in the per institute JeS submissions (SLA agreement for RAL), are definitive, and should be regarded as the true figure if there is any discrepancy with numbers in this common case text.

<u>Cost Estimate Process</u>. Costs in this project are dominated by staff effort. To arrive at staff costs we have used a full work breakdown structure, as described in Appendix A. Planned work is broken down into workpackages, sub-packages, and tasks, with estimated resources required for each task, including a planned taper with time, working towards a sustainable VO service for the UK. Our plan assumes a list of named staff with known skills. We have therefore allocated individual staff fractions to each task. Integrating across tasks we therefore have a reliably costed staff plan.

<u>Underlying cost assumptions</u>. We have used current (2006) salary scales, with current predictions of salary grades and spine points for the period of the project. Note that this does not include the likely effects of the pay negotiations currently underway, or the process of job evaluation underway in all Universities (as part of the 'Framework Agreement'); this may result in increased salary costs to be met under the proposed grants. Non-staff costs are priced at current (July 2006) price levels. None of the costs are given in cash-planned form.

<u>FEC costing methods</u>. Each University has slightly different procedures for calculating its Full Economic Costs from the directly incurred costs. These procedures however all follow the same basic method, following Research Council guidance, so that we can summarise costs by broad headings.

6.2 Cost Categories

<u>Directly Incurred staff effort</u>. All staff to be used are named staff, and we have planned an effort taper by dropping individual staff from the project at various points. These costs are therefore very

well determined.

Investigator costs. Investigators are costed at either 10% or 5% of their time.

Other Directly Allocated Staff. Practices vary from one institution to another, but most follow a formulaic approach to recharging an appropriate amount of clerical and system manager time, proportional to directly incurred staff volume.

Equipment costs. We assume that key data services are funded and in place, including the equipment necessary. To create a coherent VO service, however, data centres need to run additional core services, such as Registries, Job Execution Service, and MySpace manager. These will need a separate server and extra MySpace storage. In addition each site will need a further server to run new VO applications. To provide for this we have budgeted for 2 dual-core CPUs (at £3.5K each) and 10TB of storage (at £10K each), making a total of £102K plus VAT.

Travel Costs. Our experience with AstroGrid, just as with all other e-science projects, is that very extensive travel is required. This is partly because of the distributed nature of the project, requiring staff to attend many planning and discussion meetings in various combinations; partly because of running training workshops across the UK; partly because of the collaboration with European partners, which we expect to continue; and partly to attend global meetings such as the twice yearly IVOA workshops, ADASS, and GGF. For this operational phase, development planning meetings will reduce, but training workshops and other visits to UK Departments will increase. Our model is to allow £4010/individual/year. This is based on (i) one international trip (£1500) with five nights away (5 x £150) ; (ii) one European trip (£500) and (iii) a dozen UK trips (12 x £100) , with a dozen nights away in total for the UK and European trips (12 x £130).

Note : in principle we would prefer to hold a budget travel in a central grant, so its expenditure can be carefully planned and controlled by the Project Manager, as we have done for the first two AstroGrid projects. However, because we receive only 80% of costs, and travel does not attract any indirect costs, the institution holding the central grant would need to absorb all the deficit. Reluctantly therefore we propose to hold separate travel budgets.

Consumables. Consumables include personal computing equipment for staff, and maintenance for this equipment and the core servers, as well as standard consuambles. Precise practices vary between institutions, Details can be found on the JES forms.

Estates and Indirect Costs. Practices vary between institutions, Details can be found on the JES forms.

6.3 Working Allowance and Contingency

Working Allowance (WA). Following standard procedure, we propose to hold a Working Allowance to protect against risk. We have constructed a full risk register (see Appendix D) and a method for calculating the cost of addressing risks that actually eventuate. On this basis we have calculated a WA of £901,557, which is approximately 10% of budget. This will be held within the Edinburgh grant. If the Project Manager believes it necessary to spend from the WA, he will make a proposal to the AstroGrid Consortium Board. If the ACB endorse this proposal, we will seek formal authorisation from the PPARC Oversight Committee.

Contingency. Following standard procedure, in order to allow for possible exceptional circumstances which could have a significant impact on AstroGrid activities we recommend that PPARC hold a project contingency of 10% of the project full economic cost, including Working Allowance. This contingency is not included in the costings shown in Annex B or in the submitted JES forms.

Annex A : Workpackage Details

Please note: effort is shown thus: 1.0 [0.5] FTE

The first figure is for 2008, the second for 2011-2012.

A0 : Leadership, coordination and management

Responsible Institutes : Edi, Cam, Leic

WP Description: Delivery of the AstroGrid service will require careful planning and management to balance the operational and development activities, ensuring that all outputs fully meet the prioritised needs of the community. This WP will ensure that the AstroGrid service meets the scientific needs of the UK research community, in both capturing those needs, converting these into technical requirements, balancing the outcomes, and being responsible for the end user support activities of the AstroGrid service.

WP Inputs :

1. Science cases from community
2. Emerging and maturing I.T. technology
3. Strategic priorities from Advisory bodies and Consortium Board
4. Funding agency resource profile

WP Outputs :

1. Science requirements
2. Technological opportunities
3. Science and technology presentations
4. Documents and reports
5. Planning documents
6. Schedules of work
7. Progress reports
8. Oversight materials

A0.1 Policy and Leadership

This sub package is responsible for determining the strategic direction of the consortium activities, setting the top level goals of the consortium, managing the strategic links with key external partners (e.g. ESO, Euro-VO).

Effort: 0.95 [0.95] FTE

Tasks and Justification :

Science Leadership

Initiate new research programmes within astronomy, utilising the new escience methods, in conjunction with colleagues from other HEIs, both national and international

Present, on behalf of AstroGrid, academic and technical results and proposals at a wide range of national and international meetings, conferences, seminars and workshops

Liaise with the UK and European astronomical communities in defining, evaluating, organising development and operation of the VO system

Actively investigate funding opportunities within the areas of astronomical research, astronomical computational systems, and related eScience areas. This includes submitting research grant applications at the PI and co-I level, as a senior member of the AstroGrid leadership team.

Maintain contacts with external e-science projects within the UK and elsewhere to ensure that common and interoperable systems are developed and that best practice is utilised in turn by AstroGrid and the Euro-VO

Maintain contact with related astronomical projects in other countries (USA, Japan etc) to ensure that the tools and VO systems developed and in operation are interoperable with those in the UK.

Act as secretary to the International Virtual Observatory Alliance (IVOA), and member of the IVOA Executive committee

Participate in external working groups – liaison activities for instance ELT data flow definition activities.

Policy and Planning

AstroGrid consortium strategy

Determination of '5 year-plan'

Top level financial control

A0.2 Management

Direct people, resource and project management including grant administration etc.

Effort: 1.35 [1.35] FTE

Tasks and Justification :

Science Management

Codify science requirements into use cases which are then used by the development team in creating the Virtual Observatory software systems

Monitor project progress in ensuring that science requirements are met and agrees changes where required through the management team and project board

Determine appropriate research methodologies for research, applying where possible the new technological capabilities presented through the AstroGrid project

Write reports to relevant bodies (thus PPARC oversight committees, science committee, etc) concerning the scientific progress of the AstroGrid and VOTECH Virtual Observatory project

Lead team of researchers – including recruiting, selecting and managing the work of the

AstroGrid science team, and directing the work of the Euro-VO Technology Centre science team (currently through end 2008, with expected further Euro-VO leadership from 2009 onwards

Manage the development of test implementations of science cases to utilise the tools and capabilities being constructed through the VO

Technical Management

Manage Support, Operations and Development activities. This includes defining processes, agreeing Service Level Agreements, planning resource allocation and defining deliverables for all three activities. Support and Operations are on-going activities whilst new developments will be subject to the usual Project Planning processes developed within AstroGrid. All activities to be reported as agreed by the AstroGrid Management Team.

R&D Management

Establish and maintain links with other VO bodies in order to collaborate on the creation and maintenance of standards. Monitor emerging technologies and plan the assessment and prototyping of new technologies. Agree with Project Manager how they might be integrated into mainline services. Maintain links with UK e-Science and JISC developments and recommend where project needs to accommodate new and forthcoming approaches.

Administration

Administer project grant, including the collation of expenses, approval and payment of invoices and production of finance reports to Oversight bodies.

A1 : User Support

Responsible Institutes : All

WP Description: The primary function of the AstroGrid service is to enable the creation of new science by the UK community. This WP provides support to the community in their use of the VO service. Three main activities will be carried out, the creation of a 'help desk' system, automated where possible, but providing access to real staff - who are the experts - as required. The small AstroGrid science team will be responsible for user engagement, supporting science outreach such as workshops, presentations, demonstrations of system use. Later activities will focus more on the capture of new requirements driving the shape of future functionality and interaction with new missions / facilities, to ensure that the VO meets their scientific requirements for downstream data/information distribution/access. The small 'Science Call' programme, will allow for the support of a small number of independently peer-reviewed programmes, generating specific functionality for those topical science projects.

WP Inputs :

1. Specifications for quality assurance
2. Specifications for service levels
3. Community science requirements
4. AstroGrid system components
5. User science cases
6. AstroGrid system specification

WP Outputs :

1. Service Level Agreements
2. Call handling processes
3. Functioning web presence
4. User information and documentation
5. Workshop materials
6. User defined science work flow processes
7. Documentation

A1.1 Help Desk :

First point of contact for all users (science and systems administration) with a question, error report or enhancement suggestion. Given the potential volume of calls, as much automation here will pay dividends in effort saved answering simple or known problems.

Effort: 1.2 [1.0] FTE

Tasks and Justification :

Identify and deploy suitable Trouble Ticketing system

Gather requirements for Problem Reporting and Change Management (PR&CM) system. System must support bug reporting, change requests, enhancement requests and requests for new functionality. System must be easy to use for all users. Evaluate candidate systems, deploy and document chosen system. Train relevant people in its use.

Create Help Desk Service Level Agreement (SLA)

Gather requirements for and create SLA to define service users can expect from Help Desk. Use industry standard templates for SLA.

Run Help Desk

Act as clearing house for Problems Reports and Change Requests, allocating requests to appropriate personnel. If report or request is science use related, manage and resolve issues.

A1.2 Science Engagement

This sub-package provides the vital scientific support to the UK astronomy community. Tasks include science interaction with the community, plus the development of training and help systems, quality assurance of the VO service. Note the amount of science support provided ramps down to a minimal level in the years 2010-2012.

Effort: 1.95 [1.1] FTE

Tasks and Justification :

Science user requirements

Collect and ranks scientific requirements for the development of new capabilities

Website

Design and maintenance of the AstroGrid on-line presence

Workshops

Organisation and support of science and technical development workshops, initially at the rate of ~6-9 per year.

User Education

Covering talks, seminars

Tutorials

Production of on-line tutorials, and material for inclusion in the science workshops

User guides

The on-line manuals and FAQs describing use of the VO service

User tools help

Specific instruction manuals for key capabilities such as the work flow system, AstroScope, the task launcher etc.

A1.3 Science Call

This sub-package will be responsible for the operation of the 'AstroGrid Science Call programme'. This programme has a small amount of enabling science effort attached to it – to aid in the development of science focused tools in support of successful programmes. However, it is assumed that some additional deployment or engineering support will also be attached to this programme if required.

Effort: 0.5 [0.5] FTE

Tasks and Justification :

Science case capture

Determination of the needs of the supported programmes and definition of technical requirements.

Science workflow development

Science capability development. If deployment or engineering support is required this will be seconded from the relevant technical groups.

Science verification

Quality assurance and testing of the developed capabilities

Documentation

The generation of documentation and on-line help materials detailing the capabilities generated in the support of each science programme. This ensures re-use bythe wider community of the new functionality so developed.

A2 : VO Service Operations

Responsible Institutes : All

WP Description: In order to facilitate science using the VO the services which comprise the VO need technical and administrative support. The purpose of this package is to provide such support in the form of a Help Desk facility, deployment of AstroGrid services against existing data and resources as defined by the ACB, SAG and science community in general, technical user education and documentation and direct assistance to the curators of datasets not included in the above list.

WP Inputs :

1. Specification of service levels
2. Identification of key datasets and resources not already VO-enabled
3. Systems administration usage requirements

WP Outputs :

1. Service Level Agreements
2. Technical call handling processes
3. Workshops, documentation, Self Paced Instruction modules

A2.1 Technical Support

Centralised Help Desk and support infrastructure providing assistance to systems administrators and on-site AstroGrid deployment teams.

Effort: 2.1 [1.4] FTE

Tasks and Justification :

Define SLA for SysAdmin support

Gather requirements for and create SLA to define service Systems Administrators can expect from System Support. Use industry standard templates for SLA.

Define SLA for application programmer support

Gather requirements for and create SLA to define service application programmers can expect from System Support. Use industry standard templates for SLA.

Define processes for managing support requests including escalation paths etc

Define normal and exception handling for problem reports and change requests. Include full escalation and dispute processes

Deliver SysAdmin and Programmer Support

Includes all aspects of call management and problem resolution including reporting, bug fixing, patching, Field Change Orders (i.e. critical patches for deployed systems) and maintenance of problem resolution system (an application to assist users in diagnosing their problem – and possibly even resolving it – before raising a support request. Typically such systems record the symptom(s) and resolution or workaround for known problems and greatly reduce the demand on the support desk if regularly maintained and reviewed)

Provide support to Deployment teams (see: A2.2 and A2.4)

Backup support to on-site teams. Includes troubleshooting, advice, remote testing and configuration of installed base to incorporate new systems.

A2.2 Deployment

Before comprehensive science research can be undertaken the VO services need to be deployed against existing and emerging astronomical data and processing assets. This sub Work Package is designed to ensure this is achieved.

Effort: 2.7 [1.1] FTE

Tasks and Justification :

Deploy AG components to core AG sites

On-site visits to deploy and configure AG components to core AG institutes followed by tech and science workshop for local system administrators, programmers and astronomers.

Publish new Releases

Define, prepare, build, test and manage creation and publication of a release based upon a given software baseline.

Identify and encourage non-core Data Centres to deploy AG components

Work with astronomers and systems administrators to gain support for and deliver deployment of AG systems as appropriate.

Maintain deployed systems

Administer AG components deployed at core AG institutes. This includes global core components such as Registry, VOSpace etc.

A2.3 Technical engagement

AstroGrid is essentially an infrastructure, providing access to various astronomical assets in a homogeneous manner. In common with other such powerful systems, astronomers and application developers who really wish to realise the full potential offered by the AstroGrid services will need to understand how to programmatically exploit that potential. This sub Work Package is design to impart that knowledge.

Effort: 2.15 [0.75] FTE

Tasks and Justification :

Programmer documentation

Maintain and publish documentation for programmers. Includes API, FAQ, Tutorials and HowTos

Website

Maintain web presence for all users (science and technical) and project members.

Workshops

Deliver technical workshops focused on application programming and scripting.

A2.4 VO enabling data sets

The more data that is VO-enabled, the wider the opportunity for astronomical research becomes. It is not cost effective for AstroGrid staff to visit every site and deploy the required services. This sub Work Package is designed to ensure the curators of such data received all the help and information they require to make their data assets available to the VO community.

Effort: 0.7 [0.2] FTE

Tasks and Justification :

Work with Data Centres to deploy and Register DSA against their data holdings

Help Data Centres build metadata for data holdings and then publish that metadata to the VO registries.

A3 : VO Engineering

Responsible Institutes : All

WP Description: With the AstroGrid services deployed in a production environment comes the requirement for maintenance, enhancement and packaging of the code base. This WP will provide tertiary support to the HelpDesks of A1 and A2 above producing patches, workarounds or bug fixes in response to discovered issues. In addition, emerging technology and platform changes as well as new opportunities and standards mean the code base will need to be enhanced or amended to keep pace. These changes (reactive and proactive) must then be packaged such that they can be successfully deployed into the working VO with no (or at least minimal) service interruption.

WP Inputs :

1. Problem reports and enhancement suggestions from A1 and A2
2. New and maturing technology opportunities
3. Information about new IVOA standards from A4
4. Changes and upgrades to platform software and hardware
5. Service levels

WP Outputs :

1. Workarounds, patches and bug fixes
2. Maintained and functionally extended code base
3. Reference implementations of new IVOA standards
4. Major and Minor releases

A3.1 Maintenance

Provide tertiary support to A1 and A2 in the form of workarounds, patches and bug fixes. Plan to ensure code complies with latest standards and works with latest platforms.

Effort: 0.9 [0.9] FTE

Tasks and Justification :

Define processes

Define how change requests (bugs, maintenance, enhancements, new features etc) are captured, prioritised, implemented and published.

Bug fixing

Identify, isolate and fix bugs as they reach the top of the fix queue (according to the processes defined in 3.1.1)

Standards compliance

As standards change, investigate impact of and plan for the introduction of those new standards (see 3.2.1)

Manage platform and utility upgrades

As new platform components are released (e.g. new OS release, Java upgrades etc) and as use requires, plan, test (if necessary change code base to support) and release guidelines and new code to support upgrades

A3.2 Code Enhancement

Ensure the code base supports new and maturing standards and platforms and makes best use of new technology as it emerges. This sub Work Package is also designed to help build reference implementations of standards agreed at the IVOA, with input from A4.

Effort: 3.0 [3.05] FTE

Tasks and Justification :

Extend existing code to utilise new standards, interfaces etc

Based upon assessment and plans in A3.1, update code base to support new standards and plan publication of that code.

Add new functionality

Plan, implement, test and release new features based upon change requests received and as managed by processes defined in 3.1.1.

Enhance and improve existing codebase

Continue to refine and improve code base as opportunities arise.

Incorporate new technology

Take advantage of new technology as appropriate by evaluating, planning and incorporating in exiting code base.

Build reference implementations of new standards

Work with standards bodies to implement and beta test reference implementations of new standards where those new standards have a significant impact on the existing AG code base or where it is to Ags advantage to create said reference implementations. Plan development and introduction within the context of existing AG work.

A3.3 Release packaging

Any system as complicated as the AstroGrid infrastructure requires careful Integration and Release management to ensure trouble-free deployments and upgrades. Throughout AstroGrid 1 & 2, this process has been refined and works well. This sub Work Package will ensure that vital work continues into the production environment of this new phase.

Effort: 0.5 [0.5] FTE

Tasks and Justification :

Integration, testing, and Release Management

Ensure new code (bug fixes, support for new standards, new functionality etc) integrates with published code base. Prepare and publish new releases (patches, point and full upgrades etc).

A4 : VO New Technology

Responsible Institutes : All

WP Description: This work package involves all activities relating to the development of new standards and the assessment and introduction of new technologies.

WP Inputs :

1. Feedback from engineers and astronomers re VO usage.
2. IVOA mailing list traffic and wiki developments.
3. Problems with existing systems: help desk reports.
4. Journal articles, e-science project developments, conferences and meetings.

WP Outputs :

1. New and amended standards promoted through the IVOA.
2. Guidance to engineering team for standards reference implementations.
3. Working papers on new technologies.
4. Prototypes of new technologies applied to VO situations.

A4.1 IVOA Standards

Virtual Observatory standards are created under the auspices of the IVOA (International Virtual Observatory Alliance), a voluntary grouping of the world's VO projects of which AstroGrid is a founding member. We have contributed and are contributing to standards on data access, resource registration, personal data storage, authentication and authorisation, application execution etc. Our involvement means that we can ensure that new standards are not inimical to the way AstroGrid operates and allows us the opportunity to promote unique features of our software as standards to the worldwide community.

Effort: 0.6 [0.6] FTE

Tasks and Justification

Participate in definition of IVOA standards

Join in with IVOA mailing list discussions (currently covering 13 working and interest groups) and attend twice-yearly interoperability meetings.

Identify need for new standards

Where the project identifies a need for a new standard it will assign persons to develop working papers and drafts to submit to the IVOA. Such efforts may be entirely intra-project but may involve collaborations with other VO projects.

A4.2 New Technology

AstroGrid relies heavily on the team's ability to identify and utilise leading edge technologies. Our foresight in adopting web service technologies from the beginning of the project is the prime factor in our success at producing a truly workable architecture for the Virtual Observatory. Our prime contractor status in the EuroVO VOTech project is evidence of that ability. In that project we are leading Europe in testing advanced data mining and visualisation technologies for data exploration and adopting semantic web technologies for resource discovery and authorisation. AstroGrid must continue to assess and prototype new technologies in order to remain in its pre-eminent position in Europe.

Effort: 0.9 [0.9] FTE

Tasks and Justification :

Identify and Assess New Technology

Attend e-Science, JISC and other technology conferences. Monitor the adoption of technologies within other fields of science, academia and industry. Implement technology demonstrations. Recommend where VO-compliant prototypes might be developed.

Prototype New Technology

Create working prototypes which make use of new technologies to interface with or provide new services to users or other components of the VO, particularly those developed or used by the project. Where these technologies are adopted by the project, assist with their uptake.

Annex B : Summary of Resources Requested

All the planned staff effort uses named staff with known skills. Salaries and expected increments are known for all staff. We have a complete model of expected staff effort versus task for each individual for each planned year of the project. (This is available on request). This level of detail is not expected to be completely accurate or fixed, but as a model is reliable enough to produce a staff effort plan by institute and work package. We plan a significant tapering of effort during the lifetime of the project. To make this plausible in terms of local management, we produce this taper not by slowly varying fractional contributions, but by dropping individual staff from the project at various points.

Tables on the succeeding pages show staff effort by year and institution; costs to PPARC by institution, year, and cost type; and costs to PPARC by work package and institution.

B1 : Staff Effort Overview by Institute

The Table below summarises staff effort, grouped by Institution. All staff start on the same date - October 1st 2007, i.e. Y1 = Year-1. October 2007 - September 2008 and so on. (Staff names are available only in the confidential version of the proposal]

Name	Instn	Type	Y1	Y2	Y3	Y4	Y5	Total
S1	Cambridge	Proj.Sci.	12 sm	9sm	9sm	9sm	9sm	48
S2	Cambridge	Eng.	12sm	12sm	12sm	12sm	12sm	60
S3	Cambridge	Eng/Sci	12sm	12sm	12sm	12sm	12sm	60
S4	Cambridge	Sci	6sm	6sm	6sm	6sm	6sm	30
S5	Cambridge	Arc.Dev.	6sm	6sm				12
S6	Cambridge	AppDev	6sm					6
S7	Edinburgh	Eng.	12sm	12sm	12sm	12sm	12sm	60
S8	Edinburgh	Eng.	12sm	12sm	12sm	12sm	12sm	60
S9	Edinburgh	SysMan	6sm	6sm	6sm	6sm	6sm	30
S10	Edinburgh	Arc.Dev.	6sm	6sm				12
S11	Edinburgh	Admin	1.2sm	1.2sm	1.2sm	1.2sm	1.2sm	6
S12	Leicester	ProjMan	12sm	12sm	12sm	12sm	12sm	60
S13	Leicester	R&DMan	6sm	6sm	6sm	6sm	6sm	30
S14	Leicester	SysMan	6sm	6sm	6sm	6sm	6sm	30
S15	Leicester	ArcDev	6sm	6sm	6sm	6sm	6sm	30
S16	Leicester	Eng	12sm	12sm	12sm	12sm	12sm	60
S17	Leicester	Eng	12sm	12sm	12sm	12sm	12sm	60
S18	Leicester	Eng	12sm	12sm	12sm			36
S19	Leicester	Eng	6sm					6
S20	Leicester	Sci	6sm					6
S21	MSSL	ArcDev	6sm	6sm	6sm	6sm	6sm	30
S22	MSSL	SysMan	6sm	6sm				12
S23	MSSL	Eng	12sm	12sm	12sm	12sm	12sm	60
S24	Manchester	Sci	9sm	9sm	9sm	9sm	9sm	45
S25	Manchester	SysMan	3sm	3sm	3sm	3sm	3sm	15
S26	Manchester	Eng	6sm	6sm	6sm	6sm	6sm	30
S27	Manchester	Sci	6sm	6sm	6sm	6sm	6sm	30
S28	RAL	ArcDev	6sm	6sm	6sm	6sm	6sm	30
S29	RAL	ArcDev	6sm	6sm				12

B2 : Full economic costs by Year, Institution and Cost Type

At the time of application, PPARC is expected to pay 80% of these costs but this percentage is expected to rise during the term of this project.

Investigators

	2007-08	2008-09	2009-10	2010-11	2011-12	Totals
Edinburgh	12180	12180	12180	12180	12180	60,900
MSSL	4514	4583	4606	4606	4606	22,915
Cambridge	5749	5749	5749	5749	5749	28,745
Manchester	6096	6478	6677	6882	7094	33,227
Leicester	46295	46295	46295	46295	46295	231,475
RAL	8263	8490	8746	9008	9278	43,785
Portsmouth	3368	3368	3368	3368	3368	16,838
Totals	**86,465**	**87,143**	**87,621**	**88,088**	**88,570**	**437,885**

Researchers

	2007-08	2008-09	2009-10	2010-11	2011-12	Totals
Edinburgh	135051	140791	120362	124683	129109	649,996
MSSL	93445	90432	82531	78359	78359	423,125
Cambridge	175264	174063	160980	155191	155597	821,095
Manchester	93962	98667	103624	108842	113456	518,551
Leicester	201678	201678	192546	174281	165148	935,330
RAL	82630	84906	43726	45038	46389	302,689
Portsmouth	0	0	0	0	0	0
Totals	**782,030**	**790,537**	**703,768**	**686,394**	**688,058**	**3,650,786**

Other staff

	2007-08	2008-09	2009-10	2010-11	2011-12	Totals
Edinburgh	22184	22789	20969	21609	22377	109,928
MSSL	10856	10974	11120	11270	11399	55,619
Cambridge	13146	13146	13146	13146	13146	65,730
Manchester	4117	4117	4117	4117	4117	20,586
Leicester	80238	65068	37620	32497	32581	248,002
RAL						
Portsmouth	0	0	0	0	0	0
Totals	**130,541**	**116,094**	**86,972**	**82,639**	**83,620**	**499,865**

Estates

	2007-08	2008-09	2009-10	2010-11	2011-12	Totals
Edinburgh	29516	29516	24831	24831	24831	133,525
MSSL (inc other)	22069	20756	18128	19164	19164	99,281
Cambridge	15430	14462	15057	12601	12601	70,151
Manchester	31857	31857	31857	31857	31857	159,285
Leicester	77471	72441	60703	52319	48965	311,897
RAL	0	0	0	0	0	0
Portsmouth	248	248	248	248	248	1,240
Totals	**176,591**	**169,279**	**150,824**	**141,020**	**137,666**	**775,379**

Indirect costs

	2007-08	2008-09	2009-10	2010-11	2011-12	Totals
Edinburgh	117149	117149	98554	98554	98554	529,960
MSSL	92039	86561	75604	70125	70125	394,453
Cambridge	163408	153155	138283	133455	133455	721,756
Manchester	75747	75747	75747	75747	75747	378,735
Leicester	202068	188946	158330	136462	127714	813,519
RAL	0	0	0	0	0	0
Portsmouth	1349	1349	1349	1349	1349	6,745
Totals	**651,760**	**622,907**	**547,867**	**515,692**	**506,944**	**2,845,168**

Travel

	2007-08	2008-09	2009-10	2010-11	2011-12	Totals
Edinburgh	22055	22055	18045	18045	18045	98,245
MSSL	13321	11951	9946	8921	9266	53,404
Cambridge	28070	24060	20050	20050	20050	112,280
Manchester	18040	18040	18040	18040	18040	90,200
Leicester	39090	39090	39090	39090	39090	195,450
RAL	6000	6000	4000	4000	4000	24,000
Portsmouth	201	201	201	201	201	1,003
Totals	**126776**	**121397**	**109372**	**108347**	**108691**	**574,582**

Equipment

	2007-08	2008-09	2009-10	2010-11	2011-12	Totals
Edinburgh	19975	0	0	0	0	19,975
MSSL	19975	0	0	0	0	19,975
Cambridge	19975	0	0	0	0	19,975
Manchester	19975	0	0	0	0	19,975
Leicester	19975	0	0	0	0	19,975
RAL	20000	0	0	0	0	20,000
Portsmouth	0	0	0	0	0	0
Totals	**119,875**	**0**	**0**	**0**	**0**	**119,875**

Consumables

	2007-08	2008-09	2009-10	2010-11	2011-12	Totals
Edinburgh	12868	10868	9143	9143	9143	51,165
MSSL	8448	7945	6939	6436	6436	36,203
Cambridge	21008	21008	21008	21008	21008	105,040
Manchester	7245	8798	8798	8798	8798	42,437
Leicester	20195	17110	14573	12760	12036	76,673
RAL	0	0	0	2000	2000	4,000
Portsmouth	0	0	0	0	0	0
Totals	**69,764**	**65,729**	**60,461**	**60,145**	**59,421**	**315,518**

Totals

	2007-08	2008-09	2009-10	2010-11	2011-12	Totals
Edinburgh	370978	355348	304084	309045	314239	1,653,694
MSSL	264666	233200	208873	198881	199355	1,104,974
Cambridge	442050	405643	374273	361200	361606	1,944,772
Manchester	257039	243704	248860	254283	259109	1,262,996
Leicester	687009	630628	549155	493702	471828	2,832,321
RAL	116893	99396	56472	60046	61667	394,474
Portsmouth	5165	5165	5165	5165	5165	25,826
Totals	**2,143,800**	**1,973,084**	**1,746,882**	**1,682,322**	**1,672,969**	**9,219,057**

Working Allowance	**901,557**

B3 : Costs by Work Package and Institute

Monetary amounts are Full Economic Cost; at the time of application, PPARC is expected to pay 80% of these but this percentage is expected to rise during the term of this project.

	A0	A1	A2	A3	A4	Total	Equipmt	Travel	Other	Totals
	(SY)	(SY)	(SY)	(SY)	(SY)	(SY)	(£)	(£)	(£)	(£)
Edinburgh	1.00	1.00	6.10	2.80	3.60	14.50	19,975	98,245	51165	169,385
MSSL	0.50	0.80	5.25	2.45	0.00	9.00	19,975	53,404	36203	109,582
Cambridge	3.00	4.05	2.55	7.30	1.60	18.50	19,975	112,280	105041	237,296
Manchester	0.50	6.25	1.75	2.00	0.00	10.50	19,975	90,200	42437	152,612
Leicester	5.50	1.80	8.00	8.35	1.85	25.50	19,975	195,450	76673	292,098
RAL	0.50	0.70	2.80	0.00	0.00	4.00	20,000	24,000	4000	48,000
Portsmouth	0.50	0.00	0.00	0.00	0.00	0.50	0	1,003	0	1,003
Totals	**11.50**	**14.60**	**26.45**	**22.90**	**7.05**	**82.50**	**119,875**	**574,582**	**315,519**	**1,009,976**

Annex C : Status of AstroGrid

C1 AstroGrid capabilities in 2006

The current release of AstroGrid is the 2006.3 release of July 2006. This release offers a number of powerful capabilities, helping the astronomer find, get and work with a wide range of astrophysical data. Early science use of AstroGrid is being presented at the 2006 IAU General Assembly meeting, in the Special Session 'The Virtual Observatory in Action: New Science, New Technology, and Next Generation Facilities' (17-22 Aug 2006).

With the current 2006.3 release of AstroGrid the astronomer can:

- Find data and applications by searching the 'registry' (a kind of 'astro-google')
- Use 'AstroScope' - a powerful tool for searching and exploring data over a region of the night sky - be they images, spectra, or catalogues. The user enters a target name or search box, the system then automatically discovers which archives might have the data the user needs, sends the queries to those archives, and graphically displays the results. The user can then explore the results, and by simple point and click can either visualise individual data sets, or save any number of the data back to their local disk space or to their 'MySpace'.
- Use the 'Application launcher' – this gives a common interface to a wide range of well known astronomical applications. And you can work on data held in your MySpace.
- Use the 'Query Builder' to send their database queries to a wide range of databases, using one interface, one query language (based on standard SQL99), and get results returned in a standard XML file format – VOTable
- Use the 'Workflow Builder' to create simple or powerful sequences of tasks to find and process data. A range of examples and help sheets are available to guide the novice user.
- Use a prepackaged 'Parameterised Workflow' to carry out a number of common processes:
  - the redshift maker: create you own object catalogues from multicolour image data (Sextractor), generate a federated source list (XMatch), and generate the statistical photometric redshifts for these objects (Hyper, Bpz)
  - colour cutter: give a colour criteria (e.g. H-K > 3, g-r < 2) and return the objects meeting those criteria from a range of optical and IR catalogues (e.g. ING Wide Field Survey, 2MASS).
  - the movie maker: enter a start and end time, a generate a movie of the sun (from either TRACE or SOHO-EIT) data
- Visualise any of the data with TopCat, Aladin or other powerful client applications designed to fully exploit data provided through AstroGrid in standard VO formats.

C2 AstroGrid Science and Tools:

The capabilities available through the AstroGrid system have been developed to meet the specific needs of the UK astronomy community. A number of key science topics have been identified, with science cases from these acting as test cases for the use of the evolving AstroGrid system. Further, the AstroGrid science themes create a framework in which user defined science cases can be developed building upon the science services and data/tool access capabilities present in the system. Specific cases falling within a theme in turn create the drivers for new or expanded capability. These current AstroGrid main science themes are:

- *Multi-lambda imaging*. This science case builds on top of the study of deep or large fields, with e.g. science aims to understand the properties of galaxy evolution as a function of distance, observed by different facilities at different wavelengths. The redshift maker is one of the science services developed as part of this theme. An additional science case is the study of clusters from deep near-infrared and optical data.
- *Stellar populations*, which builds on the selection of brown dwarfs candidates using the ColourCutter. Additional science cases include the study of Gould Belt objects and the study of the IMF in clusters.
- *Morphologies* and in particular study of low surface brightness galaxies and HII, SNR, PN in Halpha surveys.
- *Extreme Objects* and the study in particular of the environments within which supernova and gamma ray bursts are located.
- *Sun-Earth connection* building on Solar/STP science cases for which the SolarMovieMaker has been developed.

A case study illustrates in specific terms how the astronomer can make today of AstroGrid to solve a specific problem, in this case: 'Finding local brown dwarfs or young massive stars'. Cool or young obscured stars have distinctive Spectral Energy Distributions between 0.5-2 micron wavelength, as they are brighter in the near Infra-Red than in the optical. Radio and X-ray measurements distinguish between low- and high-mass young stars. UV emission allows a more detailed spectral classification of hot stars. Using AstroGrid, a single query through 'AstroScope' can provide:

- Deep optical and NIR catalogues and images from the Isaac Newton Group's Wide Field Survey
- IR and radio catalogues IRAS, 2MASS, FIRST
- Any known X-ray detections in 1XMM (and now 2XMM beta)
- UV spectra from the ESA INES archive.
-

Data for this particular case is easily discoverable and accessible from a range of data providers, including that provided through the AstroGrid consortium data centres, e.g:

- CASU (Cambridge)
  - Deep optical images and source catalogues from the Isaac Newton Telescope Wide Field Survey;
  - IPHAS Halpha survey images
  - Selected Spitzer survey images such as the ELAIS N1 region;
  - HST ACS Ultra Deep Field images
  - The Faint Images of the Radio Sky at Twenty-one cm catalogue
- LEDAS (Leicester)
  - 1XMM X-ray source catalogues
  - Digital Sky Survey images
- WFAU (Edinburgh)
  - The 6dF optical survey and cross-identifications
  - 2MASS all-sky IR survey
  - UKIDSS IR sky survey
  - USNO-B astrometric catalogue
  - SuperCosmos surveys

- Jodrell Bank (Manchester)
  - MERLIN
  - VLA Deep Field high resolution radio images

Many international data centres products are also made available through the AstroGrid registry. Standard VO access methods connect to data entres and resources such as:

- USA:
  - NED (The NASA/IPAC Extragalactic Database)
  - HEASARC (high energy and many other catalogues)
  - STScI, IRSA and MAST (NASA and other mission catalogues and images including HST and Spitzer)
  - SDSS images and catalogues
- Spain:
  - ESA archives (ISO and XMM data)
- Canada
  - CADC (Gemini and other data)
- Japanese Virtual Observatory
  - Subaru/XMM survey (IR/X-ray)

New data are contnue to come 'on-line' to the VO user. In the near future X-ray data from all the major missions hosted at LEDAS (Leicester) will b available, followed by images and spectra such as UVES from the European Southern Observatory archive in Munich and expanded access to Vizier (Strasbourg). Next-generation surveys and telescopes are already planning how to make their data available to VOs; these include UKIDSS, VISTA, e-MERLIN and ALMA.

Functionality enhancement by end 2006:

There will be significant performance and data set access enhancements through to the end of 2006 including:

- Further key data sets, including access to WFCAM-UKIDSS (with development of appropriate authorisation systems). (Issue: UKIDSS is a public survey, but only actually public to ESO astronomers!)
- Access to an increased range of reduced image data e.g. including authorised access to UKIDSS IR survey data (by Q2 2006).
- Increased access to radio data
  - Visualisation of spectral data cubes using a modification of the solar movie maker and/or the next generation Aladin
- Direct access to the MERLIN archive and other RadioNet members' data.
- Access to a wider range of US data with the implementation of OpenSkynode, SSA and SIA protocols through AstroGrid
- Access to a wider range of European data including SIA/SSA interface access to ESO Science Archive Data - importantly including UVES reduced spectra by end Q2 2006
- Access to improved compute power, based on current experiments involving the installation of the Redshift maker service on a 128 node compute cluster at RAL.
- Access to an improved range of STP data, e.g. Lancaster's SAMNET magnetometer dataset. Bison data from Birmingham will also be accessible.
- Improvements in response to user feedback

  - easier methods to construct workflows (e.g. Workbench workflow builder)
- Access to small tools such as coordinate conversion (via the Workbench)

Visualisation:

A range of 'helper' applications allow for quick visualisation of data discovered through the use of 'AstroScope', or results saved in your MySpace. For example, VOSpec allows you to visualise spectra found via AstroScope. The 'Plastic' protocol allows passing of information between client applications across the AstroGrid service layer. Thus one could select a number of data points in one application, and see those same points in another. For example select extremely red objects as found in tabular data visualised by Topcat, and see those objects in image space viewed through Aladin.

Using AstroGrid, you can save data in your personal 'MySpace' area. Tabular data are usually in VOTable format, for cross matching, sending to a photometric redshift tool and so on, or exporting as plain text to your desktop). Large FITS images may be made available via a VOTable containing basic parameters (position, wavelength etc.) and a pointer to the data which can be downloaded or passed on to source extraction or other tools.

Solar System Science with AstroGrid:

AstroGrid provides services to a broad range of end users. For the solar and solar-terrestrial physics community, it provides access to an increasingly wide variety of Solar System data sets and applications via a single access infrastructure. The 'Helioscope' application gives users easy access to heliospheric datasets, breaking traditional boundaries between different areas of Solar System research. The Solar Movie Maker Science Service provides an easy-to-use tool for generating movies of solar images. The AstroGrid workflow is a programming environment where users can develop their own science workflows, combining information from multiple datasets and catalogues. Finally, AstroGrid provides bridging between data and models, as demonstrated by work on the Coupled Thermosphere Ionosphere Plasmasphere (CTIP) model.

The *HelioScope* application allows users to retrieve data for a time range of interest, from a variety of Solar System providers including solar image archives, time-series repositories and catalogues. In its initial version, Helioscope queries the Virtual Solar Observatory and the NASA Coordinated Data Analysis Web system, and returns information on available files for the requested time range. The user can visualise this information and select data for download. Helioscope is modeled on the AstroScope service developed by AstroGrid for night-time astronomy archives.

Connecting AstroGrid and the VO to Computational Grids:

As part of the VOTECH and AstroGrid projects, we have been collaborating with experts in distributed computing to build a flexible and modular infrastructure to allow astronomers within the AG workflow to seamlessly submit thousands of parallel computational jobs distributed over a heterogeneous and unseen computer grid. Version 0.9 on the "VOtechbroker", as it is called (see astro-ph/0510844), is now being integrated into the AG infrastructure and will provide a suite of advanced statistical algorithms run over computing nodes at Portsmouth, Cambridge (COSMOS) and the National Grid Service. The VOtechBroker presently contains algorithms for the computation of the n-point correlation function (both in series and in parallel) and Gadget, an N-body simulation code. Because of the modular nature of VOtechBroker, other algorithms can be added via a well-defined API, and new computer resources can be added using a simple plugin technology. VOtechBroker is built on open-source grid technologies like GridSAM, JSDL and MyProxy. The VOTechbroker has been tested on data from the SDSS and over 10000 jobs have been run spread over 3 separate computational nodes. Eventually, results will be returned to the AG MySpace.

Additionally, proof of concept use of applications run on EPCC machines, actioned from the AstroGrid workbench have been carried out.

C3 Current and future Consortium Data Centre activities

This section lists the key science data products that will be accessible from the core AstroGrid consortium partners. In addition, through participation in the emerging Euro-VO, and accessing via adherence to standard CO protocols, the UK AstroGrid user will be able to gain full access to all data and application resources held in Europe resulting from our participation in ESO, ESA and other international missions and facilities.

C3.1 Cambridge (CASU):

- VISTA – IR science data pipeline and processed products, developed as part of the VFDS/VEGA consortium activity. All UKIRT WFCAM data including UKIDSS and PATT data (in collaboration with VDFS team (QMUL, CASU, WFAU) .Currently 30TB, growing at 30TB per year. In future will contain VISTA Pipeline products expected to be 50-100TB per year from late 2007.
- VST (VLT Survey Telescope) – Pipeline processing based on that developed for IPHAS, an evolution of the optical ING Wide Field Survey pipeline. VST Atlas, VPHAS (VST Photometric H-Alpha Survey) expected to be 10-20TB per year from late-2007.
- Pipelines and processed product archive for the INT Wide Field Camera and WHT instruments.
- Cambridge holds a number of legacy archives including those for the ING, UKIRT, AAO telescopes.
- Hosts a mirror of the CDS Vizier system
- Cambridge Planck Analysis Centre (CPAC): Level 3 – component separation.
- Cambridge is also involved in the (currently suspended) Gemini WFMOS data pipelining definition.
- GAIA data flow system: Cambridge is lead member of the UK consortium aiming to develop the photometric and spectroscopic pipelines for GAIA. It is currently anticipated that the final data products will be made available through ESA, although the UK Gaia consortium may develop the science access system. Edinburgh, MSSL and Leicester as also partners.

C3.2 Edinburgh (WFAU):

- SuperCOSMOS Science Archive (SSA) (now) from scans of Schmidt and Palomar plates images and catalogues; SQL interface all sky three band plus proper motions
- 6dF-z (now) southern sky z-survey based on DENIS selection spectra; SQL interface
- WFCAM Science Archive (WSA) (now) includes both UKIDSS and PATT data IR images and catalogues; SQL interface In collaboration with VDFS team (QMW, Cambridge, Edinburgh)
- Various ESO-VST surveys (2007 -) Several teams have requested data management by VDFS optical images and catalogues In collaboration with VDFS team (QMW, Cambridge, Edinburgh)
- VISTA Science Archive (VSA) (2008 -) For most of the proposed VISTA surveys IR images and catalogues; SQL interface In collaboration with VDFS team (QMW, Cambridge, Edinburgh)
- GAIA (2012 -) Part of collaboration led by Cambridge for photometric archive. Supplementary proposal for user access development to be led by Edin in two years time
- WFMOS (under consideration) Massive survey expected with Gemini instrument: Images and Spectra
- USNO-B
- SDSS DR1-5
- 2MASS

C3.3 Leicester (LEDAS, XMM-Newton Survey Science Centre, Swift Science Centre and SuperWASP):

- SWIFT (BAT/XRT/UVOT) (2005-): Pointed observation data GRB targets & planned targets (raw science data: images, spectra, time series, object catalogues)
- SuperWASP (2004-): Optical survey data (object catalogues, light curves, images)
- XMM-Newton (EPIC/RGS/OM) (2000-): pointed observation data (raw science data, object catalogues (1XMM, 2XMM), images, spectra, time series)
- Chandra (ACIS/HRC/LEG/HEG) (1999-): Pointed observation data (raw science data, object catalogues, images, spectra, time series) (CXC mirror)
- ROSAT (PSPC/HRI/WFC) (1990-2000): X-ray/EUV survey data, pointed observation data (raw science data, object catalogues, images, spectra, time series)
- Lobster (2010- ?): X-ray survey data

LEDAS, the first online astronomical database and archive access service in the UK, also provides access to hundreds of other astronomical catalogues from ground-based observations and other space missions.

C3.4 MSSL (SURF):

- Solar-B (2006-): UK EIS Spectra, US/Japan Optical Telescope: Active Region Images, Velocity Maps, Magnetograms; US/Japan X-ray Telescope: Images (~ 10 Tbyte/year)
- SDO (2008-): HMI instrument data: Full-Sun Helioseismology data sets, Images, Velocity Maps, Magnetograms, AIA instrument data: Full Sun EUV/UV images, High cadence, high volume data set (~ 500 Tbyte/year). Distributed archive with Stanford mission data centre

- SOHO (1995-): CDS Spectral data, EIT Image data
- ReSIK (2001-2003): Bragg crystal spectra
- Yohkoh (1991-2001): Soft X-ray Telescope Images, Hard X-ray Telescope raw data, Bragg crystal spectra, Wide band spectrometer data
- SMM/XRP (1981-1989): Active Region Bragg crystal spectra; flat scanning and Curved spectrometers
- RGO Solar (1918-1979): RGO Solar patrol data from Cape Observatory; Original plate images digitised

C3.5 Manchester:

- MERLIN Archive: pioneered creation of a uniform and consistently processed archive of PATT and Key Program data sets [for radio interferometry]
- Remote radio interferometric imaging tool: pioneering application of AstroGrid components for user-driven imaging of MERLIN data sets.
- e-MERLIN: next-generation fibre-linked radio interferometer with microJy sensitivity at 40 mas resolution over 5 arcminute fields, and > 32k spectral channels. Archive will include raw data, provisional images and spectra, and allow remote imaging.
- ALMA: Manchester is bidding to host ALMA Regional Science Centre with mirror of ALMA data archive. Archive s/w has ben developed for ESO by Manchester team.

C3.6 RAL:

- EISCAT (1981-): Radar measurements of ionosphere (Electron density and temperature, ion temperature, line of sight velocity, ion-neutral collision frequency, ion composition)
- Ionosonde Database (1930-): Ionsospheric sounding data from ~200 ionosondes worldwide. (Digital sounding parameters, digital images and paper archives.)
- Solar and geomagnetic activity indices (1868-): Geomagnetic activity indices, solar indices, interplanetary medium data (Reports and digitial values of various solar-terrestrial activity indicators.)
- SOHO (1995-): Solar observatory (Images, spectra, time series)
- TRACE (1998-): Solar observatory (Images)
- CHIANTI (Updated 2006): Atomic data and software for analysis of spectra from astrophysical plasmas. (Database and associated software.)
- Cluster (2000-): In situ measurements of space plasma (Magnetic field, electrons and ions)
- Double Star (2004-): In situ measurements of space plasma (Magnetic field, electrons and ions)
- Solar-B (2006-): Solar observatory (images, spectra, time series)
- STEREO (2006-): Solar observatory with two spacecraft (stereoscopic images)
- SDO (2008-): Solar observatory (images, spectra, time series)

In addition to the above datasets, RAL provides access to large data storage and computing cluster facilities such as the Petabyte Atlas Datastore and the National Grid Service.

C4 AstroGrid Users and Deployments

As of mid 2006 there are some 300 registered users of the AstroGrid testbed system. These are users of the 'uk.ac.le.star' community. The target for the end of 2007 is to have the majority of professional UK astronomers registered with AstroGrid.

We should note that there are several other installations of AstroGrid components, where we do not centrally log user numbers. For instance AstroGrid installations including the following communities made use of the AstroGrid workbench in the first two week of Jul 2006:

- uk.ac.le.star AstroGrid testbed
- za.ac.saao SAAO
- uk.ac.ucl.star UCL
- astrogrid.cam Cambridge
- jscc.ru RVO – Russia
- ipi.ac.uk RVO – Russia
- mssl.ucl.ac.uk MSSL/ UCL

http://software.astrogrid.org/monitor/status.xml gives a dynamic listing of deployed AstroGrid components.

C5 AstroGrid, the IVOA, and other VO Projects

AstroGrid is a major contributor to the International Virtual Alliance (IVOA – http://www.ivoa.net).The IVOA is the forum within which AstroGrid is able to develop and agree necessary VO standards. With strong AstroGrid staff involvement, IVOA standards have been evolving in a way advantageous to AstroGrid. Some problematic standards (Astronomical Data Query Language (ADQL); SkyNode; aspects of Registry) are being reworked. New standards are coming into play (Universal Worker Service; Single Sign-On; VOSpace) that cover features traditionally offered by AstroGrid, and these will allow both wider use of AstroGrid components and access by AstroGrid users to more resources. There is renewed interest in using Grids, and a possible move to a common standard (Uniform Worker Service) for the interface between the IVO and compute grids. De facto standards (Astronomy Runtime; PLASTIC) in support of desktop application by AstroGrid and VOTech have increasing acceptance, reducing the need to define extra standardsin IVOA.

AstroGrid is cementing links with the SAAO in CapeTown. Two AstroGrid staff members visited SAAO in Jul 2006 - and have successfully helped SAAO staff deploy the AstroGrid VO system infrastructure components.The SAAO are now actively planning in use of the AstroGrid system as part of their data archive distribution system. The VO model appeals to the SA situation, as they will be able to cost effectively publish their science data products directly through the VO - this benefiting the UK community who are partners in the SALT telescope (http://www.saao.ac.za) through the UK SALT consortium.

Links with the Japansese Virtual Observatory are increasing. A delegation from the Japan-VO project visited AstroGrid Feb 2006 for a week. Collaborations in a number of areas resulted: in terms of developing a science workflow whereby JVO Suburu data would be input as data for use by the Redshift maker, in areas of workflow. During a visit to the JVO in May 2006 by members of the AG team, links were strengthened, resulting in a common approach to development of the VO Query Language standard (which was put forward at the following IVOA Victoria May 2006 meeting).

AstroGrid have worked with the Russian Virtual Observatory project. They have an installation of the AstroGrid software, with their developers beginning to develop applications for their community – some of which we expect to be able to re-deploy in the UK.

C6 Knowledge Transfer

AstroGrid interacts rigorously with the technical community.

- AstroGrid team members are involved with the e-Science Centres, exchange of expertise and best practice is resulting. For instance, usage of the PetaByte store at RAL is being explored through AstroGrid and RAL's eScience Centre.
- AstroGrid has a significant presence at the UK All Hands Meeting – this year 2006 additionally organising a BoF session 'Usable Systems in the Global Environment'
- Andy Lawrence is a member of the CLRC e-science advisory board.
- The AstroGrid PS is co-chair of the Astro-Research Group within the Global Grid Forum https://forge.gridforum.org/projects/astro-rg/. In this context AstroGrid were prime organisers of the joint IVOA/GGF Astro-RG workshop held at GGF 17, Tokyo, May 2006 – see http://www.ggf.org/gf/event_schedule/materials.php?event_id=4
- AstroGrid are initiating technical requirements into the global grid computing domain through this avenue, in conjunction with their international partners.
- Astrogrid staff have attended and contributed in a range of e-science forum. These have included working with JISC (Linde is a member of the JISC Integrated Information Environment committee) and the DTI core eScience programme (Walton is a member of the core programme User Group).
- The AstroGrid PS is a member of the EBI/Sanger Institute 'Ensembl' Science Advisory Board (see http://www.ensembl.org/)

AstroGrid has been active in ensuring that training and education benefits from the project. In particular, AstroGrid staff are involved in the supervision of a number of PPARC eScience PhD students (at the IoA, IfA, Leicester, etc). AstroGrid is continuing to develop a proposal to promote the use of IT in the teaching of space science and astronomy in secondary education, through its participation in the BNSC 'Space Initiative' group. The AstroGrid PS has also been a member of the JISC Support of Research committee's assessment of eScience in Education panel.

AstroGrid is a frequent participant at Research Council organised knowledge transfer events, for instance the recent Mar 2006 BBSRC workshop on 'Storage and retreival of large data sets'. AstroGrid expect to seek funding for a PIPSS fellow to facilitate industry exploitation of AstroGrid developed data handling and access techniques.

Annex D : Full Risk Analysis

D1 Risk Register

Terms used above:

Risk areas:

- *Technical* : risks which arise from the technologies chosen
- *Functional* : risks which arise from the architecture
- *Operational* : risks that derive from the delivered system in operation
- *Social* : risks arising from the communities with which the project is concerned or involved
- *Personnel* : risks arising from the personnel involved in the project
- *Time & Money* : risk that we exceed budget or timescales

The rating of each risk is based on:

- *P : Probability of the risk being realised*
- *I : Impact of the risk on the project in the short-term*
- *D : Damage that would be caused to the project in terms of its eventual success*

We have devised a way of calculating from the cost (C) of mitigating a risk, the contribution (WAC) to the Working Allowance of any specific risk, as:

$$\pounds WAC = \frac{P}{10} \times \left(\frac{I + D}{20} \right) \times \pounds C$$

The rating values are:

	P: Probability	I: Impact	D: Damage
VH: Very high	10	10	8
H: High	9	8	6
M: Medium	7	6	5
L: Low	5	4	3
VL: Very low	3	2	2

D2 Risks contributing to WA

R001: Loss of senior personnel

Risk Description	Senior personnel (PM, PS) leave project
Rating	P: M; I: H; D: L
Owner	PL
Avoidance Action	n/a
Mitigation Action	Hire new person
Mitigation Cost	Recruitment costs: £7,500
WA Contribution	£3,412 (£3,412 for years 1-3)

R002: Project administration takes up more time

Risk Description	Allowance of 0.1 FTE is insufficient to administer project
Rating	P: L; I: L; D: VL
Owner	PL
Avoidance Action	n/a
Mitigation Action	Increase allocation (by 0.1)
Mitigation Cost	£10,000 pa = £50,000
WA Contribution	£7,500 (£4,500 for years 1-3)

R003: Help Desk software fails to meet needs

Risk Description	Help Desk software fails to meet the needs of the project
Rating	P:L; I: VH; D: VH
Owner	PM
Avoidance Action	Model support process, involve all participants, dry run process manually, identify needs, and evaluate commercial as well as OSS tools.
Mitigation Action	Identify shortfall in deployed tool, identify which of other tools meets this shortfall and deploy it. Potentially deploy commercial system. If extra personnel can help, deploy from other tasks.
Mitigation Cost	For deploying commercial system: £20,000 + £2,000 pa = £30,000
WA Contribution	£13,500 (£13,500 for years 1-3)

R004: AstroGrid system does not allow for easy problem identification

Risk Description	The deployed software does not make it easy to identify a problem from the symptoms. This means help desk and/or engineering staff spend much more time finding problems.
Rating	P: M; I: H; D: M
Owner	PM

Avoidance Action	Ensure appropriate tracks set out by components and these can be discovered by help desk.
Mitigation Action	Add more people to help desk; re-engineer software.
Mitigation Cost	Assume 0.5 extra support person over two years (years 2-3) until software works adequately: £45,000 x 2 yrs = £90,000
WA Contribution	£40,950 (£40,950 for years 1-3)

R005: Site hosting help desk is inaccessible

Risk Description	The site hosting the help desk and associated systems is subject to a major hack or is subject to some disaster.
Rating	P: VL; I: VH; D: M
Owner	PM
Avoidance Action	Ensure systematic backups of help desk data and systems. Ensure offsite storage of backups or replication of data/systems.
Mitigation Action	Re-site systems at alternative location.
Mitigation Cost	New hardware: £20,000
WA Contribution	£4,500 (£4,500 for years 1-3)

R006: Turnaround time on solving problems is unacceptable

Risk Description	Large number of problems and/or insufficient people assigned to fix them means that turnaround time becomes unacceptable to end users.
Rating	Years 1-2: P: VL; I: M; D: VH Years 3-5: P: M; I: M; D: VH
Owner	PM
Avoidance Action	In the short term, reassign people from other activities. Longer term requires more personnel.
Mitigation Action	Hire new personnel: assume 0.5 engineer and 0.5 scientist
Mitigation Cost	£100,000 pa = £200,000 (yrs 1-2); £300,000 (yrs 3-5)
WA Contribution	£189,000 = £42,000 + £147,000 (£91,000 for years 1-3)

R007: Help desk requires full time administrator

Risk Description	The running of the help desk and administration of trouble tickets requires the engagement of a full-time administrator.
Rating	P: M; I: M; D: H
Owner	PM, PS
Avoidance Action	Deploy help desk system that can be managed by a small number of part-time people and which automates as much of help desk process as possible.
Mitigation Action	Hire administrator, assume for years 2-5.
Mitigation Cost	£70,000 pa = £280,000
WA Contribution	£117,600 (£58,800 for years 1-3)

R008: Scientists are unable to use the technologies chosen

Risk Description	The technologies used in the AstroGrid system (Java, WebStart, Tomcat, …) cause problems for astronomers such that they are unable to use them. (Most such problems ought to have been resolved in AG2.)
Rating	P: VL; I: H; D: VH
Owner	PM, PS
Avoidance Action	Trial software at as many astronomy locations in UK as possible. Ensure only the simplest technologies used for essential tools or alternative versions developed.
Mitigation Action	Develop alternative versions of tools (if only few affected) or find alternative technologies and rebuild tools.
Mitigation Cost	Additional 6 months effort to reengineer software. Personnel cost: £45,000
WA Contribution	£10,800 (£10,800 for years 1-3)

R009: Architecture not favourable to astronomers

Risk Description	The architectural decisions re interfaces, security etc. are not found to be usable by astronomers (e.g. community-based identity, client-based user interface).
Rating	P: VL; I: VH; D: H
Owner	PS, PM
Avoidance Action	Gather feedback from astronomers. Include some testing with astronomers NOT attending workshops.
Mitigation Action	Re-engineer components affected.
Mitigation Cost	Additional 12 months effort: £120,000
WA Contribution	£28,800 (£28,800 for years 1-3)

R010: Insufficient number of scientists employed to meet support calls

Risk Description	The need for science support is greater than planned
Rating	P: L; I: H; D: VH
Owner	PS
Avoidance Action	Ensure spread of workshops across UK. Provide post-workshop support material on website.
Mitigation Action	Hire extra scientist.
Mitigation Cost	Probably risk only in yrs 3-5 as science engagement tails off. Cost: £90,000 pa = £270,000
WA Contribution	£108,000 (£36,267 for years 1-3)

R011: Departments will not run community services

Risk Description	If astronomy departments will not run community services, this task will fall upon the AstroGrid support team.
Rating	P: VL; I: M; D: M
Owner	PS, PM
Avoidance Action	Make community admin as simple as possible so that department secretaries or administrators can run it. Investigate provision of some added value to system. Install community services before workshops and train administrators in its use.
Mitigation Action	Hire extra support person.
Mitigation Cost	£50,000 pa = £250,000
WA Contribution	£41,250 (£24,750 for years 1-3)

R012: Science call needs to be extended

Risk Description	Popularity of science call and unavailability of other avenues makes it necessary to extend science call into twice per year.
Rating	P: VL; I: L; D: L
Owner	PS
Avoidance Action	Ensure technical workshops available to those who wish to interface with AstroGrid components for their research work. Provide channels of communication for researchers to talk to AstroGrid technical people.
Mitigation Action	Provide extra 0.5 engineer in years 1-3
Mitigation Cost	£60,000 pa = £180,000
WA Contribution	£18,900 (£18,900 for years 1-3)

R013: Insufficient resources supporting deployment

Risk Description	Deployment continues into years 2-3 and requires a significant level of support
Rating	P: M; I: L; D: L
Owner	PM
Avoidance Action	Provide easily deployable components; train team in configuring, testing and fixing deployments.
Mitigation Action	Retain deployment support for years 2-3.
Mitigation Cost	£90,000 pa = £180,000
WA Contribution	£44,100 (£44,100 for years 1-3)

R014: Core data centres do not deploy DSA to key datasets

Risk Description	Staff in core data centres (those represented by consortium) do not deploy Dataset Access component so denying access to key datasets. This might be because of security worries.
Rating	P: VL; I: VH; D: L

Owner	PI, PM
Avoidance Action	Ensure staff are fully informed of DSA development, have access to versions for testing and channels to express any concerns which are then satisfactorily addressed. Make separate servers available for DSA deployment (already part of this proposal).
Mitigation Action	Add datasets to another location's holdings or engage with another holder of that data.
Mitigation Cost	Assume problem only at one location and require extra effort for the transition, say 3 months for one sys admin person: £60,000 / 3 mths = £15,000
WA Contribution	£5,475 (£5,475 for years 1-3)

R015: Non-core data centres require more support

Risk Description	Although it is expected that non-core data centres will deploy the AstroGrid DSA component, it may happen that they require considerably more support than allowed.
Rating	P: L; I: L; D: VL
Owner	PM
Avoidance Action	Ensure adequate documentation for DSA deployment, invite non-core data centre personnel to technical workshops, perhaps run specific DSA workshops.
Mitigation Action	Provide specific support for this activity. Say extra 0.25 engineer for years 4-5 (probably adequate support available in years 1-3).
Mitigation Cost	£30,000 pa = £60,000
WA Contribution	£9,000 (£0 for years 1-3)

R016: Deployment requires more hardware than planned

Risk Description	Plans are for same kit at each of six partner sites; it may happen that one or two sites take a much higher hit than others and need to purchase more equipment.
Rating	P: M; I: L; D: H
Owner	PM
Avoidance Action	Ensure architecture allows for dynamic shifting of load.
Mitigation Action	Purchase double set of equipment at each of, say, two sites. Assume this is not until significant use of system, so years 4-5.
Mitigation Cost	£20,000 x 2
WA Contribution	£14,000 (£0 for years 1-3)

R017: Help desk equipment proves inadequate to meet load

Risk Description	If the help desk equipment provided proves inadequate for the load taken, it will adversely affect the service.
Rating	P: VL; I: L; D: M
Owner	PM

Avoidance Action	Ensure adequate and pessimistic load testing of hardware for help desk system.
Mitigation Action	Purchase more equipment.
Mitigation Cost	£10,000 (estimate)
WA Contribution	£1,350 (£1,350 for years 1-3)

R018: Site structure prevents AstroGrid services from working

Risk Description	Site (non-core) is unable to deploy AstroGrid services because of its systems structure: e.g. firewall blocks AstroGrid component access; software standards prevent core AstroGrid software installation etc.
Rating	P: L; I: L; D: H
Owner	PM
Avoidance Action	AstroGrid software is based on common products so unlikely to be a problem except in versioning of those products.
Mitigation Action	If the problem is relatively common, develop work-around for the issue, else deploy components at different site for use of the problem site personnel.
Mitigation Cost	Workaround cost: 0.5 engineer = £60,000
WA Contribution	£15,000 (£15,000 for years 1-3)

R019: Essential tools not deployed

Risk Description	Developers of tools considered necessary to AstroGrid success do not deploy them to VObs.
Rating	P: M; I: H; D: L
Owner	PS
Avoidance Action	Persuade PPARC to fund tools conversion projects. Ensure sufficient developer-oriented documentation and channels of communication and run several technical workshops oriented to developers.
Mitigation Action	Deploy tools on AstroGrid hardware. Assume one or two tools per year cannot simply be 'wrapped' so will require re-development. The likelihood of this will increase as take-up increases and pressure comes from astronomers for specific tools, so assume risk is applied to years 3-5.
Mitigation Cost	0.20 engineer pa = £72,000
WA Contribution	£27,720 (£9,240 for years 1-3)

R020: Developers switched from new functionality to maintenance

Risk Description	Because estimates for maintenance load are too low, engineers are switched from new development to maintenance.
Rating	P: L; I: L; D: M
Owner	PM

Avoidance Action	see 105
Mitigation Action	In the short term, new developments may be delayed but if the problem persists, new developers need to be employed so as not to lose global VObs initiative.
Mitigation Cost	Assume one extra developer in years 3-5: £120,000 pa = £360,000
WA Contribution	£81,000 (£27,000 for years 1-3)

R021: Need to purchase essential software

Risk Description	To date AstroGrid has used only open source components. It may prove necessary to purchase commercial software where no open source alternative of sufficient robustness or performance is available; e.g. need for commercial XQuery interface to registry database.
Rating	P: L; I: L; D: H
Owner	PM
Avoidance Action	Ensure software designed to allow for any shortfall in technologies chosen. Seek out commercial alternatives that are free for academic use (e.g. through IBM Academic Initiative).
Mitigation Action	Purchase necessary software
Mitigation Cost	Assume purchase cost of £20,000 and licensing of £2,000 pa for years 2-4 = £28,000.
WA Contribution	£6,300 (£4,200 for years 1-3)

R022: More effort required on new technology developments

Risk Description	New technologies arise which other VObs partners begin to develop and AstroGrid has too few people assigned to this task to participate effectively.
Rating	P: L; I: L; D: M
Owner	RM
Avoidance Action	Track new technologies; adapt existing trials to VObs environment instead of starting from scratch; form partnerships with other VObs projects and external groups; encourage other astronomy projects to invest in appropriate new tech developments.
Mitigation Action	Hire extra engineer.
Mitigation Cost	Assume for years 3-5: £120,000 pa = £360,000
WA Contribution	£81,000 (£27,000 for years 1-3)

R023: New standards require substantial re-engineering

Risk Description	The IVOA adopts some standard that is significantly different to that of AstroGrid and requires a change in architecture and to several components.

Rating	P: VL; I: M; D: H
Owner	RM, PM, PI
Avoidance Action	Ensure close monitoring of all IVOA developments, including those which happen off-list. Hold out for AstroGrid-friendly standards in approval committees. Have personnel closely involved and active in all lists; form alliances with key personnel in lists including local visits and joint efforts on development of standards and reference implementations.
Mitigation Action	Deploy engineers to incorporate new standards or introduce façade which emulates standard.
Mitigation Cost	Assume requires 3 engineers for 3 months; occurs once in year 3 and once in year 5. £30,000 x 3 x 2 = £180,000
WA Contribution	£32,400 (£16,200 for years 1-3)

D3 Risks not contributing to WA

R101: Scientists do not use AstroGrid software for their research

Risk Description	Scientists simply do not want to use the AstroGrid way of working for their research.
Rating	P: VL; I: H; D: VH
Owner	PS
Avoidance Action	Ensure workshops and tools calls go out to influential astronomers.
Mitigation Action	Study why astronomers are not using the tools provided and address the issues raised in software development, training and support.

R102: Non-core data centres do not deploy DSA to key datasets

Risk Description	Data centres not part of AstroGrid consortium do not use DSA to VO-enable their datasets and these are key to the success of the UK-VO effort.
Rating	P: L; I: M; D: H
Owner	PI, PS
Avoidance Action	Make DSA as easy to deploy and administer as possible.
Mitigation Action	Bring peer-pressure to bear on owners of datasets. Advertise access to non-UK mirrors.

R103: Non-core data centres do not deploy DSA to non-key datasets

Risk Description	Data centres not part of AstroGrid consortium do not use DSA to VO-enable their datasets but these are not key to the success of the UK-VO effort.
Rating	P: M; I: L; D: VL
Owner	PS
Avoidance Action	Make DSA as easy to deploy and administer as possible. Core data centres should offer to host datasets not owned by them.
Mitigation Action	Offer to host foreign datasets. Get potential users to bring pressure to bear on dataset owners.

R104: Non-core sites do not deploy AstroGrid components

Risk Description	Sites outside the consortium do not deploy community or MySpace components for their users or do not make their tools available to VObs users.
Rating	P: ; I: ; D:
Owner	PI, PS
Avoidance Action	Make it easy to deploy components. Demonstrate benefits to sites which host these components.

Mitigation Action	Get local astronomers to bring pressure to bear.

R105: Insufficient personnel on maintenance

Risk Description	The project has assigned too few people to the maintenance of deployed software.
Rating	P: L; I: H; D: VH
Owner	PM
Avoidance Action	Ensure AG2 project properly addresses issues of robustness of components.
Mitigation Action	Switch developers from new functionality engineering to maintenance.

D4 Working allowance calculations

	Yrs 1-5	Yrs 1-3
R001	£3,412	£3,412
R002	£7,500	£4,500
R003	£13,500	£13,500
R004	£40,950	£40,950
R005	£4,500	£4,500
R006	£189,000	£91,000
R007	£117,600	£58,800
R008	£10,800	£10,800
R009	£28,800	£28,800
R010	£108,000	£36,267
R011	£41,250	£24,750
R012	£18,900	£18,900
R013	£44,100	£44,100
R014	£5,475	£5,475
R015	£9,000	£0
R016	£14,000	£0
R017	£1,350	£1,350
R018	£15,000	£15,000
R019	£27,720	£9,240
R020	£81,000	£27,000
R021	£6,300	£4,200
R022	£81,000	£27,000
R023	£32,400	£16,200
	£901,557	**£485,744**

Annex E : References

E1 VO Science papers at the IAU General Assembly

The IAU General Assembly in Prague in August 2006 has a conference (Special Session 3) devoted to the VO entitled "The Virtual Observatory in Action : New Science, New Technology, and Next Generation Facilities". The numbered of registered attendees is 506. AstroGrid will feature strongly at this meeting. The following Astrogrid related papers are being given :

Dalla, S., Fletcher, L., Walton, N. A., 'Solar Active Region emergence and flare productivity'

Gonzales-Solares, E., Oliver, S., Walton, N. A., 'Near-IR properties of Spitzer selected sources'

Lawrence, A: 'The Virtual Observatory : what it is and where it came from'

Prema, P, McMahon, R. G., Walton, N.A., 'Galaxy formation and evolution using multi-wavelength multi-resolution imaging data in the Virtual Observatory'

Richards, A. M. S., et al, 'The MERLINImager - a customised radio interferometry image server provided by AstroGrid'

Tedds, J. A., Law-Green, D., Watson, M. G., Noddle, K. T., Morris, D., Walton, N. A., 'The 2XMM Pre-Release Catalogue: A Test Case for VO Cross Correlation of Large Archives'

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Annex F : Letters of Support

Here we append letters of support from :

Dr Masatoshi Ohishi (National Astronomical Observatory, Japan). Leader of the Japanese Virtual Observatory project, and currently chair of the International Virtual Observatory Alliance.

Dr Bob Hanisch (Space Telescope Science Institute, USA). Project Manager of the US National Virtual Observatory project.

Dr Neil Geddes (Rutherford Appleton Laboratory). Director of the CLRC e-Science Centre, Grid Operations Director for the National Grid Service, and former manager of the PPARC e-science programme

Dr Andrew Jaffe (Imperial College London). Chair of the AstroGrid Science Advisory Committee.

Professor Gerry Gilmore (Institute of Astronomy, Cambridge). PI of the UK Gaia activities, and co-ordinator of OPTICON.